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Research Article

Exploring the Effect of MBL Temperature Sensor and Group Cooperative Learning on the Science Practical Ability of Fifth Grade Students in the Heat-to-Matter Effect Unit

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Abstract

In 2014, the Ministry of Education of Taiwan released their Curriculum Guidelines for Year 12 Basic Education. The goal of the Guidelines is to cultivate the students' scientific literacy. The content design of the effect of heat on matter in the fifth grade comes from the activities in daily life. Due to the advancement of science and technology, the Microcomputer-based Laboratory (MBL) can assist students in studying science, so that the students can improve their practical ability. In addition, the Guidelines also emphasize teamwork, thereby enabling the students to develop better scientific literacy through interactive learning. This research design uses the MBL temperature sensor to integrate into the unit teaching, and conducts group cooperative learning, which is expected to promote them to learn science more efficiently. Through the evaluation results, it is found that the practical experience of integrating MBL temperature sensor into teaching can enable the students to have a better practical ability in their experimental prediction performance and their experimental planning performance.

Keywords: Microcomputer-based Laboratory (MBL); Group cooperative learning; Science practical ability; Learning performance

Introduction

The Ministry of Education [1] of Taiwan released the Curriculum Guidelines for Year 12 Basic Education. According to the Guidelines, the concept of curriculum development is fundamentally based on the spirit of holistic education, adopting the concepts of taking initiative, engaging in interaction, and seeking the common good to encourage students to become spontaneous and motivated learners, therefore the school education should follow the Guidelines, leading students to properly develop various abilities so as to interact with themselves, others, society, and nature, thereby helping them to apply and practice, and experience the meaning of life. According to the curriculum objectives, it must build students' scientific literacy, so that they will have scientific knowledge, inquiry and practical ability, and scientific attitude; at the same time, in real life, they can communicate effectively, participate in decision-making on social issues, and problem solving, etc., where problem solving refers to the ability to successfully handle events, its process includes four main items of inquiry and practice: problem discovery, planning and research, demonstration and modeling, and expression and sharing.

In order to carry out the teaching activities of inquiry and practice, the content design of the heat-to-matter effect unit in the fifth grade of elementary school in Taiwan comes from the activities in the students' daily life. At the same time, through the progress of the course, the students are encouraged to understand the concept of temperature, and the effect of heat on the temperature change of substances, in this teaching process, traditional thermometers are still used. Due to the advancement of technology, the Microcomputer-Based Laboratory (MBL), like a laboratory using digital tools, can help students learn science, and also allow them to have the experience of doing science [2,3] such as the MBL temperature sensor, which enables students to use better, faster, and more accurate temperature measuring instruments, and improves their practical ability to study science [4].

In point of fact, the specific connotation of the core competencies in the Guidelines also emphasizes the interpersonal relationships and teamwork, especially the ability to understand the feelings of others and be willing to interact with their peers. In primary school science teaching, group learning is often carried out in teams. From the perspective of social constructionism [5], this is a very important learning field. Students learn through interactions with each other and the construction of scaffolding, allowing them to develop better teamwork in the Zone of Proximal Development (ZPD) [6].

The purpose of this study is to observe as to whether the students can use the MBL temperature sensor and whether they are under the influence of group cooperative learning in the study on the heat-to-matter effect unit, and to better understand their performance of scientific practice learning ability in this unit.

Research motivation and purpose

During COVID-19, we have felt the pressure brought by the epidemic, but have also realized the impact of scientific and technological progress. Taking temperature measurement as an example, the temperature sensors around us are usually digital temperature sensors, and traditional glass tube thermometers are rarely used; however, in classrooms this glass tube thermometer is still used.

The temperature sensor is an MBL used for temperature measurement in life, which makes the MBL measurement tool that allows the students to have more teaching opportunities for active exploration [3]. According to [4,7] , the main educational advantage of the MBL system is that experimental data can be collected at any time, and this data is also immediately available for analysis and display, therefore, the students can easily generate large amounts of data and analysis results in experiments in a short period of time. Not only that, the MBL system increases the data capacity and flexibility, giving students more opportunities to explore and learn through investigations. [8] Showed that the simultaneous display of graphics by MBL can help students retain the interpretation results in their long-term memory because of the simultaneous and salient nature of the graphics. This turned out to be true, as a 20-second delay in the display of the graph would affect the students' performance. In a student chemistry experiment, [9] observed that the MBL group was able to focus on the interpretation of what was happening rather than remembering past data.

