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RESEARCH ARTICLE

The narrative inquiry of a science teacher's experience of developing physics experiments: from a mere conveyer to a dynamic collaborator

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ABSTRACT

This research aims to study a science teacher's experience in developing physics experiments through narrative inquiry. The participant is a Korean secondary school science teacher who was in graduate school as a student studying gifted education. The data was collected over approximately 9 months. Collected data include observation of the participant's module participation, in-depth and periodic interviews, and the participant's assignments. The research outcomes are as follows. Firstly, the atmosphere of the modules was permissive and harmonious. As one of the student-teachers, she could ask and discuss freely. Secondly, she could develop physics experiments from her 'own curiosity'. This might influence her position to change from rather passive to active. Thirdly, she could be able to achieve scientific inquiry as a student and a teacher. Fourthly, through hands-on activities, by applying researcher', student's, and teacher's point of view, her profession as a science teacher has been strengthened. Lastly, Teacher A's experience appeared meaningful in terms of enhancing teacher efficacy. The experience of developing the physics experiment became a turning point for her from a mere information conveyor to a dynamic collaborator.

Key words: Developing physics experiments, narrative inquiry, scientific inquiry, science teacher education

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Introduction

In science education, the importance of experiments has been emphasised in terms of their effectiveness and function (Hofstein & Lunetta, 2004). Experiments verify and generalise hypotheses, defined as a specific observation or manipulation of nature (Lawson, 1995). Experiments in science education are called 'experimental classes'. This refers to learning experiences that are part of science education activities in schools (Hofstein & Lunetta, 2004). According to Wolfinger (2000), in experimental classes, students search for evidence to support or deny hypotheses. Beyond the simple manipulation of activities, time 'before' and 'after' the experiment in terms of 'learning scientific concepts and reviewing results' (Chin, 2003; Friedrichsen, & Thomas, 2003, authors' emphasis).

In science education, experimental activities are recognised as one of the effective teaching strategies (Hodson, 2005; Kipnis & Hofstein, 2007), as it requests learners' hands-on activities. According to Yang et al. (2006), to join in an experiment, learners touch the materials and tools in their hands. At the scene, they interact with experimental materials and tools. In addition to this, they observe and understand phenomena in experiments.

Science education values the 'process', that is, scientific inquiry. In scientific inquiry, students need to focus on the research 'process' rather than getting the right answer (Harwood et al., 2002, authors' emphasis). Through exposure to the actual experimental process, students could improve their cognitive development, problem-solving skills, inquiry skills, and experimental skills by participating in the research process (Hofstein & Lunta, 2004).

The success of science education in schools could be largely determined by the expertise of science teachers (Oh et al., 2008). Teacher expertise in science could be expressed in terms of qualities, roles, and capabilities of their scientific inquiry. To be an expert science teacher, therefore, these components should be possessed (Friedrichsen & Thomas, 2005; Krell et al., 2020; Mulholland & Wallace, 2005; Van Driel et al., 2001, 2002; Zohar, 2004). Teacher expertise in science education could be defined by one's scientific inquiry competency. There is ongoing research (Lee & Yang, 2020; Rushton & Reiss, 2019; Tatto, 2021) exploring the required teacher expertise in research and experimentation in science education. This expertise includes not only the basic abilities of experimental performance (Sim, 2006; Yang & Kim, 2021), but also various aspects of teacher research proficiency, such as sensitivity and vision to identify research problems, ability to structure research, data processing and analysis skills, and clear language communication (Kwak & Hong, 2022), the scientific inquiry.

This is not limited to a science teacher's competence itself. It is crucial as these components influence the science teacher's teaching activities. The investigative ability and expertise of science teachers affect the form of students' experimental activities (Harlen, 2004), and therefore, could expand the boundary of students' learning from knowing the experimental procedure to perceiving scientific inquiry. In terms of the professional performance of science teachers in practice, scientific inquiry skills would be considered as the utmost aspect as they could be achieved and enhanced by accomplishing professional knowledge and professional performance in practice (So, 2003).

According to Alake-Tuenter et al. (2012), science teachers who have professional skills could promote students' scientific inquiry, which is related to the ability to develop experiments. Professional science teachers consider all of the experimental activities and processes as an important aspect (Millar et al. 2002). The actual participation of students is crucial as well. So, when a science teacher plans a class through an experiment, each experimental activity is expected to be carried out by the students themselves. In science classrooms, through hands-on activities, students could design their experiments to find answers to the tasks consistently considering the purpose of the task. In the scene, science teachers should be able to lead the students to see the whole procedure of the experiment in a systematic way (Millar et al., 2002). Through participation in scientific experiment activities (Girault et al., 2012; Karelina & Etkina, 2007), students could achieve knowledge and attitudes toward logical connections of science. Promoting metacognitive thinking and analytical thinking, understanding scientific concepts, and acquiring procedural knowledge (Koretsky et al., 2008; Marzin & de

Vries, 2008) are available through hands-on activities with professional science teachers' guidance. Their knowledge and beliefs about experimentation and assessment have an impact on the effectiveness of science learning (Hofstein & Lunetta, 2004) in terms of expanding students' views toward science.

