Teaching Pupils to Design Comparative Experiments with Web-Based Inquiry Unit During COVID-19 Pandemic: A Pilot Study

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Abstract: The COVID-19 pandemic caused many students away from the classroom. Its affecting region was so large and the inquiry learning had to move to online from offline. Although many studies had investigated the effectiveness of web-based inquiry learning, few of them conducted that under the pandemic. The pandemic took many new characters into education, such as the demand for the Internet. Hence, we conducted the pre-posttest quasi-experiment to investigate the effectiveness of online science inquiry during the pandemic. Under the instruction of teachers online, 30 fifth-grade students (19 males and 11 females) in a Chinese city completed a web-based inquiry learning program in the Web-based Inquiry Science Environment (WISE) platform. The experimental design ability test (EDAT) was conducted before and after web-based inquiry learning as the pre-test and post-test. The students' attitude to web-based inquiry learning was also measured. The results showed, different from the studies before, the students' score on experimental design ability decreased after web-based inquiry learning, especially in Asking Questions and Making Hypotheses subscales of EDAT significantly. No significant gender difference was detected. The students showed not a high attitude toward web-based inquiry learning. The possible factors causing that results and implications were discussed.

1. Introduction
Since January 2020, large-scale new coronavirus pneumonia has swept the world. Due to September 30, 2020, there have been 34.16 million confirmed cases of COVID-19, including 1 million deaths according to WHO (https://covid19.who.int/). According to data released on the official website of UNESCO, due to September 30, Beijing time, the pandemic has affected the learning of about 851 million students worldwide, accounting for 48.7% of the total number of registered students in the world. When the epidemic was the worst, this proportion was even reached 90% (https://en.unesco.org/covid19/educationresponse/).

The epidemic has had a huge impact on global education, and the governments around the world took a series of actions to face this challenge. On January 27, 2020, the Ministry of Education of the People's Republic of China issued the "Notice of the Ministry of Education on the Postponement of the 2020 Spring Semester". It encouraged all localities to use the Internet and web-based educational resources to provide students with learning support and ensure that "classes are suspended without suspension of learning" (http://www.moe.gov.cn/srcsite/A06/s3321/202002/t20200212_420435.html).
However, science education during the pandemic still faced many problems. Science inquiry learning is vital in science education[1], and it is usually held in an offline environment. Under the effect of the pandemic, the inquiry learning had to move to online from offline. That was a challenge for both the teachers and students. Many problems associated with modern technology appeared ranging from downloading errors, issues with installation, login problems, and so on[2]. Also, the students were not familiar with this new learning method and could not interact with each other conveniently as they did in the offline environment[3]. 

Many studies had investigated the effectiveness of web-based inquiry learning[4–6], including the research of WISE (Web-based Inquiry Science Environment)[7]. However, few of them conducted that under the pandemic, which took many new characters into education, such as the demand for the Internet. 

Over time, education departments, schools, teachers, students, and parents have gradually moved from being at a loss at the beginning to gradually adapting to online learning methods. A variety of online teaching models emerge in an endless stream. The "Play instructional videos on TV" mode, the "Instructional live broadcast" mode, the "Teaching resource sharing" mode and the "Self-study + online Q&A" mode all provide better ideas for online teaching.[8] However, few studies especially focused on science inquiry learning online. Also, rare empirical studies investigated these models' effect to improve learning achievement.

Hence, this study aims to conduct a pre-post-test quasi-experiment to know whether online science inquiry learning in a hurry is feasible under such special circumstances and investigate the effect of web-based inquiry learning, on improving the students' experimental design ability. Also, we would like to give some suggestions and recommendations for web-based inquiry learning during a crisis-like situation.

In particular, this study aims to answer the following two research questions:

- Does web-based inquiry learning improve fifth-grade students' ability to design experiments during the pandemic?
- What is the students' attitude to web-based inquiry learning during the pandemic?

The hypotheses are as follows.

- The web-based inquiry learning could significantly improve the students' experimental design ability during the COVID-19 pandemic.
- The students hold a positive attitude toward web-based inquiry learning during the COVID-19 pandemic.

2. Method

2.1. Participants

Altogether 30 fifth graders (19 males and 11 females) of an elementary school were recruited to be the participants of the experiment by distributing posters online. The age of the students was 11 on average. All of the participants have a strong interest in online scientific inquiry courses and have the conditions for online learning at home. Also, they acquired the basic skills of using computers to learn.