Further, there are also studies from a qualitative point of view, through Vygotsky's theory, which regards tools as important moderators, and examines how technological tools mediate students' science learning in interaction [10]. However, some scholars have compared MBL with Simulation-Based Laboratories (SBL) and found that MBL tools have obvious benefits to students' learning in many aspects [11].

There is little research on the usage of MBL tools in general courses. At present, the usage of traditional glass tube thermometers as measurement tools in the science courses of elementary schools may be incorrect in operation or inaccurate interpretation, which hinders the students from learning the course content. If elementary school students can also use the MBL temperature sensor as a tool for understanding science, it will be more helpful for their learning, and at the same time, solve the instructional difficulties of teachers.

Cooperative learning, on the other hand, is teaching students to work together in small groups and to facilitate their own and others' learning [12]. Not only that, by arranging a suitable group learning environment, at the same time, teachers will demonstrate the skills of interaction and cooperation, and guide the students to rely on each other, help and share resources, so that everyone in each group should take responsibility for learning [13].

In addition, the motivation theory proposed by [14] emphasizes that in the operation of groups, the usage of cooperative structures can increase the chances of success of low-achieving students, through peer encouragement and teacher rewards, to meet the affiliation between individuals, and the psychological needs of interaction can trigger the students' learning motivation. From the perspective of social interaction, through the interdependence of learning outcomes and methods, groups must work together so as to enhance the students' learning performance and interests [12]. Also, in social imitation theory, [15] believed that human beings learn by observing and imitating each other, and cooperative learning can improve their learning opportunities.

Since the Curriculum Guidelines in the field of natural sciences [16] emphasizes the core competencies, it is hoped that in addition to basic knowledge, students can also know how to apply them practically to solve problems in life as "*student performance*" and "*learning content*" in the curriculum are closely related. The former refers to the learning performance of the students' scientific inquiry ability and scientific attitude when they are expected to face science-related issues at various learning stages; the latter shows their understanding of science knowledge as a necessary starting point in the process of inquiry and problem solving. Since the ability of inquiry can be regarded as problem solving, the teaching implementation should aim at cultivating the students' ability to solve problems. The planned learning activities should be centered on problem-solving strategies, and follow the steps of identifying problems, collecting relevant information, formulating solutions, selecting and implementing of solutions, followed by program evaluation and improvement procedures for meaningful instruction.

In the above discussion of problem solving, [17,18] pointed out that due to the development of modern information transmission, the previous focus on the acquisition of knowledge and skills has increased the ability to learn and solve problems. These changes all show that people are faced with their living environment. Therefore, the most effective way to cultivate students' problem-solving ability is to let them be responsible for their work and to solve problems by themselves. In order to evaluate these abilities, [19] used written products to demonstrate the students' performance on practical assessments, and used the teacher development rubrics to evaluate their performance expectations. Not only that, according to the backward design of teaching activities [20], the teacher's role in evaluating should be an assessor and setting rubrics to judge the overall performance of the students' work. Therefore, the practical evaluation strategy can be designed by teachers to simulate the situation, so that the students can actually participate in the experimental operation or observation in the situation, solve problems in the form of group thinking, and at the same time, according to the students' performance in the practical process, using objective rubrics so as to measure practical performance.

Research purpose and questions

The usage of the MBL temperature sensor integrated into the teaching, and the interaction of the students in group cooperative learning, both highlight the uniqueness and importance of research in this teaching field. Aiming at the MBL temperature sensor integrated into teaching and group cooperative learning, the purpose of this research is to better understand the scientific practice ability performance of fifth-grade students in elementary schools in the heat-to-matter effect unit. Through this research, it is expected to promote students to be more efficient in the science of learning. Therefore, the most important question of this study is: in the heat-to-matter effect unit, what impact does the MBL temperature sensor integrated into the teaching and group cooperative learning have on the fifth grade students' scientific practice ability?

