A Project entitled

Developing Manual for Designing Chatbot and the Effects of Mathematics Educational Chatbot on Students' Learning

Submitted by

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submitted to The Education University of Hong Kong

for the degree of Bachelor of Education (Honours) (Secondary) in Mathematics

in April 2022

Declaration

I, Yeung Man Lok , declare that this research report represents my own work under the supervision of Assistant Professor Dr. Yuen Man Wai, and that it has not been submitted previously for examination to any tertiary institution.

Yeung Man Lok
8th April, 2022

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Acknowledgements

I wish to thank various people for their generous and kind support of this honours project. I would like to express my deepest gratitude to my supervisor Dr. Yuen Man Wai for his assistance and continuous guidance during the development of this honours project.

Special thanks should be given to Mr. Ng Tsz Kit for his help in data collection and advice in literature review and data analysis. I would like to extend my thanks to Mr. Chow Chi Chung for his help in collecting data.

Abstract

The research examines the effects of mathematics educational chatbot on students' learning. Two studies were conducted. In study 1, chatbot is treated as an additional revision material in the traditional classroom setting and the learning topic is "Inequalities". A quasi-experimental design was used and participants were 43 Form 5 students (n=25 in the experimental group and n=18 in the control group). In study 2, chatbot is treated as a self-learning resource and the learning topic is "Measures of Central Tendency". 105 Form 2 students used the chatbot. 45 students completed the questionnaires and 33 students completed pre-test and post-test. The study results examine that chatbot as an addition revision material can significantly enhance learning motivation and reduce mathematics anxiety. A manual of chatbot development is constructed for teachers.

1. Introduction

Educators are keen on implementing novel technologies and pedagogies for better learning effectiveness in mathematics education. For example, implementing e-book (Turel, & Sanal, 2018), mobile augmented reality (Chen, 2019), blended learning (Ma, & Lee, 2021) in learning mathematics and the design of the above instructional materials and learning environment is based on ARCS model. In this study, we developed an ARCS-based chatbot for learning mathematics which aims to investigate the effects of mathematics educational chatbot on students' mathematics motivation, anxiety and academic performance. Nevertheless, for this novel instructional material, we want to develop a manual for in-service teachers as a shortcut to designing chatbots based on the data received in the studies.

2. Literature Review

2.1 Chatbot in Education

Chatbots are widely used in an array of domains such as Marketing, Health Care, Entertainment, and the like (Adamopoulou, & Moussiades, 2020). Chatbots are computer software to simulate interactive conversation with users by using natural languages (Murad et al., 2019). Chatbots are powered by Artificial Intelligence (AI) technologies to support learning and teaching (Okonkwo & Ade-Ibijola, 2020). Education chatbots aim to provide students personalised learning environment according to their learning pace and needs. Moreover, personalised feedback is offered and enquiries are answered instantly (Cunningham-Nelson et al., 2019; Clarizia et al., 2018).

Due to the change in learning mode and advanced technology, the application of chatbots for educational purposes has become more ubiquitous in recent years. Under the COVID-19 pandemic, online learning reigns across the globe. The downside of online learning is low interaction between teachers and students, however, chatbot is a convenient method for teachers to answer students' doubts (Kasthuri, & Balaji, 2021). Learning by using chatbots has become ubiquitous since mobile technology evolved rapidly and this interactive learning experience is not limited by space and time (Zhou et al., 2020).

2.2 Roles of Education Chatbots and Cognitive and Social Support

Education chatbots can play different roles. Firstly, chatbot with AI can be treated as an intelligent tutor to simulate teachers' intelligence (Hwang, & Tu, 2021). Chatbot can guide the students to solve the problems by providing hints and tips (Nguyen et al., 2020). Besides students, educators take advantage of education chatbots. Secondly, chatbot can be treated as an intelligent assistant for education purposes. Labour costs and the huge workload of administrative staff and teachers, such as manually answering frequently asked questions about the assignments can be reduced (Hien et al., 2018). Thirdly, in the social aspect, chatbots can be treated as virtual companions to their users to provide social support and develop emotional connections (Shum et al., 2018).

Ng (2022) pointed out the importance of cognitive and social support under remote or online learning. The use of chatbot itself aims to construct students' knowledge. Chatbot as virtual companion is a possible way to deal with the issues such as disconnectedness in online learning. Social support is conducive to students' school engagement and academic self-efficacy (Fernández Lasarte et al., 2020). Education chatbot may be a potential tool to provide cognitive and social support to students to enhance their learning effectiveness.

2.3 Existing Education Chatbots

Smutny and Schreiberova (2020) conducted a systematic review of educational chatbots available on Facebook Messenger and they found 89 active chatbots in which 47% of chatbots consist of questionable educational content. Moreover, there is a lack of discussion techniques and human conversation stimulation. Besides, there are 5% of chatbots used for mathematics education. 40% of education chatbots on Facebook Messenger are developed in the platform "Chatfuel", however, this commonly used building platform was founded to simplify businesses' communication with customers through conversational messaging and marketing (Chatfuel, 2022).

2.3.1 Education Chatbots in Secondary Mathematics

There are various chatbots covered different mathematics learning topics are developed by educators and researchers. For example, Laksana and Fiangga (2022) developed a chatbot for teaching system of linear equations in three variables to grade 10 students. Nguyen et al. (2020) created a chatbot for grade 12 students to learn the properties of functions.

The empirical studies on education chatbots in secondary mathematics are rare. Anh and Ngan (2021) developed an education chatbot for grade 11 Vietnamese high schools students to learn trigonometric functions and trigonometric equations. In their empirical research, they found the comments from students after using the chatbot. Students pointed out that "diverse questions with different difficulty levels" and "providing solutions for incorrect answers" are part and parcel of using chatbot. Moreover, around 90% of respondents agree that the advantages of using chatbot is significantly more than traditional teaching.

Cai et al. (2021) developed an educational chatbot named MathBot for users to learn the arithmetic sequences. They conducted a series of studies and found that learners slightly prefer video tutorials compared to chatbots while learners prefer chatbots compared to written tutorials. Nevertheless, there is no significant difference in learning gains between students learning through chatbots and online video and written tutorials.

2.4 Mathematics Anxiety and Mathematics Motivation

Suinn and Winstson (2003) defined mathematics anxiety as the feeling of fear, worry and tension when somebody is situated in mathematics-related activities. Wang et al. (2015) found that mathematics academic performance and mathematics anxiety are negatively associated. The negative association is modest for students with low intrinsic motivation in mathematics. There is a myriad of factors of mathematics anxiety. O'Leary et al. (2017) stated that people with a high level of mathematics anxiety reported a lack of support from teachers. Moreover, their research found that teachers can reduce students' mathematics anxiety by providing extra help, encouraging, explaining the questions to them clearly, and providing them with more practice and examples (O'Leary et al., 2017).

Mathematics motivation captures the extent to which people are motivated to perform the mathematical tasks well, value the importance of competence of mathematics and embrace the challenge from mathematics (Gottfried et al., 2007; Wang et al., 2015). The way of presenting learning materials would influence pupils' mathematics motivation (Vansteenkiste et al., 2006). Alavi et al. (2002) reported that one of the solutions to promote students' mathematics motivation is information technology-enhanced learning.

2.5 ARCS Model

Motivational design refers to "the process of arranging resources and procedures to bring about changes in people's motivation" (Keller, 2010). ARCS model proposed by Keller (1987) is a commonly used motivational design model and ARCS is an acronym of four elements, namely "attention", "relevance", "confidence" and "satisfaction". Keller (2009) defined those four components as follow:

Attention: Teachers have to capture students' interest and stimulate their curiosity.
Relevance: Teachers should cater for students' needs and learning goals for positive attitude.
Confidence: Teachers can help students to trust that they are able to success.
Satisfaction: It is important for teachers to reinforce students with internal or external rewards.

ARCS model is widely used in a technology-integrated learning environment in order to enhance individual motivation and academic achievement (Li, & Keller, 2018). Overall, students show positive attitudes towards ARCS learning materials in existing researches. For example, GeoGebra with ARCS model significantly enhance students' mathematics motivation (Wah, 2015) while Turel and Sanal (2018) found that ARCS based e-book helps students to enhance motivation and also alleviate their mathematics anxiety. Students receive higher academic achievement in Algebra and Geometry by using mobile augmented reality with ARCS model (Chen, 2019). Therefore, ARCS is a potential model to apply in educational chatbots.

2.6 Research Gap

2.6.1 The Lack of Empirical Studies

Okonkwo and Ade-Ibijola (2021) found that the merits and challenges of education chatbots are highlighted in many existing research studies without empirical investigation. Moreover, we also find a lack of empirical studies regarding integrating the ARCS model into mathematics educational chatbots. Therefore, our studies aim to determine whether or not ARCS-based mathematics chatbot influence students' mathematics motivation, achievement and anxiety.

A dearth of studies compare chatbots used in different teaching and learning settings. In the traditional classroom, teachers would teach mathematics to students face to face. The Education Bureau (2017) in Hong Kong is promoting self-directed learning using information technology. Many schools advocate self-learning and provide learning materials for students. Our studies want to compare the effectiveness of using educational chatbot in traditional classroom settings as additional revision material and a learning resource in a self-directed learning setting.

2.6.2 Learning Culture in Hong Kong

Teachers in Hong Kong reported that the examination-oriented learning culture influenced teachers' decisions on how to teach and exercise drilling is one of the preferences (Lee, 2019). If students do not understand, they must keep drilling the exercise until they know. During exercise drilling, students need the teacher's explanation for their incorrect answers. Chatbot is a potential learning tool for exercise drilling since it provides personalised feedback for students and reduces teachers' workload. Lau (2021) found that students doing too many questions would reduce their learning motivation and make them feel bored and helpless. ARCS-based chatbot may keep students motivated and solve the problems from exercise drilling.

"Inequalities" and "Measures of Central Tendency" are the topics taught in drilling exercises in Hong Kong. They are the topics that do not cover in previous related studies. In this paper, we want to investigate two more questions. Firstly, we want to examine the effectiveness of educational chatbots in Hong Kong classroom settings for two selected topics. Secondly, we want to determine that is the education chatbot a compensation for the downsides of exercise drilling or not.

2.6.3 Manual for Making Chatbot from the Teachers' Perspective

Smutny and Schreiberova (2020) pointed out that educational chatbots on Facebook Messenger platform are still in the early stage to treat as AI teaching assistants. The existing chatbots focus on replying personalised messages or suggesting learning content which is still at basic level. They suggested that more actual conversations are needed to be analysed for future development. Okonkwo and Ade-Ibijola (2021) also pointed that the functionality of chatbot systems is the future research direction.

Therefore, in our studies, we will summarise and categorise the actual conversations from student participants. Firstly, we want to construct a manual for in-service teachers or chatbot developers so that they can follow the principles to develop a chatbot for students. The manual includes the flow of making chatbot, dos and don'ts, design principles with the use of pedagogies. Secondly, the actual conversations received in the studies are the resources for developers to create tools for teachers so that they do not need to develop the chatbot from the beginning.

3. Research Questions

1. Is there a significant difference in mathematics quiz scores of students who learn and do not learn with chatbot?
2. Is there a significant difference in learning motivation of students who learn and do not learn with chatbot?
3. Is there a significant difference in mathematics anxiety of students who learn and do not learn with chatbot?
4. How could teachers develop quality mathematics educational chatbots?

4. Development of Chatbot Sir

We developed "Chatbot Sir" which is an ARCS-based chatbot for learning selected mathematics topic by using the platform "Chatfuel". Students can access the chatbot in Facebook Messenger with their own account. There are two learning topics provided by Chatbot Sir: "Inequalities (Chinese Version only)" and "Measures of Central Tendency (English Version only)".

Chatbot Sir has features such as guidance and personalised feedback. Cai et al. (2021) and Aleven et al. (2016) adopted a progression model. Firstly, developers can draft the potential students' responses such as common mistakes made by students in exercises. Secondly, set the feedback or explanation for students' responses or provide new questions for students.

4.1 Uses of Gamified Element and Interactive Feedback

In Quiz Mode, learner can choose the difficulty (i.e. basic or advanced types of question set) based on their readiness. Not only could Chatbot Sir assign the questions and give answer directly, it can also provide interactive feedback based on particular answers especially the common mistakes. Supports and hints are gradually provided when the number of attempts increase. Moreover, the scores are recorded as gamified element for correct answer during the quiz according to the number of attempts that learner made (i.e. 3 marks for first attempt; 2 marks for second attempt; 1 mark for third attempt). Students will receive presents according to their scores received. If the learner cannot give the correct answer for basic question with a lot of guidance provided, the quiz is stopped and chatbot will suggest learner to choose revision mode first. Gamification like points, feedback in educational context helps to increase students' engagement and motivation to complete the tasks (Nah et al., 2014).

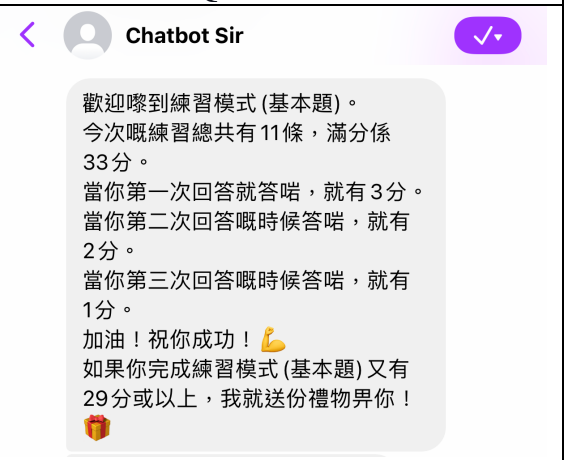
In Revision Mode, user can choose the topic and then Chatbot Sir will provide examples and guide user to learn. Learner can ask Chatbot Sir questions like "How to find the solutions for inequality connected by "or"?. Chatbot will analyse the question by artificial intelligence powered by Chatfuel and provide automatic feedback.

