Ph.D. Dissertation in Education

Students' Unintended Learning in Primary School Practical Science Lessons: What is Learned and How it Occurs

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Abstract

This dissertation investigates unintended learning in primary school practical science lessons. I use the term "unintended" learning to distinguish it from the "intended" learning that appears in teachers' learning objectives. Data were collected using audio and video recordings of 22 lessons taught by five teachers in Korean primary schools with 10- to 12-year-old students. Pre-lesson interviews with the teachers were conducted to ascertain their intended learning objectives. Students were asked to write short memos after the lesson about what they learned and post-lesson interviews of students and of teachers were undertaken to gather more detailed information about student learning.

This study's data suggested three types of knowledge that students learned unintentionally: factual knowledge gained by phenomenon-based reasoning, conceptual knowledge gained by relation- or model-based reasoning, and procedural knowledge. Most unintended learning found in this study fell into the factual knowledge type. One of the types of factual knowledge observed in this study was factual knowledge that can be associated with students' future learning. As opposed to factual knowledge, only a few cases of conceptual knowledge were found to have occurred as a result of relation- and model-based reasoning. In the cases of conceptual

knowledge learning, the students engaged in relation- or model-based reasoning with help from the teacher. This can give us an implication of the teachers' role in unintended learning. Both explicit and implicit procedural knowledge were also found in this study. Explicit procedural knowledge can be described both verbally and in writing and implicit procedural knowledge cannot be stated explicitly and only can be acquired by practice. This means that students' practice, such as trial and error and coping with unexpected situations in practical work, could give them opportunities for unintended learning, especially opportunities to learn implicit procedural knowledge.

The results also suggested that there were three associated features of unintended learning that occurred: students expressing their interest, maintaining their interest, and connecting to prior knowledge. These findings also indicated that the process of intended and unintended learning is different in that teacher's effort to make students be interested in the task comes first in the process of intended learning, whereas unintended learning originated from students' spontaneous interest and curiosity. Polanyi's concept of intellectual passion would posit that unintended learning occurred because of the heuristic passion of the student in the sense that it was driven by students' interest and curiosity. However, I observed that most unintended learning was localized at the individual student or a small group level, which means that students' persuasive passion to share their

learning was limited.

This study is significant in that it suggests how unintended learning can be facilitated as an educative opportunity for meaningful learning by exploring what and how students learned unintentionally. In summary, this study showed that students learned various types of knowledge associated with multiple reasoning processes. Among these types of knowledge, there was knowledge that could be helpful for their future learning and that was associated with a sophisticated level of reasoning, such as model-based reasoning. This study also found that unintended learning could be meaningful learning in that it initiated from students' own interest and curiosity. These findings indicate that teachers need to be aware that unintended learning can take place in the lesson so that they can help students to develop the ideas into unintended learning. I also suggest practical implications for both pre-service and in-service teacher professional development and for science educators.

Keyword: unintended learning, practical work, primary science, heuristic passion, implicit procedural knowledge

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Table of contents

Abstract i

List of figures vii

List of tables ix

Chapter 1. Introduction **1**

1.1. Personal motives for this study 1
1.2. The purpose of this study 2
1.3. Summary of study design 6
1.4. Synopsis 7

Chapter 2. Theoretical framework and literature review **10**

2.1. Pragmatic approach to learning 10
2.2. Learning in schools 12
2.2.1. Formal learning and informal learning 12
2.2.2. Characteristic of informal learning 16
2.2.3. Types of unintended learning in school 18
2.2.4. Previous research on unintended learning in school 20
2.2.5. Previous research on unintended learning in science lessons 23
2.3. Learning in practical science lessons 26
2.4. Motivation for science learning in practical work 30

Chapter 3. Design and method of the study **35**

3.1. Selection of research settings 35
3.2. Context of research settings 38
3.3. Ethics 45
3.4. Data collection 46
3.4.1. Pre-lesson interviews 46
3.4.2. Audio and video recording and field notes in the lesson

.... 48
3.4.3. Short student memos after lesson and post-lesson interview.. 49

3.5. Data processing.. 50
3.6. Data analysis.. 54
3.6.1. Identifying the unintended learning 54
3.6.2. Coding for knowledge and reasoning of unintended learning 58
3.6.3. Coding for experience that led to unintended learning 63

Chapter 4. Multiple learning paths: The types of knowledge associated with unintended learning.. 66

4.1. Factual knowledg gained by phenomenon-based reasoning .. 67
4.2. Conceptual knowledge gained by relation- and model-based reasoning 75
4.2.1. Relation-based reasoning... 75
4.2.2. Model-based reasoning.. 79
4.3. Procedural knowledge by practice...................................... 83
4.4. Summary and discussion.. 86

Chapter 5. Unintended but meaningful: Features associated with unintended learning from Polanyi's perspective 92

5.1. Features associated with unintended learning 93
5.1.1. Students expressing their interest.............................. 94
5.1.2. Students maintaining their interest............................. 99
5.1.3. Connecting to prior knowledge................................ 102
5.2. Sharing individuals' unintended learning with a whole class104
5.3. Interpreting the unintended learning from the perspective of Polanyi 107
5.4. Summary and discussion...111

Chapter 6. Conclusions and implications 113

6.1. Summary 113

6.2. Conclusions and implications 116
6.3. Limitation of the study 126
6.4. Future directions 127

References 129

Abstract in Korean 143

Appendix A: IRB letter of approval 148

Appendix B: The consent forms of teachers, students, and parents 150

Appendix C: The example of transcription of pre-lesson interview 157

Appendix D: The example of transcription of student discourse 160

Appendix E: The example of short student memo after lesson169

Appendix F: The example of transcription of post-lesson interview 170

List of figures

Figure 2.1. Characteristics of formal and informal learning 14

Figure 2.2. The relations between curricula 22

Figure 3.1. The process of data collection.. 46

Figure 3.2. Example of a short memo 50

Figure 3.3. Data processing procedure... 53

Figure 4.1. A girl putting a lightbulb in her ear to feel that it is warm 68

Figure 4.2. The part of a third grader's textbook in middle school dealing with nichrome wire emitting the light and heat when electricity flows.... 70

Figure 4.3. Placing the ruler to check if it let electricity flow.................. 72

Figure 4.4. Checking whether linking the wires between the two batteries let electricity flow 72

Figure 4.5. Checking whether batteries touching each other let electricity flow 72

Figure 4.6. The electric circuit that Enu tried to make 73

Figure 4.7. Teacher explaining the reason of the color change 76

Figure 4.8. Electric circuit with two parallel batteries............................. 79

Figure 4.9. Student shaking the battery.. 82

Figure 4.10. Adjusting the focus by moving the stage of the microscope 84

Figure 4.11. Making a slide for observing a leaf using a microscope 85

Figure 4.12. Types of knowledge and reasoning in unintended learning and the teacher's role in unintended learning 88

Figure 5.1. Watching a friend playing with a neodymium magnet, the student learned how strong such magnets are 99

Figure 5.2. The parts of the battery case that students argued about in terms of connecting the wire 100

Figure 5.3. Teacher sharing a small group's unintended learning with the whole class 107

Figure 5.4. The process of intended and unintended learning in a lesson110

Figure 6.1. Practical implications for teachers 125

List of tables

Table 3.1 Overview of teacher participants 37

Table 3.2 Overview of the observed lessons 44

Table 3.3 The number of student participants 44

Table 3.4 Examples of unintended learning and exclusion from unintended learning 57

Table 3.5 Example of coding for factual knowledge and phenomenon-based reasoning 61

Table 3.6 Example of coding for conceptual knowledge and model-based reasoning 62

Table 3.7 Example of coding for procedural knowledge by practice 63

Table 3.8 Example of coding for experience that led to unintended learning 65

Table 5.1 Experiences that led to unintended learning 96

Chapter 1. Introduction

1.1. Personal motives for this study

My personal motivation for engaging in this research stems from my own personal trajectory as a primary school teacher. My research interest stemmed from situations where practical work did not go well. The practical work in the textbook had clear expected results that students needed to produce. Most of the students that I taught often used expressions such as "ruined experiment" or "failed" when they could not produce the expected result. This is unpleasant situation for both students and teachers in that the teacher has to manage practical work within a limited time and students seem to fail to learn what teacher or textbook intended. Although this was not a pleasant situation for me, I questioned whether this always has to be a negative situation. Sometimes I saw students who tried to figure out a problem that they had during practical work and students who acquired a sort of know-how in making practical work successful, both of which can be referred to as unintended learning. It was from situations such as these, where practical work did not go well yet unexpected student learning resulted, that my interest in this research topic began. In addition to these personal and practical motives, this dissertation was also motivated by a larger research conversation.

1.2. The purpose of this study

People are always learning, anytime and anywhere. A great deal of learning takes place in everyday life outside of formal education. School is the most common type of formal education, but at the same time school is part of students' everyday life space. Students in OECD countries including Korea spend an average of 802 hours in lessons per year, and students spend 4-6 hours a day in school (Charbonnier & Truong, 2014). School can be the place where students learn informally from everyday life as well as a place where formal learning occurs. However, students' informal learning in school has received little attention because school is typically thought of as a place where the teacher teaches and the students learn. Students' informal learning in school is learning that a teacher had not intended. In this study, I use the term *unintended* to describe students' informal learning in school to distinguish this from informal learning in outside of school. The use of *unintended*, unlike *informal*, places a greater emphasis on the fact that this informal learning might have taken place in a particular lesson where intended formal learning was also occurring. Also, *unintended* makes clear the distinction between a teacher's intended learning objectives and outcomes (both are terms widely used in the classroom) and those outcomes that were from the teacher's perspective wholly unintended.

Research dealing with learning belief, ideology, or culture that is not explicitly intended but that students learn anyway has been done under the name *hidden curriculum* in school education. There has been research that has shown that students may have learned beliefs or ideologies that were hidden beneath the curriculum or text whether teacher was aware of it or not (Apple, 1979). Life in school also causes students to get used to the norms and culture of the school and classroom. Students experience the expectations of the school and the teachers so they learn how to behave in the school and classroom (Jackson, 1990). Unlike the research into students' unintended learning of ideology or culture that has been done so far, little research focusing on the students' unintended learning of knowledge has been done.

It is important to notice what is happening in the lesson, what experiences students have, and what knowledge students learn from these experiences because this will guide us in finding ways to teach students and how to support student learning (Van Es & Sherin, 2002). In particular, the importance of exploring what students experience and learn in science lessons is highlighted in the context of teaching science as inquiry. Teaching science as inquiry requires teachers to listen to and interpret students' ideas and to use those ideas to help students investigate authentic questions (Hammer, 2000).

Previous research has clearly shown evidence that students have learned knowledge that teachers did not intend for them to learn (Hart, Mulhall, Berry, Loughran, & Gunstone, 2000; Shon & Moon, 2011). However, these kinds of learning were described in negative ways and positioned as problematic situations that cause scientific misconceptions or ineffective lessons. There are a few studies arguing that these unintended learning situations can be utilized as learning opportunities for acquiring scientific knowledge; however, these studies only provided a theoretical discussion and little empirical evidence (Kang, 2006; Lenox, 1985). Therefore, the empirical research is necessary to explore what and how students really learn unintentionally in science lessons.

This study aimed to explore students' unintended learning, especially in primary practical science lessons. Practical lessons are a unique feature that distinguishes science education from most other disciplines (Wellington, 1998). Although unintended learning can take place in any type of school lesson, exploring unintended learning in practical science lessons will give us unintended learning findings that are unique to science education. In particular, looking at primary school science can be the first step in that the primary science curriculum has more practical lessons than the secondary science curriculum (Lee, Lee, & Shin, 2011).

This research had two broad research questions and sub-questions as follows:

1. What kinds of unintended learning occur in primary school practical science lessons?
   - What kind of knowledge did students learn unintentionally?
   - What kinds of reasoning were used in students' unintended learning?

2. How does unintended learning occur in primary school practical science lessons?
   - What are the features associated with the unintended learning that occurs?
   - Can unintended learning acquired by students be shared with other students in their class?
   - What are the educational implications of unintended learning from the perspective of intellectual passion?

1.3. Summary of study design

This qualitative study was undertaken by observing practical science lessons given by five primary school teachers in Korea. I first prepared a list of teachers that I could access and then selected five teachers to include high-, middle-, and low-achieving schools, both homeroom teachers and science subject teachers, and both female and male teachers in order to represent a variety of schools and teachers.

Data from several sources were collected before the lesson, during the lesson, and after the lesson. (i) Pre-lesson interviews were carried out with the teachers to ask about their objectives for student learning for the lessons and procedures they had planned. (ii) A total of 22 practical science lessons were observed and audio-and video-recorded. Ethnographic field notes were also made during the observations. (iii) After each lesson, students were asked to write a short memo about what they had learned in the lesson, either intended or unintended. Post-lesson interviews with teachers and some of the students were also conducted and audio-recorded. Students were asked, during post-lesson interviews, about what they had learned and similarly teachers were asked to reflect on their lessons.

1.4. Synopsis

This dissertation has two chapters of research findings.

Chapter 4: Multiple learning paths: The types of knowledge associated with unintended learning

This section examined what knowledge students learned unintentionally and what kinds of reasoning students used during this learning process. The epistemological reasoning suggested by Driver, Leach, Millar, and Scott (1996) was used for the analysis. This framework was meant to explore the interaction between development of knowledge and reasoning and not to assess the reasoning ability of an individual (Tytler & Peterson, 2004). Therefore, this framework can provide a useful basis for describing students' epistemological reasoning and knowledge. The knowledge that students had in this study was categorized into factual, conceptual, and procedural knowledge. These categories of knowledge were drawn from the common definition of knowledge given by philosophers and recent educational researchers (Krathwohl, 2002; Oakeshott, 1962; Polanyi, 1967; Ryle, 1949).

Chapter 5: Unintended but meaningful: Features associated with unintended learning to occur from Polanyi's perspective

This section presents an account of the how unintended learning occurred and its educational value from Polanyi's perspective. Polanyi has been one of the foremost science philosophers who have criticized objectivity. Most science philosophers who were against objectivity, such as Kuhn, paid attention to how scientific knowledge could be justified, but Polanyi paid attention to how scientific knowledge was pursued (Jacobs, 2000). Polanyi used the concept of passion to emphasize the importance of personal participation in pursuing scientific knowledge. As his idea that the process that regards scientific inquiry as a human endeavor can indicate what science learning should look like (Jacobs, 2000; Kim & Kim, 2003), Polanyi's perspective was used to interpret the educational value of unintended learning in this study.

In this study, I investigated the features associated with the unintended learning that occurred and also examined whether unintended learning was shared with the whole class. The findings were interpreted based on the concept of Polanyi's concept of intellectual passion, which consists of heuristic and persuasive passion.

After these two chapters of findings, Chapter 6 provides a summary of these two findings and concluding remarks and implications for teaching and learning practical work and teacher professional development. The limitations of this study and suggestions for future research are also provided.

Chapter 2. Theoretical framework and literature review

2.1. Pragmatic approach to learning

This research framed unintended learning based on a pragmatic approach (Östman & Wickman, 2014) that combined a view of learning as a social construction with a view of learning as individual cognition. Kelly, McDonald, and Wickman (2012) identified three epistemologies that informed different learning theories in science education: the disciplinary perspective, the personal ways of knowing perspective, and the social practices perspective.

The disciplinary perspective considers “the important role of disciplinary knowledge for science learning.” (Kelly et al., 2012, p. 282). For instance, philosophy of science has played an important to role in the development of science curricula because it focuses on knowledge within scientific communities. The personal ways of knowing perspective is “concerned with the ways that individual learners conceptualize knowledge.” (Kelly et al., 2012, p. 282). This perspective draws from the aspects of psychology that deal with the ways in which individual learners process information and arrange their understanding in an organized structure. The social practices perspective considers “the social practices that determine what counts as knowledge in a local, contingent context.” (Kelly et al., 2012, p. 282). This perspective draws from the sociocultural theory that explains how learning is related to cultural and historical contexts. Therefore, the focus in this perspective on learning is the role of participation and social interaction.

Each perspective emphasizes different aspects of learning, but all of these aspects are necessary to understand science learning. By drawing on two traditions of epistemology, the social practices perspective with recognition of the personal ways of knowing perspective, the pragmatic approach to learning in this study does not dismiss individual cognition but posits that learning is accomplished by participating in social activities and internalized by individuals. Therefore, learning can be thought of as occurring through participation and interaction in this study as well as occurring within individual cognition. In practical science lessons especially, learning includes participating in activities and interacting with the instruments and materials that are presented for hands-on activities as well as interacting with peers and teachers. By using a pragmatic approach, this study tried to understand how unintended learning occurred from the activities in the class as well as what kinds of knowledge individual students learned.

2.2. Learning in schools

2.2.1 Formal learning and informal learning

School education is the most familiar type of formal education. Although learning often takes place in a formal education context, a great deal of learning also takes place outside of formal settings in everyday life or the workplace. In contrast to formal learning, which takes place in a formal setting, this type of learning is called informal learning. Werquin (2010) defined formal learning as “learning that occurs in an organized and structured environment and is explicitly designated as learning” and informal learning as “learning that results from daily activities related to work, family, or leisure. It is not organized or structured in terms of objectives, time, or learning support” (p. 21-22). These two types of learning differ in how much learning is (1) structured, (2) intentional, (3) self-directed, and (4) experience related (Choi, 2011).

The characteristics of formal learning and informal learning are described as follows. The description below was deliberately made mutually exclusive in order to contrast the characteristics of the two types of learning by describing the most extreme images of them. This is not to suggest that these two types of learning are mutually exclusive, rather that these two types of learning are on a continuum (See Figure 2.1). This will be discussed at the end of this section.

Formal learning takes place in a structured space and time. For instance, students go to school and enter the classroom where their teacher and friends are in the morning. Because the times of the lessons are fixed, students do not have control over when they have breaks and can learn by themselves. As opposed to formal learning, informal learning has no structured space and time, so it can take place anywhere and anytime.

Formal education involves teaching and learning. Teaching is an intentional activity (Frye & Ziv, 2005). For instance, a curriculum in a school suggests to teachers what they should teach, and lessons are planned by teachers based on this curriculum (Nelson et al., 1992). The learning in a lesson that follows the plan might be less dynamic than informal learning. Informal learning is incidental and there is no intent.

As mentioned earlier, students must come to school and have to learn when and what the teacher teaches. As opposed to formal learning, informal learning does not involve anyone controlling what is being learned other than the learners themselves. Self-directed learning means that there is more personal autonomy, self-management, learner control, and autodidaxy (Candy, 1991). These characteristics indicate that informal learning allows more possibility of having self-directed learning than formal learning does.

Lastly, formal learning involves a curriculum that includes disciplinary knowledge that is regarded as being worthwhile to teach. There has been criticism that since curricula tend to be disconnected from students' everyday experience (Avraamidou & Osborne, 2009), school learning tends to estrange students from the real world. Many studies have argued that school learning needs to be more contextualized and connected to students' everyday experiences (Rivet & Krajcik, 2008; Na & Song, 2014). As opposed to school learning, informal learning originates from students' everyday lives and experience. Rogers (2005, p. 99) expressed this contrast by describing formal learning as "education in preparation for life" and informal learning as "education in and through life."

Figure 2.1. Characteristics of formal and informal learning.

Traditional formal learning may tend towards the left end of the continuum in Figure 2.1. However, recent formal learning has been shifting towards the center, with more student-centered teaching and learning by contextualizing the content to students' everyday lives or experience in ways such as context-based approaches and STS in science education (Bennett, Lubben, & Hogarth, 2007; King & Ritchie, 2012). Informal learning has also been shifting towards the center from the right end of continuum in Figure 2.1. In other words, formal education has been trying to teach students in a more informalized way and informal education has been trying to support informal learning in a more formalized way. There has been an increase in awareness of the need to pay attention to informal learning, and studies have been done to determine how to support informal learning (Hawley & Banard, 2005; Marsick & Watkins, 2001). Shin (2012) has argued that the cases of informal learning need to be archived and used as opportunities to educate others.

School is the most well-known form of formal education. However, since school is not only a place where formal learning takes place but is also a part of students' everyday life, informal learning can also occur there. Informal learning can take place during break time and even when students are in class, taking place in addition to the formal learning that the teacher intended. As mentioned earlier, recent informal learning studies have argued that cases of informal learning need to be noticed and that these cases can be used as learning opportunities for others. Therefore, this section gives implications about the informal learning in school that also needs to be explored and how these occurrences can be utilized as learning opportunities for other students as well.

2.2.2 Characteristics of informal learning

In this section, the general characteristics of informal learning and the unique characteristics that informal learning in school can have will be discussed. Also, the informal learning that can occur in a school context will be redefined based on the characteristics of informal learning discussed in this section.

Informal learning is based on the theory of learning from and through experience (Marsick & Watkins, 1990). However, not all experiences lead to learning. Dewey argued that experience can be valued as educative when the experience can affect past, present, and future experiences of an individual, and when the experiences can interact with environments or others (Na & Song, 2014). This means that experience itself cannot be learning but rather that an activity and educative experience that can lead to learning requires thought and reflection.

Marsick, Watkins, Callahan, and Volpe (2006) reported the characteristics of informal learning by reviewing the related literature. Informal learning occurs in non-routine practice such as failure, and it is tacit and non-conscious or semi-conscious. They argued that attention is necessary in order not to overlook learning opportunities and active action is also needed to lead this learning opportunity to actual learning. Furthermore, Billett (1994) reported that there are a great deal of learning opportunities in informal learning, but informal learning often fails to develop into more complex forms of knowledge unless the learner has the intellectual capability to connect or guidance to link them.

