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Evaluation of the M-Orchestrate app for Scaffolding Pupils' Collaborative Science Inquiry during COVID-19

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Abstract: This article reports on an evaluation study of enhancing pupils' science learning with the collaborative inquiry-based learning model, namely, WeEngage, WeCollect, WeAnalyse, WeExplain and WeReflect as a scaffold embedded in the m-Orchestrate app for students to conduct their online collaborative science inquiry. An evaluation study was conducted to understand students' perceptions on using the m-Orchestrate app for collaborative science inquiry during COVID-19.

Keywords: Collaborative inquiry-based learning, science learning, m-Orchestrate app

1. Introduction

Inquiry-based learning supported by Information and Communications Technology (ICT) tools, especially mobile devices, has been a desirable innovative approach to instructional practices in science education (Bell et al., 2010; Linn & Eylon, 2011). However, ICT-rich classrooms are complex, highly variable and unpredicatable with many constraints (Roschelle, Dimitriadis, & Hoppe, 2013). Research evidence indicates that students lack collaborative inquiry-based learning skills in conducting the learning activities across formal and informal settings (e.g., Lakkala, Lallimo, &Hakkarainen, 2005; Sharples, 2013), especially during COVID-19 where all the lessons have to be conducted online. "How to scaffold students to conduct collaborative science in a mobile learning environment more effectively" remains an issue to be addressed. Thus, the focus of this research is to develop a mobile learning app termed "m-Orchestrate" ("m" stands for mobile, and "orchestrate" means management) that provides a practical solution to this question.

2. Design principles of the m-Orchestrate app

The design of the m-Orchestrate learning app integrates mobile technology into science curriculum, assessment, collaboration and inquiry-based pedagogy grounded in social constructivist theories with a more generic pedagogical structure as scaffolds for learners' inquiry (Hakkarainen, Lipponen, & Jarvela, 2002; Sharples, 2013; Vygotsky, 1978). The pedagogical structure is comprised of five elements: "*engage, explore, analyze, explain and reflect*" developed from the "inquiry-based learning model" in our earlier study (Song, 2014; Song, 2016), which is employed in the design of inquiry phases in the m-Orchestrate-based learning. The adoption of these inquiry phases servers as a scaffold for students to facilitate their collaborative knowledge construction. The specific features of the m-Orchestrate app was presented in the next section.

3. Features of M-Orchestrate App

The m-Orchestrate app is a learning system that aims at supporting teacher orchestration and student collaborative science inquiry in a mobile learning environment (Song, Cao, Tam, & Looi, 2019). The design of this app adopts the collaborative science inquiry model, which is one of the collaborative inquiry-based models underpinned by social constructivist theories. The collaborative science inquiry model consists of five phases and adds "we" as a prefix before them to stand for collaboration, namely, WeEngage, WeCollect, WeAnalyse, WeExplain and WeReflect.

Figure 1 presents (1) technologies used to develop the app and (2) functionalities to support teaching and learning in collaborative science inquiry. The front-end interface of this app is powered by Unity, which is a visualizing development engine compatible with both iOS and Android mobile devices. Laravel, JavaScript and AJAX provide synchronous web services and API communication to support real-time interactions.

On the m-Orchestrate app, teachers can view, monitor and manage the inquiry status of each group. Then, resources and feedback are available to be assigned if needed. Such interventions can be addressed to corresponding groups, inquiry phases and activities. Thus, teachers can orchestrate diverse learning trajectories preciously and "just in time".

The app provides various functions for students to conduct inquiry-based learning activities collaboratively. Some functions are available in all phases (e.g., Mind Map and Chat Room) and some are specific for an inquiry phase (e.g., data analysis and KWL tables).