4.2 Application of ARCS Model

The designed functions and features in the Chatbot Sir are intertwined with four elements in ARCS Model.

Elements of "ARCS" Model	Functions or Features Applied in Chatbot
Attention	- Different tactics such as the use of emoji are used to arouse students' curiosity.
Relevance	- Students can ask questions about the topics. - In quiz mode, students can choose basic or advanced questions based on their readiness so that they can adjust learning pace and needs by themselves.
Confidence	- If students answer incorrectly, chatbot will not reveal the solution immediately but give the hint for students in order to clear students' misunderstanding or misconception. This aims to avoid students feeling the sense of failure.
Satisfaction	- Positive feedback and praise statements such as "Excellent" are given to students for correct answers or high score in exercises. - Reward system is set up. Students can collect emojis and get the medals.

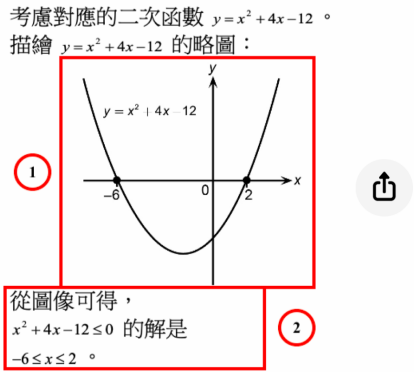
Screenshot of Chatbot Sir (Inequalities):

Revision Mode	Quiz Mode
	
Chatbot Sir: "Hi, [user's name]! I am Chatbot Sir, what do you want to do today?😆 Should you have any questions, please chat with me directly🦁 If you want to restart the conversation, type "Hello"!" Two Buttons: "I want to do exercise."; "I want to do revision."	Chatbot Sir: "Welcome to quiz mode "Basic Questions". There are 11 questions and the full marks is 33. You'll get 3 marks if you answer correctly in the first attempt. You'll get 2 marks if you answer correctly in the second attempt. You'll get 1 mark if you answer correctly in the third attempt. Good luck! If you get 29 marks or above, I will give you a present! 🎁"

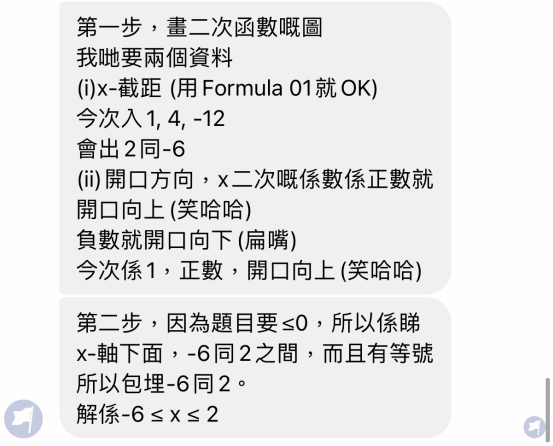
User: “I want to do revision.”
Chatbot Sir: “Which part do you want to know? If you have any other questions, you can chat with me directly.👩”
User: “17.2 Solving Quadratic Inequalities in One Unknown by Graphical Method”

利用圖解法
解二次不等式
$x^2+4x-12\le 0$ 。

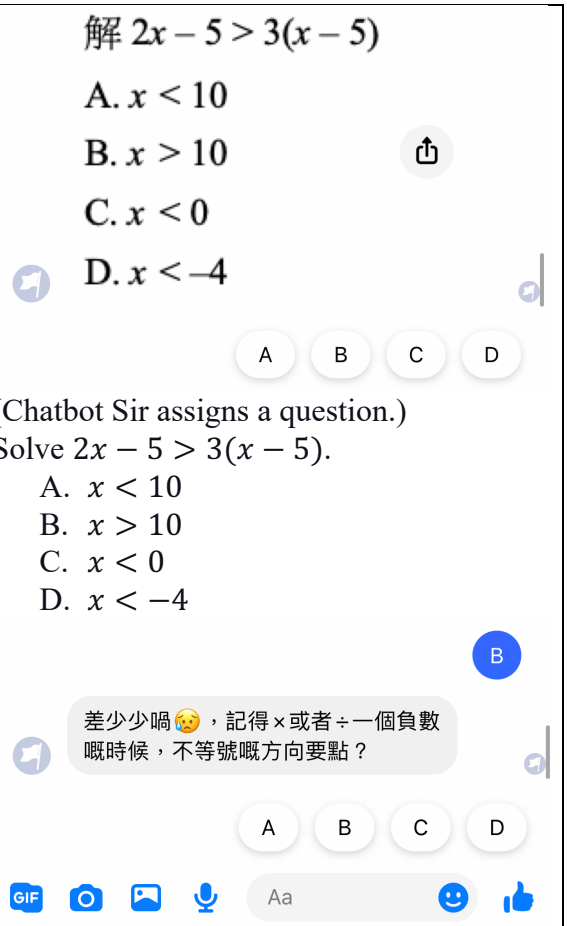
(Chatbot Sir provides an example in the topic asked by user.)
Chatbot Sir:
“Solve quadratic inequality $x^2+4x-12\le 0$ by graphical method.”



(Chatbot Sir solves the example first.)
Chatbot Sir:
“Consider the graph of corresponding quadratic function $y=x^2+4x-12$:
Figure 1
From the graph, the solution of
$x^2+4x-12\le 0$ is $-6\le x\le 2$.”



(Chatbot Sir explains how to solve the example.)
Chatbot Sir:

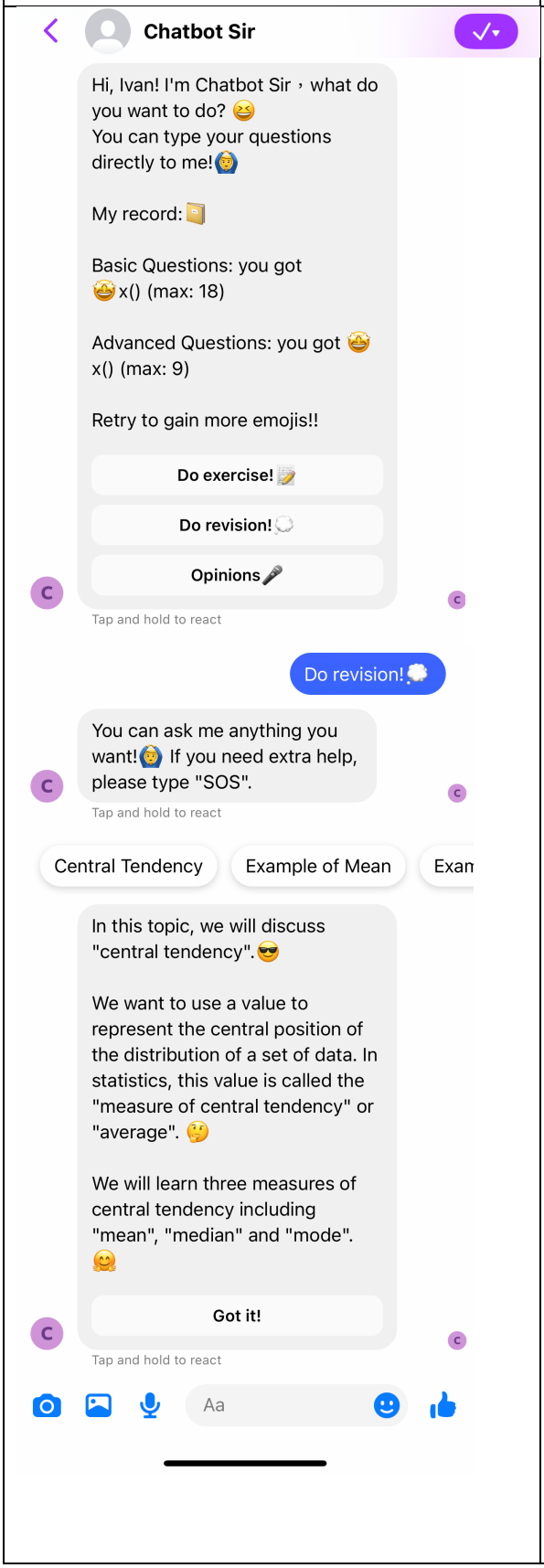
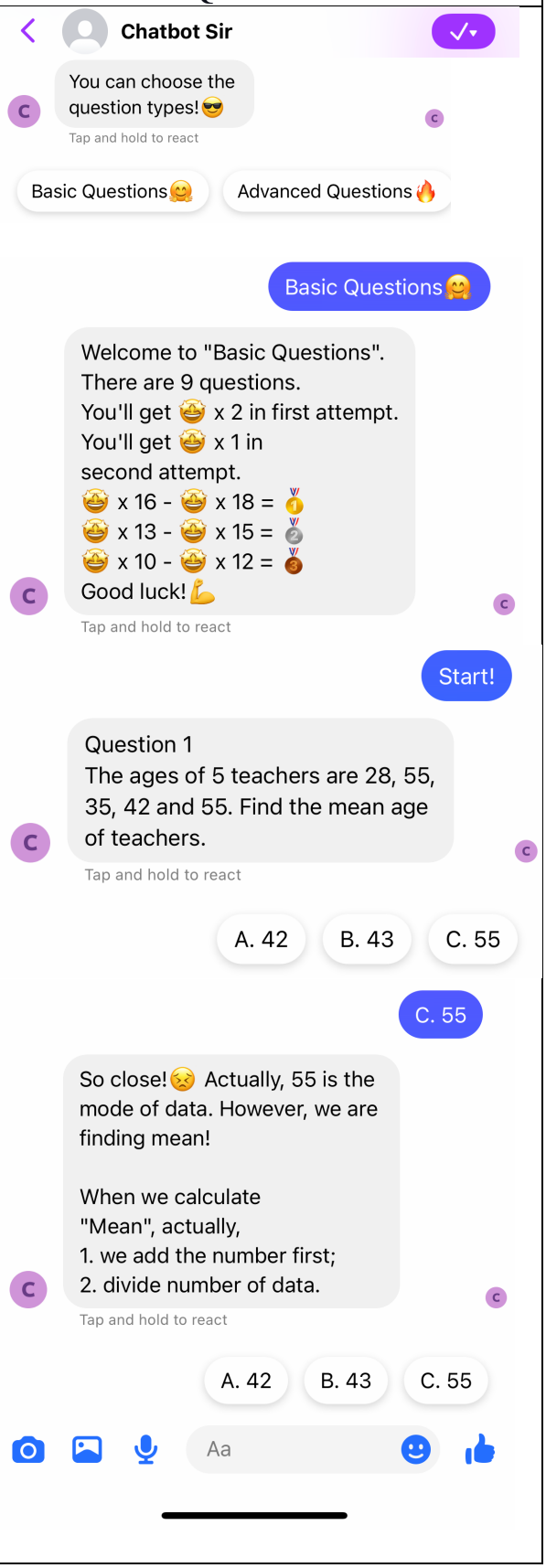


(Chatbot Sir assigns a question.)
Solve $2x-5>3(x-5)$.
A. $x<10$
B. $x>10$
C. $x<0$
D. $x<-4$

User answer B.
Chatbot Sir: “Very close 😢, remember that if we multiply or divide the whole equation by a negative value, what will happen in the direction of the inequality sign?”

"Step 1: we can draw the graph for corresponding quadratic function, we need two information to do so (i) x-intercepts (by using calculator formula 01) We can input 1, 4 and -12. We will get 2 and -6 (ii) direction of opening If the coefficient of square of x is positive, it opens upwards (like smile). If it is negative, it opens downwards (like pouting). We have "1" this time, which is positive, open upwards (like smile). Step 2: since the equation in question is finding "≤ 0", we consider x-axis below, x starts from -6 to 2. Since we have equal sign, -6 and 2 are included. We get "$-6 \leq x \leq 2$"."	

Screenshot of Chatbot Sir (Measure of Central Tendency):

Revision Mode	Quiz Mode
	

5. Methodology

There are two empirical studies to answer the research questions. In study 1, Chatbot Sir is treated as an "additional revision material after class" provided by teacher. Participants use it as a tool for revision after learning the topic. In study 2, Chatbot Sir is treated as a "self-learning resource".

Quantitative data collected from tests and questionnaires completed by research participants will be analysed to answer research questions 1 to 3. Qualitative data such as words received from questionnaire and interview as well as the replies from students while using chatbot will be described and analysed to answer research question 4.