To be a professional science teacher, the subject of inquiry and materials used in the experiment should be appropriate for students' level and capacity. When creating experimental assignments, science teachers should consider not only the objectives of the experiment but also the whole procedure and phenomenon of the experiment so that the students could think about them carefully and expand their understanding.

Despite the importance of actual, hands-on, experimental activities in terms of achieving scientific inquiry as a professional, and strengthening teacher expertise and efficacy, in the real world, cookbook-style experiments (Domin, 2007) have been done. The students in the classroom would simply perform experiments by following the given process to achieve the goal, and such experiments only promote low-level cognitive skills, and the students would not consider the laboratory as a place that could develop their problem-solving skills (Hart et al., 2000). There could be various reasons for this tendency. Firstly, teachers did not learn science in practical ways. Studies on science teachers' experiment experience and scientific inquiry (Crawford, 2000; Keys & Bryan, 2001) have shown that the development of pre-service and in-service science teachers' expertise was significant through inquiry-based scientific hands-on activities (Baek & Kim, 2011; Baek et al., 2015; Jeon et al., 2009; Ko & Lee, 2014; Kwak, 2009; Lee et al., 2010; Lee & Yang, 2020; Oh & Cho, 2010). Due to a lack of experience with the actual scientific inquiry process during teacher training, science teachers are often revealed as not confident instructors of experimental lessons (Crawford, 2000; Jin & Jang, 2007; Windschitl, 2002; Yang et al., 2006; Zacharia, 2003). Secondly, teachers themselves do not possess scientific inquiry as rather than curiosity about science experiments, they care more about the written facts of knowledge. In some cases, pre-service teachers who have completed experimental courses often appeared to have a poor understanding of inquiry (Baek et al., 2015), and in-service teachers who have not learned about 'science as inquiry' appeared as not able to implement inquiry-based classes (Sim, 2006), because the teachers themselves did not have a chance to learn science subjects practically. The lack of experience in experiments is linked to the absence of scientific inquiry. Some science teachers themselves often face difficulties in experimental design and data interpretation. Possessing scientific inquiry requires a somewhat different understanding from traditional learning and instructional methods (Supovitz & Turner, 2000) as it is about the 'curiosity' of learners.

As a result, the noticeable problem that occurs in schools for both pre-service and in-service science teachers is their sense of teaching efficacy (Lim, 2003; Seo & Park, 2005). The lack of prior knowledge, lack of time and resources, misunderstandings of the purpose of experiments, and lack of confidence (Baek et al., 2015; Bevins et al., 2019; Fitzgerald et al., 2019) of science teachers undermine the implementation of effective science experimental lessons. Accordingly, science teachers tend to rather avoid experimental classes and frequently, conducting experimental classes becomes a huge burden on them (Jeon et al., 2009; Moon & Kim, 2009). Teachers with low teaching efficacy in experimental activities tend to conduct teacher-centred classes rather than inquiry-based classes (Kang & Wallace, 2005). In such teacher-centred classes, students' leadership in experimental activities could be expressed rather limited, and this would influence the students' achieved knowledge and skills through the experimentation become also limited.

This has a grave consequence of offering a limited understanding of experiments to students. Because inquiry-based learning through experiments is yet not well implemented in schools in Korea. They find it challenging to guide students in authentic inquiry/inquiry-based learning (Sim et al., 2010) since it emphasises the creation of new knowledge, rather than just acquiring existing knowledge. Through complete and holistic experience from start to finish of scientific experiments, people can achieve authentic inquiry. Authentic inquiry involves the process of researchers finding research questions, analysing and interpreting data, and drawing conclusions for problem-solving (Coburn, 2000; Koomen et al., 2014; Windschitl, 2002, 2004). However, as mentioned above, teachers had not many chances to learn in that way. Without actual and holistic experience of experiments and scientific inquiry, it was not feasible for them to teach their science class in inquiry learning.

As shown above, the lack of inquiry experience of science teachers has influenced both learners and teachers. Consequently, science teacher efficacy in scientific inquiry has appeared lower than overall science teacher efficacy (Kim et al., 2010).

Teachers in general need to constantly develop their expertise. The feature of expertise keeps changing. In science, it is the same (Kwak & Hong, 2022). For science teachers, their development of expertise could be their scientific inquiry competence. It would take over a long period (Adey et al., 2004). Teachers should constantly study how subject matter knowledge is manifested in different contexts and develops accordingly (Osborn, 1998).