Research Methods and Design

The teaching science content of this study is the heat-to-matter effect unit in the fifth grade of elementary school. It is divided into three parts: the first part is the change of matter after heating, including the volume change of liquid, gas, and solid after heating; the second part is the propagation of heat, including heat conduction, heat convection, and heat radiation; the third part is heat preservation and heat dissipation. In the general traditional teaching design, tactile cold and heat or a glass tube thermometer is used as the basis for sensing temperature; for example, in the heat conduction activity, the teaching activity requires students to touch the iron rod to perceive that it is hot, as the plastic rod does not feel hot. While the students who use the MBL temperature sensor measure and record the temperature change; for example, part of the teaching concept map is as shown in (Figure 1).

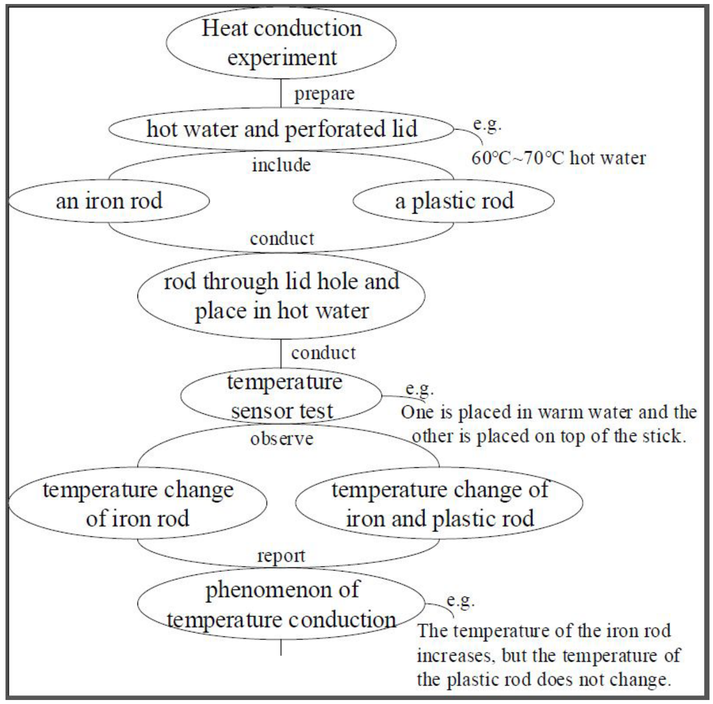

Figure 1: Teaching concept map of MBL temperature sensor integrated into teaching (Example).

In addition, in the teaching process of group cooperative learning, it is divided into four stages. First, the learning tasks are explained before each experimental activity; secondly, after the students understand the learning tasks and their responsibilities, they start the learning activities; thirdly, the teacher walks between the groups to assist those who need assistance; finally, to carry out teaching activities of evaluation and reflection [21]. The main teaching field of group cooperative learning is in the classroom, with the experimental table as the grouping unit, allowing the students to have the opportunity to interact with their peers.

To sum up, this study is concerned with two factors: the MBL temperature sensor integrated into teaching, and the group cooperative learning. This research adopts the quasi-experimental research method, and the evaluation content is mainly based on the students' scientific practice ability; the part about the evaluation of scientific practice ability is to present questions on paper by means of interviews, and for students to use their own perspectives, and then write out the process of inquiry to achieve the purpose of introspective, communicative, and minds-on [19], and then the assessment data will be based on rubrics converted to quantitative data for further analysis.

Research object and research design

In this study, group teaching of 422 students in 16 classes in fifth grade was conducted in the classroom. The group experimental design of this study: the MBL temperature sensor integrated into teaching and the group cooperative learning (MBL-cooperative group), with 154 students in six classes; the MBL temperature sensor integrated into teaching but no group cooperative learning (MBL group), four classes with 109 students; only group cooperative learning without the MBL temperature sensor integrated into teaching (cooperative group), three classes with 79 students; finally, neither the MBL temperature sensor integrated into teaching nor the group cooperative learning (control group) , 80 students in three classes. This study hopes to understand whether there are differences in the learning of the four groups during the research process? After the teaching activities, this study conducts the assessment of scientific practice ability. The experimental design of this study is as shown in (Table 1).

Group	Experimental treatment	Post test
MBL-cooperative group	X_1 X_2	O
MBL group	X_1	O
cooperative group	X_2	O
control group		O

Table 1: The experimental design of this study.