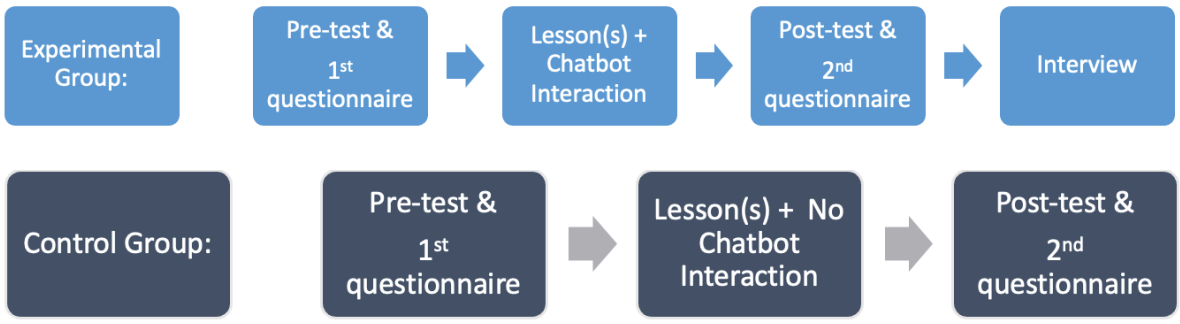
5.1 Study 1 Design

5.1.1 Introduction

Study 1 is implemented in authentic classroom settings. Teacher provides Chatbot Sir to students in experimental group after teaching "Inequalities". The medium of instruction of Chatbot Sir is Chinese. It aims to examine the effectiveness of using chatbot as an additional revision material after class and collect students' opinions about it. The data is used to answer all 4 research questions. The target research participants are Form 5 students. 43 students from secondary schools took part in the study (n=25 in the experimental group and n=18 in the control group).

5.1.2 Research Procedure

A quasi-experimental design is adopted in the study and participants are separated into the control group and the experimental group.



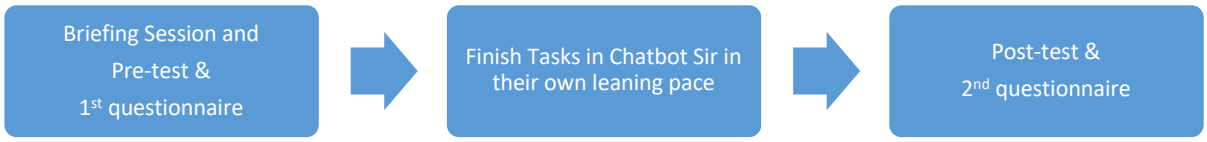
Students from both groups have to attend 10 lessons to learn the whole chapter of "Inequalities". Students from the experimental group have to access the Chatbot Sir for at least 30 minutes after class. The duration of the whole study is 3 weeks. Students from the control group should not access any mathematics education chatbots during the experiment. Pre-test and questionnaire should be completed before the first lesson. Post-test and questionnaire are required to be finished after using the chatbot. The tests aim to assess students' academic performance in "Inequalities". The content of the pre-test and post-test are slightly different. The interview will be conducted at the final step. 13 participants from the experimental group are invited to take part in a 10-minute interview individually.

5.2 Study 2 Design

5.2.1 Introduction

Study 2 is conducted in a secondary school. The teacher provide Chatbot Sir to participants who are required to finish the tasks in Chatbot Sir after school at their own pace of learning. The learning topic of Chatbot Sir is "Measures of Central Tendency" from the junior secondary syllabus. The medium of instruction of Chatbot Sir is English. It aims to examine the effectiveness of using chatbot as a "self-learning resource" and collect students' opinions about it. The data will be used to answer all 4 research questions. The target research participants are Form 2 students. 105 students from secondary schools were invited to use Chatbot Sir. 45 students finished questionnaires. 33 students finished pre-test and post-test. They should not study the same learning topic before. The duration of the whole study is 10 days.

5.2.2 Research Procedure



Participants have to complete pre-test and first questionnaire during the briefing session. After that students are given one week to complete three self-paced learning tasks:

Task	Task 1	Task 2	Task 3
Time Needed	30 minutes	30 minutes	30 minutes
Content	Participants have to enter revision mode and learn the examples of "Mean", "Median" and "Mode".	Participants have to enter quiz mode and finish the basic questions.	Participants have to enter quiz mode and finish the advanced questions.

Participants can start the next task when they attempt all questions in the previous task. After one week, participants have to complete post-test and second questionnaire. All participants have to complete the student interview form in the second questionnaire.

5.3 Instrumentation

5.3.1 Test

Pre-test and post-test papers are designed to assess the students' mathematics academic performance. The test papers are attached in Appendix 10.1 for reference.

5.3.2 Questionnaires

Existing instruments with good reliability and validity are selected. There are two parts in the questionnaire. Motivation and level of mathematics anxiety are measured respectively.

For the former, "Reduced Instructional Materials Motivation Survey (RIMMS)" developed by Keller (2010, pp. 283–284) and modified by Loorbach et al. (2015) is selected. It uses a five-point Likert scale for 12 items and there are four scales for four dimensions "attention", "relevance", "confidence" and "satisfaction". The total scale is 0.81 Cronbach's alpha coefficient for the above four constructs are 0.89, 0.80, 0.86 and 0.89 respectively. It is noted that 0.8 to 0.9 represent reliability at a moderate to a high level (Peterson, 1994; Murphy, & Davidshofer, 1988; Nunnally, 1978). Wang et al. (2020) validated the survey for participants in middle school between the ages of 14 to 17.

For the latter, "Abbreviated Math Anxiety Scale (AMAS)" proposed by Hopko et al. (2003) is selected. It uses a five-point Likert scale for 9 items such that the overall score ranges between 9 and 45. The analysis yields strong internal consistency (Hopko et al., 2003). Primi et al. (2014) validated the instrument for participants in high school ages ranging between 14 and 19 years old.

The questionnaire is attached in Appendix 10.2 for reference.

5.3.3 For the Interview

There are two aims of the interview. Firstly, it aims to ensure the effect on students mainly comes from implementing educational chatbot instead of other factors. Secondly, it aims to collect the views of students towards the use of chatbot for learning mathematics in order to determine what features are students expected. Interview questions are modified from the existing research papers (Topal, Eren, & Geçer, 2021; Chen, Widarso, & Sutrisno, 2020). There are 7 questions in the interview.

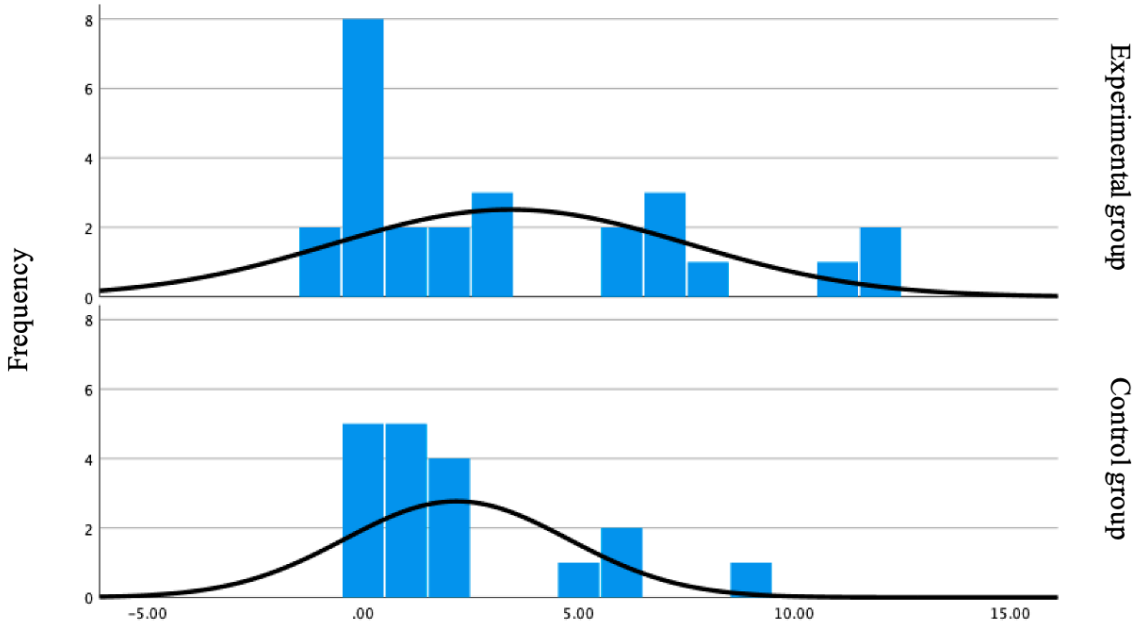
The interview form is attached in Appendix 10.3 for reference.

6. Quantitative Result

6.1 Is there a significant difference in mathematics quiz scores of students who learn and do not learn with chatbot? (Research Question 1)

Study 1

Chatbot is treated as an additional revision material. Participants completed pre-test and post-test which assess their mathematics academic performance. "Paired samples t-test (α=0.05)" is used to compare pre-test and post-test results before and after the intervention in the experimental group (n=25) and control group (n=18).



In the experimental group:

	Paired Differences							Significant	
				95% Confidence Interval of the Difference					
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	One-Sided p	Two-Sided p
Academic Performance	-3.560	4.1541	0.8308	-5.2747	-1.8453	-4.285	24	0.000128	0.000256

According to the data analysis, we can see that the significant one-sided p in academic performance is 0.000128 which is less than 0.05. It is concluded that there is a statistically significant improvement in academic performance for the students in the experimental group.

In the control group:

	Paired Differences							Significant	
				95% Confidence Interval of the Difference					
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	One-Sided *p*	Two-Sided *p*
Academic Performance	-2.1667	2.5952	0.6117	-3.4573	-0.8761	-3.542	17	0.001	0.003

According to the data analysis, we can see that the significant one-sided *p* in academic performance is 0.001 which is less than 0.05. It is concluded that there is a statistically significant improvement in academic performance for the students in the control group.

The data analysis found that both students using chatbot as an additional revision material and attending traditional mathematics lessons without using chatbot can significantly enhance students' academic performance.

Since there is a statistically significant improvement in academic performance for both groups, we want to find that is there a significant improvement in score difference between the control group and experimental group. "Independent samples t-test (α=0.05)" is used.

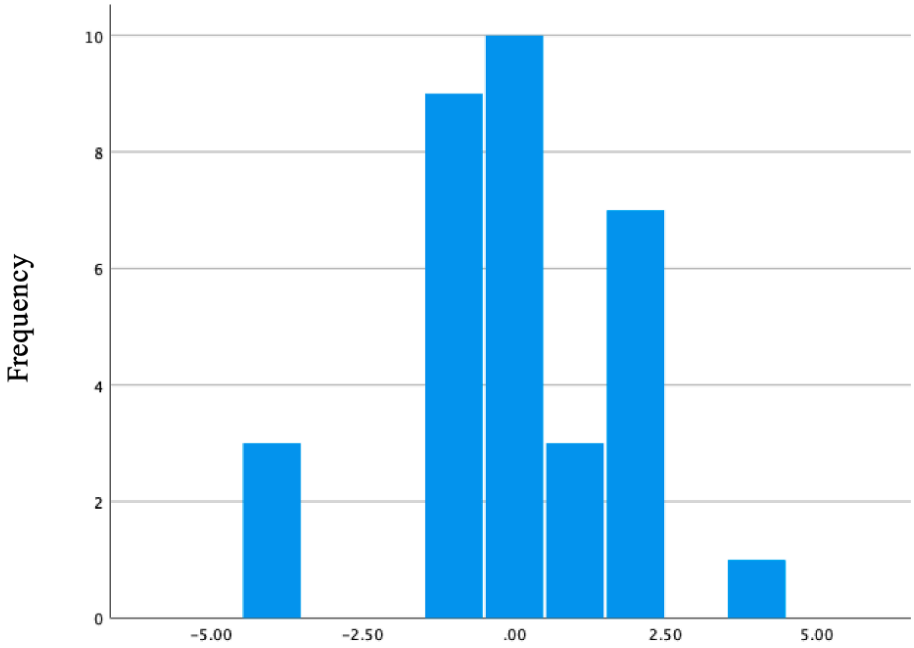
	t-test for Equality of Means							
			Significant				95% Confidence Interval of the Difference	
	t	df	One-Sided *p*	Two-Sided *p*	Mean Difference	Std. Error Difference	Lower	Upper
Difference in between Pre-test and Post-test	1.238	41.702	0.111	0.223	1.25641	1.01494	-0.79225	3.30507

Equal variances are not assumed in the test. According to the data analysis, we can see that the significant one-sided *p* is 0.111 which is greater than 0.05. It is concluded that there is no statistically significant improvement in score difference between the experimental group and control group.

The data analysis found that students using chatbot as an additional revision material do not have a significant difference in mathematics academic performance improvement compared to students attending traditional mathematics lessons without using chatbot.

Study 2

Chatbot is treated as a self-learning resource. "Paired samples t-test (α=0.05)" is used to compare the pre-test and post-test results before and after the intervention of participants using chatbot (n=33).



Difference in Quiz Score Before and After the Intervention

	Paired Differences							Significant	
				95% Confidence Interval of the Difference					
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	One-Sided *p*	Two-Sided *p*
Academic Performance	0.0000	1.8028	0.3138	-0.6392	-0.6392	0.000	32	0.500	1.000

According to the data analysis, we can see that the significant one-sided p in academic performance is 0.500 which is greater than 0.05. It is concluded that there is no statistically significant improvement in academic performance for the students.