School is the place where formal learning takes place and at the same time is a part of the everyday life space where informal learning can also take place. Informal learning in school has a learning context that is distinct from the informal learning that occurs in other places, and it is difficult to separate it from the learning that teacher intended. Therefore, informal learning in school shares common characteristics with informal learning in general, but the characteristic that students are learning something the teacher did not intend needs to be emphasized in order to distinguish informal learning in the classroom from informal learning in other places. For this reason, instead of referring to informal learning in school, this study suggests the term *unintended learning*. Unintended learning can be defined as learning that a teacher did not intend the students to learn. This will help us to make a clear distinction between a teacher's intended learning objectives and outcomes that a teacher did not intend.

2.2.3 Types of unintended learning in school

In the previous section, the term *unintended learning* was suggested in order to distinguish informal learning in school from other informal learning. There are various types of unintended learning that can occur in the classroom. This can be visualized as a comparison with what was intended to be taught from the teacher's perspective.

Firstly, students might learn the belief or ideology of the content that teacher teaches. For instance, students may learn the naïve inductivist model of science or learn that scientific knowledge is objective knowledge from the method in which practical work is performed and the way scientific concepts are described (Hodson, 1996). Also, examples or the descriptions of scientists in textbooks can influence students' image of scientists, such as giving the idea that scientists are male, have glasses, or wear lab coat (She, 1995). As these beliefs or ideologies are hidden beneath the curriculum or textbook, a teacher might not know that there is such a belief or ideology in the curriculum or textbook.

Secondly, students might learn norms and culture from the procedures they are taught. For instance, students can learn how to get praise or avoid punishment from the teacher's responses (Jackson, 1990). Students can also learn the classroom norm that students should produce the right answer by experiencing the way a teacher responds to their answer (Chang & Song, 2016).

Thirdly, students may learn content that a teacher did not intend, and it may either be related or unrelated to the intended learning. For instance, student can incidentally learn the collocations that teacher did not intend to teach through reading in their English lessons (Webb, Newton, & Chang, 2013). Students can also expand their scientific knowledge by asking a teacher questions about things that were not part of the planned lesson (Oh, Lee, & Kim, 2007).

To sum up, (1) students may learn a belief or ideology that is hidden beneath the curriculum or textbook but that is not recognized by the teacher, (2) students can learn norms and culture from a teacher's procedures that the teacher did not explicitly intend, and (3) students may learn content that a teacher does not intend. The focus of this study is on the third type of unintended learning described above: content that a teacher does not intend.

2.2.4 Previous research on unintended learning in school

There has been some discussion in the literature on student learning that has not been planned in the curriculum. Generally curriculum is regarded as a plan to guide student learning in class. There are various definitions of curriculum and there are slight differences between them. Dewey (1902) said that "curriculum is a continuous reconstruction, moving from the child's present experience out into that represented by the organized bodied of truth that we call studies . . . are themselves experience—they are that of the race" (p. 11-12). Tyler (1957) defined curriculum as "all the learning experience planned and directed by the school to attain its educational goals" (p. 79). These definitions refer to the prescriptive curriculum that plays a role in providing what should happen in class, whereas there is also descriptive curriculum that describes curriculum as student experience. For instance, Hass (1987) defined curriculum as the set of actual experiences that each individual student can have.

Taking these different definitions into account, curriculum can be distinguished into three types: designed curriculum, taught curriculum, and learned curriculum. Designed curriculum can also be referred to as written curriculum, recommended curriculum, or intended curriculum (Nelson et al., 1992). Taught curriculum and learned curriculum can also be called actualized curriculum (Nelson et al., 1992).

There has also been some discussion in the literature about the student learning that can happen between intended curriculum and actualized curriculum. Two types of this kind of student learning are hidden curriculum and null curriculum. Hidden curriculum is what unintentionally produces changes in student value, perception, and behaviors. Jackson (1990) pointed out that students learned various things that were not included in the official curriculum that the teacher taught in classroom, calling this hidden curriculum.

While hidden curriculum indicates what was not intended but nevertheless learned, null curriculum indicates what is not taught because it has been excluded from the designed curriculum. Figure 2.2 shows the relations between curricula. Eisner (1994) argued that it is necessary to consider what schools do not teach as well as what they do teach.

Eisner's view of null curriculum was not simply that it is what is not taught in schools. He argued that what is included and what is excluded may send a message to students about what is more important and what is not worthwhile to study. For instance, we study certain selected theories and histories but not others. This can happen for political, social, and/or religious reasons or simply because it is physically impossible to teach everything in schools. Whatever the reasons, decisions are made intentionally about what to include and exclude from the designed curriculum. In other words, the null curriculum is about the missed opportunities for student learning.

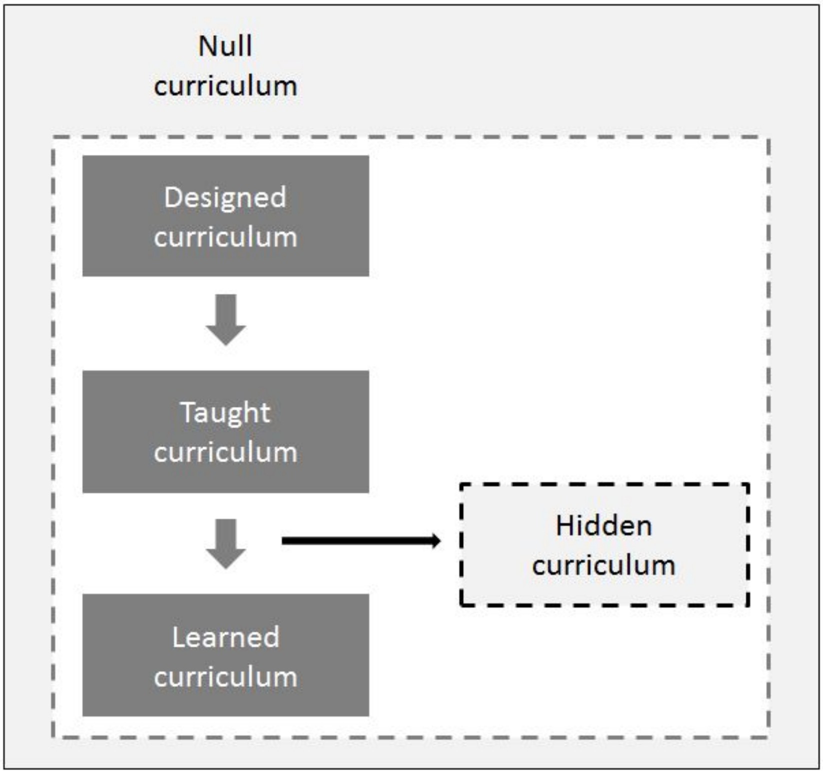


Figure 2.2. The relations between curricula.

Both hidden curriculum and null curriculum give us an indication that there are more possible opportunities for students to learn more than what has been planned in the designed curriculum. However, the research about hidden curriculum shows that it is more likely to learn beliefs or ideologies hidden beneath the curriculum or textbook that a teacher does not recognize or to learn norms and culture from teacher's teaching procedures (Cotton, Winter, & Bailey, 2013). This study's aim was to focus on unintended learning where students learn content that teacher did not intend, which can be distinguished from the unintended learning discussed in research on hidden curriculum. The unintended learning in this study may have things in common with null curriculum in terms of dealing with content that is not taught because it has been excluded from the designed curriculum. The following section will explore previous research dealing with unintended learning where students learn content that a teacher did not intend.

2.2.5 Previous research on unintended learning in science lessons.

It is difficult to find research dealing with unintended learning as a keyword. However, research related to unintended learning can be found in research dealing with unexpected experiences in science education and student learning that occurs in addition to what the teacher intended.

Among the research dealing with unexpected experiences in science lessons, there is research dealing with instances where practical work did not go well and was not what the teacher intended. Teachers have considered this situation problematic, as students may not achieve the intended learning when practical work does not go well. The research of Lee, Jhun, Hong, Shin, Choi, and Lee (2007) and Yoon (2008) also reported that teachers had difficulties in dealing with this situation. Nott and Smith (1995) also showed that teachers regarded this situation as negative and tried rigging or conjuring practical work. However, they argued that this situation can be utilized as opportunity for productive discussion. For instance, Lee and Joung (2013) introduced a case where students learned something when practical work did not go well. The observed science lesson was about the relationship between the length of a vertical spring and hanging mass. The teacher intended the students to do practical work that involved measuring the increased length of a spring when masses were hung by the students on the spring. However, a group of students saw that the length of the spring did not increase even though they hung the provided masses. They asked the teacher for help and the teacher stretched the spring several times by force. Seeing this, a student in another group wrote a journal entry that (s)he learned that stretching a spring by force several times when the spring does not stretch well will make the spring stretch easily. The teacher definitely did not intend for the spring not to work well nor did the teacher intend to teach that stretching a spring several times by force was would make it work.

Shon and Moon (2011) described the case of a student who experienced an unexpected situation. Students filled a glass with water and put a paper on the glass. After that, they turned the glass upside down to observe that water did not come out of the glass because of air pressure. However, some students failed to accomplish this and tried to determine why they could not succeed in doing it. The students succeeded in the end and determined how to make this practical work successful. These instances show us that teachers do not need to rig or conjure the situation, rather utilize it as opportunity for learning from it.

There is research dealing with student learning that occurs in addition to what the teacher intended. For instance, Oh et al. (2007) examined student learning as a different type of knowledge sharing. They introduced an example of student learning that was not just retrieving the knowledge that teacher intended to teach them but expanding that knowledge by asking the teacher questions. The teacher planned to teach the fact that ultrasonic waves are utilized to figure out how deep the ocean is and to teach how to calculate the depth of ocean using ultrasonic waves. However, one student’s question became an opportunity to learn that ultrasonic waves are utilized to determine what the bottom of the ocean looks like, which was not planned as intended learning, when the teacher responded that ultrasonic waves can pass through all obstacles. From the perspective of knowledge expansion in the lesson, this example indicates that unintended learning can be worthwhile to share and the teacher's role can be important.

2.3. Learning in practical science lessons

In particular, this study explored unintended learning that occurred in practical lessons, as the practical lesson is the unique feature that distinguishes science education from most other disciplines (Wellington, 1998). In this section, a literature review about practical work has been done to help understand what and how students have been expected to learn in practical work.

Practical work has been widely and frequently used in school science since 1960 in some countries including Korea (Yang, Kim, & Cho, 2007). Practical lessons have unique characteristics, such as hands-on activities, and a less formal learning environment than lecture-based lessons in that students have more freedom to do what they want rather than sitting and looking at the teacher and they can have conversations in groups (Hofstein & Lunetta, 2003). Hofstein and Lunetta (1982) reported that rich benefits can be provided to student learning by doing practical work. For instance, practical work can improve students' understanding of scientific concepts and the nature of science, skills, interest, and motivation.

However, questions have been raised about the role and effectiveness of practical work (Qualter, Strang, Swatton, & Taylor, 1990). Tobin (1990) reported that practical work was not effective in learning scientific knowledge. As students only focused on completing the provided task, there was little opportunity for students to think about the idea or concept that practical work was about. Students' interest does not always increase when the amount of practical work is increased (Reid & Tracey, 1985). Although the opportunity to do practical work has been provided to both younger and older students, interest declines as practical work gets more structured (Okebukola, 1986). Striving for correct answers and concerns about what ought to happen in practical work can also interfere with learning the nature of science (Hodson, 1993).

As the views on science, science teaching, and learning have changed, the way that practical work has been utilized and taught has also been required to change (Duschl & Grandy, 2008). Some research that has raised questions has not criticized the practical work itself but criticized the way that practical work has been utilized and taught (Hofstein & Lunetta, 2004). How then have the views of science, science teaching, and learning changed and what and how do we expect students to learn from practical work?

Science has previously viewed objective knowledge as being produced by experimentation. The concern was not about how knowledge was produced but more about the justification of knowledge (Duschl & Grandy, 2008). Objective knowledge was believed to be transmitted to science in the form of a truth statement. However, the current view of science has cast doubt on the way that logical positivists explained how knowledge is produced by arguing that there is no absolute objective knowledge that experimentation can produce (Duschl, 2007). The evidence acquired by observation cannot be objective but is influenced by the observer's experience, background, and beliefs (Brown, 1993). There have been many science philosophers who were against logical positivism, Polanyi being the one of them. Most science philosophers who were against the ideas of logical positivism such as Kuhn tended to argue more about how scientific knowledge could be justified, but Polanyi argued more about how scientific knowledge was pursued (Jacobs, 2000). Polanyi discussed the characteristics of knowledge using the concept of the passion that scientists have in pursuing knowledge. He also argued that there was a tacit dimension of knowledge that could not be described in words but that scientists knew how to do. The characteristic of knowledge that Polanyi argued for was a denial of the view that knowledge was objective. This change in view of science expects students to learn that doing science is not producing the objective knowledge that is truth but rather a human activity (Duschl, 2007).

This change in the view of science teaching and learning has influenced the way that practical work needs to be taught and how students are expected to learn from it. Since the current view on science teaching and learning emphasizes that the student is an active and social individual (Duschl & Grandy, 2008), it has been argued that teaching should provide students the opportunity to interact with others and to manage their ideas rather than simply passively doing what teacher tells them to do.

In summary, practical work is expected to help students learn scientific knowledge, procedural knowledge such as skills for doing science, and the nature of science. As views on science, science teaching, and learning have changed, practical expected to help students learn that experimentation does not automatically produce objective knowledge and that experimentation is a type of human activity by doing a practical work. Also when students do practical work, they are expected to be a more active learner in constructing their ideas with their peers.

2.4. Motivation for science learning in practical work

Section 2.3 discussed what and how students have been expected to learn from doing practical work and how participation has been important both when scientists pursue knowledge and when students learn science. What then motivates students' participation in science learning, especially when they do practical work? As this study aimed to explore student learning in practical work, this section will discuss motivation for science learning by connecting the student's motivation in education and scientist's motivation in doing science. This will help us to determine how science learning needs to be encouraged in practical work. The most well-known person behind the idea that personal participation is important in pursuing scientific knowledge is Michael Polanyi (Jacobs, 2000). Therefore, the component of motivation for students in learning and the component for scientists in pursing knowledge that Polanyi argued will be discussed in this section.

Motivation means a drive to action (Bandura, 1986), and this can be divided into intrinsic motivation and extrinsic motivation (Harackiewicz, 2000). Intrinsic motivation can be referred as pleasure or satisfaction and extrinsic motivation can be thought of as reward. As Deci (1998) argued that "intrinsically motivated behavior is done because it is interesting" (p, 149), interest and intrinsic motivation are practically used as synonyms (Tobias, 1994). However, as interest is one of the factors that results in intrinsic motivation, motivation has a more complex relation. The interest that provokes intrinsic motivation can be divided into two: personal interest and situational interest (Hidi & Harackiewicz, 2000). Personal interest is a preference that individuals have for certain activities or domains of knowledge and situational interest is the interest stimulated as a consequence of being in a certain environment or situation. Unlike personal interest, situational interest is more likely to be influenced by a teacher in the short term (Abrahams, 2009). Therefore, in school settings teachers make an effort to provoke students' situational interest in order to make student more engaged or to achieve effective science learning. On the other hand, an interest where a student becomes fascinated by a situation that a teacher did not intend is personal interest.

Polanyi also emphasized personal commitment in pursuing knowledge and argued that intellectual passion is a necessary condition for scientists pursuing knowledge (Polanyi 1958). Intellectual passion is closely associated with motivation and interest as discussed earlier. According to Polanyi, intellectual passion has two components: heuristic passion and persuasive passion. Heuristic passion is an inspiration to pursue knowledge, while persuasive passion is a drive to share that knowledge with others. Polanyi suggested that these passions are not merely a psychological byproduct but have a logical function to contribute in science. The excerpt below argues that heuristic passion, such as consistent interest and effort, is crucial to solving any problem.

> Obsession with one's problem is in fact the mainspring of all inventive power. Asked by his pupils in jest what they should do to become "a Pavlov," the master answered in all seriousness: "Get up in the morning with your problem before you. Breakfast with it. Go to the laboratory with it. Eat your lunch with. Keep it before you after dinner. Go to bed with it in your mind. Dream about it." (Polanyi, 1958, p. 127)

Polanyi also mentioned that heuristic passion is a mainspring of originality and/or creativity for individual scientists. Once a person discovers or produces some knowledge, it is natural that the person wants to share it with others or persuade others, and this desire to share or persuade is called persuasive passion. Examples of this might include publishing papers in the scientific community and teaching students in schools. Polanyi said that heuristic passion often leads to persuasive passion, and active persuasive passion will make science knowledge and community flourish. He also argued that these passions should be supported by the community:

> Articulate systems which foster and satisfy an intellectual passion can survive only with the support of a society which respects the values affirmed by these passions, and a society has a cultural life only to the extent to which it acknowledges and fulfils the obligation to lend its support to the cultivation of these passions. (Polanyi, 1958, p. 203)

Intellectual passion is also relevant in science education in the sense that heuristic passion functions as an inspiration to pursue knowledge in the classroom and persuasive passion drives students to share what they have learned (either intentionally or unintentionally) with other students in their class. Heuristic passion is more complicated than just curiosity or interest, but within an educational context students' own curiosity or interest is an example of heuristic passion that students can present. In this sense heuristic passion, which encompasses a students' own curiosity and interest, can itself be seen to be an integral component in what Hidi and Harackiewicz (2000) refer to as personal interest, which Abrahams (2009) has claimed is an important component of effective science learning. Persuasive passion can manifest itself in an educational context both in terms of a teacher's passion for teaching (Carbonneau, Vallerand, Fernet, & Guay, 2008) and students' desire to share their learning or knowledge with other students in their class and/or their teacher. Indeed, it has been suggested (McNeill, Lizotte, Krajcik, & Marx, 2006; Osborne, Erduran, & Simon, 2004) that this form of persuasive passion is a form of argumentation and scientific explanation. In this sense, I would suggest that a lesson needs to be an interplay between the heuristic and persuasive passions (see Chapter 5) of both students and their teacher in order to maximize the effectiveness of any learning—including unintended learning.

Chapter 3. Design and method of the study

This qualitative study is based on naturalistic inquiry that holds descriptive approach rather than prescriptive approach by using the data collected from the natural settings (Lincoln & Guba, 1985). This chapter describes the design of the study and methods of data collection and analysis used in this study. How science lessons taught by each of the five teachers were selected and their representativeness will be explained. The context of research settings will also be described as well in order to help understand the characteristics of Korean practical science lessons and the observed lessons taught by each teacher. This chapter will also explain how this study was performed ethically and how the data was collected and analyzed.

3.1. Selection of research settings

This study took place in Korean primary school practical science lessons taught by five teachers. Lessons were selected in order to represent a variety of schools and teachers (See Table 3.1). I prepared a list of teachers that I could access and selected five teachers to ask to participate. When selecting the teachers, I wanted to include high-, middle-, and low-achieving schools, both homeroom teachers and science subject teachers,[1] and both female and male teachers. Unfortunately, as selection was dependent on the list of teachers that I could access, the lessons were taught by teachers who had more than 10 years' experience could not be observed. The locations of schools were also restricted to Seoul and Gyeonggi Province. However, as Korea has a national curriculum, the textbooks and the types of practical work that students in Seoul and Gyeonggi Province area do are more likely to be the same as what students in other areas do. I expected that observing multiple cases of lessons from a variety of school achievement levels and teacher types and both genders of teachers would help to generalize the results of this study.

[1] There are two types of teacher who teach science in primary school in Korea. Homeroom teachers (담임교사) teach science and other subjects. Science subject teachers (과학전담교사) teach science to all the students in a same grade.

Table 3.1

Overview of teacher participants

School	School location	School Achievement*	Teacher	Teacher type	Student grade (age)	Teachers' Teaching experience (years)	Teachers' Subject specialism
A	Seoul	Low	Mr. Lay	Classroom teacher	5th grade (10-11 year-old)	6	Science
B	Gyeonggi	High	Mrs. Yuna	Science subject teacher	5th grade (10-11 year-old)	5	Science
C	Seoul	Middle	Mr. Sun	Classroom teacher	5th grade (10-11 year-old)	4	Computer
D	Seoul	Middle	Mrs. Rose	Science subject teacher	6th grade (11-12 year-old)	7	Science
E	Seoul	Low	Mr. June	Science subject teacher	6th grade (11-12 year-old)	4	Science

*The achievement was categorized based on the school ranking of the national assessment in 2011.

3.2. Context of research settings

Korean science lessons have a unique cultural and historical context that distinguishes them from other countries (Leem & Kim, 2013). Korea has a highly structured and controlled national curriculum. The textbooks and guidebooks for teachers are based on the national curriculum. Only one kind of textbook and guidebook for teachers of primary school science has been developed and published by the government. Schools in Korea are legally required to use these textbooks as stated in Article 29 of the Elementary and Secondary Education Act of 2014: “Schools must use the textbook that the nation has copyrighted or the textbooks which are authorized and qualified by the Minister of Education.” For these reasons, Korean primary school teachers should use the textbook in their lessons (Ryu, Choi, & Kim, 2014).

Yang et al. (2007) showed that most practical lessons in Korean primary schools were precisely structured in that all the activity and instructions were given by teachers and textbooks. Although Korean primary school teachers perceived that inquiry-based teaching and learning is important, their practice mostly aimed at more acquisition of declarative knowledge with less emphasis on inquiry (Yang, Jeong, Hur, Kim, Kim, Cho, & Oh, 2006).