In this research, the term 'experiment' is understood as the focus is on the activity itself, rather than the procedure of learning (This contains experimental activities). By considering the context, subjects in the experiment, and the whole procedure contained in the experiment, the term 'inquiry' is perceived as the possibility of high-level cognitive activities such as knowledge and attitude, promotion of metacognitive and analytical thinking, understanding scientific concepts, and acquisition of procedural knowledge. The meaning of 'physical experimental development' used in this study, therefore, refers to the whole procedure of an experiment conducted and the analysis of the tasks. It is also connected to scientific inquiry in terms of expanding learners' views and perceptions in terms of conducting hands-on scientific experimental activities with curiosities.

This study aims to explore a science teacher's experience in designing, developing, and completing a physics examination: scientific inquiry. By using the qualitative research methodology of narrative inquiry, the meaning of the physics experiment development experience of a science teacher would be studied in-depth.

The research questions for this study are:

What was the experience of the research participant in the procedure of developing physics inquiry?

In which ways did the experience impact the participant and what kinds of changes were observed?

Research Methodology

Narrative Inquiry

Narrative Inquiry is a research methodology used to describe the essence of human experience. Its purpose is to analyse and interpret the stories of research participants from the researchers' perspective, by creating reconstructed narratives.

Clandinin & Connelly (2000) emphasised the importance of living, telling, retelling, and reliving experiences with research participants to reveal and construct the meaning of their experiences. Narrative inquiry could be seen as a social interaction attempting to justify oneself through sharing one's knowledge of experience with others (Lee, 2012). At the same time, narrative inquiry could be understood as a collaborative activity between researchers and participants. When conducting the narrative inquiry, attention should be paid to the three common factors and three-dimensional exploratory space of temporality, sociality, and spatiality (place) (Clandinin, 2013; Clandinin & Connelly, 2000). By doing so, those two interact socially and environmentally over a long period in one or several places (Clandinin & Connelly, 2000).

The procedure of narrative inquiry could be divided into five stages: living in the field, from field-to-field texts, composing field texts, from field texts to research texts, and composing research texts (Clandinin & Connelly, 2000). Researchers engage in extensive and diverse reflection on their relationships with research participants, analyse and synthesise stories, and construct valuable narratives. By exploring the stories of research participants, researchers could expand their narrative worlds and enhance reflective contemplation (Kim, 2019).

Research Participant: Teacher A

The participant in this study is a secondary school science teacher in Korea who was a graduate student in the science-gifted education programme at K University. In her second year of graduate school (3rd term), Teacher A took the 'Design and Development of Physics Experiments' module. The participant voluntarily expressed her willingness to participate in the research and signed a consent form. The data confirmed by the participant were used only in composing the research texts.

Table 1. Research Participant

Name (Anonymised)	Gender	Year of teaching experience	Level of school where the participant works	Experience of gifted children Education	Experience of submitting research articles
Teacher 'A'	Female	10 years	Secondary School	Yes	Yes

The research participant: 'Teacher A'(*hereafter*) is 37 years old, and she has been working as a science teacher at a secondary school in a large city in Korea since 2012. She was teaching science subjects before entering graduate school for science-gifted education in her school. At the time of research participation, Teacher A was holding ten years of teaching. Also, she had experience in coaching students for science invention contests and science experiment competitions such as *student science invention contests* or *student science exploration Olympiads* for several years.

The process of developing a physical experiment for learners, organizing the results after conducting the experiment, and writing it in the form of a thesis was a very new experience for Teacher A. What was even more surprising was the fact that it was the first time for a secondary science teacher who participate in the lecture of graduate school to develop such a physical experiment. At that point, the participant had several questions in her mind. She was self-questioning about her experience, expertise, and experimentations that she had done before and required competence to be a professional science teacher.

Data Collection

The field research texts were collected over a total of nine months from March 2022 to October 2023. The data were collected in three different ways; lecture attendance observation (+ observation notes), interviews (3 times of in-depth interviews and occasional ad-hoc interviews + interview transcriptions), and additional field data such as Teacher A's research notes and photos were also collected.

Firstly, lecture attendance observations were conducted over a 45-hours during the 'Design and Development of Physics Experiments' module, and with the consent of the research participant, the scene of lectures was recorded and transcribed. The transcriptions were created by following Roulston's (2010) transcription guidelines.

Also, one of the researcher's observation notes, the research participant's research notes, and experimental reports were collected altogether.

Secondly, ad hoc interviews and in-depth interviews were conducted regularly during the term, and in-depth interviews were conducted in three phases. These in-depth interviews constituted the primary field text for this study, with the first phase taking place during the term, the second near the end of the term, and the third after the end of the term. These in-depth interviews were conducted with a focus on Seidman's (2019) three perspectives of 'lifelong focus', 'reconstruction of embodied experience', and 'reflection on meaning'. Interview schedules and locations were selected with the participant's convenience in mind, and interviews took approximately 1 hour 30 minutes to 2 hours. All the interviews were voice-recorded and transcribed right after the interview was over. The immediately transcribed and analysed interview data towed the direction of subsequent interviews.

The collected data for 15 weeks are shown as below.