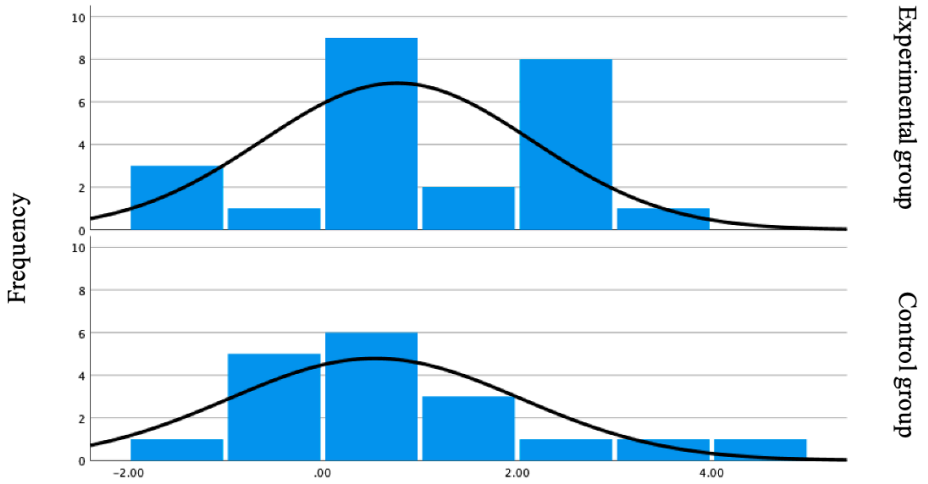
The data analysis found that students using chatbot as a self-learning resource cannot significantly improve students' mathematics academic performance.

6.2 Is there a significant difference in learning motivation of students who learn and do not learn with chatbot? (Research Question 2)

Study 1

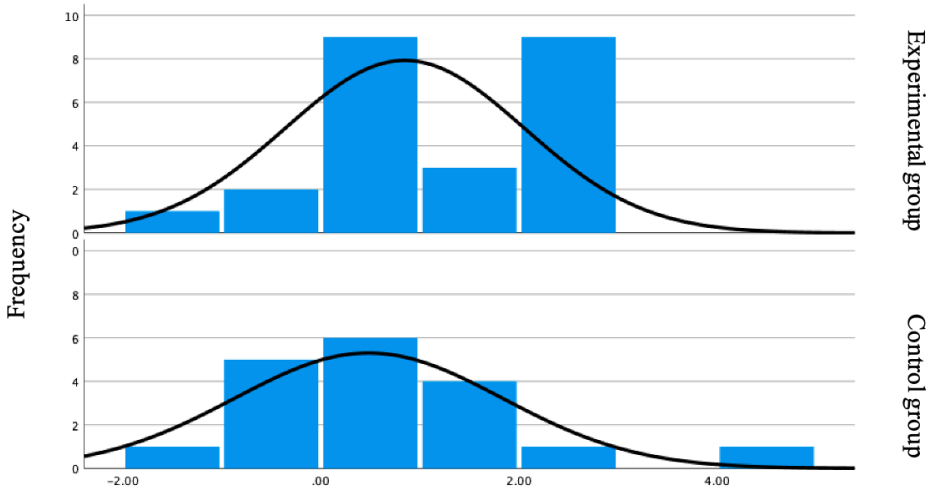
Chatbot is treated as an additional revision material. Participants completed "Reduced Instructional Materials Motivation Survey (RIMMS)" in pre-questionnaire and post-questionnaire. "Paired samples t-test (α=0.05)" is used to compare the questionnaire results before and after the intervention in the experimental group (n=24) and control group (n=18).

Attention:



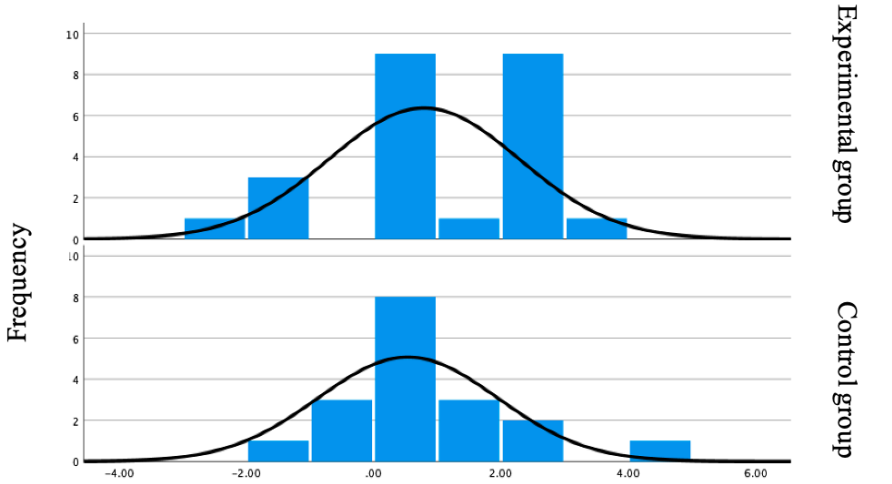
Difference in Motivation (Attention) Score Before and After the Intervention

Relevance:



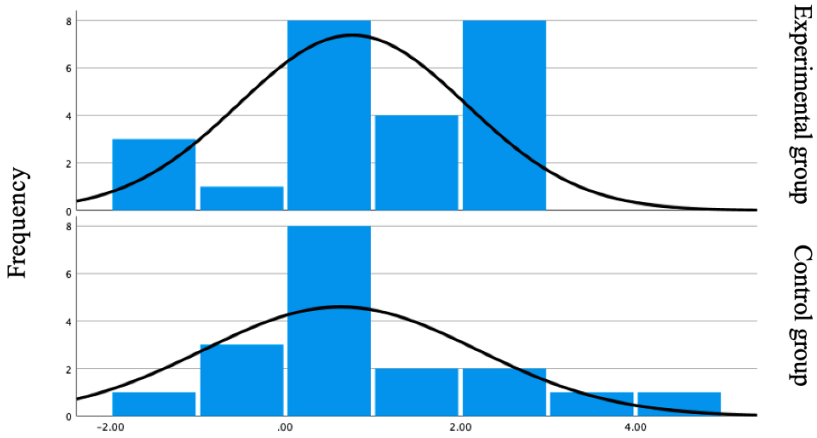
Difference in Motivation (Relevance) Score Before and After the Intervention

Confidence:



Difference in Motivation (Confidence) Score Before and After the Intervention

Satisfaction:



Difference in Motivation (Satisfaction) Score Before and After the Intervention

In the experimental group:

	Paired Differences							Significant	
				95% Confidence Interval of the Difference					
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	One-Sided *p*	Two-Sided *p*
Attention	-0.7639	1.3918	0.2841	-1.3516	-0.1762	-2.689	23	0.007	0.013
Relevance	-0.8472	1.2078	0.2465	-1.3572	-0.3372	-3.436	23	0.001	0.002
Confidence	-0.7917	1.5030	0.3068	-1.4263	-0.1570	-2.580	23	0.008	0.017
Satisfaction	-0.7639	1.2984	0.2650	-1.3122	-0.2156	-2.882	23	0.004	0.008

According to the data analysis, we can see that the significant one-sided *p* in all four aspects of motivation including attention, relevance, confidence and satisfaction are 0.007, 0.001, 0.008 and 0.004 respectively. All of them are less than 0.05. It is concluded that there is a statistically significant improvement in all four aspects of motivation for students in the experimental group.

In the control group:

	Paired Differences							Significant	
				95% Confidence Interval of the Difference					
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	One-Sided *p*	Two-Sided *p*
Attention	-0.5370	1.5001	0.3536	-1.2830	0.2089	-1.519	17	0.074	0.147
Relevance	-0.4815	1.3539	0.3191	-1.1548	0.1918	-1.509	17	0.075	0.150
Confidence	-0.5370	1.4149	0.3335	-1.2406	0.1666	-1.610	17	0.063	0.126
Satisfaction	-0.6296	1.5630	0.3684	-1.4069	0.1476	-1.709	17	0.053	0.106

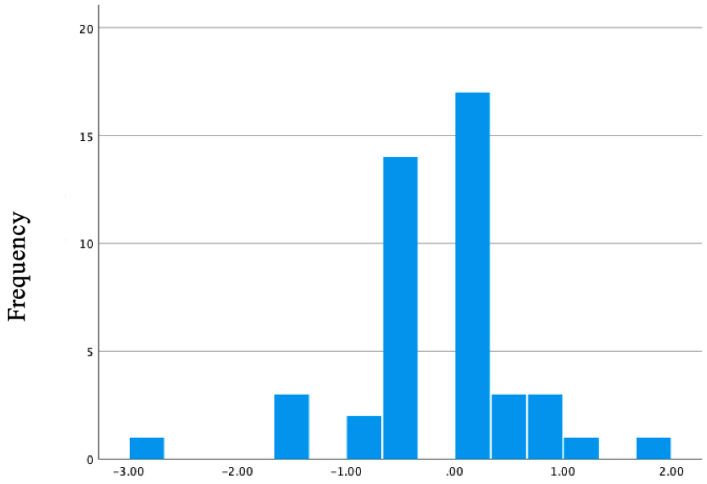
According to the data analysis, we can see that the significant one-sided *p* in all four aspects of motivation including attention, relevance, confidence and satisfaction are 0.074, 0.075, 0.063 and 0.053 respectively and all of them are greater than 0.05. It is concluded that there is no statistically significant improvement in any one of four aspects of motivation for the students in the control group.

The data analysis found that students using chatbot as an additional revision material can significantly enhance students' mathematics motivation in all four aspects, while students attending traditional mathematics lessons without using chatbot cannot.

Study 2

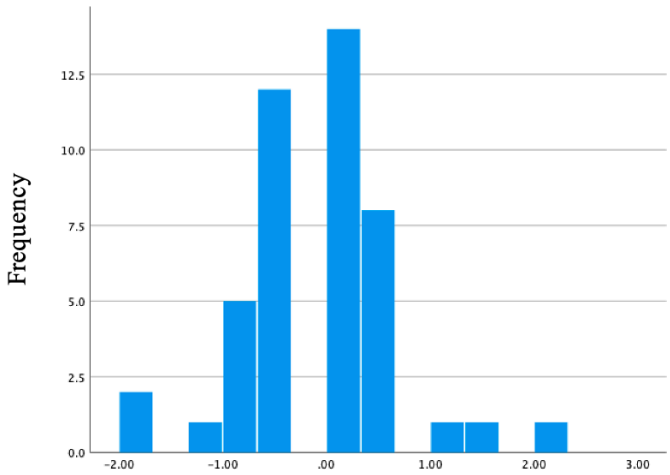
Chatbot is treated as a self-learning resource. "Paired samples t-test (α=0.05)" is used to compare the questionnaire results before and after the intervention of participants using chatbot (n=45).

Attention:



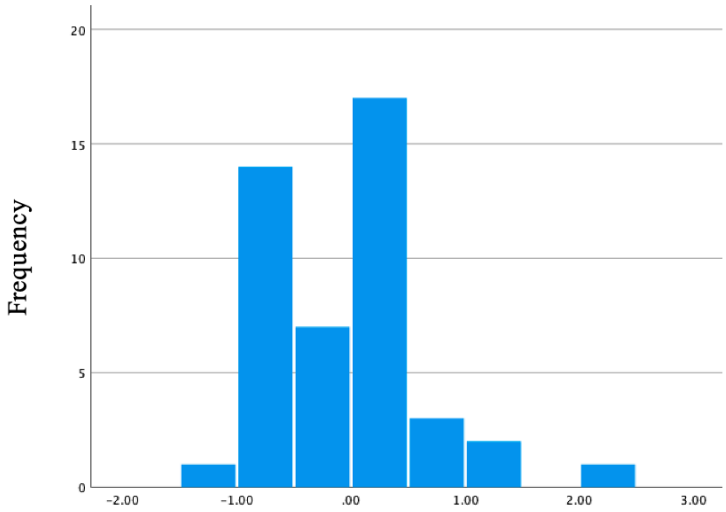
Difference in Motivation (Attention) Score Before and After the Intervention

Relevance:



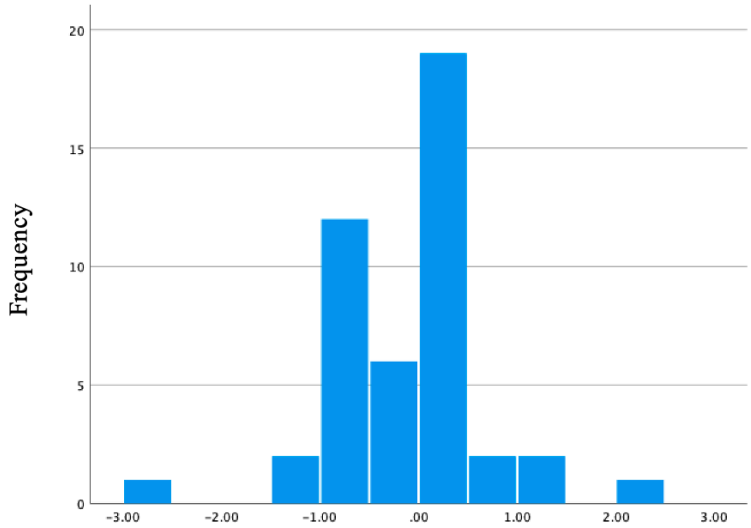
Difference in Motivation (Relevance) Score Before and After the Intervention

Confidence:



Difference in Motivation (Confidence) Score Before and After the Intervention

Satisfaction:



Difference in Motivation (Satisfaction) Score Before and After the Intervention

	Paired Differences							Significant	
				95% Confidence Interval of the Difference					
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	One-Sided *p*	Two-Sided *p*
Attention	0.2075	0.7117	0.1061	-0.0064	0.4213	1.956	44	0.028	0.057
Relevance	0.1926	0.7230	0.1078	-0.0246	0.4098	1.787	44	0.040	0.081
Confidence	0.1407	0.6647	0.0991	-0.0590	0.3405	1.420	44	0.081	0.163
Satisfaction	0.1852	0.7472	0.1114	-0.0393	0.4097	1.662	44	0.052	0.104