X_1 is the MBL temperature sensor integrated into teaching, X_2 refers to group cooperative learning, and O is the assessment of scientific practice ability of the heat-to-matter effect unit. The MBL temperature sensor used in the research is the PS-2125 temperature sensor produced by PASCO, and used in conjunction with the tablet computer; instead of using the MBL equipment, the cooperative and control group used their hands to touch the conductive substances or used a glass tube thermometer to measure the temperature.

Teachers who participated in the actual teaching of this study had to go through an 8-hour workshop first. In the study, teachers should first fully understand the usage of traditional glass thermometers and MBL temperature sensors in teaching activities, and introduce the characteristics and implementation of the cooperative learning methods. The course also allows the teachers to conduct practical instructional exercises, with three researchers' observing the teachers' performance and then give guidance as and when required.

Evaluation Research Tools

There are nine steps in the development process of the assessment of scientific practical ability used in this study. First, organize the research team, including a science education professor and five science teachers and science tutoring researchers, to conduct evaluation, discussion, and compilation; secondly, using the main axis of practical evaluation of the situation, design a situation in which the ice cubes gradually melt in the water; third, carry out a two-way coding of students' learning performance, and design scientific practice ability assessment questions; fourth, after each discussion, select the student's trial work, then revise and rewrite the assessment to determine the arrangement of the sentences; fifth, after three classes of pre-tests, and then discussion, establish rubrics; sixth, teaching 16 classes respectively; seventh, after teaching, carry out the students' assessment of scientific practice ability; eighth, according to the rubrics, convert the students' writing assessments into quantitative data; ninth, after the evaluation and analysis, the teacher should give feedback on the students' learning in the classroom.

The evaluation content of the scientific practice ability in this study is divided into two parts. The first part is the expected performance of the students in thinking about imaginative creation in intelligence, which is the ability to imagine what might happen based on known scientific knowledge and scientific methods (Experimental predicted performance, C1). The second part is the planning and execution of problem-solving, including that students can plan simple exploration activities (Experimental planning performance, C2), students can think about and operate suitable items, equipment, instruments, and other resources (Equipment readiness performance, C3), students can carry out measurement and detailed records (Document planning performance, C4), students use rational intelligence to reason (Reasoning ability performance, C5). Students are expected to connect the scientific phenomena they observe and record with the knowledge they have acquired, and to put forward their own ideas.

The reliability of the assessment of the scientific practice ability of this study was examined by the correlation between the intra-rater and the inter-rater. Students from three classes were selected and scored by two trained teachers, and the intra-rater reliability was verified using the intraclass correlation coefficient (ICC). The same case was evaluated twice by the evaluator, and the interval between the two evaluations was within one week. The ICC values of the two evaluators were equal to 0.965 and 0.964, both of which were $\geqq 0.75$, indicating good intra-tester reliability. Then, Krippen dorff's α coefficient was used to measure the consistency of the raters. Krippen dorff's α was 0.934, which can be said to have a fairly stable consistency in the evaluation of this practice.

Research result

According to the design of this study, two factors need to be considered at the same time, one is the MBL temperature sensor integrated into teaching, and the other is the group cooperative learning. A univariate two-way analysis of variance was used to explore and understand the learning performance of the fifth-grade students on the assessment of scientific practice ability in this unit.

In order to understand whether there is an interaction between the MBL temperature sensor integrated into teaching and group cooperative learning, a univariate two-factor analysis of variance was completed with the performance of the scientific practice ability assessment as the response variable. The results are as shown in (Table 2).

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Temperature sensor integrated into teaching	205.16	1	205.16	66.35	.00*
Group cooperative learning	4.59	1	4.59	1.49	.22
Temperature sensor integrated into teaching* Group cooperative learning	32.71	1	32.71	10.58	.00*
*p＜.05					

Table 2: Two-Way ANOVA results based on MBL temperature sensor integrated into teaching and group cooperative learning.

According to the statistical results in Table 2, there is a significant interaction effect (F=10.58, p < .00) in the overall total score of the scientific practice ability assessment. It can be found that whether the MBL temperature sensor is integrated into teaching, and/or whether it is grouped in cooperative learning, there is a significant interactive effect.

Next, comparisons of pure main effects were performed to understand where the main effects occurred. First, based on whether the MBL temperature sensor is integrated into the teaching as the classification basis, and then based on whether the group cooperative learning is used as the classification basis, the independent sample t-test analysis of the group cooperative learning and the MBL temperature sensor integrated into the instruction is carried out, respectively, as shown in (Table 3).