2.2. Materials

Web-based Inquiry Science Environment (WISE) is an American inquiry-based science education special website resource funded by the National Science Foundation (NSF). It provides free online learning for students in grades 4-12 Science platform. WISE is the main result of the "Knowledge Integration Environment" (KIE) research project hosted by Professor Marcia. C. Linn of the University of California, Berkeley. The platform uses network technology to provide online discussion, data collection, and automatic Tools for drawing, freely proposing arguments, resource sharing, visualized data charts, real environment experiment simulations, etc. In the WISE platform, students can collect real-time data by controlling computer simulation experiments developed by NetLogo. At the same time, students can also use online forums to reach a consensus and explain the phenomena observed in the empirical data. After 25 years of careful iteration, the WISE platform has become the
The Thermodynamics Challenge WISE unit designed by researchers at UC Berkeley was translated into Chinese and modified according to Chinese Elementary School Science Curriculum Standard and fifth-grade students' learning capability. This unit is based on the theory of knowledge integration. Through the four steps of inducing ideas, adding ideas, distinguishing ideas, reflecting and organizing ideas, students were guided to conduct scientific inquiry. Students conducted scientific investigations by operating virtual simulations to simulate experiments (see Figure 1). Through the study of this unit, students can experience a complete scientific inquiry process: Asking questions, Making hypotheses, Designing and Implementing experiments to explore by using the NetLogo simulation model, and Drawing conclusions by collecting evidence and analyzing charts. The whole process could cultivate students' awareness of "thinking like a scientist" and improve their scientific inquiry ability and scientific literacy.

**Figure 1.** The interface of the Thermodynamics Challenge WISE unit

2.3. **Instruments**

2.3.1. **Experimental design ability pre-test and post-test.**

The instruments were adapted based on the questionnaire of Zhao et al[9]. We advised that in accordance with the requirements of scientific inquiry in the science curriculum standards of Chinese primary schools. Each test has two scientific inquiry questions about daily life. Do seeds need water for germination? Which glass fiber or cotton has a better heat insulation effect? Is air necessary for candles to burn? Which one is more helpful for language learning between concept map and mind map? Each question includes 5 items, corresponding to five dimensions of science inquiry, including Asking questions, Making hypotheses, Designing experiments, Implementing experiments, and Drawing conclusions. Each item scores 10. The difficulty level is designed to be similar between pre-test and post-test.

2.3.2. The survey of students' attitudes to web-based inquiry learning.

The instruments were adapted based on the attitude questionnaire of Nam et al[10]. We replaced initial contents with web-based inquiry learning and removed some unrelated items. The final survey includes 6 items and the students rate them from 1-5 according to a Likert 5-point scale. The content
of the questionnaire has been revised for several rounds of discussions with frontline teachers and subject experts and has certain expert validity. The Cronbach $\alpha = .691$.

2.4. Procedure
Ding Talk was chosen as our platform for communicating with students, because of its powerful functions, simple operation, and high public recognition in China. The researchers established a DingTalk group one day in advance and invited students to join the group. Also, the students were asked to download Google Chrome in advance to prepare for class. Pre-test and post-test were conducted before and after the learning at the Ding Talk group. At the beginning of unit learning, the lecturer spent ten minutes introducing the platform and projects to the students through the DingTalk video conference, guiding the students to log in and familiarize themselves with the platform. Next, we gave students two hours to independently explore the WISE platform. Meanwhile, the teacher would observe the students' exploration situation through the backstage of the WISE teacher terminal. When students encountered problems, the three teaching assistants would guide the students using DingTalk’s remote assisting function. After completing half of the unit, the teacher would show some typical errors about the students’ operations and ask them to analyze and discuss. After learning the whole unit, students needed to finish their research reports and shared their findings with the class by screen sharing.

3. Results
SPSS 25 was used to analyze the data, and the results are as follows.

3.1. Students' experimental design ability in total and subscales
To compare the students’ total experimental design ability, the paired t-tests were employed. The mean total scores of the pre-test and post-test were 55.00 and 48.75 ($t= -1.502, p=.147$). To compare the students’ experimental design ability in each dimension, the paired t-tests were employed respectively and the results are shown in Table 1.
It was found that the students obtained higher scores in Designing experiments and Drawing conclusions after the experiment, but not significantly ($t= 1.163, p=.257$; $t= 0.617, p=.543$, respectively). However, the students’ scores in Asking questions and Making hypotheses reduced significantly ($t= -2.460, p=.022$; $t= -2.769, p=.011$, respectively).

| Dimensions                  | Mean of pre-test | Mean of post-test | t      | p    |
|-----------------------------|------------------|-------------------|--------|------|
| Totally                     | 55.00            | 48.75             | -1.502 | .147 |
| Asking questions            | 11.25            | 7.08              | -2.460 | .022 |
| Making hypotheses           | 9.58             | 4.58              | -2.769 | .011 |
| Designing experiments       | 10.83            | 12.50             | 1.163  | .257 |
| Implementing experiments    | 10.83            | 10.83             | 0.000  | 1.000|
| Drawing conclusions         | 12.50            | 13.75             | 0.617  | .543 |