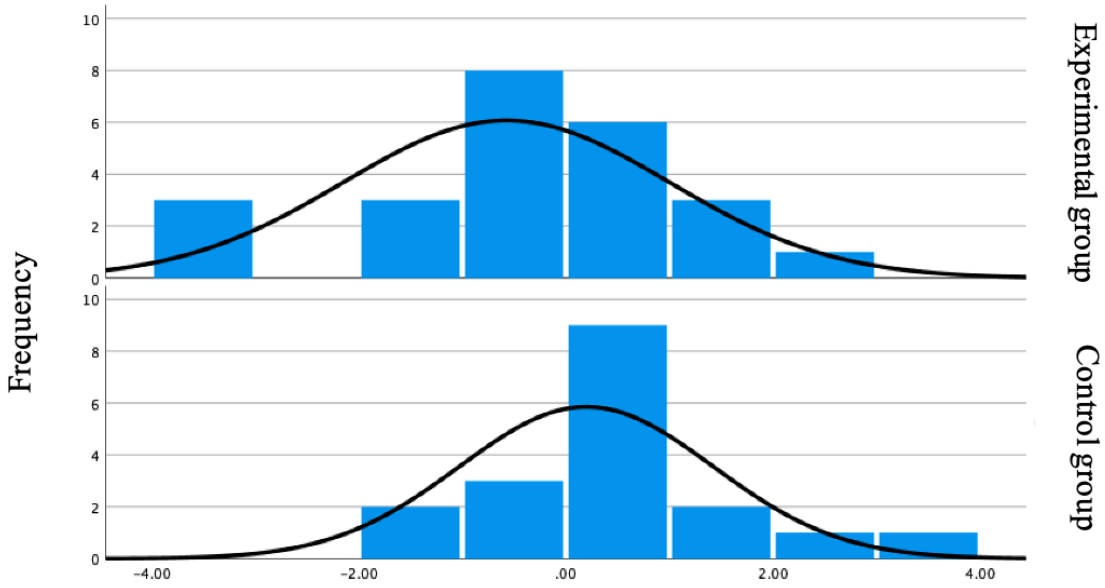
According to the data analysis, we can see that the significant one-sided *p* in all four aspects of motivation including attention, relevance, confidence and satisfaction are 0.028, 0.040, 0.081 and 0.052 respectively. The first two are less than 0.05 while the last two are greater than 0.05. It is concluded that there is a statistically improvement in attention and relevance of motivation for the students and there is no statistically significant improvement in confidence and satisfaction for the students.

The data analysis found that students using chatbot as a self-learning resource can significantly enhance students' mathematics motivation in attention and relevance but not in confidence and satisfaction.

6.3 Is there a significant difference in mathematics anxiety of students who learn and do not learn with chatbot? (Research Question 3)

Study 1

Chatbot is treated as an additional revision material. Participants completed "Abbreviated Math Anxiety Scale (AMAS)" in pre-questionnaire and post-questionnaire. "Paired samples t-test (α=0.05)" is used to compare the questionnaire results before and after the intervention in the experimental group (n=24) and control group (n=18).



In the experimental group:

	Paired Differences							Significant	
				95% Confidence Interval of the Difference					
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	One-Sided *p*	Two-Sided *p*
Anxiety	0.57407	1.5764	0.3218	-0.0916	1.2397	1.784	23	0.044	0.088

According to the data analysis, we can see that the significant one-sided p in anxiety level is 0.044 which is less than 0.05. It is concluded that there is a statistically significant improvement in anxiety level for the students in the experimental group.

In the control group:

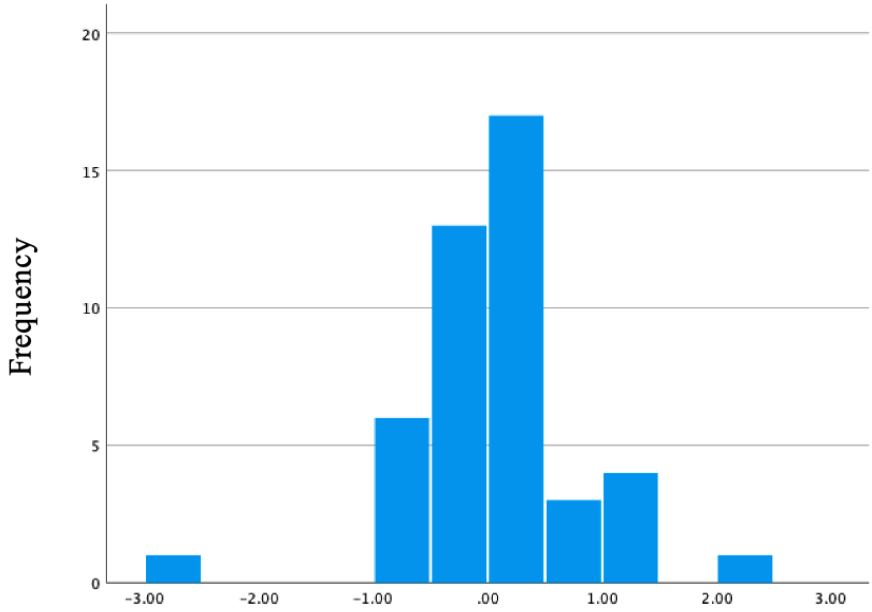
	Paired Differences							Significant	
				95% Confidence Interval of the Difference					
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	One-Sided *p*	Two-Sided *p*
Anxiety	-1.9753	1.2264	0.2891	-0.8074	0.4124	-0.683	17	0.252	0.504

According to the data analysis, we can see that the significant one-sided *p* in anxiety level is 0.252 which is greater than 0.05. It is concluded that there is no statistically significant improvement in anxiety level for the students in the experimental group.

The data analysis found that students using chatbot as an additional revision material can significantly improve students' mathematics anxiety while students attending traditional mathematics lessons without using chatbot cannot.

Study 2

Chatbot is treated as a self-learning resource. "Paired samples t-test (α=0.05)" is used to compare the questionnaire results before and after the intervention of participants using chatbot (n=45).



Difference in Anxiety Score Before and After the Intervention (Post – Pre)

	Paired Differences							Significant	
				95% Confidence Interval of the Difference					
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	One-Sided *p*	Two-Sided *p*
Anxiety	-0.0420	0.7322	0.1092	-0.2619	0.1780	-0.385	44	0.351	0.702

According to the data analysis, we can see that the significant one-sided *p* in anxiety level is 0.351 which is greater than 0.05. It is concluded that there is no statistically significant improvement in anxiety level for the students.

The data analysis found that students using chatbot as a self-learning resource cannot significantly improve students' mathematics anxiety.

Summary

Is there a significant improvement for students?

		Traditional Classroom	Chatbot as an additional revision material	Chatbot as a self-learning resource
Academic Performance		YES*	YES*	NO
		*NO significant difference in score improvement between two groups		
Learning Motivation	Attention and Relevance	NO	YES	YES
	Confidence and Satisfaction	NO	YES	NO
Mathematics Anxiety		NO	YES	NO

7. Qualitative Result and Developers' Manual

The last research question: ***How could teachers develop quality mathematics educational chatbots?*** A manual for designing a mathematics educational chatbot is developed using the data collected by the chatbot and the feedback received from the interview. This manual aims to assist teachers in getting started with making mathematics educational chatbots and providing more directions for teachers to develop education chatbots. The manual consists of 5 parts:

7.1 The Frequently Responses from Users and Possible Solutions

There are some questions frequently asked by the students. Nevertheless, there are some messages frequently sent by students. If the teacher wants to develop the chatbots, the following questions and replies are highly recommended to add during the chatbot development.

The messages replied from 105 students' Facebook accounts in study 2 can be summarised into five categories. The first category is the normal conversation. For example, students ask questions about the learning topic or answer the questions asked by the chatbot. The second category is unexpected responses. For example, students ask questions which are not about the learning topics. The third category is the misuse of chatbot. The fourth category is the emotional expression from students. The fifth category is the opinions from students.

7.1.1 Normal Conversation

Messages sent by students	**Frequency**	**Suggested Replies / Follow-up Actions for Students**
1. Answer what chatbot asked	N/A	N/A
2. I don't know / Idk	5	Provide hints for users
3. Ok	2	Continue the conversation
4. Exit	2	Redirect students to the homepage
5. Thank you / Thx	1	Reply: "You're welcome!🥰"
6. Bye	1	Reply: "I'll be waiting for you.😉"

7.1.2 Unexpected Students' Responses

Some of the unexpected students' responses are categorised as follows:

Questions asked or Messages sent by students	**Frequency**	**Suggested Replies for Students**
Type 1: Students usually ask the questions about Chatbot Sir itself		
1. What is your name? / Who are you?	3	Reply: "I'm [chatbot name].🤓"
2. How are you?	1	Reply: "Couldn't be better since I am studying with you!😚"
3. Where are you from?	1	Reply: "I am a chatbot developed by [developers' name]!😎"
Type 2: Students may ask what they want		
1. The foreign languages	4	Reply: "Sorry that I don't understand😖, could you ask the question in another way?"

2. I go to sleep	1	Reply: "Have a good dream!🤗"
Type 3: Students may ask the questions about other learning topics		
Students ask questions not related to the selected learning topics in two studies (i.e. "Inequalities" and "Measures of Central Tendency"). For example, asking for the example of circumference of circle.	2	Reply: "It is difficult for me😖, I will forward your questions to [teacher's name], he/she will reply you very soon!"
Type 4: Students may ask for basic calculation		
For example, "1+1"	2	Future Direction: Add an extension.

7.1.3 Misuse of Chatbot

Some of the students misunderstand the instruction given from chatbot or send the invalid command to the chatbot.

Messages sent by students	**Frequency**	**Suggested Replies for Students / Explanation from Teachers**
1. Typing the words in buttons instead of clicking the buttons	16	For the students who use the chatbot in the first time, it is suggested that teachers can hold a short briefing session and point out some common misunderstandings from students.
2. Giving wrong information to the chatbot such as "giving the wrong class and class number" intentionally	1	
3. Typing the words with no meanings such as "abc" to the chatbot	3	Reply: "Sorry that I don't understand😣, could you ask the questions in another way?"

7.1.4 Emotional Expression

When the chatbot cannot analyse students' questions or provide proper responses to the students several times, students will become annoying and express their emotions by sending messages to chatbot.

Messages sent by students	**Frequency**	**Suggested Replies for Students**
1. Foul languages	3	Reply: "It hurts me!🥺"
2. Sending the emojis to chatbot (Both emojis with "positive" and "negative" emotion are received)	2	Positive emotions: Reply: "Thank you [users' name]! 😍" Negative emotions: Reply: "Sorry [users' name]! Please give me some opinions!"; Redirect to opinions collection
3. Giving a thumb up in Facebook	2	Reply: "Thank you [users' name]! 😍"
4. Showing appreciation to chatbot such as "I like this"	1	Reply: "Thank you [users' name]! 😍"

5. Scold the Chatbot such as "Idiot"	1	Reply: "Sorry that I can't answer you sometimes but I'll learn more to improve myself!🤷 Please give me some opinions!"; Redirect to opinions collection
6. Omg	1	Give an emoji (such as 😚) to the user and continue conversation
7. Haha	1	Give an emoji (such as 😚) to the user and continue conversation
8. Questions / Mathematics is hard	1	Reply: "Don't worry!😇 I'll study with you!"

7.2 Students' Expectations in the Chatbot

71 students have reported the parts they like and dislike most in Chatbot Sir and the functions they want to add in Chatbot Sir in study 1 interview and study 2 post-questionnaire. This part will summarise students' expected elements and functions in mathematics education chatbot.

7.2.1 Elements

- More Questions and Other Mathematics Topics (6 responses)
  Students expect more questions and examples can be provided by chatbot. Besides two selected topics, students hope that more mathematics topics can be included.

- Visual aids (5 responses)
  Students comment that visual aids such as emojis, GIFs, photos and videos are their favourite and expected elements in chatbot. Hyperlinks can also be added so that students can have more extra learning resources from the internet such as videos.

- Hints for Questions (4 responses)
  Students ask for the hints from chatbot in order to complete the questions. Students review that hints for the questions are their favourite part of the quiz mode in chatbot.

- Voice Messages (3 responses)
  Chatfuel provides a feature "Audio" for developers to upload the audio file. Teachers can record the messages such as explaining the concepts. Students point out that listening to teachers' oral explanations is easier to understand the concept than reading words. Teachers can also record some comments or feedback like "Good job!", "Excellent". This kind of interaction is expected from students.

- Frequently Asked Questions (FAQs) List (2 responses)
  There are many questions received from users. Developers can check for the FAQs from students. Not only can the developers improve of accuracy for chatbot responses, a FAQs list can be added as a function so that students can know what questions did other students ask. They may have a deeper understanding and find inspiration from FAQs list.

- Difficulty Levels (2 responses)
  Students point out that choosing the difficulty levels of questions is extremely important. One of the students also suggests having a small quiz in the beginning and chatbot can assign the questions based on their readiness.

7.2.2 Functions

In the existing chatbot development platforms, there are some limitations. 71 students suggested some expected functions, however, it is not easy to be solved in our chatbot. The following items are the future directions for developers.

- Translation (3 responses)
  Some schools offer mathematics lessons in English as the medium of instruction. However, English may not be their first language. Students suggested that translation can be provided to make it easier for them to understand.

- Calculator (2 responses)
  For the sake of convenience, students are expected that the chatbot can answer some basic calculations such as elementary arithmetic so that chatbot can be used as a calculator.

- Timer (2 responses)
  Students replied that they expected the chatbot could count the time spent on every question and chatbot could remind students of the suggested time or even set the time limit in the quiz.