Table 2. Collected Data

Methods	No. of times	Total length	Additional data
Lecture observation	15 times	30 hours	Field notes (15 sets)
Ad-hoc Interview	13 times	8 hours	Transcriptions (13 sets)
In-depth interview	3 times	6 hours	Transcriptions (3 sets)
Field data	15 times	n/a	Photos of the class, Teacher A's research notes

Data Analysis

By listening to the note repeatedly, researchers transcribed in a way that maximizes the story talked by the participant. One interview was analysed immediately after the interview was done to refine the direction of the subsequent interview. During the data analysis process, the constant comparison, discussion, and categorisation of the collected data were conducted. The flow of data collection and analysis were repeatedly conducted using a continuous comparative method. In the process of analysing and interpreting the field text, the research text was composed by reviewing the research team. The research text was constructed through discussion by a group of researchers, and the process of constructing field texts, research texts, and confirmation was recurrently performed among the researchers The semi-final version of the research narrative was confirmed with the participant so that the participant could discuss the parts she wanted to delete or add. After that, the final research narrative was confirmed.

Trustworthiness of the Study

Narrative inquiry explores the meaning of human individual and unique experiences. The researcher analyses and interprets the stories of participant(s) and reconstructs them into narratives, and since individual experiences have individuality and uniqueness, repetition of experiences does not appear as similar results. Therefore, the reliability of narrative inquiry can be seen as the 'trustworthiness' (Polkinghorne, 1988) of the record or transcription (Webster & Mertova, 2007). In each process, member checking was conducted (Lincoln, & Guba, 1985). Member checking represent the procedure of checking the correctness of the narrative from the participant through the participant. In this study, data are collected from various angles to ensure the truthfulness of the research. The data collected through various methods and the research text was composed by containing as much details as possible. The procedure of interpretation was also triangulated via four researchers' point of views. This called as peer debriefing (Patton, 2005) that represents the questions and answers time of researchers. In the composition of the field text, two of the researchers participated in the entire lecture as insiders. They prepared observation notes and interviewed the participant in various forms such as in-depth interviews, occasional interviews, online interviews. Data such as self-reflection texts and photos were also collected and analysed. Through various data collection methods, the reliability of this study could be strengthened.

In addition to this, researchers' perceptions were also triangulated. Firstly, at the data collection stage, each researcher listened and discussed about the stories for the direction setting of the forthcoming interviews. Secondly, at the stage of data analyses, by focusing on the stories and data sets from the participant, the research text was composed and written in consideration of the personal context. Efforts were made to reconstruct the participant's stories with sincerity. The story was jointly constructed through research members' cross checking, and then confirmed by the participant.

The data from the field were used to secure the truthfulness of the research as the collected data were supporting each other through triangulation.

Teacher A's Story

This study intends to explore a science teacher's experience of developing a practical physics inquiry.

Mere Conveyer: The Eager of Developing Physics Experiments

In the first year of science teaching at her school, she was asked to take on various roles as a science teacher. She had relatively little experience at the time, but she was given a significant number of science-related tasks, including conducting a thorough investigation of the experiment tools in the science lab, and managing the modernisation project for the lab.

One day, even though teacher A had only just begun to teach science, she was assigned to give a public lecture to science teachers with less than five years of experience. The scale of the public lecture was significant with scholarship recipients' and numerous new science teachers' participation.

The public lesson at that time was a big event. Colleagues with scholarships came to watch, even the school vice-commissioner was present, it was a truly public occasion. However, I had just switched to teaching science subject and was a newcomer with only one year of experience in science teaching. Although I had many years of experience of teaching at the school, I was essentially a first-year science teacher. It was challenging for someone with such a short tenure to conduct a public lesson, especially when the attendees were scholarship recipients and new science teachers with less than 5 years of experience. (2022. Jul. 16.)

Teacher A, at the time, expressed that she did not understand why such a large-scale public lesson was entrusted to her. She thought that she needed to choose the contents in the science textbook, but she would also have to create a slightly more special lesson that was not in the textbook. She felt burdened and had a sense of helplessness as she was not sure where to start developing these experiments and designing the teaching materials.

Teacher A was consistently asked to conduct more public classes by her school. One of the difficulties she faced while making the science teaching aids was that it required a lot of time and effort.

One day, I had to prepare for a public class at school, and I chose the earth science part. Then I realised that the topic of lunar phases was not something that students could easily grasp since the moon is far away. Therefore, I created a model of the moon phase that allows students to observe and confirm it. Since the textbook was on paper, I made a three-dimensional model, or rather, a teaching aid. However, I felt that it was difficult to do such things, not only during school classes but also in reality, due to the amount of time and effort it takes. (2022. Jul.16.)

In her school, Teacher A was asked to conduct a large-scale public lesson. During the process of preparing for a public class, Teacher A made science teaching aids, and then sought ideas and advice from fellow science teachers. However, although her colleagues occasionally provided opinions about the science aids. The atmosphere was mostly encouraging her to persevere solely, and the depth and quantity of feedback were limited. She said that the most difficult thing about the process of making science teaching aids was that she had to do it 'alone' in the end.