These characteristics of Korean primary practical lessons were observed in the lessons in this study. Teacher participants also planned their lessons based on the textbook and the guidebook for teachers. The learning objectives and experiments that teacher participants actually arranged were more or less the same as those in the textbook and the guidebook for teachers. Only a lesson from Mr. Sun was slightly different in that he decided to make a microscope slide with leaf instead of using the ready-made slide that textbooks and guidebook suggested. All the practical work that teacher planned was either for verification of knowledge or followed a discovery-based approach with step-by-step instructions from the teachers.

The lessons taught by each teacher had their own context. The school that Mr. Lay taught at was a low-achieving school located in Seoul. There were two science laboratories and there was an assistant who prepared the materials for practical work. All the observed lessons were in one of the science laboratories, but since this laboratory was not the one where the assistant stayed, the assistant only did preparation for the lesson and did not help at all during the lessons. While Mr. Lay had taught science as a homeroom teacher in the first year that he became a teacher, he had not taught science for the next five years because during that time there had been science subject teachers, so this was only his second year of teaching science. In the year that the data for this this study was collected, Mr. Lay became a homeroom teacher and taught science as well as other subjects. He told me that he wanted students to learn the proper scientific concepts and to become more interested in science by experiencing success in doing practical work. He emphasized having a successful experience in practical work by using word *success* several times. However, since he was a homeroom teacher, he told me that he had little time to do a test run of the practical work before the lesson because he needs to prepare other subjects and to do paperwork as well.

The school in which Mrs. Yuna taught was a high-achieving school located in Gyeonggi Province. There were two science laboratories and all the science lessons that Mrs. Yuna taught as a science subject teacher were in the science laboratories. As there was no assistant in the science laboratory, Mrs. Yuna prepared the practical work by herself, and she told me that she tended to do a test run of the practical work before the lesson. The lessons that Mrs. Yuna taught were highly structured in that teachers in her school were required to submit a weekly lesson plan and the school compelled teachers to stick to it. She told me that she usually prepared a few questions in her presentation file for the lesson that she used to check students' conceptual learning after doing the practical work. This shows that she emphasized conceptual knowledge in her science practical lessons.

The school in which Mr. Sun taught was a middle-achieving school located in Seoul. All the observed lessons were in the science laboratory, and there was an assistant who stayed in the science laboratory. All the preparation for the practical work was done by this assistant, who had been selected as the best assistant by Seoul Metropolitan Office of Education (SMOE). Unlike what occurred in Mr. Lay's lesson, I observed that assistant in this school helped teachers during the lessons. Mr. Sun told me that he had little time to prepare science lessons as he was a homeroom teacher who taught several subjects and he could get a lot of help to prepare the science lessons from the assistant. He described his lessons as being more spontaneous than planned. He was the only teacher participant who planned the lessons in a slightly different way from what the textbook suggested. However, he also tended to do the practical work in the textbook with very little alteration.

The school in which Mrs. Rose taught lesson was the same school as Mr. Sun's. She taught science as a science subject teacher. She told me that almost every time practical work was going to be done in class she did a test run before the lesson. As was the same school with the award-winning assistant, the assistant helped her a lot with preparing practical work. Her unique way of teaching was that she gave the students about three to five minutes to read the textbook before they started practical work. The purpose of this activity was to prepare students to be aware of what to learn and what to do. She described her lessons as being more focused on scientific concepts than inquiry. She tried to do practical work as inquiry but she often found that the results the students obtained in their practical work were not the same as what she had planned. She decided not to do practical work as inquiry because she found that it was not effective in the scientific conceptual learning.

The school where Mr. June taught was a low-achieving school. It had a low socio-economic status so it received funds[2] from the SMOE. The observed lessons were in the science laboratory and this school also had a science laboratory assistant. Mr. June taught science as a science subject teacher and also often did test runs of practical work before his lessons. The assistant often prepared the materials but he told me he also tried to double-check them. He had four years of teaching experience, but this was the first time he taught science. He believed that he should do all the practical work the curriculum suggested and that the practical work was the means to achieve the learning objectives. He said that in his lessons that he tended to provide the learning objectives at the beginning of the lesson and to explain the concept from the results that students got. So he thought that it was important to get the right results from the practical work. This was why he usually did a double check of the materials before the lessons.

[2] This kind of school is called 교육복지특별지원 사업 대상 학교.

The number of lessons during which each teacher was observed was determined on the basis of their availability and the number of science lessons that they would teach during the period of observation, with a minimum of three (Mr. Sun and Mrs. Rose) and a maximum of eight (Mr. June). Mrs. Yuna and Mr. June are science subject teachers who teach science to all students in a grade, thus I was able to observe lessons in two different classes that Mrs. Yuna and Mr. June taught. I observed four of Mrs. Yuna's lessons, which consisted of two lessons each from two different classes. I was able to observe eight of Mr. June's lessons, which consisted of four lessons each from two different classes. Twenty-two lessons were observed over a five-month period from March 2014 to July 2015. I observed each teacher's lessons consecutively, meaning that no lesson came in between the lessons that I observed. The overview of the observed lessons from each teacher is presented in Table 3.2.

The student participants were Grades 5 and 6 students whose age ranged from 10 to 12 years old. A total of 149 students consented to participate in this study. Table 3.3 shows the number of student participants from each teacher's class.

Table 3.2

Overview of the observed lessons

Teacher	Class	Observed lesson	Contents of practical task
Mr. Lay	1	4 lessons	Electric circuits: Conductor, parallel, & series circuits
Mrs. Yuna	2	4 lessons	Electric circuits: Parallel & series circuits
Mr. Sun	1	3 lessons	Leaves: Structure and function
Mrs. Rose	1	3 lessons	Acids and bases: Indicators, reaction of acid and base
Mr. June	2	8 lessons	Magnetic field: Electromagnets

Table 3.3

The number of student participants

	Mr. Lay	Mrs. Yuna		Mr. Sun	Mrs. Rose	Mr. June		In total
		Class A	Class B			Class C	Class D	
Number of student participants	23	18	28	19	17	18	26	149

3.3. Ethics

As this study involved direct contact with minors, the Institutional Review Board (IRB) of Seoul National University monitored all the procedures, including teacher and parental consent, student assent processes, and data collection. I orally explained all the possible ethical issues to the teachers and students, and all the required documentation was provided to students, parents, and teachers before commencing this study. In accordance with guidelines for conducting ethical research, I use pseudonyms for the names of the schools and for all participants in this study.

3.4. Data collection

For the data collection, a total of 22 practical science lessons taught by five teachers were observed. These were also audio- and video-recorded. Additional data included pre-lesson interviews with the teachers, field notes, short student memos after lessons, and post-lesson interviews with the students and teachers (See Figure 3.1). In this section, I describe each data source and how the data were collected.

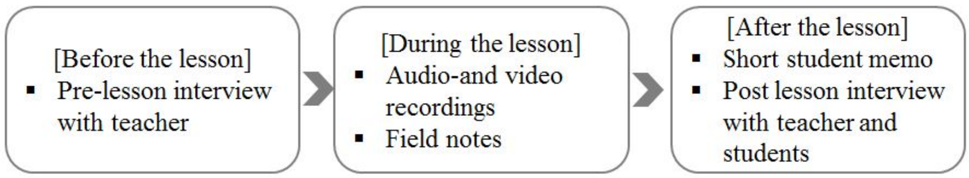


Figure 3.1. The process of data collection

3.4.1 Pre-lesson interviews

Pre-lesson interviews were carried out with the teachers to ascertain details of the lessons to be observed. I decided to do pre-lesson interviews because the objectives and tasks that teachers have planned can be different from the objectives and tasks that national curriculum and textbook suggest. During the interviews, the teachers were asked about their objectives for student learning for the lesson and procedures they had planned for the experiments.

The pre-lesson interview started with an open request such as "Please tell me about your lesson plan that I will observe." After the open request, follow-up questions were asked in order to gather more detailed information about the lesson or to make clear what teacher had said. Therefore, there were no prepared questions, and the pre-lesson interview was not a structured interview. Only one pre-lesson interview was conducted with science subject teachers even though they were observed teaching two lessons because both lessons had the same learning objectives with the same theme for each of the two separate classes. Therefore, a total of 17 pre-lesson interviews for 22 practical lessons were audio-recorded and transcribed.

The teachers in this study explained the plans for their lessons by showing the textbook or guidebook for teachers.

Researcher: Did you plan this based on the textbook and workbook?

Mrs. Yuna: Yes, I usually plan [the lesson] within the textbook and workbook.

Researcher: Then, are learning objectives same as those in guidebook for teachers? The learning that students are expected to…

Mrs. Yuna: There is not much difference.

This showed that teachers in this study planned their lessons based on the textbook or guidebook for teachers. The learning objectives and experiments that teacher participants in this study actually arranged were more or less the same as those in the textbook and the guidebook for teachers.

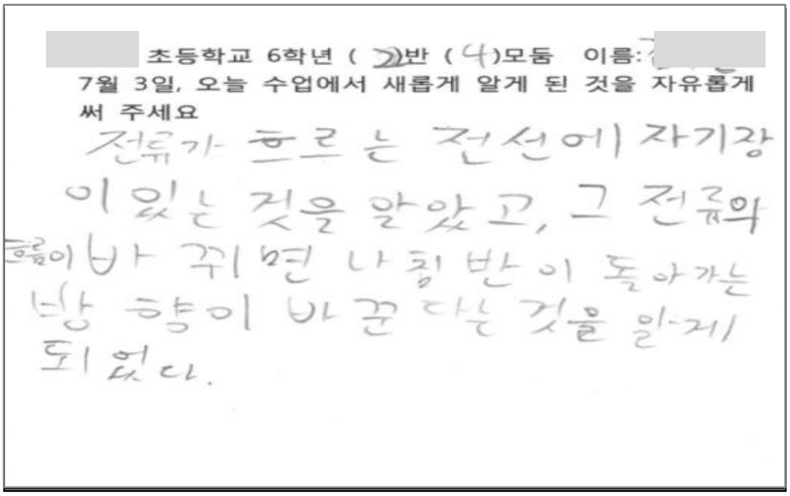
3.4.2 Audio and video recording and field notes in the lesson

A total of 22 practical science lessons taught by the five teachers were observed and audio- and video-recorded. In addition to whole-class recordings, audio and video recordings were also made for a group of students from each lesson who consented to this study. A fixed camcorder was set up to capture as much as detail about students' practices as possible and an audio recorder was placed on the group's desk in order to obtain high quality recordings of the students' discourses. In addition, a hand-held camcorder was sometimes used to capture much more detailed information than fixed camcorders can. Where possible, the researcher had a conversation to confirm if learning had occurred and, if so, what they had learned and how they had learned it. These conversations were audio-recorded.

Ethnographic field notes were made that included details about the classroom structure, student seating arrangements, and a general description of the lesson. For instance, the learning objectives that the teacher provided to the students during the lesson, the general description of each activity, and the time when each activity changed were written in the field notes. Field notes also included notes about when unintended learning was observed so that these could subsequently be examined on the video for more detail.

3.4.3 Short student memos after lesson and post-lesson interview

After a class, students were asked to write a short memo about what they had learned in the lesson (See Figure 3.2). The learning that students wrote about in these memos was utilized to pick up on unintended learning in the audio and video recordings. Most of short memos were about the intended learning but there were a few instances of learning that teacher did not plan for in this lesson. This data also was one of the complementary data sources used to confirm the unintended learning from the video.


초등학교 6학년 (2)반 (4)모둠 이름:

7월 3일, 오늘 수업에서 새롭게 알게 된 것을 자유롭게 써 주세요

전류가 흐르는 전선에 자기장이 있는 것을 알았고, 그 전류의 흐름이 바뀌면 나침반이 돌아가는 방향이 바뀐다는 것을 알게 되었다.

Figure 3.2. Example of a short memo. The transcription of this example is as follows: “I learned that there is a magnetic field when electricity flows through the wire and I learned that the direction that the needle of the compass turns will change when the direction of the electricity flow is changed.”

Post-lesson interviews with teachers and some of the students were also audio-recorded. The students were asked what they felt they had learned. Teachers were asked to reflect on their lessons with the aim of determining which aspects of the observed learning had been intended by the teachers.

3.5. Data processing

The collected data were organized as ready-analyzed data sources. The main data sources for analysis were transcriptions of unintended learning episodes from the audio and video data and transcription of post-lesson interviews.

The data processing for selecting unintended learning episodes was as follow.

Firstly, each pre-lesson interview with a teacher was transcribed to identify the learning objectives of the lesson. The teachers' learning objectives, which appeared in the pre-lesson interview, were described as intended learning. Secondly, based on what had been identified as intended learning from the pre-lesson interviews, audio and video recordings were reviewed to identify unintended learning episodes. Unintended learning was defined as any student learning that was found to occur that had not been planned by the teacher for that specific lesson. Episodes of unintended learning were selected as such when a student underwent an experience that the teacher did not intend and, at the same time, students reflected on this experience by mentioning the experience or doing some action because of this experience. When I identified discourse or behavior that appeared to be student learning that the teacher had not intended, I stopped to watch the video and listen to the discourse closely several times and checked against the teachers' objectives. Thirdly, the selected unintended learning episodes in the second step were cross-checked with field notes and student memos. The noted unintended learning in the field notes and student memos was used to confirm the selected unintended learning episodes. In addition, I checked whether there were any missed episodes from the second step that I had noted in the field notes or students had noted in their memo. If there was one, I went back to the audio and video data to confirm it and included it as an unintended learning episode. Fourthly, the finalized episodes of unintended learning were transcribed. In order to determine the nature of the unintended learning, I transcribed the selected episodes' audio data of the discourse between teachers and students, discourse among students, and behavior of the teacher and students. In addition to unintended learning episodes, the post-lesson interview with teacher and some of the students were also transcribed. Figure 3.3 shows how data were processed.

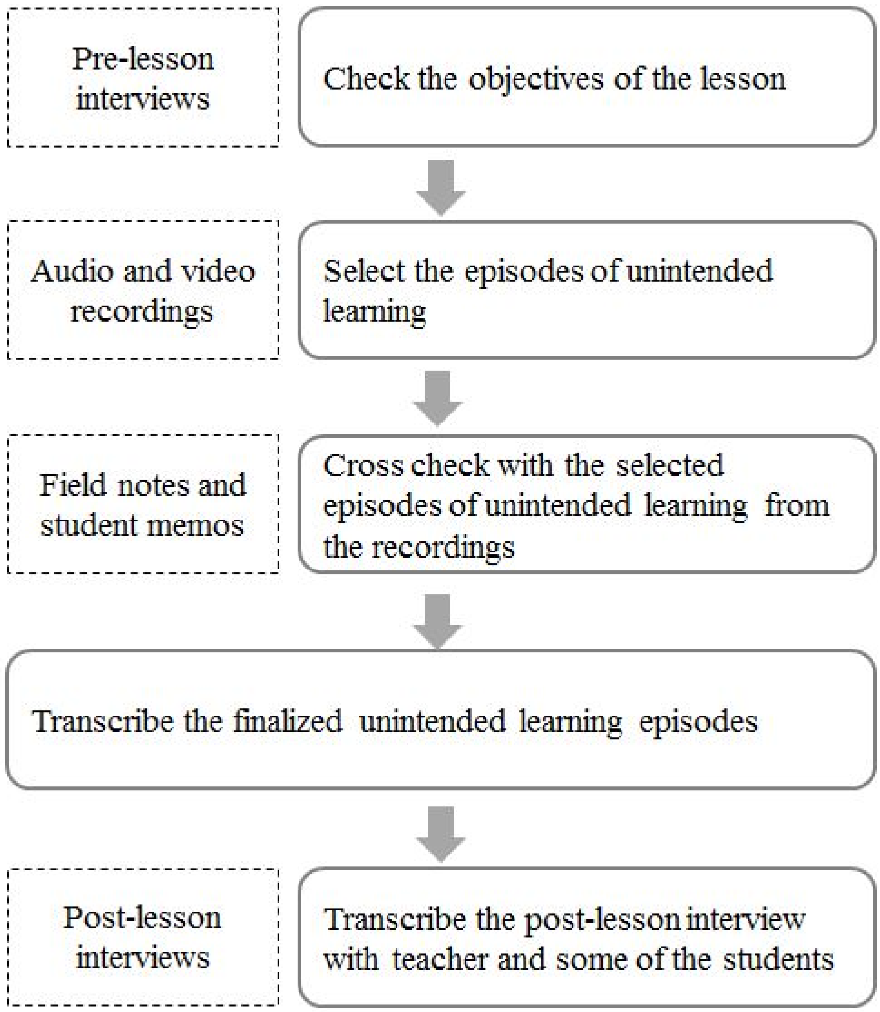


Figure 3.3. Data processing procedure

3.6. Data analysis

3.6.1 Identifying the unintended learning

The unintended learning was identified in the transcriptions of selected episodes of unintended learning. The learning was coded as a form of statement based on the students' discourses or behaviors (See Table 3.4).

To secure the reliability of the analysis in this study, member checking was done (Guba & Lincoln, 1989; Miles & Huberman, 1994). The unintended learning identified in two lessons was subsequently checked with the teacher of those lessons to ascertain whether it had in fact been unintended; the teacher confirmed this in both cases.

In addition, in order to check on the reliability of the analysis, I and an invited science education researcher independently analyzed five more lessons. As a first step, selecting unintended learning episodes of two lessons was done separately by both researchers. As a second step, both researchers separately identified unintended learning from the selected episodes of unintended learning. While the number of unintended learning identified by the invited researcher was larger than mine was, the invited researcher's list of examples of unintended learning included all of the examples I had identified. The additional examples of unintended learning that had been identified by only the invited researcher were not able to be unambiguously confirmed as having been learned in that specific lesson. For example, the invited researcher mentioned that students seemed to learn how to negotiate their different opinions (see Table 3.4). However, as neither the researchers nor the class teacher were able tell with certainty whether the students learned this in this lesson, we decided not to consider this unintended learning in this study. After the invited researcher and I agreed not to include such ambiguous unintended learning, three more lessons were analyzed independently for examples of unintended learning, and total agreement was found in all three cases. After checking for reliability, the researcher analyzed the rest of the data.

Seventy-nine instances of unintended learning were identified in this study. In the four lessons delivered by Mr. Lay and Mrs. Yuna, there were 12 and 14 examples of unintended learning, respectively. In the three lessons delivered by Mr. Sun and Mrs. Rose, there were 8 and 10 examples of unintended learning, respectively. The remaining 35 examples of unintended learning were identified throughout Mr. June's eight lessons. I would like to emphasize here that the number of examples of unintended learning reported here may be lower than the number that actually occurred. Only observable instances could be analyzed unless complimentary data such as interview or short student memo reveal it as I could not know what students learned if it is internal. In addition, only learning that was unambiguously unintended by the teacher was included, with examples that were considered ambiguous being excluded. Also, any unintended learning by students who had asked to be excluded from the study, although they were in the class, was not analyzed in this study.

Table 3.4

Examples of unintended learning and exclusion from unintended learning

Teacher objectives (Intended learning)	Students will learn the structure of leaves. ▪ By observing the leaves with the naked eye, students will learn that there are the different shapes of veins. ▪ By making a preparation of leaf epidermis and observing with a microscope, students will learn that there are stomas in the leaves.

[An episode of unintended learning]

1 S1: *It has a smell.*
2 S4: I can't smell anything. This is why you smell this [Leaf A] and that [Leaf B].
3 S1: [Smelling again] It smells.
4 S4: [Smelling again] I can't smell anything. *How about Junho [S2]?*
5 [Ellipsis]
6 S1: [Smelling the end of leaf again]
7 S4: Not there.
8 S1: *It is same whether here [the end of leaf] and here [the middle of leaf]. How is it different?*
9 S4: How is it the same?
10 S1: Then if here and here is different, this can be different. What is the same?
11 S4: So it is different.
12 S1: So this could have no smell. Here it has a smell.
13 S4: *I thought you said that the middle of leaf has a smell.*

Example of unintended learning found by both researchers	Students learned that the end of leaf has a smell and the middle of the leaf has no smell. (See Line 1)
Example of exclusion from unintended learning found by the invited researcher	Students learned that how to negotiate their different opinions by asking for a second opinion (See Line 4) or the other's reason (See Lines 8 and 13). (Reason for exclusion: This was excluded because it was not possible to ascertain unambiguously whether the skill of negotiation had been learned in this specific lesson.)

3.6.2 Coding for knowledge and reasoning of unintended learning

Identified examples of unintended learning in section 3.5.1 were coded for knowledge that students learned and for reasoning that students engaged.

Knowledge can be categorized in various ways. Ryle (1949) categorized knowledge as propositional knowledge and procedural knowledge. In an educational context, Bloom’s taxonomy of knowledge has been widely used for learning goals (Bloom, Engelhart, Furst, & Krathwohl, 2002). Krathworhl (2002) developed a revised Bloom’s taxonomy and categorized knowledge as factual knowledge, conceptual knowledge, procedural knowledge, and metacognitive knowledge. Propositional knowledge can be viewed as factual knowledge and conceptual knowledge in the revised Bloom’s taxonomy. These overlapping categories of knowledge were used to guide my analysis and the categories are defined as follows:

- Factual knowledge: The facts that students observed
- Conceptual knowledge: Conceptually connections between the facts that students observed or their prior knowledge
- Procedural knowledge: Empirical knowledge that students learn about how to do things

I also analyzed what reasoning students used in their unintended learning. However, since most unintended learning was ignored or missed by the teachers, they made few deliberate efforts to give students enough time for cognitive processes. For this reason, discourse about unintended learning was not supported by teachers and it occurred in a short period of time. This made it difficult to discover what cognitive processes were used in students' unintended learning. However, from the students' behaviors, discourse, and type of knowledge acquired I was able to infer what cognitive process they used. The epistemic reasoning framework that Driver et al. (1996) developed was intended to explore the interaction between development of knowledge and reasoning rather than to assess the reasoning ability of an individual (Tytler & Peterson, 2004). Therefore, this framework can provide a useful basis for describing students' epistemological reasoning and knowledge. Epistemological reasoning has been categorized into three types of reasoning (Driver et al., 1996): phenomenon-based reasoning, relation-based reasoning, and model-based reasoning. Each type of reasoning has been defined as follows:

- Phenomenon-based reasoning: in which explanation and description are not distinguished and the purpose of the experimentation is to observe.
- Relation-based reasoning: in which an explanation is cast in terms

of relations between observable or taken-for-granted entities, found by fair testing or other controlled variables.