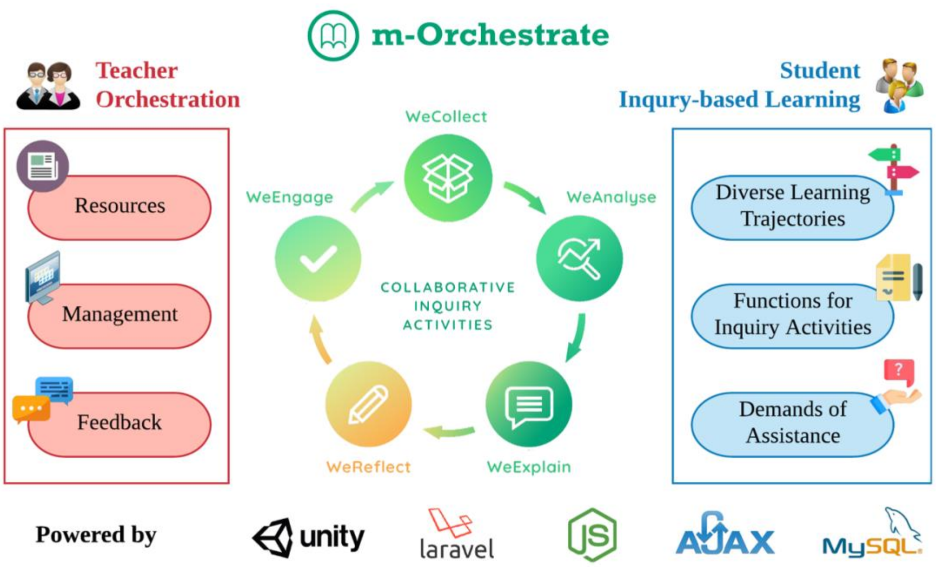

Figure 4. Technologies and features on the m-Orchestrate app.

4. Collaborative Science Inquiry on M-Orchestrate App

4.1 Functionalities to Support Students' Collaborative Science Inquiry

Five collaborative inquiry-based phases, namely, WeEngage, WeCollect, WeAnalyse, WeExplain and WeReflect are embedded in the m-Orchestrate app (refer to Figure 1). The functions of each phase are presented below:

- In WeEngage, the teacher provides resources to activate students' prior knowledge and students work in groups to raise their inquiry questions;
- In WeCollect, group members plan how to solve the inquiry questions, and divide the tasks to each member, then collect data in text, picture, spreadsheet or video format;

- In WeAnalyse, group members choose collected data in text, picture, spreadsheet or video format from WeCollect phase for analysis;
- In WeExplain, group members make a slideshow to present their whole inquiry process. The slides can be selected from the logged data in each inquiry phase, including the analysed data results, or uploaded pictures beyond the app;
- and in WeReflect, students reflect on what they know and what they want to know about the inquiry topic and what they have learned in the collaborative inquiry process.

The five inquiry phases are not linear. Students can work back and forth among these phases whenever they want. All these features are summarized in Table 1. In each inquiry phase, the features of location-based multimedia notes, collaborative Mind Map and Chat Room are provided. The location-based multimedia notes can help students record their inquiry findings and experiences in text, audio, image and video formats. The collaborative Mind Map allows students to work online simultaneously. The Chat Room enables students to communicate across class, group and individual levels. The student dashboard can help users identify the name, members, and completion rate of groups and the latest updates in the inquiry project.

Table 12. ***Students' Inquiry Behaviours on the m-Orchestrate App***

Inquiry Phase	Function	Functionality for student inquiry
All phases	Notes	For making location-based notes with texts/audios/images/videos
	Mind maps	For structuring information and synthesizing ideas collaboratively
WeEngage	Inquiry questions	For raising inquiry questions
		For commenting on the raised questions
		For deciding the question(s) to explore
WeCollect	Tasks	For planning inquiry tasks
		For division of labour
		For collecting text/image/video/spreadsheet data
WeAnalyse	Data analysis	For analysing collected text/image/video/spreadsheet data
WeExplain	PPT slides	For presenting and elaborating findings
WeReflect	KWL tables	For reflecting on different topics

4.2 The Use of M-Orchestrate App During the Outbreak of COVID-19

Due to the outbreak of COVID-19, Hong Kong primary schools conducted most teaching and learning activities online. One class of students from a Hong Kong primary school were invited to adopt the m-Orchestrate app in their science learning to conduct collaborative inquiry learning activities. The inquiry topic of "prevention of diseases during the coronavirus pandemic" was reported in this paper as an example (see *Figure 5*).