What Teacher A felt different from before as she teaches science was that experiments in science require 'exploration through activities'. Since she taught science, coaching students for science-related competitions has been the biggest role for her. Teacher A mentioned that she needed to develop her own curriculum to teach the gifted programme, but she was at a loss as to where to start and what to do.

I have been constantly worrying about the gifted education classes as well. The reason is that I was not sure how to teach the gifted students. Should I refer to the textbooks that others have made, or should I create something on my own? What should I do to create a proper textbook? Can I just use the excellent materials that others have made? These kinds of questions kept bothering me. (2022. Jul. 16.)

She received various kinds of gifted education training before, but she always felt unsatisfied because the content of the training mainly focused on the definition of gifted students and introducing excellent teaching materials. Though teacher A felt that her skills improved a lot through the process of preparing for multiple public science lessons, at the same time, she also felt a sense of inadequacy.

But, ⋯ , after receiving 6 months of training and having a lot of responsibilities at school as a science teacher, I always felt inadequate. I felt like I needed to study more, and that's what led me to attend graduate school this time. (2022. Jul.16.)

Teacher A wanted to find answers on how to conduct gifted classes, and that was the reason for her enrolling in a graduate program studying 'science-gifted education'.

Reach to the Starting Point of Developing Physics Experiments

In the second term of her first year in the master's program, Teacher A came across a module called 'Physics Inquiry and Science Gifted Education Practicum (*hereafter Physics Practicum*)' and decided to join the module.

As someone who has experienced the difficulty of working alone, I believe that the professor's suggestion to develop an experiment through this course is a necessary starting point. The need for it has already been felt by many people in the field. (2022. Jul.16.)

In the 'Physics Practicum' module, she could develop various physics experiments and had chances to write a paper with fellow graduate students. At the beginning of the module, she just focused on performing the experiments and did not pay attention to various aspects such as considering the experimental environment or recording research notes. To her, the experiment was the linear steps to go rather than the procedure of experience. Recording data is a fundamental aspect of the experiments because the same result must be obtained when others repeat the experiment, but at that time, she could not recognise the meaning of the recording.

Last year, we didn't even know what we were supposed to do. The professor pointed out basic things like "Why aren't you taking pictures? Why aren't you recording this data?" and helped us from there. At first, it took us some time to understand what the professor was saying when he asked us to do things, but now that we've done it, it's like "What are you going to do? Take some pictures or something". and we understand right away. (2022. Jul.16.)

Over time, she could achieve the perspectives of a researcher. She realised that the process of conducting experiments, recording the procedure of the experiments, and organising results itself is the most important thing that should be regarded as 'a journey of researcher A (Teacher A)'. The flow step-by-step procedure of inquiry was recognised meaningful procedure, and it was gradually becoming more vividly efficient.

The development of physics experiments in the 'Physics Practicum' module was supposed to be carried out according to the interests of each graduate student. The professor of the module suggested several experimental ideas to explore as a starting point. For the idea expansion, Teacher A and fellow graduate students reviewed experiment ideas. They also reviewed previous research, designed experiments, obtained necessary materials, and conducted experiments altogether. While they were conducting experiments, they collected various kinds of data. They took photos and wrote a paper.

Exploring the Procedure of Developing Physics Experiments: Trials & Errors

Teacher A expressed her desire to develop a physics experiment that was caused by her *own curiosity*. She believed that she would have opportunities for actual inquiry designing and conducting in graduate school.

When I came to graduate school, I felt like this was an opportunity to have a new experience of developing something. And the experiment that I developed could be used in my own class. So, my biggest desire was to try my own experiment which I developed from my curiosity and questions (2022. Jul.16.)

Furthermore, Teacher A wanted to develop the physics experiment she created into a programme. She believed performing physics experiments in the programme would be able to assist enhancement of students' investigative abilities, and consequently, they could experience the whole journey of a scientific 'inquiry'. For this, the experiment had to be something new, attractive and charming, rather than simply finding predetermined answers.

Teacher A began to search for experiments related to the concept of 'refraction of light' as that was the experiments she developed in the 'Physics Practicum' module. While searching for related materials, she found an experiment where a glass rod disappeared when inserted into vegetable oil. Although the experiment seemed interesting in explaining the concept of 'refraction of light', it lacked a variable that could be manipulated. After much consideration, she came up with an idea to increase the refractive index of sugar water to the point where a glass rod is not visible. She thought that if students conducted this experiment, they could understand the concept of refraction of light.

I was looking for other experiments that involve refraction besides the typical ones. (···) While searching for ideas, I discovered that glass objects disappear when submerged in plant-based oil. I found this phenomenon interesting and thought it would be a fun and engaging subject for students since objects disappear right before their eyes. (···) I researched the theoretical aspect and found that by dissolving sugar in water, the refractive index increases, which is like the phenomenon of glass disappearing in plant-based oil. From this, I thought of developing an experiment using this concept. (2022. Jul.16.)