- Model-based reasoning: in which theories or models are evaluated in the light of evidence and the relationship is recognized as provisional and problematic.

Based on the definition of knowledge and reasoning explained above, each example of unintended learning identified in Section 3.5.1 was analyzed and Table 3.5 shows how I analyzed it. The process and examples of analysis was shared with colleagues and was presented in conferences as well. According to Shenton (2004), 'peer scrutiny of research', such as discussion with colleagues and presenting at conference, is one of the techniques for increased credibility in qualitative research.

The transcription in Table 3.5 shows that students learned that a light bulb did not light up when two batteries were placed in opposite directions. In this episode, as students simply stated the fact that they observed, student learning was coded as factual knowledge and the associated reasoning was coded as phenomenon-based reasoning.

Table 3.5

Examples of coding for factual knowledge and phenomenon-based reasoning

[Part of the transcription of Mr. Lay's lesson on July 3, 2014] S1: Press the battery. It doesn't work. S1: Is this because wire is bent? [S1 changed the direction of the battery.] S2: The direction of battery was different. S1: It was not [lit up] because the direction [of the battery] was opposite. S3: These two [batteries] should have been put in the same direction but this [battery] was opposite to this [battery].	
Unintended learning	Students learned that light bulb is not lit up when two batteries were placed in opposite directions.
Type of knowledge	Factual knowledge
Type of reasoning	Phenomenon-based reasoning

Table 3.6 shows another example of coding for conceptual knowledge. The students whose discussion is shown in Table 3.6 learned that the compass needle moved towards the battery because of the magnetic field. They explained what they observed with their prior knowledge of magnetic fields. Therefore, the student learning was coded as conceptual knowledge associated with model-based reasoning.

Table 3.6

Examples of coding for conceptual knowledge and model-based reasoning

[Part of the transcription of Mr. Lay's lesson on July 3, 2014] S1: Look! If I do like this, it happens like this. Amazing. [S1 is trying moving the battery on the compass and watching the needle moving.] S1: It [Compass needle] is moving after the battery. S2: This, this is because this [battery] is a magnet. S1: Really? S2: A little bit of magnetic field? S1: This is fun, isn't it?	
Unintended learning	Students learned that the compass needle moved towards battery because of the magnetic field.
Type of knowledge	Conceptual knowledge
Type of reasoning	Model-based reasoning

Table 3.7 shows another example of coding for procedural knowledge by practice. Students whose discussion is shown in Table 3.7 learned that pressing a battery made it connect when circuit did not work well. About 10 minutes after the lesson started, the students learned how to make the circuit work by pressing the battery with the teacher and then afterwards applied this procedural knowledge.

Table 3.7

Examples of coding for procedural knowledge by practice

[Part of transcription of Mr. Lay's lesson on July 3, 2014] [Time 10:55] T: [Light] goes off and on. S1: [It] goes on! Oops. S3: It worked just before. S2: Oh, it worked. T: Press this. S1: It works when we press this. S1: Try this. S2: It works. [Time 21:18] S2: The light is weak. S1: Do you know why? S2: It works. S1: Because it was not pressed. S1: Press this [the battery].	
Unintended learning	Students learned that pressing battery made the battery connect when circuit did not work well.
Type of knowledge	Procedural knowledge

3.6.3 Coding for experience that led to unintended learning

The analysis of the occurrences of unintended learning was conducted by inductive coding. The coding procedure began with in vivo codes by using common words on the initial transcribed discourse, behavior, and situations. In vivo codes that share a common theme were categorized and labeled as a common theme. Table 3.8 shows how I analyzed the initial experience that led to unintended learning and categorized the common theme. As a result, six categories were deductively grouped: playing with prepared material for practical work, trying additional things, being interested in phenomena that happened coincidentally, being interested in other students' activities, solving a problem when practical work did not go well, and listening to what other students were saying. This analytic process was also shared with colleagues and science researchers in group discussions and conferences to secure the credibility (Shenton, 2004).

Table 3.8

Example of coding for experiences that led to unintended learning

Raw data from transcription	In vivo code	Common theme	Occurrence context
[The part of transcription of Mr. Lay's lesson on July 3, 2014] S1: Press the battery. **<u>It doesn't work.</u>** S1: **<u>Is this because</u>** wire is bent? [S1 changed the direction of the battery.] S2: The direction of battery was different. S1: It was not [lit up] because the direction [of the battery] was opposite. S3: **<u>These two [batteries] should have been</u>** put in the same direction but this [battery] was opposite to this [battery].	'It doesn't work'	Practical work went wrong	Solving a problem when practical work did not go well
[The part of transcription of Mr. Lay's lesson on July 3, 2014] T: **<u>[Light] goes off and on.</u>** S1: [It] goes on! Oops. S3: **<u>It worked just before.</u>** S2: Oh, it worked. T: Press this. S1: **<u>It works when</u>** we press this. S1: Try this. S2: It works.	'It worked just before'. But it does not work now.		

Chapter 4. Multiple learning paths: The types of knowledge associated with unintended learning

In this chapter, the aim was to investigate what knowledge students learned that their teacher did not intend them to learn. The following questions were used to guide my data analysis and discussion:

1. What kind of knowledge did students learn unintentionally?
2. What kinds of reasoning were used in students' unintended learning?

What I found in this section is that there were three types of knowledge that students learned unintentionally: factual knowledge gained by phenomenon-based reasoning, conceptual knowledge gained by relation- or model-based reasoning, and procedural knowledge by practice. Most unintended learning found in this study fell into the factual knowledge category and only a few cases of conceptual knowledge were found. Although only a few cases of conceptual knowledge, I found that students who engaged in relation-based or model-based reasoning with help from the teacher so that they could learn conceptual knowledge. Based on these findings, the teacher's role to scaffold the unintended learning to the higher level of reasoning was discussed. I also found that students learned both explicit procedural knowledge, which can be described both verbally and in writing, and implicit procedural knowledge, which cannot be stated explicitly and only can be acquired by practice.

4.1. Factual knowledge gained by phenomenon-based reasoning

The knowledge that students learned unintentionally in this study was mostly factual knowledge that was based on a description of what they observed. Fifty out of 79 cases of unintended learning was found to be factual knowledge. This can be inferred as engaging the phenomenon-based reasoning.

In one of Mr. Lay's lessons where the learning objectives were that light bulbs in parallel are brighter than the light bulbs in series, Jane found that a light bulb gets warm when electricity flows through it and put the light bulb in her ear to feel that it was warm (See Figure 4.1).

Figure 4.1 A girl putting a lightbulb in her ear to feel that it is warm

Researcher:	Why are you putting this in your ear?
Jane:	It is warm
	[5 minutes later]
Researcher:	You put this in your ear because it is warm.
	Did you know that a light bulb is warm before [today's lesson]?
Jane:	No.
Researcher:	Did you learn [this] today?
Jane:	I didn't learn [it] today but last time I touched it and it was warm.
	But I didn't put in my ear [last time].
Researcher:	In previous practical work?
Jane:	Yes.
Jane:	As it is brighter, it is warm.
	[5 minutes later]
Researcher:	I have one more question. You told me that it is warm.
	When you said that, weren't you curious why it was warm?

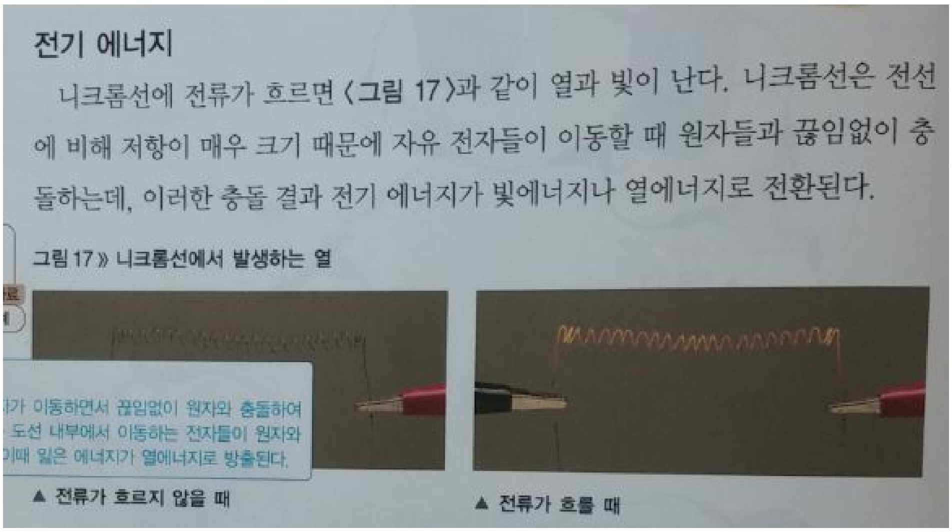
Jane: No, I wasn't curious.

Researcher: Then didn't you think about why it was warm? Then you just thought it was warm?

Jane: Naturally, as this was lit up, as electricity flows, I knew that it was warm.

As can be seen in the transcription above, Jane discovered that a light bulb gets warm when it is lit up during the practical work in school and she even experienced that a light gets warmer when it gets brighter. However, when I asked her whether she was curious about the reason the light bulb got warm, she answered that she was not. This shows that Jane learned the factual knowledge by phenomenon-based reasoning but failed to have an opportunity to reason why it happened.

As in Jane's case, I can observe that most cases of unintended learning remained at factual knowledge gained by phenomenon-based reasoning. Driver et al. (1996) also reported that young students tended to have more phenomenon-based reasoning than relation-based or model-based reasoning. It should be careful here to note that engaging in phenomenon-based reasoning itself does not represent a low level of reasoning ability (Tytler & Peterson, 2004). Driver et al. (1996) mentioned that even advanced thinkers also engage in phenomenon-based reasoning and that different situations may demand different types of reasoning. I am not saying that students in this study were not able to engage in relation- or model-based reasoning but that they failed to have an opportunity to engage other types of reasoning that could have been appropriate. For instance, the phenomenon that Jane found can be linked to the conceptual knowledge that she will learn when she becomes a third grade student in middle school (See Figure 4.2). The textbook explains that nichrome wire emits light and heat when electricity flows. The experience that Jane had of the light bulb being warm might help her future learning, but having a chance to reason why it happened might also help her future learning (Na & Song, 2014).


전기 에너지

니크롬선에 전류가 흐르면 〈그림 17〉과 같이 열과 빛이 난다. 니크롬선은 전선에 비해 저항이 매우 크기 때문에 자유 전자들이 이동할 때 원자들과 끊임없이 충돌하는데, 이러한 충돌 결과 전기 에너지가 빛에너지나 열에너지로 전환된다.

그림 17 » 니크롬선에서 발생하는 열

▲ 전류가 흐르지 않을 때

▲ 전류가 흐를 때

Figure 4.2 The part of a third grader's textbook in middle school dealing with nichrome wire emitting the light and heat when electricity flows

I also could observe 25 cases in this study where students tried things that they were curious about and described what they observed. This mostly led the unintended learning of factual knowledge. Among 25 cases of unintended learning that occurred when student tried thing that were curious about, 23 cases were found to be factual knowledge. For instance, in Mr. June's class about magnetic fields, the intended learning goals were that (a) a magnetic field will be produced by an electric current in a coil of wire and (b) the direction of a magnetic field will be changed when the direction of electric current is changed. For these learning objectives, the teacher prepared a series of practical tasks that had been suggested by the textbook. I found that Jiyeon and her group members tried several things that teacher did not expect them to do during this practical work. Firstly, Jiyeon put her steel ruler on the switch to check whether it let electricity flow (See Figure 4.3). This happened after her group finished the first practical task that the teacher had assigned. Later on, after finishing the second practical task, Jiyeon and her friends tried to link the wires between the two battery cases to check whether it let electricity flow (See Figure 4.4). Two minutes later, one student suggested that Jiyeon not connect these two battery cases firmly but to touch the sides of the cases to each other and check whether this also can let electricity flow (See Figure 4.5). When they did this series of things, there was not much discourse about what they tried. They described only what they observed and there was no more discourse about what they did.

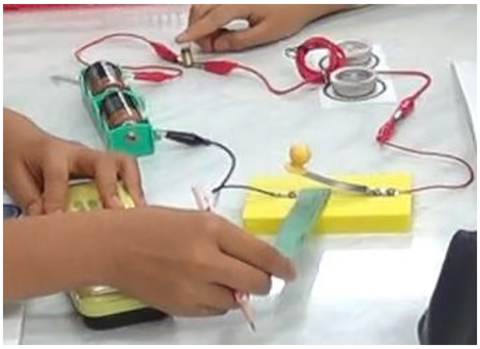


Figure 4.3. Placing the ruler to check if it let electricity flow

Figure 4.4. Checking whether linking the wires between the two batteries let electricity flow

Figure 4.5. Checking whether batteries touching each other let electricity flow

In another of Mr. June's lessons, I observed that Enu was trying to make an electric circuit that was irrelevant to the lesson (Figure 4.6). As in Jiyeon's case, Enu also tried to do what he was curious about but there was no discourse about it and his reasoning was localized at phenomenon-based reasoning. The interview with Enu after the lesson gave a clue as to why there was not much discourse or asking the teacher for help, which could have helped students do relation- or model-based reasoning.

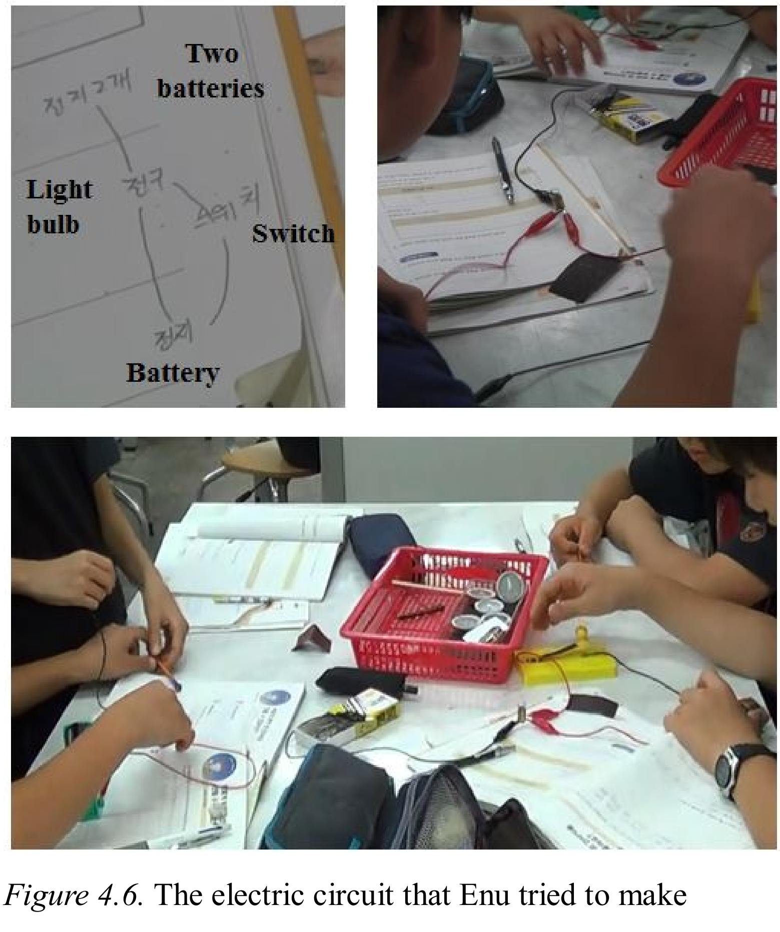


Figure 4.6. The electric circuit that Enu tried to make

Researcher:	I saw that you tried putting this into two batteries. I wonder why you did this, and why in the middle of battery.
Enu:	Um.. I just wondered whether it would work if [I] put this in the middle and not the end.
Researcher:	When you have something that you wonder, don't you ask the teacher?
Enu:	No.
Researcher:	Why?
Enu:	I feel it is better to do it.
Researcher:	Don't you wonder why it happened like that?
Enu:	I also wonder that.
Researcher:	Why don't you ask teacher during the lesson?
Enu:	Because it is lesson time.
Researcher:	During lesson time, do you think you are not allowed to ask a question?
Enu:	Because this is just something that is irrelevant to the lesson.

As you can see in the above transcription, Enu tends to try to do what he is curious about during the practical work but feels uncomfortable asking the teacher about it. Support from the teacher or a collaborative discussion with peers can help students to engage higher levels reasoning (Hogan, Nastasi, & Pressley, 1999). Oh et al. (2007) reported the example that student could have opportunity to expand their knowledge, not limited to intended learning, by asking questions to teacher about what they were curious. However, Enu seems to think that asking a question that is irrelevant to the intended lesson is not appropriate, and this is the prevalent cultural norm among Korean students (Park, Chu, & Martin, 2015). This means that the cultural norm that doing and asking about something that is irrelevant to a lesson is not appropriate made Enu lose an opportunity to engage in higher level reasoning about what he wondered about during the lesson.

4.2. Conceptual knowledge gained by relation- and model-based reasoning

I was able to observe some cases where students learned conceptual knowledge that the teacher did not intend them to learn. Fourteen out of 79 cases of unintended learning were found to be conceptual knowledge. Relatively less number of conceptual knowledge was found than that of factual knowledge in this study.

4.2.1 Relation-based reasoning

Five cases of unintended learning were found to be associated with relation-based reasoning. In Mrs. Rose's lesson about acid-base neutralization, students in Group 1 were frustrated that they did not have the result that they were supposed to have. They added dilute hydrochloric acid and added a few drops of phenolphthalein to the test tube. As they added dilute sodium hydroxide, they observed the test tube in order to note any indicator color change. However, they did not see any changes and complained that the color had not changed to red. While they were trying to figure out what the problem was, students suggested several possible reasons for it. One student said that more hydrochloric acid needed to be added because there was not enough hydrochloric acid. As they added more hydrochloric acid, they were able to observe the interesting phenomenon that only the upper part of the test tube had the color change (Figure 4.7, left picture). Once they stirred the test tube, the liquid turned transparent. Mrs. Rose came over to the group at the moment that the students were observing this phenomenon. The students told Mrs. Rose what they observed. The discourse between Group 1 and teacher is shown below.

Figure 4.7 Teacher explaining the reason of the color change

Teacher:	Didn't the color change?
Hyojin:	The color went away when [I] stirred it.
Teacher:	Right before it was stirred only this part was mixed but now whole thing is mixed.
	It went back to a non-basic state. [Figure 4.7, right picture]
	[The teacher drained some of the liquid out of test tube.]
Teacher:	I reduced the amount [of liquid] because there was too much.
	Please add more [sodium hydroxide].
Sohyun:	Feels like the sodium hydroxide will be gone.
	[The color changed dramatically to red.]
Hyojin:	Wow.
Sohyun:	It changed suddenly.

As can be seen from the above discourse, Hyojin engaged the phenomenon-based reasoning that the color changed when she stirred it. When Mrs. Rose heard Hyojin's reasoning she provided the reason that this phenomenon happened. Furtak, Hardy, Beinbrech, Shavelson, and Shemwell (2010) reported that in order to engage in higher level reasoning, there can be two types of guidance from teachers: teachers can ask the students to provide the elements of reasoning or teachers can provide an element of reasoning to students. Elements of reasoning can be promise, claim, data, evidence, or rule. This study posits that higher-level reasoning can be possible when students can provide elements to back it up, such as evidence or a rule to support their claim, rather than make a claim without any backing or with only specific phenomena. In this case, Mrs. Rose provided the element of reasoning, in this case evidence, instead of the student. Later I observed that Sohyun applied the reasoning that Mrs. Rose had provided. However, she was only able to explain what happened in terms of relations between observables: the color change and the mixing of the liquid.

Sohyun:	What are you doing?
Junho:	Look carefully [like doing magic]. [Adding sodium hydroxide into the liquid where hydrochloric acid and phenolphthalein had been mixed.]
Sohyun:	Isn’t this enough to make a color change?
Junho:	Ta-da! [Stirring the test tube where a color change had occurred at the top of test tube and making the liquid transparent.]
Sohyun:	This is because it is mixed! [Like she is not surprised to see this.] [Indicating the transparent test tube] This also has a basicity.

In this discourse, Sohyun said that the liquid which turned transparent will have a basicity. This shows that she could not understand the concept of the strength of acids and bases and that she thinks of acidity and basicity not as characteristics but as entities.

4.2.2 Model-based reasoning

Nine cases of model-based reasoning in unintended learning were found in this study. In one of Mrs. Yuna's lessons, students in Group 7 determined why a light bulb did not stay lit when one of the batteries in parallel was removed. The teacher's intended learning was that a light bulb will not go out when one of batteries is removed from an electric circuit with two parallel batteries and that the brightness of a light bulb will not change much when one of batteries is removed (See Figure 4.8).