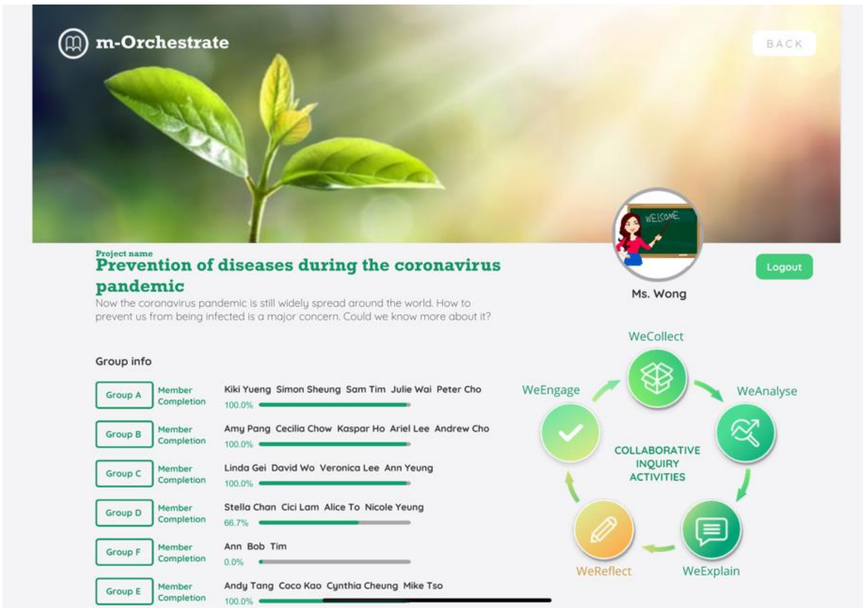

Figure 5. Homepage of project “prevention of diseases during the coronavirus pandemic”.

A sample of 21 students were involved in this study and were divided into six groups (Group A, B, C, D, E and F). The learning process of Group D was randomly chosen to illustrate how collaborative science inquiry occurs on the m-Orchestrate app in detail. The inquiry process is presented in Figure 3.

In the WeEngage phase, students raised their inquiry questions. Based on the discussion and teacher’s suggestions, they decided to explore “What types of masks can help us prevent the coronavirus? and “what are the major causes of common diseases?” (see Figure 3).

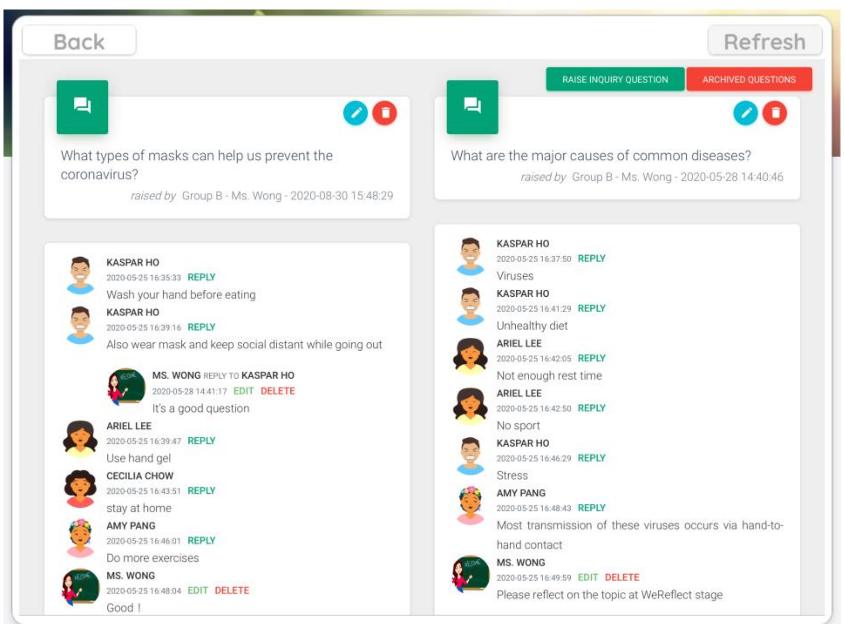

Figure 3. Raised inquiry questions in WeEngage.

Then, they moved into the WeCollect phase to plan tasks, divide work labour division, collect data and information on the Internet (see Figure 4).