Teacher A started the experiment by heating a glass beaker filled with water on a hot plate, gradually adding sugar to it and stirring it with a glass rod until the refractive index of the sugar water was equal to that of the glass. To achieve this, she had to dissolve a lot of sugar in the boiling water, which turned out to be more challenging than she had expected. The sugar powder stuck to the beaker, causing it to caramelise, and bubbles formed in the boiling sugar water. This made it difficult to observe the disappearance of the glass rod. In addition, the sugar did not dissolve as well as she had expected, and she had to be careful about safety as the experiment used a hot plate. Teacher A tried various methods to perform the experiment, such as using a small glass beaker instead of a glass rod to make it appear as if the glass disappeared in the sugar water and heating the sugar water with the glass rod inside to minimise bubble formation. She also took multiple photos to capture the scene where the glass disappeared. At the same time, she recorded not only the experimental results but also her thoughts and questions in her research notes.

Teacher A gradually increased the amount of sugar while stirring and found the exact amount of sugar that made the refractive index of the sugar water equal to that of glass. Then, she used a laser beam and a refractive index measurement device to measure the incident angle and refracted angle to determine the refractive index of the sugar water. After several trials and errors, she successfully increased the refractive index of the sugar water to the point where the glass rod was not visible. The experiment was completed at this point.

Taking Initiative: Steps Moving Forward

Afterwards, Teacher A conducted additional experiments on refraction with her fellow graduate students. The professor of the module suggested taking pictures of two flat rectangular acrylic plates placed together with water or sugar water in between. When sugar water was applied to the boundary of the two acrylic plates, it appeared to be connected like a single plate compared to the normal water. Although this concept had already been verified by the 'refraction of sugar water' experiment, Teacher A found it fascinating to experiment with different materials and methods.

The fact that the difference in refractive index between the two materials was small enough for the boundary to become invisible meant that the reflection rate was reduced. Following the idea of the professor and her fellow graduate students, Teacher A performed an additional experiment where a laser beam was directed at the boundary of the acrylic plates to measure the reflected light.

Before the professor mentioned it, Teacher A had not thought to connect 'refraction of light' with 'reflection of light' in her experiment. The reason why the glass rod could be seen in air or water is that there is a difference in refractive index between the glass rod and the surrounding medium, causing some of the light to be refracted and reflected at the surface of the glass rod. While conducting the experiment, Teacher A had only thought of it as an 'experiment' on the 'refraction of light' and was surprised to realise that the visibility or invisibility of the glass rod was also related to the 'reflection of light'. That was her moving forward to perceive scientific inquiry.

Being a Dynamic Collaborator: Strengthening Inner Strengths

Through the experience of physics experiment development, Teacher A started thinking about the application of what kinds of experiments to give to her students.

As a teacher who wanted to apply the developed experiment in actual school settings, it was meaningful for me to attend the class where we designed experiments from the perspective of teachers. Through the class, I started to think about whether the experiments in textbooks have errors or not, and how to make students of the current generation conduct experiments themselves. (2022. Jul. 06.)

Teacher A emphasised the importance of allowing gifted students to conduct experiments they want to do and guiding them to create new knowledge through their experiences.

The reason why I wanted to do this experiment, the motivation behind it, the theoretical background and the previous research, all of these were taken into account when I conducted the experiment. I felt that more experiments were needed to further understand these aspects, and I collected data and interpreted the results accordingly. The conclusion and suggestions were also included in the process. Many students lack knowledge in these areas, and I believe that teaching them about these things is part of the process of developing experiments, especially when working with gifted students. Rather than just talking about the exceptional abilities of gifted students in general, it is meaningful to give them the opportunity to conduct experiments they are interested in, and to help them create new knowledge. This is the role of a teacher, and this is what I would like to end with. (2022. Jul.16.)

Through the experience, Teacher A mentioned that she could recognise the starting point in her experiment and how to write a research paper. She became a 'slightly more experienced person' and this perception influenced her self-perception change become positive. Teacher A expressed her willingness to develop another physics experiment, then she mentioned that she should start with 'necessity'.

Developing a physics experiment, writing a paper, and submitting it to an academic journal while in graduate school meant 'completion' to Teacher A. The entire process was an experience of 'completion' that enhanced her inner strength.

⋯ , but creating this class itself took so much energy that I initially made a research report and thought, "Oh, I don't have to use this later for promotion, so I don't want to do it now". So, the report remained incomplete. However, when I came here, I completed the report and submitted it, so just the fact that I submitted it means I completed something. I want to attach meaning to what I completed. (···) I received help from many people, but now I completed it myself. I see meaning in that. (2022. Jul.16.)