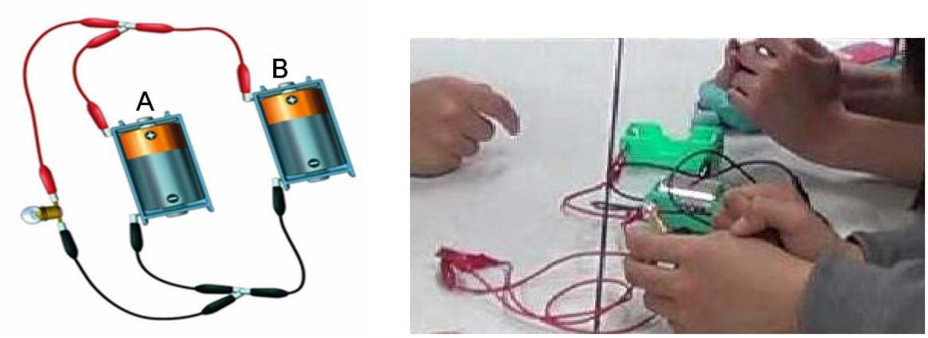


Figure 4.8 Electric circuit with two parallel batteries.

The students in Group 7, however, found that the brightness of light bulb dimmed when one of parallel batteries was removed and in the end the light bulb went out. The students wondered why it happened and they tried to guess what the reason was.

[Students removed Battery A from the circuit (see Figure 4.8)]

Dongmin: It is lit up though.

Sojin: Not very much…

Dongmin: It is lit up…

Sojin: Sort of.

Dongmin: [Talking to the teacher] It is still lit up when one of batteries was removed.

Sojin: Although it is very weak…

Dongmin: [The light bulb] suddenly went out.

Sojin: What happened? Suddenly?

Dongmin: **Why did it happen? Has the battery run down?**

Sumin: **Let's put this [Battery A] back**.

Sojin: Put it back

[Sumin put Battery A back into electric circuit and light bulb lit up.]

Sumin: Huh? It worked.

Dongmin: Is it because the battery was running out?

[Dongmin removed Battery B. After that, students observed the brighter light bulb.]

Dongmin: Yes, **it works when it has this one [Battery A].**

Dongmin: **Let's remove it [Battery A] again**.

[Battery B, which was running out, remained connected to electric circuit]

Dongmin: **See. It doesn't work. This battery is almost out.**

As you can see the transcript above, the students assumed that Battery B might be the reason why the electric circuit did not work properly when Battery A was removed. Students put Battery A back into the electric circuit and removed Battery B in order to check their assumption. They found that the light bulb became brighter when Battery B was removed than when Battery A removed. After that, they put the Battery B into the electric circuit and removed Battery A again to make sure Battery B was out. Finally they concluded that the battery running out caused the broken electric circuit.

Although students saw that the light bulb went out when one of the parallel batteries was removed, which was not what the teacher expected them to experience, they speculated about the reasons for their experience and tried to manipulate the materials they had in order to find the reasons. Finally they made a reasonable model to explain the phenomenon they experienced. This is an example of model-based reasoning. This example contrasts with other cases where students did not explore the reasons why their practical work went wrong or why they could not get the result that teacher expected.

After they determined why the electric circuit did not work well, one of the students said that the battery was not completely out and then shook the battery (See Figure 4.9). The other student said that you cannot figure out how much charge is left in a battery by shaking it. By doing so, they learned not only the reason for the electric circuit not working well but also how to determine whether a battery is out of charge or not.

Figure 4.9 Student shaking the battery

Another case of unintended learning by model-based reasoning is the case where a student examined a light bulb in order to determine what was causing a broken circuit and noticed that there was a hole in the glass. This case will be introduced in Chapter 5. This student also guessed the reason for the broken circuit and made a model to explain it. He drew on his recollection from a book that he had previously read where he had learned that a light bulb contains a vacuum in order to prevent the oxidization of the filament and he applied this to explain the phenomenon he observed.

4.3. Procedural knowledge by practice

In this study, I was able to observe 15 cases of the procedural knowledge in students' unintended learning as well as factual and conceptual knowledge. There are two categories of procedural knowledge: explicit knowledge and implicit knowledge (Polanyi, 1967). For instance, when Mr. Sun presented a lesson that a slide was made in order to observe the structure of the leaf using a microscope, students learned that they can adjust the focus by moving the stage of the microscope.

Shin:	This is out of focus. [When Shin said that the microscope was out of focus, Jin turned the stage height adjustment.]
Hyun:	Why are you lifting this?
Jin:	The science teacher [the assistant] did this.

This lesson did not include learning how to operate a microscope. It was observed that teacher in this lesson and assistant adjusted the focus of each microscope in each group (Figure 4.10, left picture). Therefore, students did not need to adjust the focus of microscope and the only thing they need to do is observing the slides. However, during the practical work, the view became out of focus, Jin recalled the method that the assistant used and related what he recalled (Figure 4.10, right picture).

This learning had not been intended by the teacher, but Jin learned the procedural knowledge of operating a microscope by observing others (Bandura & Huston, 1961).

Figure 4.10 Adjusting the focus by moving the stage of the microscope

As opposed to Hyun learning procedural knowledge that he can describe to his friends, Jihoon learned something that he could not describe while they were making a slide for observing a leaf using a microscope. Jihoon and his friends in the same group repeatedly failed to make a slide as they could not peel the leaves well (See Figure 4.11). After the several tries, Jihoon exclaimed that he had figured out how to do it.

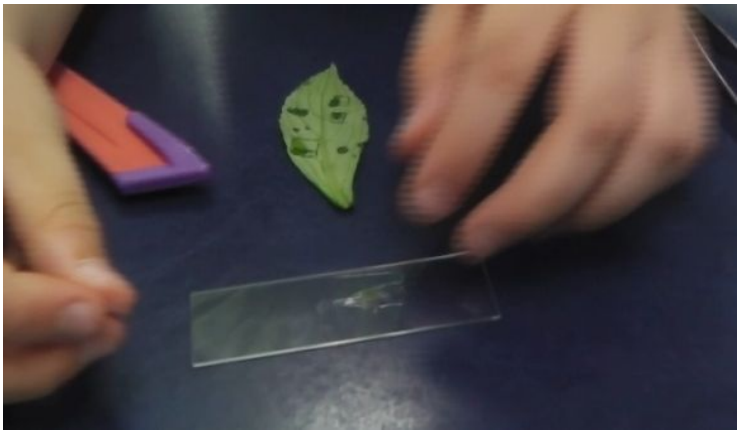


Figure 4.11 Making a slide for observing a leaf using a microscope

Jihoon:	[I] took it off, took it off. I can do it now. [I] figured out the feeling, how to do it.
Wook:	[Making a square-shaped cut on the surface of the underside of the leaf.]
Jihoon:	Really big.
Wook:	Big. [Making a bigger square-shaped cut on the surface of the leaf.] Alright, try it. [Handing over the leaf.]
Jihoon:	Look, first take this off like this.
Wook:	Oh! It really works
Jihoon:	And then when taken off it is a transparent membrane.

As can be seen in this discourse, Jihoon learned how to peel off the membrane of a leaf for making a slide. However, he could not explain it verbally but rather showed his friends by practice. This is the implicit procedural knowledge that he learned and this can only be acquired by practice (Polanyi, 1967).

4.4. Summary and discussion

In this study, I found that students learned factual knowledge, conceptual knowledge, and procedural knowledge unintentionally (Figure 4.12, left diagram). These types of knowledge were learned by means of phenomenon-, relation-, and model-based reasoning. Most of the unintended learning found in this study fell into factual knowledge gained by phenomenon-based reasoning. In general, model-based reasoning has a more complicated process of reasoning than the others. However, this does not mean that phenomenon-based reasoning represents a low level of reasoning ability (Tytler & Peterson, 2004). Wickman and Östman (2002) wrote that students can often encounter a gap between what they know and what they do not know in practical science lessons. Although it may be difficult for students to fill in the gap by themselves, it is important to give them opportunity to try to understand and determine why something happens or to apply related theories. For this, making meaning of what they observed and noticing the gap should come before filling the gap. In this sense, phenomenon-based reasoning often precedes other types of reasoning and it is not surprising that most of unintended learning in this study has been associated with phenomenon-based reasoning.

I found that factual knowledge that students gain through unintended learning can be associated with their future learning. This can help students' future learning by their being able to recall what they experienced and observed unintentionally. In this sense, factual knowledge gained by phenomenon-based reasoning might provide opportunities for educative experience in the long term.

Only 14 out of 79 cases of conceptual knowledge were found by means of relation- and model-based reasoning. There are several possible reasons why I observed only a small amount of conceptual knowledge being gained through unintended learning. One possible reason may be that the cultural norm where it is inappropriate to do something or ask about something that is irrelevant to a lesson may have made students lose opportunities to engage in relation- or model-based reasoning, and in the end students failed to learn conceptual knowledge. Another is that factual knowledge cannot proceed to conceptual knowledge if students simply do not want to explore it further. Also, environmental constraints such as lack of time make students lose opportunities to explore their unintended experiences and cause exploring these experiences to be a low priority.

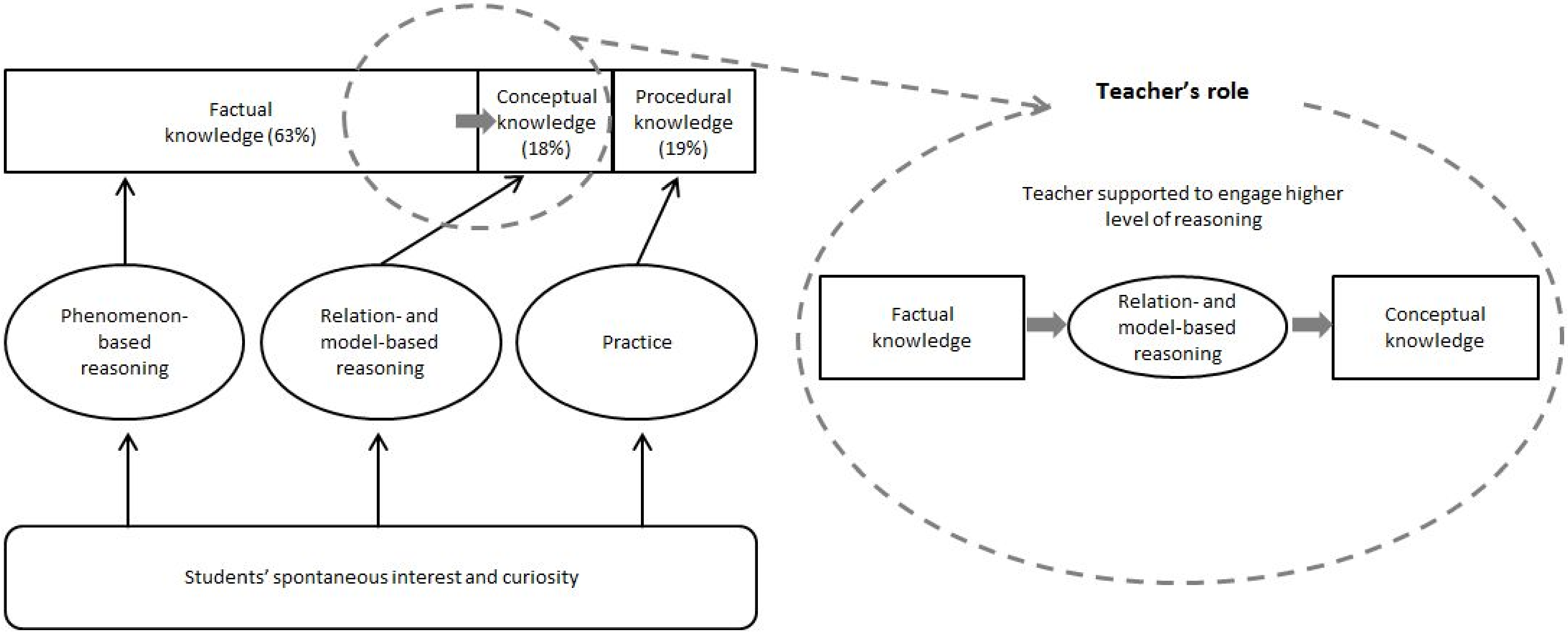


Figure 4.12. Types of knowledge and reasoning in unintended learning and the teacher's role in unintended learning.

I found the students who engaged in relation-based or model-based reasoning with help from the teacher so that they could learn conceptual knowledge (Figure 4.12, right diagram). Several studies also support that teacher can help students to engage higher level of reasoning such as model-based reasoning (e.g. Campbell, Oh, & Neilson, 2012; Furtak et al., 2010; Louca, Zacharia, & Constantinou, 2011).

However, in case of unintended learning, noticing unintended learning is required for teacher as a first step and teachers need to find the way to support students' reasoning or learning (Van Es & Sherin, 2002). It means that teacher's role is important for students to develop their ideas of unintended learning as well as intended learning. Once a teacher notices students' unintended learning, the teacher can support students to develop the ideas resulting from unintended learning by asking for the element of reasoning or by providing the element of reasoning.

Procedural knowledge was also found in this study. Both explicit and implicit procedural knowledge was found. Procedural knowledge is crucial in science. Hacking (1983) has argued that implicit procedural knowledge is necessary and that students often failed to notice when experimentation was going wrong. Reading a scale and writing a lab report are not key points; rather, noticing what is unusual or wrong is more of a core competency for doing science. Also, some people can be successful in getting results but others cannot, although they did exactly the same procedure (Polanyi, 1967). Doing the exactly same procedures does not guarantee to have the successful result. This might be caused by whether a person has an implicit procedural knowledge or not (Polanyi, 1967). Implicit procedural knowledge can only be acquired by practice. This means that students' practice, such as trial and error and coping with unexpected situations in practical work, gives them opportunity for unintended learning, especially opportunities to learn implicit procedural knowledge.

This chapter aimed to find the various types of knowledge that occurred as a result of unintended learning but failed to find evidence of learning metacognitive knowledge. Metacognitive knowledge is knowledge related to the transfer of learning (Pintrich, 2002). For instance, when students confront to new task that requires knowledge that they have not learned yet, students need to know the general strategy that will help them to think and solve the problem. This general strategy that can be transferred and applied to the task is metacognitive knowledge. However, in this study, it was hard to find evidence that the knowledge that students learned unintentionally was transferred and applied to their future learning as metacognitive knowledge. One of the reasons for this was that this study was designed to observe only a few lessons from each teacher in a short period of time, so it was not a longitudinal study. Although this study failed to find the evidence that students learned metacognitive knowledge, this is suggested for future study.

Chapter 5. Meaningful but unintended: Features associated with unintended learning from Polanyi's perspective[3]

This chapter will focus on analyzing how unintended learning occurs and especially on looking for its educational value from Polanyi's perspective of intellectual passion. The following questions were used to guide my data analysis and discussion:

1. What are the features associated with unintended learning?
2. Can unintended learning acquired by students be shared with other students in their class?
3. What are the educational implications of unintended learning from the perspective of intellectual passion?

What I found in this study is that unintended learning tended to occur when students first became interested in something and then maintained that interest. In addition, students were able to acquire conceptual knowledge

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[3] This chapter was published as: Park, J., Song, J., & Abrahams, I. (2016). Unintended Learning in Primary School Practical Science Lessons from a Polanyi Perspective. *Science & Education*, *25*(1), 3-20. Part of this article is included in Sections 2.4. Motivation for science learning in practical work and 3. Design and method of the study' as well.

when they tried to connect their current experience to their related prior knowledge. I also found that the processes of intended and unintended learning were different. Intended learning was characterized by having been planned by the teacher who then sought to generate students' interest in the intended learning. In contrast, unintended learning originated from students' spontaneous interest and curiosity as a result of unplanned opportunities. While teachers' persuasive passion comes first in the process of intended learning, students' heuristic passion comes first in the process of unintended learning. Based on these findings, I argue that teachers need to be more aware that unintended learning on the part of individual students can occur within their lesson so that they are better prepared to use these opportunities to share this unintended learning with the whole class. Furthermore, I argue the necessity of deliberate action by teachers and a more interactive classroom culture that gives students greater opportunity to pursue their persuasive passion about their unintended learning.

5.1. Features associated with unintended learning

The features associated with the unintended learning that occurred in this study were that students needed to express their interest and students' interest needed to be maintained. It also emerged that an opportunities for students to connect current experience to their prior knowledge did in some cases elicit unintended learning. Examples to support these features associated with unintended learning will now be considered. A case where students came close to losing the opportunity for unintended learning when their interest was not maintained will also be introduced.

5.1.1 Students expressing their interest

Most of the unintended learning observed in this study was initiated by students' spontaneous curiosity or interest. Sixty-eight out of 79 cases of unintended learning were found to be initiated by students expressing interest. My analysis of the occurrences of unintended learning showed that 13 were inductively categorized and 12 took place because students showed interest. One occurrence of unintended learning took place before the lessons began when students were playing with materials that had been prepared for practical work. Their curiosity about the material that had been prepared for the upcoming practical work caused the students to play and try to do some things. Twenty-five cases of unintended learning occurred when students attempted to do something that the teacher did not tell them to do. These cases occurred while they were doing their practical work, after they finished their practical work, or while the teacher was explaining the concept at the end of the lesson. These additional activities must have been caused by their interest or curiosity because they were not the tasks that teacher told them to do. Nineteen cases of unintended learning occurred when students became interested in phenomena that occurred coincidentally. When students do practical work, many other phenomena happen that are not focus of the lesson. These phenomena occur for all students when they are doing practical work, but not all students become interested in these phenomena. Unintended learning only occurred with students who became interested in these phenomena. In addition, there was a case where a student learned something by being interested in another student's activity. Twenty-two cases of unintended learning occurred when the practical work did not go well. In these cases the students did not ask the teacher for help when they faced the problem but rather tried to solve the problem themselves because they had become interested in the problem. Eleven cases of unintended learning occurred when students listened to what other students were saying and were not initiated by the interest of the students who experienced the unintended learning. Table 5.1 shows the categories of experiences that led to unintended learning.

Table 5.1

Experiences that led to unintended learning

Students' experiences		Number of occurrences
Playing with prepared material for practical work before the lesson		1
Trying additional things	While doing practical work	14
	After practical work	9
	While the teacher was explaining concepts at the end of the lesson	2
Being interested in phenomena that happened coincidentally		19
Being interested in other students' activities		1
Solving a problem when practical work did not go well		22
Listening to what other students were saying		11

Here are some examples of unintended learning that was initiated by students' interest. First example is about the unintended learning which was occurred by being interested in the phenomena that happened naturally. Even though all students in a class observed any given phenomenon, I found that only a few of the students who became interested in it learned something in addition to what the teacher intended.

The task in Mr. Sun's lesson was for the students to boil some leaves in alcohol for a few minutes to remove the chlorophyll so that when iodine stain was added to the leaves its color could be clearly seen. All the students could see that the alcohol turned green as the chlorophyll was removed from the leaves. However, not all the students became interested in this phenomenon. Only three out of the five[4] groups showed an interest in the color change of the alcohol. In student memos completed after the lesson, 13 students mentioned that they learned that alcohol turned green when leaves were boiled in it.

Jangwon:	It has taken something out. Chlo…what was it?
Minchul:	Chlorophyll.
Jangwon:	It might be Chlorophyll. That one. That was taken out of it.

The above discourse in the lesson showed that unintended learning occurred when Jangwon became interested in color change. He learned that alcohol turned green when leaves were boiled in it and also learned why it happened. If Jangwon had not been interested in this phenomenon he might not have learned that chlorophyll comes out of leaves when they are boiled in alcohol and this turns the alcohol green.

This is the example of unintended learning which was occurred by being interested in other's activity. After Mr. June's lesson of making electromagnets to compare their strength, when students were asked to write a short memo about what they had learned that day, one student, Joohyun,

[4] Only five of the six groups in the class consented to participate in this study.

noted that he had learned that some magnets are very strong. The lesson had been about electromagnets and students learned that the more wire they wrapped around a nail the stronger the resulting electromagnet would be when the electricity flowed through the wire. As there was no magnet mentioned in the practical work the researcher asked him about this in the post-lesson interview, he was asked how he had learned that. He answered that he learned it not from the practical work he had done but from the students who had played with the neodymium magnets. In this lesson, the teacher asked a student who had a learning difficulty to do his individual work in the front of the classroom and let him play with various magnets. Joohyun watched this student with interest and noticed that the magnet his friend was playing with was able to attract most of things around him; from this he learned how strong neodymium magnets are (See Figure 5.1). When the researcher asked him whether he had known this before, he responded that this was the first time he had seen a neodymium magnet attract so many things. If he had been not interested in his friend's activity, he would have not observed and noticed what his friend did in detail.

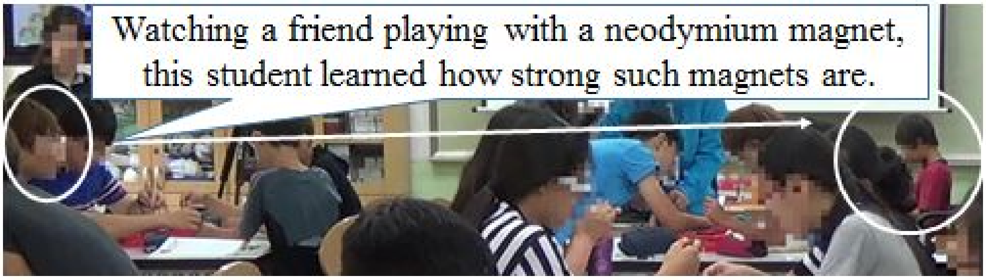

Figure 5.1. Watching a friend playing with a neodymium magnet, the student learned how strong such magnets are.

Similar to the example from Mr. Sun's lesson where Jangwon learned about chlorophyll coming out of leaves, if Joohyun had not been interested in the magnet that his friend played with he might not have learned that neodymium is strong enough to attract the steel around him.