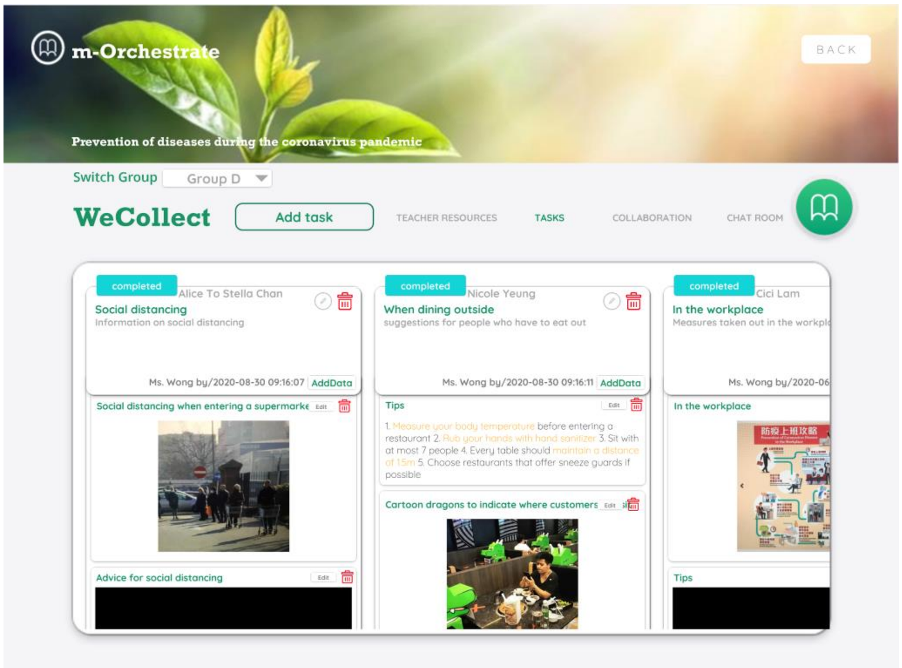

Figure 4. Tasks and collected data in WeCollect.

In the WeAnalyse phase, the students used spreadsheet and auto-generated diagram function to analyse data. Figure 5 shows that students in the Group D analysed the differences in lifetime and effectiveness between different types of masks (e.g., N95, medical mask, and cotton mask).

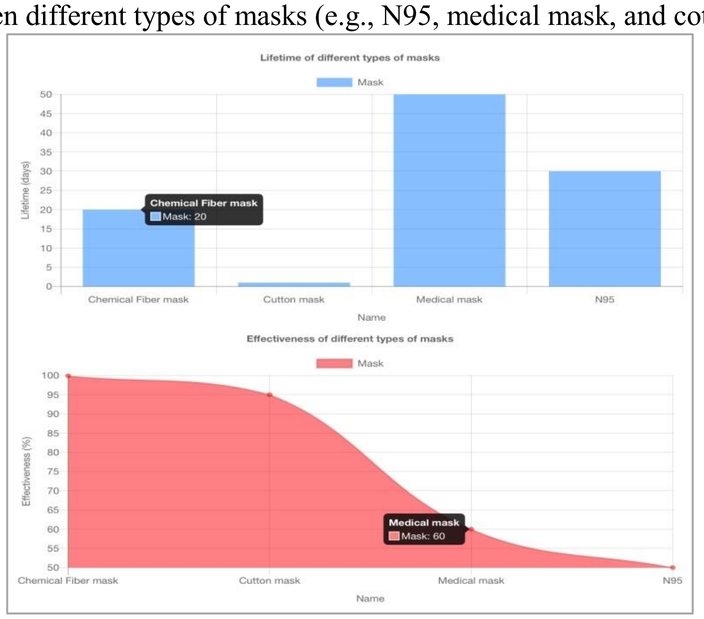

Figure 5. Results of data analysis of a spreadsheet in WeAnalyse.

In the WeExplain phase, they demonstrated the cause of coronavirus and some common types of masks in the slideshow to elaborate on their findings (see Figure 6).

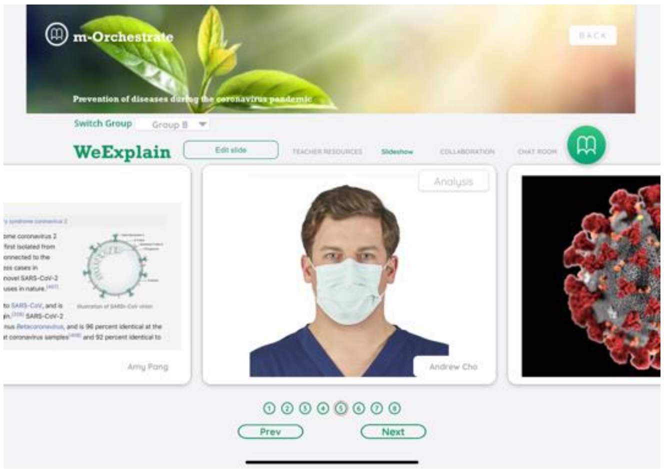

Figure 6. A slide show in WeExplain

In the WeReflect phase, they made reflections on what they know (K), what they want to know (W), and what they have learned (L) before and after the inquiry process continuously (see Figure 7).