Whilst developing a physics experiment and working together with fellow graduate students and the module instructor, Teacher A experienced the joy of completion. Within a permissive atmosphere of the module, Teacher A tried out all the experiments she wanted to. Through this, she could be brave in terms of facing failure in scientific experiments. She also could understand the importance of scientific experiment journey: inquiry. Though there were errors, still, it was her joyful journey of exploring and moving forward to the 'completion'. The meaning of completion was significant to Teacher A, and it fostered Teacher A's inner strength.

Discussion

Teacher A experienced practical experiments and understood the structure of scientific inquiry through the development of physics experiments.

Teacher A was a science teacher who was forced to perform her role as a science teacher at her previous school. To her, whole the steps in science experiments were linear things to simply follow to reach the point of a 'result' of the experiment. Through her journey at the graduate school, Teacher A could be transformed into a dynamic collaborator of scientific inquiry. There were some causes that brought this change.

Firstly, the atmosphere of the modules was permissive and harmonious. As one of the student-teacher, she could ask and discuss freely.

Collaborating with graduate colleagues and receiving feedback allowed Teacher A to overcome difficulties and explore various methods of experimentation. This highlights the importance of creating an environment conducive to fostering a shift in perspective and promoting active knowledge-construction opportunities for learners (Jang & Kim, 2017).

Secondly, she could develop physics experiments from her 'own curiosity'. This might influence her position change from rather passive to active. During the process of developing a physics experiment, characterised by the cycle of trial and error, a shift in thinking, deriving conclusions based on scientific evidence, and academic communication was available. Her own needs and curiosity were supported and assisted by colleagues at the scene, and failure was not something want to avoid. Rather than that, it was the journey science teachers should go in scientific inquiry.

Thirdly, she could be able to achieve scientific inquiry as a student and a teacher. This also highlights the need to provide inquiry experiences that assist learners in understanding the nature of science, that is, scientific inquiry. The cycle of trial and error through exploration and the process of brainstorming, shifting perspective, drawing conclusions based on scientific evidence, and academic communication was worth enough procedure to achieve scientific inquiry. This revisits Lee & Yang (2020)'s research insisting on the actual experience of experiment designing and conducting when guiding.

Fourthly, through hands-on activities, by applying researcher', student's, and teacher's point of view, her profession as a science teacher has been strengthened. The 'practical knowledge' that is unique professional knowledge only teachers can possess (Oh et al., 2008) could be accomplished through Teacher A's research journey. Teachers' practical knowledge is behavior-oriented and has personal, context-dependent, and implicit characteristics based on their own experiences (Van Driel et al., 2001). The experiences fostered Teacher A's 'inner strength' in terms of developing scientific experiments, teaching aids, and teaching methods.

Lastly, through Teacher A's experience appeared meaningful in terms of enhancing teacher efficacy. The physics experiment development experience of Teacher A is significant since she experienced inquiry-based learning as a learner, before providing inquiry-based learning experiences to students as a science teacher.

It is also rather significant that Teacher A obtained know-how for guiding students through the entire process of exploration. The whole procedure of trial and error, discussion, and writing academic papers guided her to gain a comprehensive understanding and experience in inquiry-based teaching and learning.