- Ranking (1 response)
  Students want to know their position in the class to compare their performance with others. Developers can set up a ranking to show who gets the highest scores and the position of the students.

7.2.3 User Experience (UX) Design

- More Interactions (13 responses)
  Students enjoy the personalised feedback from chatbot and talking with chatbot. Students also expect more interactions with Chatbot such as chatting with friends. For example, students hope that chatbot can like their messages. Students love the encouragement given by chatbot.

- Better Flexibility (6 responses)
  Various feedback with regard to skipping the questions and saving their progress is received and students reported that they are the important elements in the quiz mode. In the studies, it is found that some students quit the quiz mode in the midway. Developers have to facilitate the user experience so that students can have flexibility as much as possible. Chatbot can provide the progress bar or tell students how many questions are left.

7.2.4 Others

- Platforms of Using Chatbot (6 responses)
  Many students replied that they did not have Facebook account before using Chatbot Sir. Besides Facebook Messenger, they hope that the chatbot can be accessed on various platforms such as Instagram. Moreover, some cross-border students cannot access Facebook in their living places. It is suggested that teachers can provide more platforms to access chatbot, such as Instagram, WeChat, Skype, WhatsApp, Signal and the like.

- Other Functions (3 responses)
  Besides the functions for learning, students require the functions like playing music, reporting the weather, asking brain teaser, providing games and the like.

7.3 Common Problems in Designing Chatbot

71 students have reviewed the parts they dislike most in Chatbot Sir and the functions they want to add to Chatbot Sir. Here is the summarisation of students' comments:

- The Lack of Question Types (5 responses)
  In some of the existing findings, many researchers prepared question pools for Multiple-Choice (MC) questions only. However, students suggest that they want an array of question types including MC questions, shorts questions, long questions, True or False questions etc.

- Number of Messages Each Time and Message Delay (4 responses)
  Some interviewees point out the word should be clear and concise. Otherwise, it will lose the meaning of using chatbot. If the message is too long, it is difficult for students to read and it is similar to reading the words from an e-textbook. Moreover, developers can control the time to reply to students after chatbot receives the messages. Students reported that it is meaningless to set the typing time for chatbot. They want to get the answer immediately.

- Improper Distribution of Questions with Different Difficulty Levels (3 responses)
  As mentioned in the previous section, choosing difficulty levels by students themselves is crucial. Developers should classify the questions at different levels. Questions too easy or too difficult for students may harm students' learning motivation.

7.4 The Flow to Constructing Chatbot

After summarising the experimental results and the feedback from students. Here are the flow charts for developers to construct the chatbots for users.

Chart 1:
Firstly, welcome message can be set up. Secondly, two learning modes, namely revision and quiz mode, can be created. The former focuses on providing definitions and examples. The latter focuses on assigning different levels of questions to users. Finally, AI setting can be developed. Developers can pair the FAQs with the corresponding replies for users.

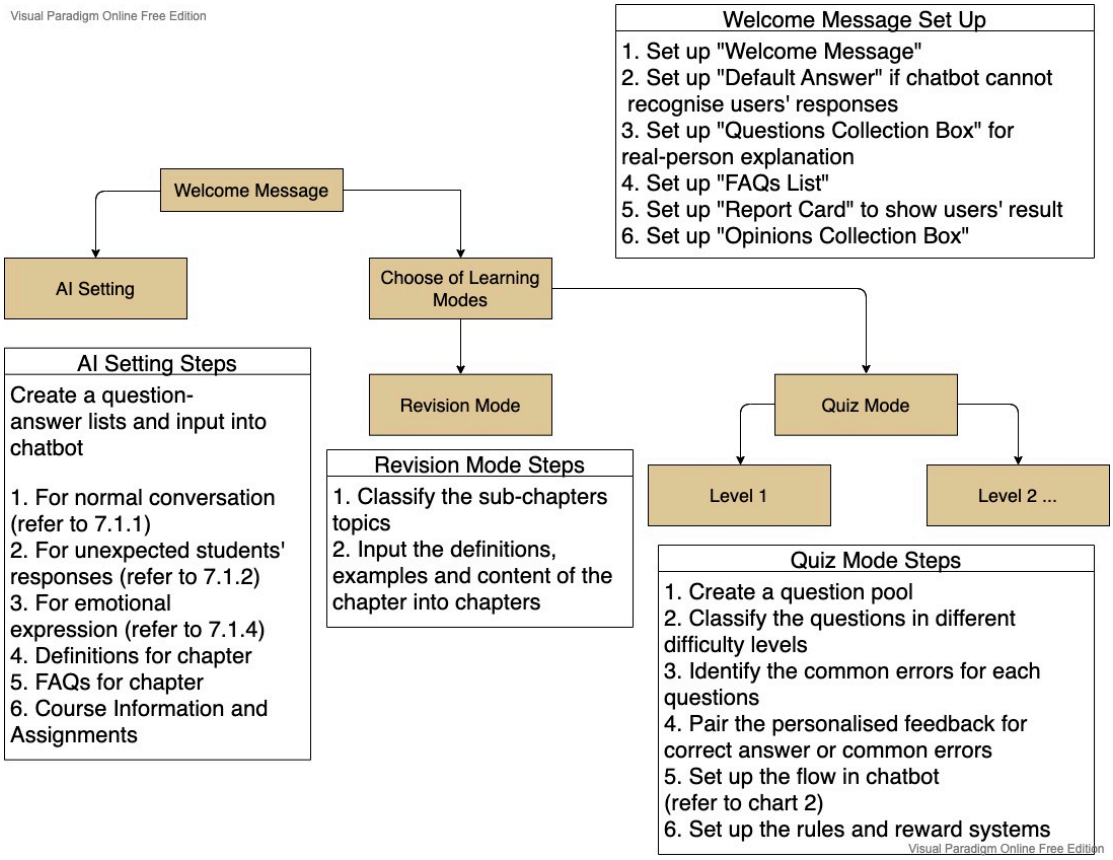
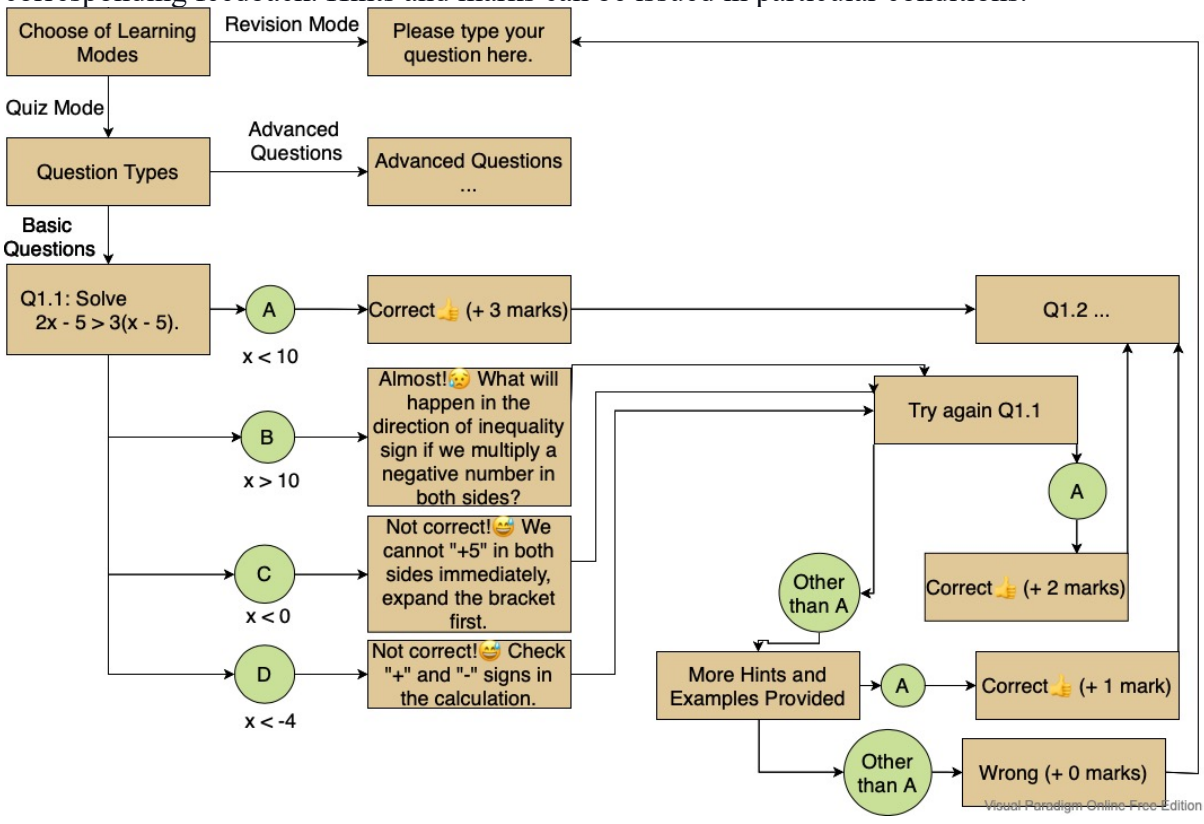


Chart 2:

The conversation graph is inspired by the work from Cai et al. (2021). In the quiz mode, developers can refer to the chart below. For each question, developers can set up the corresponding feedback. Hints and marks can be issued in particular conditions.

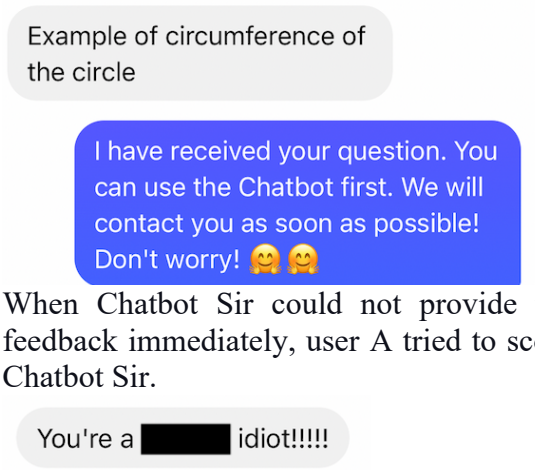
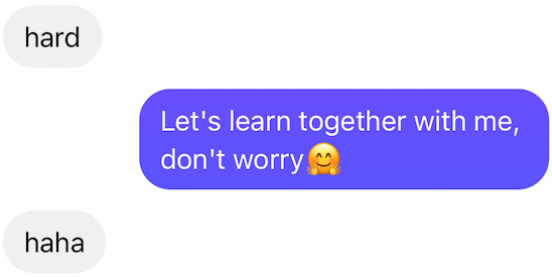


8. Discussion

8.1 Content of Knowledge is Much Important Than Interesting Conversation

Not too many students ask questions beyond the mathematics content. Only 5 questions are asked about Chatbot Sir itself among 105 users. For example, asking "What is your name?" and "How are you?". One reason is students know that all the conversations are saved and can be traced. Students are not willing to ask questions not regarding learning in order to avoid punishment from teachers. When we developed Chatbot Sir for the studies, we added some interesting messages if students asked particular questions. For example, "How old are you?" and "What do you live?". However, nobody asked the above questions. This result reminds us the content of knowledge is much more important than the "easter egg" or the interesting responses. Developers may not need to spend too much time conceiving interesting conversations for unexpected questions asked by the students.

8.2 Better Relationship does not mean Better Engagement

User A	*User B*
 When Chatbot Sir could not provide the feedback immediately, user A tried to scold Chatbot Sir.	 When user B said that the question is difficult, Chatbot Sir tried to comfort user B.

In the conversation, user B with Chatbot Sir seems to have a better relationship than user A with Chatbot Sir. However, user B stopped using Chatbot Sir very soon while user A continued to learn with Chatbot Sir. User with a better relationship with chatbot may not elicit greater engagement from users. Again, it implies the previous argument that the content of knowledge is the most important element in chatbot development.

8.3 Teachers Cannot be Replaced by Chatbot in Current Stage

There are 61% of respondents agreed that using the chatbot only is not enough for learning mathematics and 18% of respondents pointed out that explanation from teachers is part and parcel of learning.

Chatbot as an intelligent tutor:
Students reported that the chatbot could not analyse why they answered the question incorrectly. In chatbot development, developers or teachers prepare automatic feedback for the incorrect answer based on students' common mistakes or experiences. However, they cannot cover all the possibilities of incorrect answers. Chatbot itself cannot analyse all kinds of misunderstandings of students and provide follow-up replies or further actions. Therefore, students pointed out that the function of a live conversation with teachers is important.

Chatbot as a virtual companion:
As mentioned in the previous discussion section, we found that users with a better relationship with chatbot may not elicit greater engagement from users. Mou and Xu (2017) noticed that there is a difference between "human-human interactions" and "human-chatbot interactions". Humans are less open, less extroverted and less agreeable while interacting with chatbots compared to humans since the human users reported that chatbots' responses are not natural enough. Croes and Antheunis (2021) found that people have a low level of feelings of friendship toward social chatbot, moreover, the conversation of chatbot became predictable. Since chatbot is not a "real" person, it may be difficult to provide effective social support for students.

Therefore, we found that chatbot as an intelligent assistant is useful for answering students' frequently asked inquiries and providing quizzes. However, a chatbot as an intelligent tutor or virtual companion to provide cognitive and social support is ineffective. The role of teachers is still important and cannot be replaced at this stage.