		N	Mean	SD	t	df	Sig. (2-tailed)
MBL temperature sensor integrated (yes)	MBL-cooperative group	154	12.48	1.43	1.49	170.11	.14
	MBL group	109	12.12	2.23			
MBL temperature sensor integrated (no)	Cooperative group	79	10.46	1.72	-2.99	157.00	.00*
	Control group	80	11.25	1.63			
group cooperative learning (yes)	MBL-cooperative group	154	12.48	1.43	9.53	231.00	.00*
	Cooperative group	79	10.46	1.72			
group cooperative learning (no)	MBL group	109	12.12	2.23	3.09	187.00	.00*
	Control group	80	11.25	1.63			

*p＜.05

Table 3: Simple main effect analysis of scientific practice ability assessment.

According to Table 3, there was a significant difference between the cooperation group and the control group in the absence of the

MBL temperature sensor integrated into teaching ($t = -2.99$, $p < .05$). However, there was no significant difference between the MBL-cooperative group and the MBL group with the MBL temperature sensor integrated into teaching ($t=1.49$, $p=.14$). Then, whether or not in the case of group cooperative learning, the MBL temperature sensor integrated into the teaching reached significance ($t = 9.53$, $p < .05$ and $t = 3.09$, $p < .05$), that is, the MBL temperature sensor integrated into teaching had significant differences in the performance on the assessment of scientific practice ability. From this table, it can be found that regardless of whether or not group cooperative learning, the MBL temperature sensor integrated into the teaching has a better performance on the total score of scientific practice ability evaluation.

In order to find out whether the MBL temperature sensor integrated into the teaching and group cooperative learning had an interaction effect on each item in the assessment of scientific practice ability, the performance of each item was used as the response variable, and the multivariate two-factor variance was calculated, as shown in (Table 4).

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Temperature sensor integrated teaching* Group cooperative learning	Experimental predicted performance (C1)	6.58	1	6.58	9.78	.00*
	Experimental planning performance (C2)	6.68	1	6.68	11.43	.00*
	Equipment readiness performance (C3)	.16	1	.16	.96	.33
	Document planning performance (C4)	.04	1	.04	.16	.69
	Reasoning ability performance (C5)	.63	1	.63	.83	.36

*$p < .05$

Table 4: Two-Way MANOVA results based on MBL temperature sensor integrated into teaching and Group cooperative learning.

According to (Table 4), the statistical results of the MBL temperature sensor integrated into the teaching and group cooperative learning in the assessment of the scientific practice ability, experimental predicted performance (C1) ($F = 9.78$, $p < .05$) and experimental planning performance (C2) ($F = 11.43$, $p < .05$), there was a significant interaction effect, so the two items were tested for pure main effects, respectively.

In terms of Experimental predicted performance (C1), firstly, whether the MBL temperature sensor integrated into teaching is used as the classification basis, and then whether the group cooperative learning is used as the classification basis. The verification analysis is as shown in (Table 5).

		N	Mean	SD	t	df	Sig. (2-tailed)
MBL temperature sensor integrated (yes)	MBL-cooperative group	154	2.84	.93	1.32	261.00	.19
	MBL group	109	2.69	.97			
MBL temperature sensor integrated (no)	Cooperative group	79	2.01	.47	-4.15	146.31	<.00*
	Control group	80	2.38	.62			

Group cooperative learning (yes)	MBL-cooperative group	154	2.84	.93	9.09	230.93	.00*
	Cooperative group	79	2.01	.47			
Group cooperative learning (no)	MBL group	109	2.69	.97	2.70	184.15	.01*
	Control group	80	2.38	.62			

*p＜.05

Table 5: Analysis of simple main effects of Experimental predicted performance (C1).

According to the statistical results in (Table 5), it was found that in the absence of the MBL temperature sensor integrated into teaching, there was a significant difference in the Experimental predicted performance (C1) between the cooperative group and the control group in the assessment of scientific practice ability ($t = -4.15$, $p < .05$). From this table, it can be found that t is a negative value, that is, in the case of no MBL temperature sensor integrated into the teaching, the Experimental predicted performance (C1) of group cooperative learning does not have a better performance.