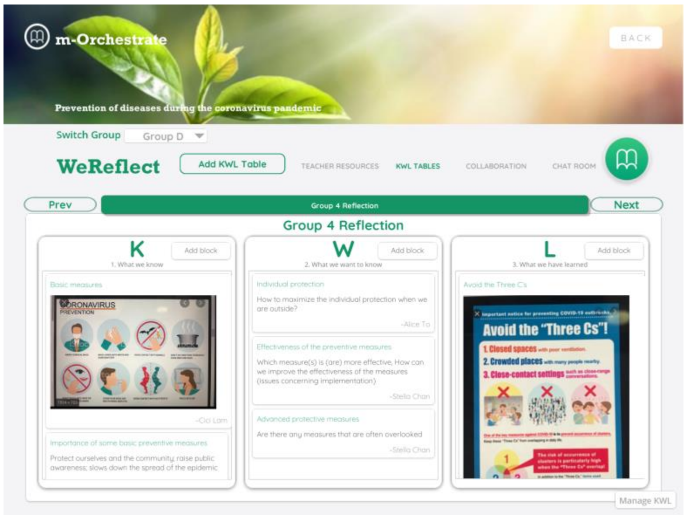

Figure 7. KWL tables in WeReflect.

5. Data Collection and Analysis

A sample of 21 students were involved in collaborative science inquiry during the outbreak of COVID-19 to evaluate the m-Orchestrate app. Data collection included a questionnaire and two focus group discussions. The questionnaire was developed to assess the students' perceptions of learning dashboard on the m-Orchestrate app. The English version questionnaire was adapted from the technology acceptance model (TAM) (Venkatesh & Davis, 2000) with 24 items in eight dimensions: perceived ease of use, perceived usefulness, attitude toward using the dashboard, social influence, facilitating conditions, self-efficacy, anxiety and behavioural intention. Responses were given on a five-point Likert-type scale, ranging from 1 for "strongly disagree" to 5 for "strongly agree". It is noted that the number of participants reported in the survey was 20 due to one invalid response.

The interview questions were constructed based on the eight dimensions of the survey with follow-up questions, aiming at understanding students' perceptions of the m-Orchestrate app for their collaborative science inquiry. A number of 17 participants were randomly chosen to be invited to the interview. Two interviews were recorded. Each of the interviews lasted about one hour.

In this study, both quantitative and qualitative data were collected for analysis. Student learning logs were used to explain the features of the dashboard on the app. Descriptive statistics were utilized to describe and compare the means with the assistance of SPSS version 26. Content analysis was used to analyse focus group interviews to triangulate the data about student perceptions of the app.

6. Results

6.1 Survey Results

The survey results are presented in Table 13. In this study, the Cronbach's alpha was 0.917, suggesting that the items have relatively high internal consistency (Cronbach, 1951). Overall, the results of the quantitative data analysis show that the students held neutral attitude towards the m-Orchestrate app with an average mean of 3.47(refer to Table 2).

Table 13. ***Descriptive Statistics of Students' Perceptions of m-Orchestrate App***

Items	N	Min	Max	Mean	SD
Perceived usefulness	20	1.67	5.00	3.58	.81
Perceived ease of use	20	1.33	4.67	3.43	.84
Attitude	20	1.75	5.00	3.65	.73
Social influence	20	2.00	5.00	3.55	.76
Facilitating conditions	20	2.33	4.67	3.67	.64
Self-efficacy	20	2.67	4.67	3.72	.58
Anxiety	20	1.67	3.67	2.70	.56
Behavioural intention	20	1.67	4.67	3.45	.85
Valid N (listwise)	20				

To be specific, the average means for the eight items were as follows: perceived usefulness (M=3.58, SD=.81), perceived ease of use (M=3.43, SD=.84), attitude toward using the app (M=3.65, SD=.73), social influence (M=3.55, SD=.76), facilitating conditions (M=3.67, SD=.64), self-efficacy (M= 3.72, SD=.58), anxiety (M=2.70, SD=.56), and behavioural intention (M=3.45, SD=.85).

6.2 Interview Results

In the two semi-structured focused interviews, 17 participants were randomly chosen to be invited. Each of the interviews lasted about one hour. In general, students held a positive orientation towards using the m-Orchestrate app to improve collaborative science inquiry.