8.4 Effective Application of Chatbot and Promoting Positive Education

In the studies, we find that chatbot is more suitable for being treated as an additional revision material instead of a self-learning resource. If teachers wish to provide chatbots for students' learning, it is suggested that they can provide the chatbots after teaching the learning content.

Keller (2010) suggests that people are motivated to learn if they can achieve the first three motivational goals successfully while people desire to learn with continued motivation if they can acquire satisfaction with the process or results of learning. Our research found that using chatbot as a self-learning resource can significantly enhance students' mathematics motivation in attention and relevance but not in confidence and satisfaction. It implies that chatbots may not be proper tools for motivating students in the long run.

Positive education combines academic learning with happiness. Happiness includes students' emotions and motivation (Kern, & Wehmeyer, 2021). We find that chatbot as a revision material can significantly enhance students' mathematics motivation and reduce mathematics anxiety. Chatbot is a potential tool for positive education.

9. Conclusion

More than 70% of respondents agree that they want to use chatbot for learning in the future. We also found that using chatbot as an additional revision material can significantly enhance students' learning motivation and reduce students' mathematics anxiety. We believe that chatbot is a potential teaching material.

9.1 Limitation

In study 1, the experimental and control groups' sample size is 24 and 18 respectively. The sample size is suggested to be expanded in the future. In study 2, the sample size is enough (n=105 for using chatbot) and (n=71 for completing the questionnaire). However, due to the adjustment of 2022 summer vacation in Hong Kong, the duration of study 2 is shortened so that students may not be familiar with the chatbot. It is suggested that the duration of the study can be extended in the future. Nevertheless, only two selected topics are used and only two grade levels are investigated in our research.

9.2 Future Directions

Other mathematics topics, grade levels and classroom settings can be examined in future studies. Our study found that using chatbot as an additional revision material or a self-learning resource, there is no significant improvement in academic performance. Future research questions are: "How to improve the existing chatbots' programme design to enhance students' academic performance?" Moreover, enhancing existing cognitive and social supports in educational chatbots can be investigated. Some research participants are interested in chatbot development. Advantages of students learning chatbot development and Artificial Intelligence can also be one of the future directions.

10. Appendix

Appendix 10.1 (Test Papers)

10.1.1 Study 1 Pre-test with Marking Scheme:

XXXXXX Secondary School
Secondary X Mathematics
Chapter XX Inequalities Pre-Test

Name：_____ ( ) Class：S ____ Date：_____ Marks：_____/19

1. (a) Solve "$2x - 5 > 3(x - 5)$ or $x + 3 \geq 0$".
   (b) Write down the least positive integer satisfying the compound inequalities in 1(a).
   (4 marks)

(a) $2x - 5 > 3(x - 5)$ or $x + 3 \geq 0$
$2x - 5 > 3x - 15$ or $x \geq -3$ 1A
$2x - 3x > -15 + 5$
$x < 10$ 1A
Therefore, we have $x < 10$ or $x \geq -3$.
Therefore, the solutions are all real numbers. 1A

(b) 1 1A

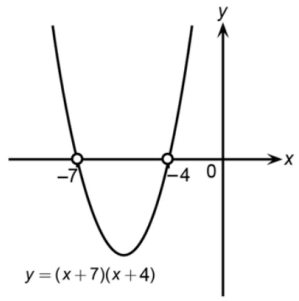
2. (a) Solve "$\frac{3x+4}{6} > \frac{x-1}{3}$ and $\frac{x}{3} + 4 > 0$".
   (b) List out all negative integers satisfying the compound inequalities in 2(a).
   (4 marks)

(a) $\frac{3x+4}{6} > \frac{x-1}{3}$ and $\frac{x}{3} + 4 > 0$
$3(3x + 4) > 6(x - 1)$ and $\frac{x}{3} > -4$
$9x + 12 > 6x - 6$ and $x > -12$
$3x > -18$ and $x > -12$
$x > -6$ and $x > -12$ 1A + 1A
$\therefore$ The solutions are $x > -6$. 1A

(b) The required negative integers are –5, –4, –3, –2 and –1. 1A

3. Solve the following quadratic inequalities by the graphical methods.
(a) $(x + 7)(x + 4) > 0$ (b) $-x^2 - x + 30 \geq 0$ (4 marks)

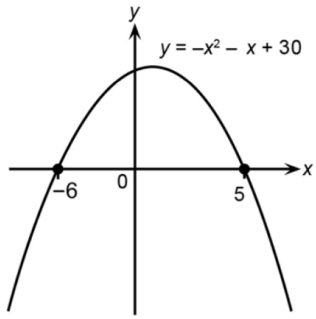
(a) Consider $y = (x + 7)(x + 4)$.
Draw the graph $y = (x + 7)(x + 4)$:



1M

From the graph, solutions for $(x + 7)(x + 4) > 0$ are $x < -7$ or $x > -4$. 1A

(b) Consider $y = -x^2 - x + 30$.
Draw the graph $y = -x^2 - x + 30$:



1M

From the graph, solutions for $-x^2 - x + 30 \geq 0$ are $-6 \leq x \leq 5$. 1A

4. Given that the graph of $y = 4x^2 + kx + (k - 3)$ has no x-intercepts, find the range of possible values of k. (3 marks)

$\because$ The graph of $y = 4x^2 + kx + (k - 3)$ has no x-intercepts.

$\therefore$ $\Delta < 0$

$(k)^2 - 4(4)(k - 3) < 0$ 1M

$k^2 - 16k + 48 < 0$

$(k - 4)(k - 12) < 0$ 1M (for finding roots)

$\therefore$ The range of possible values of k are $4 < k < 12$. 1A

5. The sum of two consecutive integers is not smaller than 35 and not greater than 43. Find the least value of the smaller integer. (4 marks)

Let x be the smaller integer，$x + 1$ be the larger integer.

∵ The sum of two consecutive integers is not smaller than 35.
∴ $x + x + 1 \geq 35$
∵ The sum of two consecutive integers is not greater than 43.
∴ $x + x + 1 \leq 43$
∴ We have "$x + x + 1 \geq 35$ and $x + x + 1 \leq 43$". 1A+1A

$$x + x + 1 \geq 35$$
$$2x \geq 34$$
$$x \geq 17 \quad (1)$$

and

$$x + x + 1 \leq 43$$
$$2x \leq 42$$
$$x \leq 21 \quad (2)$$

∵ x satisfying both (1) and (2).
∴ $17 \leq x \leq 21$ 1A
∴ The least value of the smaller integer is 17. 1A

End of Pre-test

10.1.2 Chinese Translation of Study 1 Pre-test with Marking Scheme:

XXXXXX 中學

中 X 級數學科

第 XX 章 不等式 前測卷

姓名：_____ (　　)　班別：中 _____　前測日期：_____　成績：_____/19

1. **(a)** 解「$2x - 5 > 3(x - 5)$ 或 $x + 3 \geq 0$」。

(b) 求能滿足 (a)中複合不等式的最小正整數。 (4 分)

(a) $2x - 5 > 3(x - 5)$ 或 $x + 3 \geq 0$

$2x - 5 > 3x - 15$ 或 $x \geq -3$ 1A

$2x - 3x > -15 + 5$

$x < 10$ 1A

因此，可得 $x < 10$ 或 $x \geq -3$。

因此，解為所有實數。 1A

(b) 1 1A

2. **(a)** 解「$\frac{3x+4}{6} > \frac{x-1}{3}$ 及 $\frac{x}{3} + 4 > 0$」。

(b) 列出所有能同時滿足 (a)中複合不等式的負整數。 (4 分)

(a) $\frac{3x+4}{6} > \frac{x-1}{3}$ 及 $\frac{x}{3} + 4 > 0$

$3(3x + 4) > 6(x - 1)$ 及 $\frac{x}{3} > -4$

$9x + 12 > 6x - 6$ 及 $x > -12$

$3x > -18$ 及 $x > -12$

$x > -6$ 及 $x > -12$ 1A + 1A

∴ 所求的解為 $x > -6$。 1A

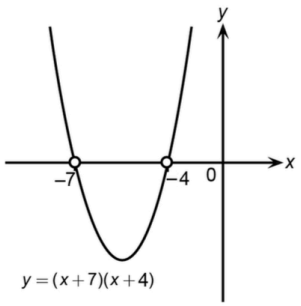
(b) 所求的負整數為 –5、–4、–3、–2 及 –1。 1A

3. 利用圖解法解下列各二次不等式。

(a) $(x + 7)(x + 4) > 0$ (b) $-x^2 - x + 30 \geq 0$ (4 分)

(a)考慮對應的二次函數 $y = (x + 7)(x + 4)$。

描繪 $y = (x + 7)(x + 4)$的略圖：

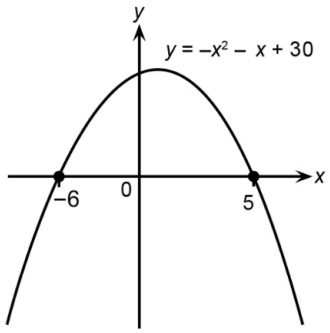


1M

從圖像可得，$(x + 7)(x + 4) > 0$ 的解是 $x < -7$ 或 $x > -4$ 。 1A

(b) 考慮對應的二次函數 $y = -x^2 - x + 30$。

描繪 $y = -x^2 - x + 30$ 的略圖：



1M

從圖像可得，$-x^2 - x + 30 \geq 0$ 的解是 $-6 \leq x \leq 5$。 1A

4. 已知 $y = 4x^2 + kx + (k - 3)$ 的圖像沒有 x 截距，求 k 的取值範圍。 (3 分)

∵ $y = 4x^2 + kx + (k - 3)$ 的圖像沒有 x 截距。

∴ $\Delta < 0$

$(k)^2 - 4(4)(k - 3) < 0$ 1M

$k^2 - 16k + 48 < 0$

$(k - 4)(k - 12) < 0$ 1M (找根)

∴ k 的取值範圍是 $4 < k < 12$。 1A

5. 兩個連續整數的和不小於 35 及不大於 43。求較小整數的最小值。 (4 分)

設較小整數為 x，則較大整數為 $x + 1$。

∵ 該兩個連續整數的和不小於 35。

∴ $x + x + 1 \geq 35$

∵ 該兩個連續整數的和不大於 43。

∴ $x + x + 1 \leq 43$

∴ 該複合不等式是「$x + x + 1 \geq 35$ 及 $x + x + 1 \leq 43$」。 1A+1A

$x + x + 1 \geq 35$

$2x \geq 34$

$x \geq 17$ (1)

及

$x + x + 1 \leq 43$

$2x \leq 42$

$x \leq 21$ (2)

∵ x 必須同時滿足 (1) 及 (2)。

∴ $17 \leq x \leq 21$ 1A

∴ 較小整數的最小值是 17。 1A

前測卷完

10.1.3 Study 1 Post-test with Marking Scheme:

XXXXXX Secondary School
Secondary X Mathematics
Chapter XX Inequalities Post-Test

Name：_____ ( ) Class：S ____ Date：_____ Marks：_____/19

1. (a) Solve "$3x - 4 \geq 4(x - 2)$ and $x - 2 > 0$".
   (b) List out all integers satisfying the compound inequalities in 1(a). (4 marks)

(a) $3x - 4 \geq 4(x - 2)$ and $x - 2 > 0$
$3x - 4 \geq 4x - 8$ and $x > 2$ 1A
$3x - 4x \geq -8 + 4$
$x \leq 4$ 1A
Therefore, the solution are $2 < x \leq 4$. 1A
(b) The required integers are 3 and 4. 1A

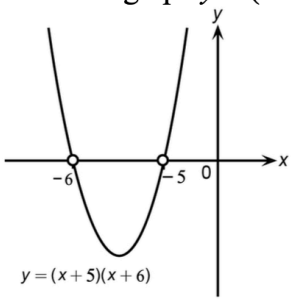
2. (a) Solve "$\frac{3x+1}{4} \leq \frac{x+2}{3}$ or $\frac{x}{2} < 3$".

   (b) Write down the greatest integer satisfying the compound inequalities in 2(a). (4 marks)

(a) $\frac{3x+1}{4} \leq \frac{x+2}{3}$ or $\frac{x}{2} < 3$
$3(3x + 1) \leq 4(x + 2)$ or $x < 6$ 1A
$9x + 3 \leq 4x + 8$
$5x \leq 5$
$x \leq 1$ 1A
∴ Therefore, the solution are $x < 6$. 1A
(b) 5. 1A

3. Solve the following quadratic inequalities by the graphical methods.
(a) $(x + 5)(x + 6) < 0$ (b) $-x^2 + 2x + 35 \leq 0$ (4 marks)

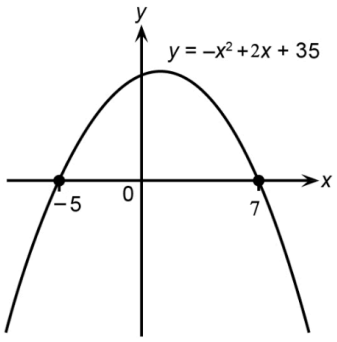
(a)Consider $y = (x + 5)(x + 6)$
Draw the graph $y = (x + 5)(x + 6)$



1M

From the graph, solutions for $(x + 5)(x + 6) < 0$ are $-6 < x < -5$. 1A

(b) Consider $y = -x^2 + 2x + 35$.
Draw the graph $y = -x^2 + 2x + 35$:



1M

From the graph, solutions for $-x^2 + 2x + 35 \leq 0$ are $x \leq -5$ or $x \geq 7$. 1A

4. Given that the graph of $y = x^2 - kx + (3k - 8)$ has 2 x-intercepts, find the range of possible values of k. (3 marks)

$\because$ The graph of $y = x^2 - kx + (3k - 8)$ has 2 x-intercepts.