Then, there were significant differences in the Experimental predicted performance (C1) of each group with or without the group cooperative learning and the MBL temperature sensor was integrated into the teaching ($t = 9.00$, $p < .05$ and $t = 2.70$, $p < .05$). From this table, it can be found that, regardless of whether the group cooperative learning is adopted or not, the Experimental predicted performance (C1) of each group in which the MBL temperature sensor is integrated into the teaching has the better performance.

Next, in the Experimental planning performance (C2) section, a comparison of pure main effects was performed. First, based on whether the MBL temperature sensor was integrated into the teaching as the classification basis, and then based on whether the group cooperative learning was used as the classification basis, the independent sample t-test analysis of the group cooperative learning and the MBL temperature sensor integrated into the teaching was carried out, respectively, as shown in (Table 6).

		N	Mean	SD	t	df	Sig. (2-tailed)
MBL temperature sensor integrated (yes)	MBL-cooperative group	154	3.12	.67	1.66	178.80	.10
	MBL group	109	2.94	.97			
MBL temperature sensor integrated (no)	Cooperative group	79	2.51	.68	-3.16	157.00	.00*
	Control group	80	2.85	.70			
Group cooperative learning (yes)	MBL-cooperative group	154	3.12	.67	6.63	231.00	<.00*
	Cooperative group	79	2.51	.68			
Group cooperative learning (no)	MBL group	109	2.94	.97	0.75	187.00	.46
	Control group	80	2.85	.70			

*p＜.05

Table 6: Analysis of simple main effects of Experimental planning performance (C2).

According to the statistical results in (Table 6), without the MBL temperature sensor integrated into the teaching, there was a significant difference in the Experimental planning performance (C2) of the scientific practice ability assessment between the cooperation group and the control group ($t = -3.16$, $p < .05$), because t is a negative value, that is, without the MBL temperature sensor integrated into the teaching, the Experimental planning performance (C2) ability of the cooperative group using the group cooperative learning method was not better.

In contrast, in the case of group cooperative learning, there was a significant difference in the MBL-cooperative group and the cooperative group in the Experimental planning performance (C2) whether the MBL temperature sensor was integrated into the teaching ($t = 6.63$, $p < .05$). From this table, it can be found that the Experimental planning performance (C2) of the MBL-cooperative group had a better performance when the group cooperative learning was adopted and the MBL temperature sensor was integrated into the teaching.

According to the above test of students' assessment of scientific practice ability, it can be found that the MBL temperature sensor was integrated into the teaching, whether or not the intervention of group cooperative learning, the fifth grade students' performance in the Experimental prediction performance (C1) and Experimental planning performance (C2), all have good scientific practice ability.

Discussion and suggestion

The MBL temperature sensor is integrated into the teaching, which can play a greater role and carry out a better problem-solving teaching plan

In the teaching activities of this research, the questions predicted by the students are used at the beginning of the activities. For example, taking the change of material after heating, in teaching, ask: Where do we need to use the heat generated by fire? What is the difference between before and after the food is heated? Do common substances in life change the same as food when heated? What happens to the water when it is heated? There are also predictions that accompany experimental planning questions. For example, will the volume of water change after being heated? How to prove it? Or, the experimental planning that triggers the application in the experiment, for example, what method is used to make the copper ball unable to pass through the copper ring? In addition, there are many situations in which temperature measurement is important when students and teachers are conducting experimental activities. For example, the water temperature does not need to be too high, about 60°C, because teachers need to remind students to pay attention to safety when operating so as to avoid burns. The temperature of the cold water is about 15°C. If ice cubes are used, the change will be more obvious. Also, after the copper balls and rings are heated, the temperature is very high, so the students should be very careful and so on.

In the activity of integrating the MBL temperature sensor into the teaching, students can easily measure the temperature change before and after heating food, the temperature change before and after water heating, the temperature change before and after heating the copper ball and the copper ring, etc. This MBL experimental equipment can be operated very practically, and its temperature changes can be detected by the curves and figures displayed by the experimental results, and the changes of the found temperature and entities can also be specifically conveyed. In contrast, in the general traditional teaching activities, the students sense the temperature changes by touch or with a glass tube thermometer, and in the experimental activities, the students are required to convey the temperature changes before and after each experimental activity. Although the students will specifically say: the food is hot, the water is hot, the iron rod is hot, but the plastic rod does not feel hot, etc., the students may not be able to express the temperature changes they perceive with specificity and confidence. Therefore, once the students are asked to explain how to measure the prediction performance of the temperature change after the ice cubes are added to the water in the scientific practical ability assessment, they can be very specific because of the practical experience of integrating the MBL temperature sensor into the teaching, as well as actually showing the ability of its experimental prediction performance.