In the focused interview, they listed several advantages and provided useful suggestions. The following interview results were constructed in terms of eight dimensions: perceived usefulness, perceived ease of use, attitude toward the app, anxiety, facilitating conditions, social influence, self-efficacy and behavioural intention.

As for the perceived usefulness of the m-Orchestrate app, all students believed five stages (WeEngage, WeCollect, WeAnalyse, WeExplain and WeReflect) embedded on the app is useful for collaborative science inquiry. Additionally, interviewees (pseudonyms were used) explained:

- *This app was very interactive. I was very clear about the division of labour in my group. When I encountered difficulties, I just left a message as a comment, my groupmates or teachers would reply to me. (Nick)*
- *In the WeCollect phase, we could divide labours and check each group member's responsibility. I think it was essential to teamwork. In addition, we could add videos, upload pictures, and record our voice to contribute the same inquiry task. It felt like a real collaboration moment! (Julie)*

Regarding the perceived ease of use, nine students held positive attitudes, while five students held neutral attitudes and one student reported it was not easy for him to use. They commented on "Mind map" and "analysing pictures and spreadsheets". Students said the Mind Map was useful in brainstorming, but it was not easy to add links between blocks. In addition, functions of analysing pictures and spreadsheets in the WeAnalyse phase were complicated which need more explicit guidance for students to use. About the interview question on students' anxiety when using the app, four students said they were anxious when they failed to upload videos and pictures because there was no message to tell them whether they upload successfully or not.

For the question of "how should the m-Orchestrate app be improved such that you will use it more frequently to support your learning?". In addition, Jack appreciated the function of Chat Room which supported students' synchronous communication on the app. However, he suggested that real-time notifications could be used to remind students, otherwise he would miss new messages from peers. In addition, Nick reported, "I noticed that there were three modes in the WeCollect phase: pending, in-progress and completed, and I felt frustrated to mark the completion status after completing every task." He suggested that these manual operations could be simplified.

As for the attitude towards the m-Orchestrate app in science inquiry, all students showed positive attitudes. They stated that it was fascinating that they could use the app to guide and support collaborative science inquiry. Students said they often got stuck on what they should do in an inquiry project. But the app helped divide the inquiry process into five phases, namely, WeEngage, WeCollect, WeAnalyse, WeExplain, and WeReflect step by step. The whole learning process was quite clear and logical, and it was easy to follow. However, 88.2% of students considered it would be better if a built-in guidance or demonstration video could be provided to grasp what the app can help them at a glance.

As for social influence, all students agreed that they would get motivated and adjust learning pace after checking group members' learning process on the m-Orchestrate app. Alice and Nick acknowledged that they could instantly see everyone's contribution on the project from the dashboard. Julie and Sandy stated that they could adjust their learning paces according to others' progress:

- *If other members have done their tasks but one team member was still working, we could ask him/her if he/she needs help. Teachers could also see the students who have not completed the task and give advice. (Julie)*
- *We could adjust the labour division to improve the whole group's efficiency if we found someone finished the required tasks very quickly. (Sandy)*

About the question on self-efficacy – Do you think you can use the m-Orchestrate app yourself for your inquiry learning without other's technical support? Most of the students (88.2%) thought it was not easy to use if there was no one around to tell them what to do. Therefore, guidance is necessary for the later implementation of the m-Orchestrate app to support primary students' collaborative science inquiry.

In terms of behavioural intention, all students stated that they understood the importance and meaning of team collaboration and acknowledged that the m-Orchestrate app could guide and motivate them to contribute more to the group project.

7. Conclusion and Future Work

This article reports on an evaluation study of enhancing pupils' science learning with the collaborative inquiry-based learning model, namely, WeEngage, WeCollect, WeAnalyse, WeExplain and WeReflect as a scaffold embedded in the m-Orchestrate app for students to conduct their online collaborative science inquiry. An evaluation study was conducted to understand students' perceptions on using the m-Orchestrate app for collaborative science inquiry during COVID-19. The results show that their perceptions were generally positive, and they reported that the app was useful for their collaborative learning. Students also provided useful suggestions for improving the app.

Future work focuses on refining the app and scaling up its implementation. Regarding of the feedback by participants, several critical bugs were identified (e.g., fail to upload videos and pictures and link between blocks in mind maps) and will be fixed up. A demonstration video will be made to instruct primary students at the beginning of using the app. For better experience of conducting collaborative science inquiry on the m-Orchestrate app during the outbreak of COVID-19, the functions to support remote collaboration will be considered, such as update notification and marking different users on their changes to the learning content.

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