$\therefore$ $\Delta > 0$

$(-k)^2 - 4(1)(3k - 8) > 0$ 1M

$k^2 - 12k + 32 > 0$

$(k - 4)(k - 8) > 0$ 1M (for finding roots)

$\therefore$ The range of possible values of k are $k < 4$ or $k > 8$. 1A

5. The sum of two consecutive integers is not smaller than 17 and not greater than 29. Find the least value of the smaller integer. (4 marks)

Let x be the smaller integer，$x + 1$ be the larger integer.

∵ The sum of two consecutive integers is not smaller than 17.

∴ $x + x + 1 \geq 17$

∵ The sum of two consecutive integers is not greater than 29.

∴ $x + x + 1 \leq 29$

∴ We have "$x + x + 1 \geq 17$ and $x + x + 1 \leq 29$". 1A+1A

$$x + x + 1 \geq 17$$
$$2x \geq 16$$
$$x \geq 8 \quad (1)$$

and

$$x + x + 1 \leq 29$$
$$2x \leq 28$$
$$x \leq 14 \quad (2)$$

∵ x satisfying both (1) and (2)。

∴ $8 \leq x \leq 14$ 1A

∴ The least value of the smaller integer is 8. 1A

End of Post-test

10.1.4 Chinese Translation of Study 1 Post-test with Marking Scheme:

XXXXXX 中學

中 X 級數學科

第 XX 章 不等式 後測卷

姓名：_____ (　　) 班別：中 _____ 後測日期：_____ 成績：_____/19

1. **(a)** 解「$3x - 4 \geq 4(x - 2)$ 及 $x - 2 > 0$」。

(b) 列出所有能同時滿足 (a)中複合不等式的整數。 (4 分)

(a) $3x - 4 \geq 4(x - 2)$ 及 $x - 2 > 0$

$3x - 4 \geq 4x - 8$ 及 $x > 2$ 1A

$3x - 4x \geq -8 + 4$

$x \leq 4$ 1A

因此，解為 $2 < x \leq 4$。 1A

(b) 所求的整數為 3 及 4。 1A

2. **(a)** 解「$\frac{3x+1}{4} \leq \frac{x+2}{3}$ 或 $\frac{x}{2} < 3$」。

(b) 求能滿足 (a)中複合不等式的最大整數。 (4 分)

(a) $\frac{3x+1}{4} \leq \frac{x+2}{3}$ 或 $\frac{x}{2} < 3$

$3(3x + 1) \leq 4(x + 2)$ 或 $x < 6$ 1A

$9x + 3 \leq 4x + 8$

$5x \leq 5$

$x \leq 1$ 1A

∴ 所求的解為 $x < 6$。 1A

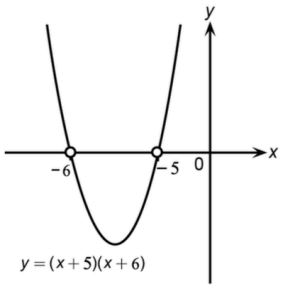
(b) 5。 1A

3. 利用圖解法解下列各二次不等式。

(a) $(x + 5)(x + 6) < 0$ (b) $-x^2 + 2x + 35 \leq 0$ (4 分)

(a)考慮對應的二次函數 $y = (x + 5)(x + 6)$。

描繪 $y = (x + 5)(x + 6)$的略圖：

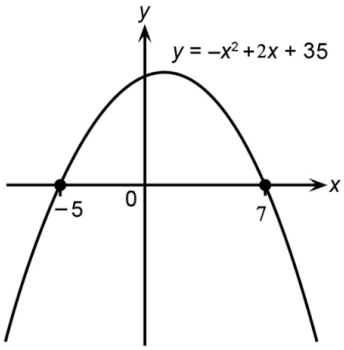


1M

從圖像可得，$(x + 5)(x + 6) < 0$ 的解是 $-6 < x < -5$。 1A

(b) 考慮對應的二次函數 $y = -x^2 + 2x + 35$。

描繪 $y = -x^2 + 2x + 35$ 的略圖：



1M

從圖像可得，$-x^2 + 2x + 35 \leq 0$ 的解是 $x \leq -5$ 或 $x \geq 7$。 1A

4. 已知 $y = x^2 - kx + (3k - 8)$ 的圖像有兩個 x 截距，求 k 的取值範圍。 (3 分)

∵ $y = x^2 - kx + (3k - 8)$ 的圖像有兩個 x 截距。

∴ $\Delta > 0$

$(-k)^2 - 4(1)(3k - 8) > 0$ 1M

$k^2 - 12k + 32 > 0$

$(k - 4)(k - 8) > 0$ 1M (找根)

∴ k 的取值範圍是 $k < 4$ 或 $k > 8$。 1A

5. 兩個連續整數的和不小於 17 及不大於 29。求較小整數的最小值。 (4 分)

設較小整數為 x，則較大整數為 $x + 1$。

∵ 該兩個連續整數的和不小於 17。

∴ $x + x + 1 \geq 17$

∵ 該兩個連續整數的和不大於 29。

∴ $x + x + 1 \leq 29$

∴ 該複合不等式是「$x + x + 1 \geq 17$ 及 $x + x + 1 \leq 29$」。 1A+1A

$x + x + 1 \geq 17$

$2x \geq 16$

$x \geq 8$

及

$x + x + 1 \leq 29$

$2x \leq 28$

$x \leq 14$

∵ x 必須同時滿足 (1) 及 (2)。

∴ $8 \leq x \leq 14$ 1A

∴ 較小整數的最小值是 8。 1A

後測卷完

10.1.5 Study 2 Pre-test and Post-test:

Pre-test:

Question 1: Find the mode of the following data: 4, 4, 8, 10, 10, 10.
Answer: 10

Question 2: Find the mean of the data.

Stem (tens)	Leaf (units)
1	0 2 3 6
2	7 9 9
3	0 5 9

Answer: 24

Question 3: If the median is 63. Find z.

Stem (tens)	Leaf (units)
5	1 5 9 9
6	1 z 9
9	0 2 5

Answer: 5

Question 4: The table shows the number of credit cards owned by 11 teachers.

Number of credit cards	0	1	2	3 or above
Number of teachers	3	3	4	1

Find the median number of credit cards.
Answer: 1

Question 5: Consider the following data: 33, 69, 80, 87, 89, 99, 99, a, b, c
If the mean and the mode of the above data are 78 and 69 respectively, then the median of the above data is?
Answer: 83

Question 6: The following shows the check-in duration (minute) of 8 residents of a hotel.
1, 2, 3, 7, 8, 8, 9, 10
It is given that the mean check-in duration of the 8 residents is 6 minutes. Hence the manager of the hotel claimed, 'Among the 8 residents, more than half can finish their check-in in 6 minutes.' Do you agree with the manager's claim?
Answer: No

Post-test:

Question 1: Find the mode of the following data: 3, 3, 9, 9, 9, 11.
Answer: 9

Question 2: Find the mean of the data.

Stem (tens)	Leaf (units)
1	1 1 4 5
2	8 8 8
3	1 6 8

Answer: 24

Question 3: If the median is 55. Find z.

Stem (tens)	Leaf (units)
4	0 2 8 8
5	3 z 8
8	1 9 9

Answer: 7

Question 4: The table shows the number of SIM cards owned by 11 teachers.

Number of SIM cards	1	2	3	4
Number of teachers	3	3	3	2

Find the median number of SIM cards.
Answer: 2

Question 5: Consider the following data: 31, 67, 78, 85, 87, 97, 97, a, b, c
If the mean and the mode of the above data are 76 and 67 respectively, then the median of the above data is?
Answer: 81

Question 6: The following shows the waiting time (minute) of 8 patients in a clinic.
2, 4, 7, 19, 20, 22, 29, 33
It is given that the mean waiting time of the 8 residents is 17 minutes. Hence the doctor of the clinic claimed, 'Among the 8 patients, more than half can finish their check-in in 17 minutes.'
Do you agree with the doctor's claim? Explain your answer.
Answer: No

Appendix 10.2 (Questionnaire)

Hello fellow student. This questionnaire aims to know more about your learning situation. Your answer will not affect your academic result. Give the answer that truly applies to you, and not what you would like to be true, or what you think others want to hear. Thank you very much for completing the questionnaire and your answer is valuable.

Class：_____ Class Number：_____

Part A:

Abbreviated Math Anxiety Scale (AMAS) (Hopko et al., 2003)

Please rate each item in terms of how anxious you would feel during the event specified.

1 (low anxiety) to 5 (high anxiety)

	1	2	3	4	5
1. Having to use the tables in the back of a math book.					
2. Thinking about an upcoming math test 1 day before.					
3. Watching a teacher work an algebraic equation on the blackboard.					
4. Taking an examination in a math course.					
5. Being given a homework assignment of many difficult problems that is due the next class meeting.					
6. Listening to a lecture in math class.					
7. Listening to another student explain a math formula.					
8. Being given a "pop" quiz in math class.					
9. Starting a new chapter in a math book.					

Part B:

Reduced Instructional Materials Motivation Survey (RIMMS)

Modified from Keller (2010, pp. 283–284)

Please rate each item.

Think about each statement by itself and indicate how true it is. Do not be influenced by your answers to other statements.

1 (not true) to 5 (very true)

Topic：Chapter XX Inequalities

	1	2	3	4	5
1. It is clear to me how the content of the learning resources is related to things I already know.					
2. The quality of the learning resources helped to hold my attention.					
3. As I worked on the learning resources, I was confident that I could learn the content.					
4. I enjoyed working with the learning resources so much that I would like to know more about this topic.					
5. The way the information is arranged on the learning resources helped keep my attention.					
6. I really enjoyed studying with the learning resources.					
7. The content and style of writing in the learning resources convey the impression that its content is worth knowing.					
8. After working on the learning resources for a while, I was confident that I would be able to pass a test on it.					
9. The variety of reading passages, exercises, illustrations, etc. inside the learning resources, helped keep my attention on the lesson.					
10. The content of the learning resources will be useful to me.					
11. The good organization of the learning resources helped me be confident that I would learn this material.					
12. It was a pleasure to work on such well-designed learning resources.					

End of Questionnaire

Chinese Translation:

您好，親愛的同學，這份問卷的主要目的是了解您的學習情況，並不影響您的學業成績。問卷的問題沒有標準答案，根據你的真實想法回答便可，不需填寫您認為其他人希望你填寫的答案。感謝您參與是次問卷。你所填寫的回覆非常寶貴。祝您學業進步。

班別：_____　　學號：_____

甲部

請按照各個情況下，你所產生的焦慮作評分，在方格內填上 v 號。

1: 完全不焦慮　　5:非常焦慮

	1	2	3	4	5
1. 必須使用數學教科書後面的表格					
2. 考前一天，想到即將到來的數學考試					
3. 看老師在黑板上寫的代數方程式					
4. 參加數學課考試					
5. 下次上課前要交一份有很多難題的作業					
6. 聽數學課					
7. 聽其他同學講解數學公式					
8. 在數學課突擊測驗					
9. 讀數學書教科書的新章節					

乙部

請為下列句子作評分，在方格內填上 v 號。

請不要因為其他句子而影響當下回答的句子答案。

1: 非常不同意　　5: 非常同意

是次課題：第十七章 不等式

	1	2	3	4	5
1. 這次教授的課題內容跟我的已有知識是相關的。					
2. 本章節的學習資源讓我保持專注。					
3. 利用本章節的學習資源，我有信心學好這個課題的內容。					
4. 我很喜歡本章節的學習資源，我希望可以了解更多這個課題。					

5. 本章節的學習資源裏編排內容的方式讓我保持專注。					
6. 我很喜歡本章節的學習資源。					
7. 本章節的學習資源的內容和風格讓我感覺到值得使用。					
8. 使用本章節的學習資源一段時間後，我有信心我可以通過考試。					
9. 本章節的學習資源的多樣性(例如文字、練習、插圖等……)幫助我保持專注。					
10. 本章節的學習資源對我有用。					
11. 本章節良好內容編排的學習資源讓我更有信心掌握學習內容。					
12. 我很高興可以使用本章節的學習資源。					

問卷完

Appendix 10.3 (Interview Questions)

Modified from Topal, Eren, & Geçer (2021) [Q1,2,4-6]:
Modified from Chen, Widarso, & Sutrisno (2020) [Q3,7]:

Q1: Did the chatbot help you to learn the learning topic?
Q2: What functions do you want to add into the chatbot?
Q3: From your experience, which parts do you like and dislike most?
Q4: What are the difficulties that you met in using chatbot?
Q5: Is chatbot a sufficient resource for learning mathematics? If not, what elements are important for learning mathematics where chatbot cannot provide for you?
Q6: Please share your feeling while using the chatbot.
Q7: Would you want to use chatbot for learning in the future?

Chinese Translation:
Q1: 請問聊天機械人可以幫助你學習相關的數學課題嗎？
Q2: 請問你有希望聊天機械人可以加入甚麼新功能？
Q3: 在你的體驗中，你最喜歡和最不喜歡甚麼部份？
Q4: 請問你在使用聊天機械人時遇到甚麼困難？
Q5: 使用聊天機械人作為學習數學的資源是否足夠？如不足夠，請問學習數學的時候有甚麼元素是重要的，但聊天機械人沒有提供給你？
Q6: 請分享你在使用聊天機械人的感受。
Q7: 請問你將來還會繼續使用聊天機械人學習嗎？

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