5.1.2 Students maintaining their interest

Unintended learning can occur when students' interest is successfully maintained. An example can be seen in a group from Mrs. Yuna's class who were constructing series and parallel circuits. The students became interested in the conductivity of certain parts of the battery case which were unlike the picture in the textbook (See Figure 5.2).

Figure 5.2. The parts of the battery case that students argued about in terms of connecting the wire.

Sujin:	Look, it should be connected here [pointing to the picture in the textbook].
Minsu:	It is ok to connect it here [Point A].
Sujin:	Just connect it here [Point B].
Researcher:	What are you arguing about?
Aram:	She said it should be connected here [Point A].
Sujin:	We are following this and this picture says to connect it here [Point A], but he said to connect it here [Point B].
Minsu:	This makes the electricity flow though.
Sujin:	But it is better to follow this [textbook].
[Ellipsis]	
Minsu:	Try it; just try it once.
Teacher:	Two more minutes. You should complete this in two minutes. [Students did not try to connect the wire to Point A but connected it to Point B as shown in the picture in the textbook.]

As can be seen from the above discourse, Minsu wanted to try connecting the wire to Point A. However, the students were not able to try this because the teacher pushed them to complete their work within two minutes. The students in this group did not try to connect the wire to Point A. When students had more time later on, Sujin had not forgotten about it and tried to connect the wire to Point A.

Sujin: See! When you connect it here [Point A], it doesn't light up. It work when you connect it here [Point B].

Minsu: No. I will do it.

[Minsu and June tried it again and it did not light up.]

Sujin: See. It doesn't work.

[A few seconds later, it lighted up.]

Minsu: It worked!

Sujin: Sorry. [You can] connect it here.

June: Our expectation was right!

In the end this group of students learned from their tests on the circuit that connecting a wire to both Point A and Point B allows electricity to flow. This shows that while unintended learning was almost lost due to a lack of available lesson time, unintended learning did occur when the students' interest was rekindled as a result of their teacher deciding to give them more time.

5.1.3 Connecting to prior knowledge

Some cases of unintended learning were found to occur when students were able to assimilate the experience to their prior knowledge. In one case a student examined a bulb in order to determine where a problem existed in a broken circuit, and the student noticed that there was a hole in the glass. The teacher's stated intended learning objectives in this lesson were that bulbs light up when electricity flows, that materials that enable electricity to pass are called conductors, and that materials that prevent electricity from passing are called non-conductors. From these stated objectives I could see that the broken circuit was not intentional, so the student unintentionally learned that the hole in the light bulb caused the broken circuit. The student, Jeongwoo, did not just learn this from what he observed but also connected this experience to his prior knowledge.

Jeongwoo: [Looking closer at the light bulb] Teacher, isn't this light bulb supposed to be a vacuum?

Teacher: [Trying to connect new light bulb] Yes.

Jeongwoo: [Showing the light bulb] But here is a hole.

Teacher: [Looking at the light bulb] Where?

Jeongwoo: [Showing the light bulb to the teacher] It didn't work as it was not a vacuum. A hole there.

Teacher: That's fine.

Jeongwoo: [It seems that he is talking to the teacher but not looking at teacher] There is a problem with the light bulb. All right. As there is a hole, it has not been a vacuum. The filament met the air. The glass in the light bulb is a vacuum but it is not as there is a hole.

Jeongwoo mumbled to himself that he thought that the hole in a glass bulb caused the filament to oxidize and break. He tried to make this experience sensible by anchoring it to his prior knowledge. In the post-lesson interview I found that he had anchored the idea from the book he read previously to make it sensible.

Researcher: Do you remember the broken bulb in your group?

Jeongwoo: Yes. It has to be a vacuum but it wasn't. It didn't work because the filament was exposed to the air too much.

Researcher: What happens when the filament is exposed to the air?

Jeongwoo: The filament is oxidized and cut off or weakened, so it cannot light up.

Researcher: How did you know this? Did you see it or did you guess?

Jeongwoo: I saw this in the book. It says the filament is oxidized when it meets the air. So I thought the hole makes the air come in and makes it oxidized and cut off . . .

This student drew on his recollection from the book which he had previously read that a light bulb contains a vacuum in order to prevent the oxidization of the filament and applied this to explain the phenomenon he observed. This example also shows an example of the meaningful learning that Ausubel (2000) and Ausubel, Novak, and Hanesian (1968) suggested occurs when a student is able to connect the new information to the relevant idea in the particular learner's cognitive structure.

5.2. Sharing individuals' unintended learning with a whole class

Seventy-eight out of 79 cases of unintended learning in this study remained either with the individual student who had learned or was localized within a small group. This was either because the teacher was unaware that the unintended learning had occurred or chose to ignore it. Although students often called out to teachers with curiosity or joy when they discovered or learned something, the teachers often responded to this with indifference and provided little specific feedback to the students on their discovery. One reason for this may be a teacher's sense of being obligated to complete what had been planned within a given time. An example of a teacher's reaction to the unintended learning that occurred in a lesson about observing two different leaves is presented below. In the short memo that I asked her to write down after the lesson, a student, Jina, mentioned that she learned that something sticky came out of the leaf when she peeled it. However, in video analysis I found that the teacher gave an indifferent response to Jina on what she found and her question.

[In group activity of observing the two different leaves]

Jina: What is this sticky thing? Hyun, what is this sticky thing?

[Hyun is touching it.]

Jina: Teacher, what is this sticky thing?

Teacher: [Without looking at it] Write it down. Don't know what it is, write it down.

As the teacher's planned learning objective for this task was exploring the different shapes of the leaves, such as the netted and parallel venation, the teacher mainly responded to what he intended to teach in the group activity. Even in a whole-class discussion, the teacher focused on what he intended students to observe using some guiding questions as shown below.

Teacher: Did you find the critical differences between the leaves of the spiderwort and the garden balsam?

Student(s): Long. The spiderwort is long.

Teacher: The spiderwort is long and the garden balsam is a bit rounded.

Teacher: And when you look closer to the leaf, do you see something that looks vaguely like a string?

Students: Yes.

In Mrs. Rose's class, however, I observed a situation in which unintended learning within a small group was shared with the whole class. In this example, Mrs. Rose noticed that students had found that a type of glass cleaner was neutral or slightly acidic. She had intended that students learn that the glass cleaner was alkaline. A group of students told the teacher that they had found that it was neutral, which they noticed was not the phenomenon that the teacher expected them to observe. Mrs. Rose told the students to write down the results they obtained when performing the task. During the subsequent whole-class discussion time Mrs. Rose explained to the whole class the intended learning, i.e., that the glass cleaner that was supposed to be alkaline had turned out to be neutral. Rather than ignoring this unintended learning she brought two different kinds of glass cleaner, one for house windows and the other for car windows, to the following lesson. She explained to the students that the glass cleaner that they used in their previous lesson was for car windows. She showed them that the glass cleaner for house windows is indeed alkaline (pH 10), while that for cars, as they had learned, is neutral or slightly acidic so as not to damage the coating of the car window.

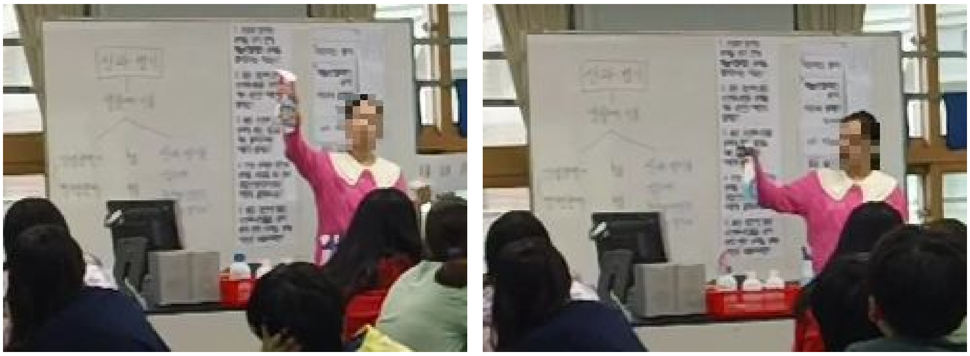

Figure 5.3. Teacher sharing a small group's unintended learning with the whole class

5.3. Interpreting the unintended learning from the perspective of Polanyi

In this section, I interpret the findings from the perspective of Polanyi's concept of intellectual passion. In this study, unintended learning was initiated by a student's heuristic passion, in contrast to intended learning that was initiated by the teacher's persuasive passion. As mentioned above, unintended learning occurred when students expressed and maintained their interest. When they became interested in a certain experience or phenomenon, students in this study learned mostly procedural knowledge or factual knowledge by describing what they observed or experienced.

Furthermore, when students had appropriate prior knowledge, their heuristic passion led them to explore the conceptual connection between what they observed and their prior knowledge. For instance, a student in this study tried to explain the reason for the broken bulb not working from a book he read previously. Therefore, the process of unintended learning, where students' heuristic passion comes first, is similar to the process of how scientists discover and construct knowledge. In this respect, unintended learning can give students opportunities to experience what science and authentic inquiry are like.

However, intended learning has a different process from that of unintended learning (See Figure 5.4). For intended learning, teachers' persuasive passion comes first and students' heuristic passion comes after it. Teachers usually spend time in planning what to teach and how to teach for students' effective learning (Abrahams & Millar, 2008) and reflect their persuasive passion to teach students. I am not suggesting that all teachers in this study taught in a manner that was equally full of persuasive passion; however, all of their teaching was initiated by their persuasive passion for knowledge. When teachers' persuasive passion for intended learning is successful, it leads to the generation of heuristic passion for intended learning within the students. In other words, when teachers use a variety of teaching strategies and when it is successful, student became more engaged in their task and learning (Olitsky & Milne, 2012).

Polanyi (1958) said all scientists come to construct the knowledge with their heuristic passion and it often leads to persuasive passion, through which scientists want to share their knowledge with others. He said that heuristic passion not only often leads to but also has to lead to persuasive passion. In the same way that scientists' persuasive passion comes after their heuristic passion, I observed that students also wanted to share what they discovered and learned during the lesson. However, I found that persuasive passion of their unintended learning was often limited in the lesson. Much unintended learning remained restricted to the individual students who discovered it or, if that student was working within a small group, to the individuals within that group. However, the one case where unintended learning within a small group was shared with the whole class observed in this study indicates that the opportunity for persuasive passion of the students' unintended learning can be given in the lesson.

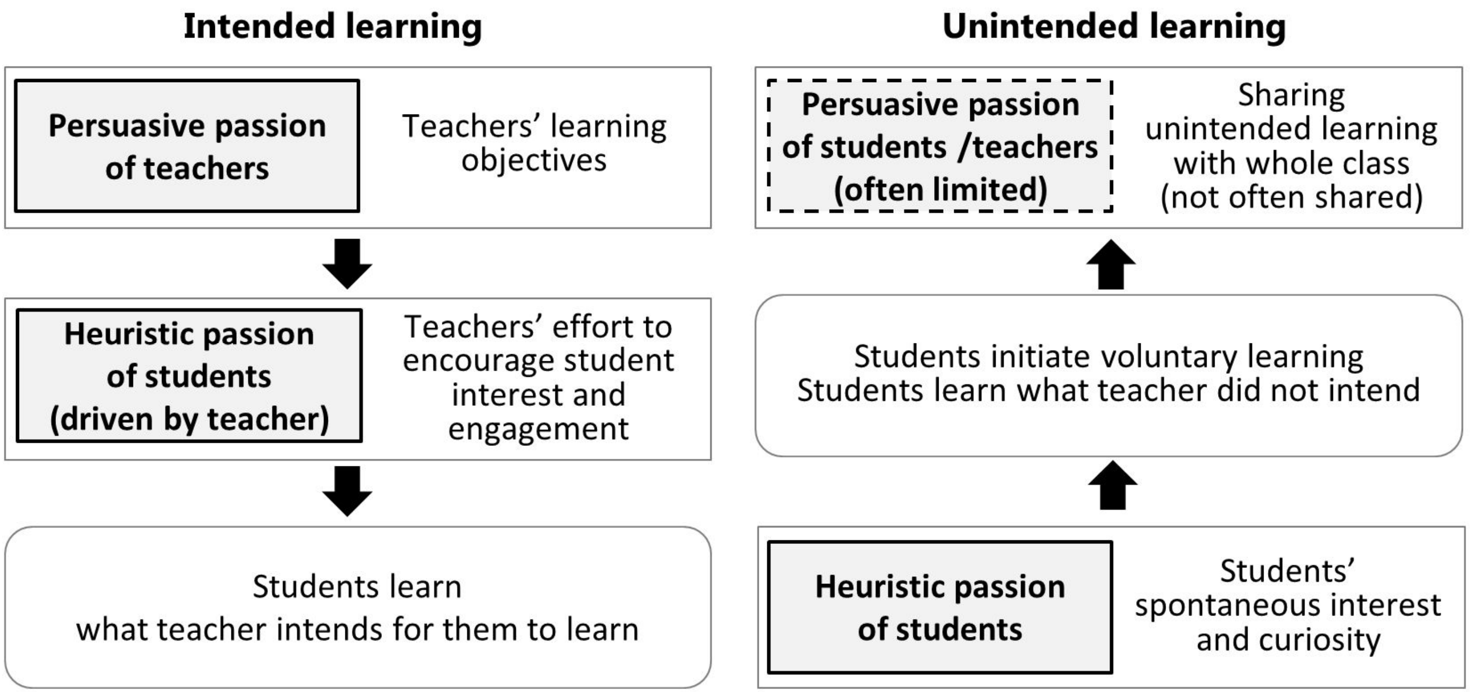

Figure 5.4. The process of intended and unintended learning in a lesson

5.4. Summary and discussion

In this study, I found that students learned not only what their teacher intended but also some things that their teacher did not. Even though it is a widely accepted phenomenon (Jackson, 1990; Marsick & Watkins, 1990), this unintended learning has not been discussed in detail within science education research and this study explored how it occurred and its educational implications from the perspective of Polanyi's (1958) intellectual passion.

It emerged that unintended learning could occur when students first became interested in something and then their interest was maintained. In addition, it was found that students were, in some situations, able to link an unintended learning experience to prior scientific knowledge. From the perspective of intellectual passion, this suggests that unintended learning arose from heuristic passion in the sense that it was driven by students' interest and curiosity. However, it was found that most unintended learning observed in this study remained restricted to an individual student or to the small group of students who worked with that individual student. It was often observed that teachers often responded indifferently to examples of unintended learning, either by ignoring them due to time limitations or by failing to notice that they had occurred. Given the power dynamic within the classroom, students who had learned something unintended were in most cases unable to share their learning with the whole class in a manner that would have seen their heuristic passion leading to persuasive passion.

From the perspective of intellectual passion, it was found that students' and teachers' intellectual passion manifested itself in a different order. In the case of intended learning it was observed that the teachers' persuasive passion was the initiator of the learning process, with the teachers trying to generate heuristic passion for the scientific knowledge amongst their students. However, unintended learning comes from students' initial heuristic passion and this then leads to their persuasive passion as they want to share their learning with their peers.

In addition, unintended learning can be an opportunity to expand authentic inquiry in that the process of learning is similar to the way scientists work. Cases from the history of science, such as unintentional discovery of penicillin, also encourage the importance of unintended learning in the class (Lenox, 1985; Roberts, 1989). Similarly Pasteur said, "Chance favors the prepared mind" (1954). Fleming's discovery of penicillin did not depend solely on his luck but also on his prepared scientific mind. This implies that it is important for teachers' role not to miss the opportunity for unintended learning and to develop the learning opportunity into scientific inquiry.

Chapter 6. Conclusions and implications

6.1. Summary

The typical image of school involves students learning what the teacher intended. However, students do not always learn only what teacher teaches, as hidden curriculum and null curriculum have pointed out. The fact that students learn things beyond what the teacher teaches is widely accepted (Jackson, 1990; Marsick & Watkins, 1990), but little empirical research has been done, especially in science education. Practical science lessons have unique characteristics that can be distinguished from other disciplines or lesson styles in that practical science lessons have hands-on activity and a less formal environment that enables students to have conversations in groups during practical work. These characteristics mean that in practical science lessons there is a greater likelihood of opportunities for unintended learning and that there can be various types of unintended learning. Therefore, there is a need to explore unintended learning in practical science lessons and its educational implications.

In this study, unintended learning has been defined as any student learning that was found to occur that had not been planned by the teacher for that specific lesson. This study explored the different kinds of unintended learning that exist and how it occurred in primary school practical science lessons. For this, I used a pragmatic approach that had a social practices perspective with recognition of a personal ways of knowing perspective. This helped me to explore how unintended learning occurred in the lessons and how it interacted with teachers and peers as well as what unintended learning occurred in individual cognitions. Twenty two lessons by five teachers were observed in Korean classrooms and one group's discourse during each lesson was video- and audio-recorded and transcribed for analysis.

Chapter 4 focused on analyzing what types of unintended learning occurred in practical science lessons. I found that students learned factual knowledge, conceptual knowledge, and procedural knowledge unintentionally. Learning these types of knowledge was associated with phenomenon-, relation-, and model-based reasoning. Most of unintended learning observed in this study resulted in factual knowledge gained by phenomenon-based reasoning. Among the types of knowledge, factual knowledge can be associated with students' future learning, which means that the unintended learning can be an educative experience that helps students in their future learning by allowing them to recall what they experienced and learned unintentionally. As opposed to factual knowledge, only a few examples of unintentionally learned conceptual knowledge, which occurred as a result of relation- and model-based reasoning, were found. In this study, the cultural norm that doing and asking about something that is irrelevant to a lesson might be regarded as inappropriate made students lose opportunities to gain conceptual knowledge via relation- or model-based reasoning. Procedural knowledge was also found: both explicit procedural knowledge that can be described verbally and written and implicit procedural knowledge that we cannot tell and can only be acquired by practice. This is because practical work gave students opportunities to learn implicit procedural knowledge due to the fact that practical work involves practices such as trial and error and coping with unexpected situations.

Chapter 5 focused on analyzing how unintended learning occurs and especially on looking for its educational value from Polanyi's perspective of intellectual passion. It was found that unintended learning could occur when students became interested in something in the first place and then their interest was maintained. When students were able to link an unintended experience to their prior knowledge, they were able to learn unintended conceptual knowledge. From Polanyi's perspective of intellectual passion, unintended learning occurred from students' heuristic passion in the sense that it was driven by students' interest and curiosity. However, it emerged that most unintended learning observed in this study was localized to an individual student or small group. It was often observed that the teacher ignored the students' unintended learning because of time restrictions or failed to notice that unintended learning had occurred. This means that students lost their opportunities to share their unintended learning with the whole class. From the Polanyi's perspective of intellectual passion, unintended learning arose from heuristic passion in the sense that it was driven by students' interest and curiosity. However, students' persuasive passion for unintended learning was limited in the sense that they did not have an opportunity to share their learning with others.

6.2. Conclusions and implications

In considering the impact of this study for school education, I return to the concept of school learning. This study holds a broad view of school learning rather than a narrow view that students learn only what teacher teaches. This reframing of student learning in school casts new light on what is meaningful learning for students and what teaching and learning should look like. The most salient characteristic of unintended learning that this study found was that it initiated from students' interest and curiosity, which can be referred as heuristic passion. This study found that the process of unintended learning was different from that of intended learning. While unintended learning was initiated by students' own heuristic passion, intended learning was initiated by teachers' persuasive passion and students' heuristic passion comes later. This means that while unintended learning was initiated by students' intrinsic motivation, intended learning was initiated by teachers' passion to teach and teachers' efforts to make students interested and motivated in what they teach. Teachers make an effort to motivate students because this will make their learning more effective. The motivation found in unintended learning and the motivation in intended learning are different in that the former comes from students' own need and the latter is provoked by others. The intrinsic motivation found in unintended learning can make students' learning powerful and meaningful in the sense that it comes from their here-and-now needs (Hidi & Harackiewicz, 2000). Historically, learning out of curiosity has been the most natural way of human learning, and it has caused development in people's everyday lives and disciplinary development in science as well (Zuss, 2012). Therefore, we should change our view of unintended learning from seeing it as learning that is irrelevant to a lesson to seeing it as something that can be meaningful to students because it comes from their intrinsic motivation. Unintended learning opportunities should not be avoided in a lesson in order for intended learning to be effective but should be brought into a lesson as legitimate peripheral learning to supplement intended learning.

However, students' unintended learning in this study was often found to be ignored by teachers. Not only teachers but also some students perceived unexpected situations for unintended learning to be irrelevant to the lesson so students avoided talking about them and discussing them with teachers. Both the schemas that teachers and students had and resources such as the time limitations and the pressures of assessment limited the agency that students had for the unintended learning. In reality, students are often under pressure to achieve success in school, which means getting good grades on tests (Mulvenon, Stegman, & Ritter, 2005). Moreover, teachers also feel pressure to teach canonical knowledge effectively due to their increased accountability for assessments such as national tests or the Trends in International Mathematics and Science Study (TIMSS) (Jones & Buntting, 2013). For these reasons there is pressure on both students and teachers not to pay attention to any unintended discovery or learning during the science lesson that arises from their own curiosity and imagination. In such a classroom culture, students may give up on exploring anything that they find or learn that seems irrelevant to the lesson objectives in order to meet the teachers' expectations or get good grades. If sufficient time and even a small amount of positive feedback on their unintended learning were given to students during the lesson, students might not become race horses with blinders who are only running forward. Effective lessons for intended learning may be compared to a high way and lessons that support unintended learning as well as intended learning may be compared to countryside road. Reaching the goal fast and efficiently might be good. However, although it takes more time, walking the countryside road with enjoying the trees and flowers can be also great experience unless students get lost. Teachers might have difficulties in trying to support both intended and unintended learning in the lessons but it is worthwhile to try it if it is meaningful to students. More studies need to be done such as action research to support both intended and unintended learning or investigating the relationship between the intended and unintended learning.