3.2. Gender differences in the experimental design ability
Significant differences between the boys and girls neither existed in the pre-test ($t = 1.981, p =.060$) nor appeared in the post-test ($t = 2.054, p =.052$). Also, we calculated the improved scores of different genders between the pre-test and the post-test and conducted the independent t-test. The results showed that no significant difference was detected between their improved scores ($t = .279, p = .783$). This supports that there is no gender difference when the students conduct experimental inquiry learning online. The results are shown in Table 2.
Table 2. Gender differences in the experimental design ability.

| Gender          | Mean of pre-test | Mean of post-test | t     | p    |
|-----------------|------------------|-------------------|-------|------|
| Male (N=15)     | 61.33            | 56.00             | 2.054 | .052 |
| Female (N=9)    | 44.44            | 36.67             | 1.981 | .060 |

3.3. Students’ attitude to science inquiry online

Students rated conducting science inquiry online (Likert scale from 1 to 5) with an average item score of 2.98, which was lower than the medium score 3. A summary of the attitude ratings is presented in Table 3. Interestingly, the students did not prefer web-based inquiry learning compared with traditional offline classroom (Mean=2.13, SD=0.900). That was the lowest score. However, the students also thought web-based inquiry learning was helpful to improve their academic performance with the mean rate of 3.77 (SD=1.135), which was the highest score.

Table 3. Results of science inquiry online attitude surveys (N=30).

| Items                                                   | Mean | SD  |
|---------------------------------------------------------|------|-----|
| I like this kind of web-based inquiry learning          | 3.00 | .910|
| Compared with this web-based inquiry learning method, I prefer the traditional classroom a | 2.13 | .900|
| Online inquiry can help me strengthen my interaction with teachers | 2.80 | .997|
| Online inquiry activities are not conducive to improving my academic performance b | 3.77 | 1.135|
| I actively participated in various tasks of online inquiry activities | 3.10 | .759|
| I think this web-based inquiry learning method is helpful to improve my comprehensive ability | 3.07 | .907|

a, b Reverse-scored items.

4. Discussion

There are numerous reasons why the effectiveness of Web-based inquiry may not yet be fully realized in the first post-test. For example, in general, online science inquiry learning requires a systematic training for teachers and students, but in this special period, the training cannot be carried out, and neither teachers nor students have relevant experience. Another restriction may have stemmed from Internet response delays, which are not uncommon during peak usage periods during the pandemic. With packet-based networks, variable delays cause latency problems in the receipt of graphic images and sounds [11]. Also, some students gave feedback that they could not hear the sound sometimes during class. This is another problem to affect the learning outcome.

The students' loss of focus on online learning is another important factor. The learners' loss of focus has become a vital factor to affect the success of online learning[12]. When teachers asked students to volunteer to answer questions online, nobody gave feedback actively. Also, the cameras of the students were almost off during class, although the instructor required them to keep cameras on at the beginning of the class. This inadequate interaction among students and teachers would lower the students' perceptions of learning in online courses[13], and the study may not be so focused on the class. The students' satisfaction with web-based inquiry learning is also attributed to the results. Studies show that students' satisfaction and relevance to the online course could affect their behaviors during learning online and even cause the students to terminate learn[14]. According to the attitude survey’s results, the students preferred the traditional classroom compared to the web-based inquiry learning. The low satisfaction with online learning would affect the students' engagement in learning online.
5. Conclusion and implications
To explore the effect of web-based inquiry learning during the COVID-19 pandemic, we investigated a pre-post quasi-experiment on WISE. Under the teachers' instruction online, the students completed an inquiry program. Also, a pre-test and a post-test were conducted to measure the students' understanding of the inquiry knowledge and their attitude to web-based inquiry learning. The results showed that no significant difference was detected in total scores between pre-test and post-test. Moreover, the scores reduced significantly in asking questions and making assumptions. Also, no significant gender difference was detected, which indicated males and females both could learn online.

As follows are the implications for practice to improve the effectiveness of inquiry learning online. First, we should extend the duration of the experiment in the future research so that the teachers and students could have more time to get used to the new technology. Second, the iteration of the course should be conducted to improve the quality. Although the course was designed carefully and revised by experts, some problems still existed during the class. Third, to address the problem of the bad condition of the Internet, the teachers could record the screen as well as teach lively. The recorded videos are accessible to the students after class so that the students with the bad condition of the Internet can also learn the same content as others.

Some limitations of this study are as follows. First, volunteer participants may not be representative of the target population, and findings from a small number of participants might restrict their generalization. Further studies with a larger sample size are necessary. Besides, a longitudinal study might shed further light on the effect of the instructional intervention used in this study.

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