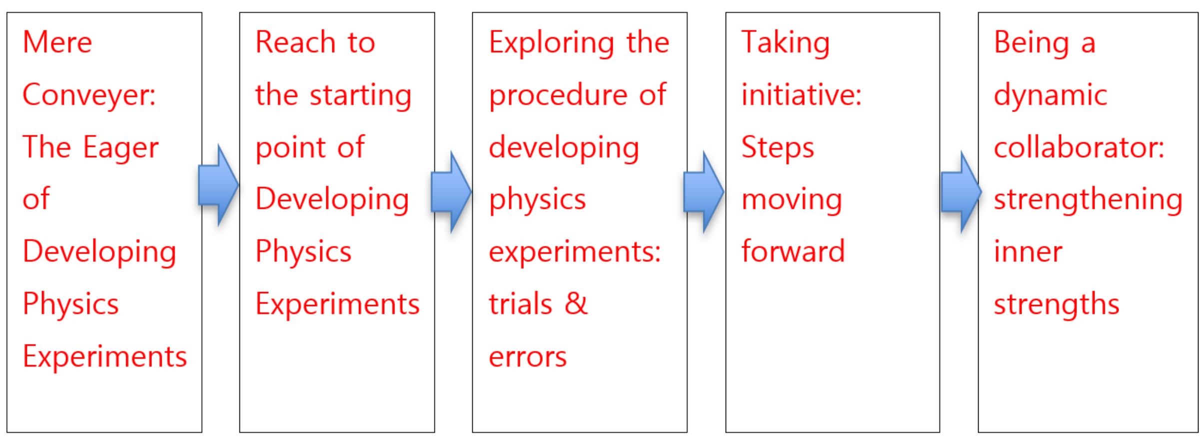

Fig. 1. The participant A's journey

Teacher A gained insights into practical inquiry and comprehended the inquiry process through creating physics experiments. Science teachers often miss out on practical inquiry during their education (Crawford, 2000; Jin & Jang, 2007; Windschitl, 2002; Yang et al., 2006; Zacharia, 2003). However, Teacher A's unique approach to developing physics experiments stemmed from her personal needs, making it a thorough and holistic journey from beginning to end, that is, authentic inquiry. Authentic inquiry typically involves researchers generating questions, analyzing data, and drawing conclusions to address problems (Coburn, 2000; Koomen et al., 2014; Windschitl, 2002, 2004). Teacher A engaged in authentic scientific inquiry while developing a physics experiment, marked by experimentation, shifts in thinking, and making conclusions based on evidence and scholarly discussions. This process of exploration, brainstorming, perspective shifting, conclusion drawing based on evidence, and scholarly communication grasped by Teacher A reinforced her position from mere conveyer of scientific ideas to dynamic collaborator of scientific inquiry (Lee & Yang, 2020).

The narrative of Teacher A underscores the significance of inquiry-based teaching in science teacher education as supported by extensive research (Kwak & Hong, 2022; Baek & Kim, 2011). It stresses the importance for science teachers to base their experimental conclusions on empirical evidence (Choi, 2017) and highlights the need for inquiry experiences that help learners grasp the essence of scientific investigation.

Teacher A's experience was beneficial in enhancing her teaching efficacy, as she first experienced inquiry-based learning as a learner before facilitating similar experiences for her students as a science teacher. In addition to this, collaboration with graduate colleagues and their feedback helped Teacher A navigate challenges and experiment with different methods. This underlines the value of environments that encourage perspective shifts and promote active learning (Jang & Kim, 2017).

Developing the experiment was not only a practical experience of scientific inquiry but also significant evidence of her self-perception achievement because she linked her own experience as a student to reconstructing and improving the experiment to be suitable for her students' ability and level.

Conclusions and Implications

Based on Teacher A's experience in developing physics experiments, this study explored her journey from mere conveyer (conducting experiments as suggested in a textbook) to becoming a dynamic collaborator (starting with curiosity, understanding, and performing scientific inquiry). Through her journey in graduate school, her perception change in the role of teacher and the science inquiry was observed.

The research questions for this study are: What was the experience of the research participant in the procedure of developing physics inquiry? In which ways did the experience impact the participant and what kinds of changes were observed?

Through developing the physics experiment, Teacher A experienced practical scientific experiments as a researcher, which she had not previously experienced. She went through a holistic experience from brainstorming experiment ideas to conducting the experiment, analysing data, and writing a paper. Through this self-directed and systematic experience, Teacher A could achieve insight into scientific inquiry that further strengthened her self-efficacy as a science teacher.

The process of developing physics experiments for students was not only a practical experience in scientific examination for Teacher A but also meaningful in terms of her competency to reconstruct and improve experiments to be suitable for her students' abilities and levels. Through her experience, she underwent scientific inquiry achieving and expanding procedures step-by-step. In the beginning, she held the perspective of a student. But later, her perception of science inquiry has been changed as a researcher-teacher who possesses a curiosity about things and would like to study things through detailed experimentation.

The trials and errors she experienced allowed her to obtain a detailed understanding of difficulties that students may face in their scientific inquiry lessons. Therefore, she could recognise the required elements to guide students at each step of the experiment. Most importantly, the experience of developing physics experiments became a catalyst for Teacher A to transform from 'a mere conveyor of information to 'a dynamic collaborator' in constructing scientific inquiry as a science teacher. This led her to re-evaluate the importance of her role as an instructor in a science classroom as a researcher and a teacher.

This study also highlights the importance of designing and conducting inquiry-based teaching in science teacher education programmes (Baek & Kim, 2011; Kwak & Hong, 2022).

As the participant of this study is one person, it cannot be generalised. However, still, the value of this study is in exploring the meaning of science teachers' experience in developing physics experiments and therefore achieving scientific inquiry. Therefore, follow-up studies are needed to investigate how science teachers apply their experience in their experiment development and how they will apply it to their actual classroom.

Ethical Statement

After formulating a research plan, it was reviewed by the IRB committee of Korea National University of Education. In order to protect the study subjects, research participants were directly recruited, and at this time, whether there were vulnerable research subjects was identified.

Written consent was obtained from the study subjects to participate in the study and the risks and benefits that may occur when participating in the study were also announced. In addition, it was announced that it was possible to withdraw participation in the study at any time during participation in the study.

In the stage of organizing the interview questionnaire, the final interview questionnaire was completed after being reviewed by a group of experts, and all information related to the personal identity of the study participants was excluded. Throughout the entire process of the study, the researcher organized the research text by checking the interview transcript and narrative with the research participants.

All interviews remain anonymous and were stored as encrypted files on the research manager's laboratory computer to prevent data leakage. The collected data was never used for research and academic purposes, and after one year after the end of the study, it will be stored and discarded with the consent of the research participants.

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