While unintended learning as a general phenomenon can occur in the field of education, in fact there are implications related to science education in light of the value of practical work and what practical work should look like. This study showed that unintended learning in practical lessons involves implicit procedural knowledge, which can only be acquired by practice. This practice is not just following the teacher's directions exactly, such as recipe-style practical work designed to have the fewest unexpected situations; instead it means a practice that involves trial and error and coping with unexpected events while doing practical work. However, current practical science lessons in formal education recommend that teachers do standardized practical work directly from textbooks and guidebooks for teachers. Kirschner (1992) pointed this out, stating that "years of effort have produced foolproof 'experiments' where the right answer is certain to emerge for everyone in the class if the laboratory instructions are followed." (p. 278). Nott and Smith (1995) reported that teachers even tried rigging or conjuring in order to avoid practical situations going wrong. Teachers should not create the myth that students can have desirable results whenever they do experiments in science by providing students only sanitized practical work. Experimentation in science is more like a complicated human activity where anyone can face difficulties in doing it: this is the nature of science. Therefore, teachers need to admit that students can face practical situation going wrong and recognize that students can learn from them by getting through them. Instead of putting a lot of effort into making sanitized practical work, teachers need to put more effort into supporting and facilitating student to learn independently from their own trial and error by providing inquiry-based practical work.

Finally, this study concludes with more practical implications for teachers. To utilize unintended learning for more learning opportunities, teachers need to be aware that unintended learning can take place and to notice students' unintended learning beforehand (Figure 6.1, Diagram A, right bottom). Bentley (1995) called an unplanned learning opportunity that teachers can make during the lesson a teachable moment. He argued that teachers should seize a teachable moment from students' spontaneous interest. To seize these moments, teachers need to be alert to what students are doing and what they are interested in. Hyun and Marshall (2003) reported a case where a teacher seized a teachable moment by paying attention to students' interest. When students observed a caterpillar during a science lesson, a student became interested in one of insects that was having difficulty in hatching. The teacher chose this interest as a discussion topic for the rest of the lesson and the rest of the students also had an opportunity to think about it. Teachers can utilize a moment of unintended learning similar to this as a bridge to the most natural way of authentic inquiry in a school science curriculum for all. Currently the Korean national curriculum for primary science includes open scientific inquiry, which enables students to choose a topic, conduct the research, and present their results. However, research has reported that teachers and students have difficulties with open scientific inquiry activities (Baek, Lim, & Kim, 2015; Lee, Jee, & Park, 2010; Shin & Kim, 2010). In particular, it has been reported that one of the most difficult things was choosing a topic for open scientific inquiry (Shin & Kim, 2010). One way of overcoming this difficulty and helping students to launch an open scientific inquiry is for teachers to encourage the unintended moment of learning to become a moment for choosing a topic of open inquiry.

This study's finding that most unintended learning resulted in factual knowledge gives us implications about how to support the interaction and discourse between teachers and students in practical science lessons (Figure 6.1, Diagram B, right center). This study is not suggesting that the fact that most unintended learning was factual knowledge and that having factual knowledge of itself are problematic; rather, this study is suggesting that there may have been missed opportunities to engage relation- or model-based reasoning to foster conceptual learning that students could have developed from factual knowledge using phenomenon-based reasoning. I observed that only a few students engaged in model-based reasoning where they made models to explain why the practical work they were doing did not work well. It may be difficult for primary students to engage in model-based reasoning to gain conceptual knowledge (Driver et al., 1996), but it is not an impossible task. Louca et al. (2011) showed that primary students also can engage in model-based reasoning with help from a teacher, such as nudging them to start thinking or scaffolding a productive discussion. Campbell et al. (2012) also found that teachers could help students to engage model-based reasoning by mediating various discursive modes in science lessons, such as elaborating and reformulating. Interaction with not only the teacher but also with peers can help students to engage in model-based reasoning. Hogan et al. (1999) reported that students were able to engage in higher levels of reasoning or give higher quality explanations when they had a chance to have both teacher-guided and peer discussions. Therefore, providing more interaction with teachers and peers can provide students with more opportunities to take descriptions of what they unintentionally observed and learned and develop them into models or explanations about these observations.

The other practical implication is giving an opportunity for students' persuasive passion about their unintended learning (Figure 6.1, Diagram C, right top). In this study, unintended learning remained with the individual or was localized within a small group due to the students' persuasive passion about their unintended learning often being limited in the lesson. The example in Mrs. Rose's classroom, however, shows that unintended learning within a small group can be shared through a teacher's persuasive passion. Furthermore, it is possible for teachers to take deliberate action to give opportunities for students to share their persuasive passion. For instance, teachers can offer a time to briefly share unintended learning that occurred in an individual or within a group with the whole class at the end of a lesson, or teachers with limited resources can have students share unintended learning on an internet bulletin board or in a learning journal that all students can access. This can give students the opportunity to reflect on what they learned that could otherwise have only been a simple experience to be forgotten soon. Having an opportunity to explain their unintended learning can also help individual students elaborate their learning as well as expand others' learning.

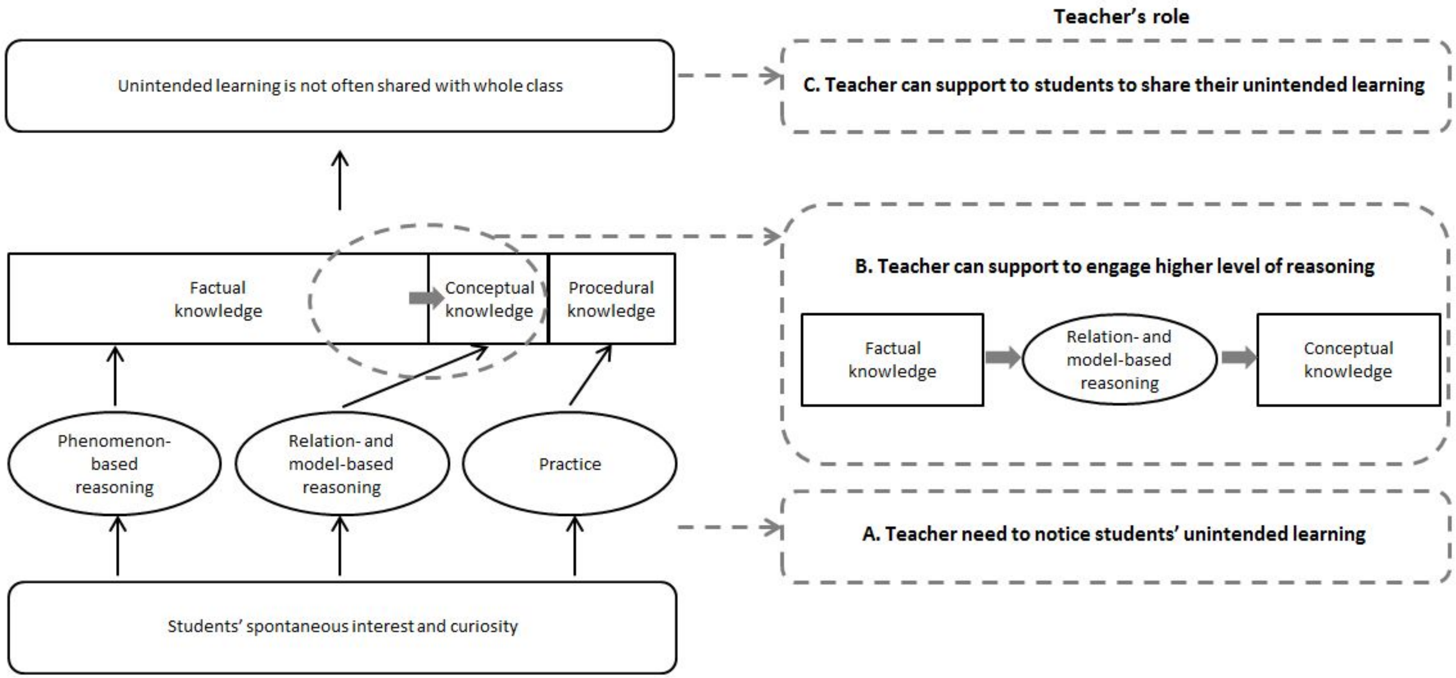

Figure 6.1 Practical implications for teachers

6.3. Limitations of the study

I acknowledge the small scale in scope and participation of this research in that it investigated unintended learning in fifth and sixth grade primary practical science lessons involving five teachers and analyzed the discourse of one group of students from each lesson.

It is impossible to catch all the unintended learning that occurred in the lessons by observing the lessons only. For this reason, this study conducted video- and audio-recording of lessons and group discourse in order to discover as many instances of unintended learning as possible by reviewing the recordings after the lessons. Recording helped me to find many instances of unintended learning; later on, however, I was able to do student post-lesson interviews about a limited number of instances of unintended learning that I had found by observation. This number was limited because since I need to a post-lesson interview right after the lesson I could only do interviews with students where I observed the unintended learning in person. For this reason, I know that I missed opportunities to collect vivid and fresh experiences and memories from every student who was observed having unintended learning in this study and asking them about what they did, what they thought, what made them think like that, and why they did.

This study explored students' unintended learning, which means the learning that teachers did not intend but that students learned. While it is beyond the scope of this study to consider the unintended learning of teachers, I can offer some suggestions for research dealing with teachers' unintended learning that I did not explore in this study.

6.4. Future directions

In considering the results obtained and the limitation of the study, I can suggest a few directions in which to proceed. This study was able to find cases of unintended learning and can explain how it occurred and what the students learned. However, I failed to investigate the students' thinking in detail at the moment when the unintended learning occurred. I suggest a case study that observes only a few students' learning and that performs in-depth interviews to determine how they think and why they think what they do.

Another interesting avenue of research related to this study would be to investigate teachers' perspectives on unintended learning. This study found a failure to share unintended learning with the whole class because teachers ignored the unintended learning or did not notice it. A study exploring teachers' experiences with students' unintended learning and how teachers view unintended learning can help to determine teachers' beliefs and resources that can limit students' agency to blossom in their learning, either intended or unintended. I also suggest action or reflective research related to unintended learning. This type of research can give implications for teacher education by reflecting how teachers themselves coped with unintended learning in lessons.

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박지선

과학교육학과 물리교육전공

교사는 가르치고 학생은 교사가 가르치는 것을 배우는 모습이 우리가 흔히 떠올리는 전형적인 학교의 수업 장면이다. 그러나 이 장면을 자세히 들여다 보면 학생들이 항상 교사가 가르치는 것만을 배우는 것이 아님을 알 수 있다. 본 연구에서는 이러한 학생의 학습, 즉 단위 수업에서 교사가 계획하지 않았지만 학생들이 학습한 것을 '의도하지 않은 학습'이라는 개념으로 정의하고 이에 대해 연구하였다. 본 연구에서 관찰하고자 하는 학생의 의도하지 않은 학습은 잠재적 교육과정과 같은 기존의 연구에서도 지적된 바 있다. 그러나 잠재적 교육과정과 관련된 대부분의 연구들은 학생들이 이데올로기 또는 가치 등을 의도치 않게 학습하게 되며 이것이 사회 구조 재생산과 관련됨을 주된 논의로 전개한 반면, 본 연구는 과학교육이라는 특정 교과목과 관련된 지식을 어떻게 학습하는가에 초점을 두고 있다는 점에서 기존의 잠재적 교육과정 연구들과 구별된다. 이에 본 연구에서는 과학 실험 수업에서 어떤 종류의 의도하지 않은 학습이 일어나고 있으며, 이러한 의도하지 않은 학습은 어떠한 배경에서 발생하고 있는지 알아보고자 하였다.

본 연구를 위해서 서울 및 경기 지역의 초등학교 5학년 및 6학년 과

학 실험 수업을 관찰하였다. 총 5명의 교사와 각 교사들의 수업을 듣는 학생들이 본 연구에 참여하였다. 수업 관찰 전 교사들에게 의도한 학습, 즉 단위 수업 학습 목표 및 계획한 교육 활동에 대해 면담을 실시하였다. 각 수업은 본 연구에 동의한 학생들로 구성된 모둠을 정하여 학생들의 활동 및 담화를 녹화 및 녹음하였으며, 관찰기록지 또한 작성하였다. 수업 후 학생들에게 해당 수업에서 어떤 것을 학습하였는지 간단하게 적는 주관식 설문을 실시하였다. 또한 수업 중 의도하지 않은 학습을 한 것으로 관찰된 학생과 교사를 대상으로 수업 후 면담을 실시하였다. 이렇게 수집된 자료를 종합하여 수업 중 학생들의 활동 및 담화를 녹화 및 녹음한 자료에서 의도하지 않은 학습을 포함하고 있는 에피소드를 추출하였다. 추출된 에피소드를 바탕으로 의도하지 않은 학습에 이르게 한 경험의 종류와 의도하지 않은 학습의 결과로 얻게 된 지식의 종류를 분석하였다. 또한 어떠한 경험들이 의도하지 않은 학습을 일어나게 하였는지도 함께 분석하였다.

그 결과, 본 연구에서는 학생들이 의도하지 않은 학습으로서 사실적 지식(factual knowledge), 개념적 지식(conceptual knowledge), 절차적 지식(procedural knowledge)을 학습하는 것을 관찰할 수 있었다. 학생들은 이러한 지식들을 의도치 않게 학습하는 과정에서 현상기반추론(phenomenon-based reasoning), 관계기반추론(relation-based reasoning), 모델기반추론(model-based reasoning)을 하였다. 본 연구

에서 관찰된 대부분의 의도하지 않은 학습들은 현상기반 추론을 통한 사실적 지식이었다. 반면 적은 수이지만 관계기반추론 또는 모델기반추론을 통한 개념적 지식도 관찰되었다. 학생들이 학습한 의도하지 않은 사실적 지식 중에는 앞으로 학습할 과학 개념들과 연관되는 것들도 있었다. 이는 학생들이 나중에 관련 개념을 학습하게 될 때 의도하지 않았지만 학습하게 된 사실적 지식을 떠올림으로써 이해를 도울 수 있다는 측면에서 의미를 갖는다. 그러므로 본 연구에서는 관찰된 대부분의 의도하지 않은 학습이 사실적 지식이라는 점을 문제시하고 부정적으로 바라보는 것은 아니다. 다만 현상기반추론에서 더 나아가 관계기반 또는 모델기반 추론을 통해 개념적 지식을 학습할 수 있는 기회가 있을 수 있으며, 이때 교사의 역할이 중요하다는 측면을 지적하고자 한다. 예컨대, 수업과 관련 없는 것을 수업 중에 하거나 이에 대해 교사에게 물어보는 것은 바람직한 행동이 아니라고 생각하는 문화적 규범 때문에 한 학생이 본인이 관찰하게 된 의도하지 않은 학습에 대해 더 알고 싶지만 교사에게 질문하지 않고 관찰에만 그치는 경우를 볼 수 있었다. 본 연구에서는 사실적 지식 또는 개념적 지식 외에 절차적 지식도 학생들이 학습하는 것을 관찰할 수 있었다. 특히, 우리가 말로는 표현하기 어렵지만 어떻게 하는지 알고 있는 일종의 암묵적 지식이라고 할 수 있는 절차적 지식을 학생들이 학습하는 것을 관찰하였다. 이는 과학 실험 수업이 다른 종류의 교육 활동과 구별되는 조작적 활동을 포함하며, 특히 실험을 하는 중 시행착

오를 겪을 수 있다는 측면에서 암묵적 절차적 지식(implicit procedural knowledge)을 학습할 기회를 제공하였다고 볼 수 있다.

이와 더불어, 본 연구에서는 대다수의 의도하지 않은 학습이 학생의 흥미로부터 시작 되며, 그 흥미가 유지 되어야 의도하지 않은 학습이 일어나는 것을 확인할 수 있었다. 또한 학생들이 알고 있는 기존 지식과 연결되었을 때 의도하지 않은 학습이 일어나는 것을 관찰할 수 있었다. 이러한 관찰 결과를 통해 의도한 학습과 의도하지 않은 학습이 이루어지는 과정이 서로 다름을 알 수 있다. 의도한 학습의 경우, 학습 목표를 효과적으로 가르치기 위하여 학생들의 흥미와 호기심을 불러일으키려는 교사의 노력이 선행되는 반면, 의도하지 않은 학습에서는 학생 스스로 흥미와 호기심을 가지고 학습한다는 측면에서 차이를 보인다. 과학 철학자 폴라니(Micheal Polanyi)의 지적 열정(intellectual passion)의 개념에서 이를 교육적으로 해석해 볼 때, 의도하지 않은 학습은 학생의 호기심 및 흥미 즉, 발견적 열정(heuristic passion)으로부터 시작되었다는 점에서 의미 있는 학습이라고 해석할 수 있다. 반면, 본 연구에서 관찰된 대부분의 의도하지 않은 학습은 개인 또는 개인이 포함되어 있는 모둠에만 머물러있어 설득적 열정(persuasive passion)이 발휘되는 사례는 거의 관찰되지 못하였다. 학생들 대부분은 자신들의 의도하지 않은 학습을 교사 및 다른 친구들과 공유하고 싶어하였으나 다른 학생들과 공유할 기회가 없었다는 측면에서 설득적 열정이 발휘되지 못하였다고 볼

수 있다.

종합해보면, 학생들은 교사가 의도하지는 않았지만 여러 가지 추론 과정을 통해 다양한 지식들을 쌓아가고 있었다. 이 중에는 앞으로의 학습에 도움이 될 내용도 있었으며, 모델기반추론과 같이 고차원적 추론 과정이 수반된 학습도 있었다. 또한 학생들의 의도하지 않은 학습은 학생의 흥미에서 시작되었다는 측면에서 개인에게 의미 있는 학습이 될 수 있음을 확인하였다. 이처럼 본 연구는 의도하지 않은 학습이 학교 교육과 과학 교육에서 갖는 교육적 의의를 찾고 이를 교육적으로 활용하기 위한 실마리를 제공하고자 하였다. 의도하지 않은 학습이 교육적으로 활용되기 위해서는 학교 교육에서 의도한 학습뿐 아니라 의도하지 않은 학습이 일어날 수 있음을 교사가 인지하는 것이 필요하며, 의도하지 않은 학습이 사실적 지식에서 개념적 지식으로 나아가는데 교사의 역할이 중요하다. 본 연구가 이러한 측면에서 과학교육 및 교사 교육에 줄 수 있는 시사점을 논의하였다.

주요어: 의도하지 않은 학습, 실험 수업, 초등 과학, 발견적 열정, 암묵적 절차적 지식

학 번: 2011-21570

Appendix A

IRB Letter of approval

SIF 16-004

심의결과 통보서

수신	책임연구자	성명	박지선	소속	과학교육과	직위	학생
	지원기관						
승인 번호	IRB No.1401/001-020						
연구과제명	초등학교 과학 실험 수업에서 발생하는 의도하지 않은 학습 (A study of unintended learning of practical work in primary science class)						
연구종류	□ 설문조사 ■ 관찰연구 □ 행동실험연구 □ 조직 및 검체 연구(혈액, 체액 등) □ 배아연구 □ 체세포복제 배아연구 □ 유전자연구 □ 유전자치료연구 □ 보관된 검체 연구 □ 임상시험 ■ 기타 (면담)						
심의종류	□ 정규심의 ■ 신속심의 □ 긴급심의						
심의일자	2014 년 1 월 24 일						
심의대상	■ 연구계획서(신규)	■ 책임연구자					
	□ 연구계획서(보완)	■ 연구참여자 동의서					
	□ 계획서 변경	■ 증례기록서					
	□ 중간보고서	■ 연구참여자 모집 광고					
	□ 중지 또는 조기종료보고서	□ 연구참여자 작성 일지					
	□ 종료보고서	□ 기타 연구참여자에게 제공되는 문서					
	□ 승인된 연구계획서의 1년 단위 지속심의	■ 기타(지도교수 서약서)					
심의결과	승인						
승인일자	2014 년 1 월 24 일	승인유효기간	2015 년 1 월 23 일 까지				
정기보고주기	□ 3개월 □ 6개월 ■ 1년 □ 기타 () ❖ 정기보고주기는 1년을 초과할 수 없음						
심의의견	1. 심의결과 제출하신 연구계획에 대해 승인하며, 개인정보보호에 유의하여 주시기 바랍니다. 2. 연구자께서는 승인된 문서를 사용하여 연구를 진행하시기 바라며, 만일 연구진행 과정에서 계획상에 변경사항(연구자 변경, 연구내용 변경 등)이 발생할 경우 본 위원회에 변경신청을 하여 승인 받은 후 연구를 진행하여 주십시오. 3. 유효기간 내 연구가 끝났을 경우 종료 보고서를 제출하여야 하며, 승인유효기간 이후에도 연구를 계속하고자 할 경우, 2014년 12월까지 지속심의를 받도록 하여 주십시오.						

2013 년 1 월 24 일

서울대학교 생명윤리심의위원회 위원장

본 위원회가 승인한 연구를 수행하는 연구자들은 다음의 사항을 준수해야 합니다.