Further, because the MBL temperature sensor was integrated into the teaching activities, the students used the specific MBL sensor to carry out experimental activities. They did know the temperature of the MBL sensor in food, water, copper balls, and etc. measurement process. So that in their experimental planning performance of scientific practical ability evaluation after the ice cubes are put into water, students can list the experimental planning of the MBL sensor test equipment and other related experimental materials in a very specific manner. In this way, the MBL temperature sensors integrated into the teaching can improve the students' problem-solving performance.

Moreover, in the case of learning with a traditional glass thermometer, the cooperative learning group showed less significant learning performance. This may be because the interaction between the students affected the teaching, or the glass tube thermometer was not easy for students to observe the temperature changes, and they want to have exclusive usage of the temperature measurement equipment. Not only that, in the in-depth discussion of each project, it was also verified in the Experimental predicted performance (C1) and the Experimental planning performance (C2).The performance of prediction ability belongs to the imagination and creation of thinking intelligence in the ability of inquiry. It points out that students are better able to predict things that may happen based on known scientific knowledge and scientific methods; in the Experimental planning performance (C2), the MBL temperature sensor is integrated into teaching, which can play a greater role and carry out better problem-solving planning and execution.

Discussion of group cooperative learning in the integration of the MBL temperature sensor into the teaching situation

In terms of individual factors in the natural science teaching situation, whether the MBL temperature sensor is integrated into teaching and group cooperative learning can enhance students' learning. However, teaching at the same time will reveal some differences in the performance of practical ability, and there is a subtle interaction between the two factors. The MBL equipment allows the teachers to focus on the timing and steps of the students to use measurement tools correctly, but it limits their interaction and increases the pressure to use the equipment. In the implementation process of group cooperative learning, the interaction between students or between teachers and students is a process of change and growth, and each class may be different. Therefore, although teaching science in elementary schools is carried out in groups, teachers should still judge the applicability of students' learning based on their professional knowledge, and should always pay attention to the shortcomings and limitations of group cooperative learning.

Discussions and suggestions on research

The design of the scientific practical ability assessment situation of the heat-to-matter effect unit can be close to the real life of students, that is, by observing the melting situation of the ice cubes in the cup in the scientific practical ability assessment, students are expected to make predictions, and then planning experiments to verify the predictions, that is, the attempt to use the problems that may arise in life to induce the students to learn, is consistent with the learning performance desired to achieve the Guidelines.

In this study, there are experimental activities in conduction, convection, and radiation in the heat-to-matter effect unit. In the initial teaching activities, tactile or glass tube thermometers were used as measurement tools. Now, we try to provide a new MBL in the teaching. The temperature sensor is used to help students construct scientific concepts and let them experience the feeling of being a scientist. It is a convenient and quick tool, which can repeat experiments and is easy to operate safely. When students ask themselves "*what if*?" they can use the MBL tools to take immediate action on their question and see the results. Integrating the MBL tools into the teaching activities can encourage students to create and answer their own hypothetical questions, proactively explore, measure, and allow them to spend less time collecting data and more time focusing on critical thinking, problem solving, and self-monitoring and other skillful activities that enable students to demonstrate their scientific ability to learn.

In addition, the practical performance evaluation of this study, besides emphasizing the connection with the teaching material content and the evaluation in real situations, also hopes to find an effective way to collect the students' practical performance data. Science practical ability assessment can measure the students' real ability to promote meaningful learning, but the cost of time, space, manpower, and material resources is far more than the general paper-and-pencil test, which is the reason why teachers are hesitant to move forward. Furthermore, although the writing evaluation of this study is also a pen and paper expression method, students can make authentic learning reactions to their own thinking and design, so that the test and scoring do not need to consume a lot of the interview evaluation costs. In practice, it is generally possible to carry out the evaluation method of authenticity.

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