1. 반드시 계획서에 따라 연구를 수행해야 합니다.
2. 위원회의 승인을 받은 연구참여자 동의서를 사용해야 합니다.
3. 모국어가 한국어가 아닌 연구참여자에게는 승인된 동의서를 연구참여자의 모국어로 번역하여 사용해야 하며 번역본은 인증 및 위원회의 승인을 거쳐야 합니다.
4. 연구참여자 보호를 위해 불가피한 경우를 제외하고는 연구 진행중의 변경에 대해서는 위원회의 사전 승인을 받아야 합니다. 연구참여자의 보호를 위해 취해진 응급상황에서의 변경에 대해서는 즉각 위원회에 보고해야 합니다.
5. 위원회에서 승인 받은 계획서에 따라 등록된 연구참여자의 사망, 입원, 심각한 질병에 대하여는 위원회에 서면으로 보고해야 합니다.
6. 임상시험 또는 연구참여자의 안전에 대해 유해한 영향을 미칠 수 있는 새로운 정보는 즉각 위원회에 보고해야 합니다.
7. 위원회의 요구가 있을 때에는 연구의 진행과 관련된 사항에 관하여 위원회에 보고해야 합니다.
8. 연구참여자 모집광고는 사용 전에 위원회로부터 승인을 받아야 합니다.
9. 강제 혹은 부당한 영향력이 없는 상태에서 충분한 설명에 근거하여 연구참여자로부터 동의를 받아야 하며, 잠재적인 연구참여자에 대해서 연구 참여 여부를 숙려할 수 있도록 충분한 기회를 제공해야 합니다.

Appendix B

The consent forms of teachers, students, and parents

IRB No. 1401/001-020　　　　　유효기간: 2015년 1월 23일

연구참여자용 설명서 및 동의서 (참여 교사용)

연구 과제명 : 초등학교 과학 실험 수업에서 발생하는 의도하지 않은 학습
연구 책임자명 : 박지선 (서울대학교 석박사통합과정)

이 연구는 초등 과학 실험 수업에서 일어나는 학생의 의도하지 않은 학습을 살펴보는 연구입니다. 귀하는 과학 수업을 하는 초등 교사로서 이 연구에 참여하도록 권유 받았습니다. 이 연구를 수행하는 서울대학교 소속의 연구원이 귀하에게 이 연구에 대해 설명해 줄 것입니다. 이 연구는 자발적으로 참여 의사를 밝히신 분에 한하여 수행 될 것이며, 귀하께서는 참여 의사를 결정하기 전에 본 연구가 왜 수행되는지 그리고 연구의 내용이 무엇과 관련 있는지 이해하는 것이 중요합니다. 다음 내용을 신중히 읽어보신 후 참여 의사를 밝혀 주시길 바라며, 필요하다면 가족이나 친구들과 의논해 보십시오. 만일 어떠한 질문이 있다면 담당 연구원이 자세하게 설명해 줄 것입니다.

담당 연구원: 박지선 (02-880-8817)

1. 이 연구는 왜 실시합니까?
이 연구는 기존의 과학 실험 수업에 대한 대안적 해석을 위해 과학 실험 수업에서 일어나는 교사가 의도하지 않은 학생의 학습을 살펴보고자 합니다.

2. 얼마나 많은 사람이 참여합니까?
서울 및 경기 지역에 위치한 공립 초등학교에서 근무하며 4-6학년 과학을 가르치고 있는 교사 6명이 참여할 것입니다.

3. 만일 연구에 참여하면 어떤 과정이 진행됩니까?
만일 귀하가 참여의사를 밝혀 주시면 다음과 같은 과정이 진행될 것입니다.

약 2-3회에 걸쳐 연구자가 귀하의 과학 실험 수업을 관찰할 것입니다. 수업 전과 후에는 과학 실험 수업에 대한 생각, 수업 계획, 수업 후 느낌 등에 대하여 면담을 실시할 것이며, 면담 소요 시간은 1시간 미만입니다. 수업 전 면담은 관찰 수업 전날 오후에 귀하의 교실에 방문하여 실시할 것이며, 수업 후 면담은 수업 당일 오후에 귀하의 교실에서 할 것입니다. 수업 관찰 및 면담 내용은 녹화 및 녹음될 것이며, 귀하의 학교, 학급, 이름 등은 다른 기호로 바꾸어 사용하므로 개인 정보는 알려지지 않을 것입니다.

4. 연구 참여 기간은 얼마나 됩니까?
약 2-3회의 과학 실험 수업 관찰과 수업 전, 후의 면담에 참여할 것입니다.

5. 참여 도중 그만두어도 됩니까?
예, 귀하는 언제든지 어떠한 불이익 없이 참여 도중에 그만 둘 수 있습니다. 만일 귀하가 연구에 참여하는 것을 그만두고 싶다면 담당 연구원에게 즉시 말씀해 주십시오.

IRB No. 1401/001-020　　　　　유효기간: 2015년 1월 23일

6. 부작용이나 위험요소는 없습니까?
예상되는 부작용이나 위험요소는 없습니다. 만일, 참여 도중 발생할 수 있는 위험요소에 대한 질문이 있으면 담당 연구원에게 바로 문의해 주십시오.

7. 이 연구에 참여시 참여자에게 이득이 있습니까?
귀하가 이 연구에 참여하는데 있어서 직접적인 이득은 없습니다. 그러나 귀하가 제공하는 정보는 초등 과학 실험 수업에 대한 대안적 해석을 하는데 도움이 될 것입니다.

8. 만일 이 연구에 참여하지 않는다면 불이익이 있습니까?
귀하는 본 연구에 참여하지 않을 자유가 있습니다. 또한, 귀하가 본 연구에 참여하지 않아도 귀하에게는 어떠한 불이익도 없습니다.

9. 연구에서 얻은 모든 개인 정보의 비밀은 보장됩니까?
개인정보관리책임자는 서울대학교의 박지선(02-880-8817)입니다. 저희는 이 연구를 통해 얻은 모든 개인 정보의 비밀 보장을 위해 최선을 다할 것입니다. 이 연구에서 얻어진 개인 정보가 학회지나 학회에 공개 될 때 귀하의 이름과 다른 개인 정보는 사용되지 않을 것입니다. 그러나 만일 법이 요구하면 귀하의 개인정보는 제공될 수도 있습니다. 또한 모니터 요원, 점검 요원, 생명윤리심의위원회는 연구 참여자의 개인 정보에 대한 비밀 보장을 침해하지 않고 관련규정이 정하는 범위 안에서 본 연구의 실시 절차와 자료의 신뢰성을 검증하기 위해 연구 결과를 직접 열람할 수 있습니다. 귀하가 본 동의서에 서명하는 것은, 이러한 사항에 대하여 사전에 알고 있었으며 이를 허용한다는 동의로 간주될 것입니다.

10. 이 연구에 참가하면 댓가가 지급됩니까?
귀하의 연구 참여시 감사의 뜻으로 삼만원 정도 되는 작은 기념품이 증정될 것입니다.

11. 연구에 대한 문의는 어떻게 해야 됩니까?
본 연구에 대해 질문이 있거나 연구 중간에 문제가 생길 시 다음 연구 담당자에게 연락하십시오.

이름: 박 지 선　　　전화번호: 02-880-8817

만일 어느 때라도 연구 참여자로서 귀하의 권리에 대한 질문이 있다면 다음의 서울대학교 생명윤리심의위원회에 연락하십시오.
서울대학교 생명윤리심의위원회 (SNUIRB)　　　전화번호: 02-880-5153

IRB No. 1401/001-020　　　　유효기간: 2015년 1월 23일

동 의 서

1. 나는 이 설명서를 읽었으며 담당 연구원과 이에 대하여 의논하였습니다.
2. 나는 위험과 이득에 관하여 들었으며 나의 질문에 만족할 만한 답변을 얻었습니다.
3. 나는 이 연구에 참여하는 것에 대하여 자발적으로 동의합니다.
4. 나는 이 연구에서 얻어진 나에 대한 정보를 현행 법률과 생명윤리심의위원회 규정이 허용하는 범위 내에서 연구자가 수집하고 처리하는데 동의합니다.
5. 나는 담당 연구자나 위임 받은 대리인이 연구를 진행하거나 결과 관리를 하는 경우와 보건 당국, 학교 당국 및 서울대학교 생명윤리심의위원회가 실태 조사를 하는 경우에는 비밀로 유지되는 나의 개인 신상 정보를 직접적으로 열람하는 것에 동의합니다.
6. 나는 언제라도 이 연구의 참여를 철회할 수 있고 이러한 결정이 나에게 어떠한 해도 되지 않을 것이라는 것을 압니다.
7. 나의 서명은 이 동의서의 사본을 받았다는 것을 뜻하며 연구 참여가 끝날 때까지 사본을 보관하겠습니다.
8. 나는 연구 수행 과정에서 과학 수업의 활동 장면 및 면담 내용에 대해 녹음 또는 녹화하는 것을 동의합니다.

______________________	__________	______________
연구참여자 성명	서 명	날짜 (년/월/일)
______________________	__________	______________
동의서 받은 연구원 성명	서 명	날짜 (년/월/일)
______________________	__________	______________
연구책임자 성명	서 명	날짜 (년/월/일)

IRB No. 1401/001-020　　　　　　　유효기간: 2015년 1월 23일

연구참여자용 설명서 및 동의서 (초등학생용)

연구 과제명 : 초등학교 과학 실험 수업에서 발생하는 의도하지 않은 학습
연구 책임자명 : 박지선 (서울대학교 석박사통합과정)

안녕하십니까? 저는 서울대학교 사범대학 물리교육과 대학원에서 공부를 하고 있는 박지선이라고 합니다. 저는 초등학교 과학 수업에서 여러분들이 어떠한 것들을 배우는지에 대해 연구하고 이를 통해 여러분들이 더 잘 과학을 배울 수 있는 방법을 찾으려고 합니다. 여러분들에게 지금부터 제가 하는 연구에 대해서 설명하고, 이 연구에 여러분들이 참여할 생각이 있는지를 물어보려고 합니다. 아래의 설명에서 이해되지 않는 말들이 있을 수 있습니다. 이해가 분명하게 되지 않는 말이나 정보에 대해서는 저에게 질문하기 바랍니다.

담당 연구원: 박지선 (02-880-8817)

1. 이 연구를 왜 하나요?
이 연구는 서울대학교 물리교육과 송진웅 교수님과 제가 과학 실험 수업에서 여러분들이 무엇을 배우고 생각하는지 알고자 실시하는 연구입니다. 지금부터 여러분에게 이 연구에 대해 설명한 후 여러분이 이 연구에 참여할지 물어볼 것입니다.

2. 왜 저에게 참여하라고 하시는 건가요?
서울 및 경기 지역에 있는 공립 초등학교 4-6학년 6학급의 학생들이 이 연구에 참여할 것입니다. 저는 여러분 학급이 그 학급들 중 하나가 될 수 있다고 생각하여 참여하고 싶은지를 묻는 것입니다.

3. 꼭 참여해야 하나요?
원하지 않으면 참여하지 않아도 되며 참여하지 않아도 여러분에게 해가 되는 일은 없습니다.

4. 연구 중에 어떤 일을 하나요?
제가 여러분이 과학 실험 수업 동안에 활동하는 모습을 촬영하게 됩니다. 더불어 여러분 중 몇몇과는 과학 수업 중에 있었던 일에 대해서 좀 더 자세히 이야기 나누고, 여러분의 생각에 대해서도 이야기 나누려고 합니다. 여러분과 보호자가 허락하면 이 연구에서 얻은 정보들은 연구하는 다른 선생님들과 공유하게 될 것입니다. 이 때 여러분의 학교, 학급, 이름 등은 알려지지 않을 것입니다.

5. 연구 참여 기간은 얼마나 됩니까?
여러분의 과학 실험 수업에 약 2-3회 참여할 것입니다. 그리고 과학 실험 수업 전과 후에 몇몇의 학생과는 이야기를 나눌 것이며, 시간은 1시간이 채 걸리지 않습니다.

6. 이 연구에 참여할 경우 위험한 내용은 없나요?
예상되는 부작용이나 위험요소는 없습니다. 만일, 참여 도중 발생할 수 있는 위험요소에 대한 질문이 있으면, 담당 연구원에게 바로 문의해 주십시오.

IRB No. 1401/001-020 유효기간: 2015년 1월 23일

7. 연구에 참여하지 않는다고 불이익이 있나요?

여러분이 연구에 참여하기 싫으면 참여하지 않을 수 있습니다. 연구에 참여하지 않아도 불이익을 당하지 않습니다.

8. 이 연구가 저에게 어떠한 도움이 되나요?

이 연구는 여러분에게 직접적인 도움이 되지 않을 수도 있습니다. 그러나 이 연구가 나중에 여러분과 같은 어린이들이 과학 학습을 더 잘 할 수 있는 방안을 찾는데 도움이 될 수 있습니다.

9. 이 연구에 참여하면 선물이 있나요?

미안하지만 이 연구에 참가하는데 있어서 여러분에게는 선물을 주지 않습니다.

10. 궁금한 것이 있으면 어떻게 하나요?

연구에 대해 궁금한 것이 있거나 읽고 나서 이해가 안 가는 것은 무엇이든 연구원 선생님(박지선, 02-880-8817)이나 부모님 혹은 보호자에게 설명을 해 달라고 하십시오. 원한다면 "학부모용 설명서"를 읽어 볼 수도 있습니다.

이 설명서는 여러분이 보관할 수 있도록 연구원 선생님이 복사해 줄 것입니다.
여러분이 이 연구에 참여하기 위해서는 부모님이나 법정 대리인도 함께 동의서 양식에 서명해야 합니다.
아래 사항을 확인한 후 연구에 참여하길 원한다면 이름을 써 주십시오.

1. 나는 이 설명서를 읽었습니다.
2. 나의 모든 궁금한 점은 완전히 이해할 수 있도록 연구원에게서 설명 받았습니다.
3. 나는 이 연구에 참여 할 것을 동의합니다.
4. 나는 연구 수행 과정에서 과학 수업의 활동 장면 및 인터뷰 내용에 대해 녹음 또는 녹화하는 것을 동의합니다.

연구 참여자 아동 명	서 명	날 짜 (년/월일)
법정대리인 명(연구 참여자와 관계)	서 명	날 짜 (년/월/일)
동의서 받은 연구원 명	서 명	날 짜 (년/월/일)
연구 책임자 명	서 명	날 짜 (년/월/일)

IRB No. 1401/001-020　　　　　　　유효기간: 2015년 1월 23일

학부모용 설명서

연구 과제명 : 초등학교 과학 실험 수업에서 발생하는 의도하지 않은 학습
연구 책임자명 : 박지선 (서울대학교 대학원생)

이 연구는 초등 과학 실험 수업에서 일어나는 학생의 의도하지 않은 학습을 살펴보는 연구입니다. 귀하의 자녀는 이 연구에 참여하도록 권유 받았습니다. 이 연구를 수행하는 서울대학교 소속의 연구원이 귀하 자녀에게 이 연구에 대해 설명해 줄 것입니다. 이 연구는 자발적으로 참여 의사를 밝히신 분에 한하여 수행 될 것이며, 귀하께서는 자녀의 참여 의사를 결정하기 전에 본 연구가 왜 수행되는지 그리고 연구의 내용이 무엇과 관련 있는지 이해하는 것이 중요합니다. 다음 내용을 신중히 읽어보신 후 참여 의사를 밝혀 주시길 바라며, 필요하다면 가족이나 친구들과 의논해 보십시오. 만일 어떠한 질문이 있다면 담당 연구원이 자세하게 설명해 줄 것입니다.

담당 연구원: 박지선 (02-880-8817)

1. 이 연구는 왜 실시합니까?
이 연구는 기존의 과학 실험 수업에 대한 대안적 해석을 위해 과학 실험 수업에서 일어나는 교사가 의도하지 않은 학생의 학습을 살펴보고자 합니다.

2. 얼마나 많은 사람이 참여합니까?
서울 및 경기 지역에 위치한 공립 초등학교에서 근무하며 4-6학년 과학을 가르치고 있는 교사 6명과 학급 학생들이 참여할 것입니다.

3. 만일 연구에 참여하면 어떤 과정이 진행됩니까?
만일 귀하가 자녀의 참여의사를 밝혀 주시면 다음과 같은 과정이 진행될 것입니다.

약 2-3회에 걸쳐 연구자가 자녀가 소속되어 있는 학급의 과학 실험 수업을 관찰할 것입니다. 학급의 몇몇 학생에게는 수업 전과 후에 수업에 대한 생각에 대해 면담을 실시할 것이며, 면담 소요 시간은 1시간 미만입니다. 수업 전 면담은 아침 자율 학습 시간 또는 쉬는 시간에 이루어지며, 수업 후 면담은 수업 당일 오후에 이루어질 예정입니다. 면담 장소는 학년 연구실 또는 상담실과 같이 조용한 곳에서 개별적으로 이루어집니다. 수업 관찰 및 면담 내용은 녹화 및 녹음될 것이며, 자녀의 학교, 학급, 이름 등은 다른 기호로 바꾸어 사용하므로 개인 정보는 알려지지 않을 것입니다.

4. 연구 참여 기간은 얼마나 됩니까?
약 2-3회의 과학 실험 수업 관찰과 수업 전, 후의 면담에 참여할 것입니다.

5. 참여 도중 그만두어도 됩니까?
예, 귀하의 자녀는 언제든지 어떠한 불이익 없이 참여 도중에 그만 둘 수 있습니다. 만일 귀하의 자녀가 연구에 참여하는 것을 그만두고 싶다면 담당 연구원에게 즉시 말씀해 주십시오.

6. 부작용이나 위험요소는 없습니까?

예상되는 부작용이나 위험요소는 없습니다. 만일, 참여 도중 발생할 수 있는 위험요소에 대한 질문이 있으면 담당 연구원에게 바로 문의해 주십시오.

7. 이 연구에 참여시 참여자에게 이득이 있습니까?

귀하의 자녀가 이 연구에 참여하는데 있어서 직접적인 이득은 없습니다. 그러나 귀하의 자녀가 제공하는 정보는 초등 과학 실험 수업에 대한 대안적 해석을 하는데 도움이 될 것입니다.

8. 만일 이 연구에 참여하지 않는다면 불이익이 있습니까?

귀하의 자녀는 본 연구에 참여하지 않을 자유가 있습니다. 또한, 귀하의 자녀가 본 연구에 참여하지 않아도 귀하의 자녀에게는 어떠한 불이익도 없습니다.

9. 연구에서 얻은 모든 개인 정보의 비밀은 보장됩니까?

개인정보관리책임자는 서울대학교의 박지선(02-880-8817)입니다. 저희는 이 연구를 통해 얻은 모든 개인 정보의 비밀 보장을 위해 최선을 다할 것입니다. 이 연구에서 얻어진 개인 정보가 학회지나 학회에 공개 될 때 귀하의 자녀 이름과 다른 개인 정보는 사용되지 않을 것입니다. 그러나 만일 법이 요구하면 자녀의 개인정보는 제공될 수도 있습니다. 또한 모니터 요원, 점검 요원, 생명윤리심의위원회는 연구 참여자의 개인 정보에 대한 비밀 보장을 침해하지 않고 관련규정이 정하는 범위 안에서 본 연구의 실시 절차와 자료의 신뢰성을 검증하기 위해 연구 결과를 직접 열람할 수 있습니다. 귀하가 본 동의서에 서명하는 것은, 이러한 사항에 대하여 사전에 알고 있었으며 이를 허용한다는 동의로 간주될 것입니다.

10. 이 연구에 참가하면 댓가가 지급됩니까?

죄송합니다만 본 연구에 참가하는데 있어서 연구 참여자에게 어떠한 금전적 보상도 없습니다.

11. 연구에 대한 문의는 어떻게 해야 됩니까?

본 연구에 대해 질문이 있거나 연구 중간에 문제가 생길 시 다음 연구 담당자에게 연락하십시오.

이름: 박 지 선 전화번호: 02-880-8817

만일 어느 때라도 연구 참여자로서 귀하의 권리에 대한 질문이 있다면 다음의 서울대학교 생명윤리심의위원회에 연락하십시오.
서울대학교 생명윤리심의위원회 (SNUIRB) 전화번호: 02-880-5153

Appendix C

The example of transcription of pre-lesson interview

연구자: 수업 어떻게 하실 건지 과정을 좀 알려주실 수 있으세요? 계획하고 있는 수업과정.

교 사: 먼저 지난 시간 복습 좀 하구요. 전지 한 개랑 전구 한 개랑 전선 두 개 사용해서 밝기 보는 거 하고 그 다음 실험관찰 쓰고 직렬, 병렬 연결이란 뭔지 정리하고 나서 직렬로 연결된 거 전지 중에서 전지 한 개 빼는 거 하구요. 병렬로 연결되는 전지에서 전지 한 개 빼는 거 하고 그 다음에 확인문제 몇 개 하고.

연구자: 복습은 항상 수업 전에 하시는 거에요? 아니면 이 차시에만 필요하다는 생각이 들어서 하시는 거에요?

교 사: 거의 매번 해요.

연구자: 그냥 이야기로 하시는 편인지 아니면 어떤…

교 사: 저번 시간에 나왔던 PPT 몇 장 정도로 하는 편이에요.

연구자: 확인문제라 하면 어떤거에요?

교 사: PPT에서 문제 내놓고 애들이 다같이 대답하는 그런거요.

연구자: 아 이거는 실험관찰이나 교과서에 있는 게 아니라 선생님이 만드시는 거에요?

교 사: 네.

연구자: 이번 수업에서 특히 유념히 여기시는 거 있어요? 예를 들어 이런 것은 어려울 것 같다, 빨리할 것 같다 이런 거.

교 사: 전지에서 직렬연결 병렬 연결 하나씩 빼는 거 처음 예상엔 잘못 할 것 같은데 잘 모르겠어요.

연구자: 지금 하시고자 하는 것들은 교과서랑 실험관찰을 바탕으로 계획하신거죠?

교　사: 네 교과서랑 실험관찰에 벗어나지 않고 하는 편인 것 같아요.

연구자: 그러면 학습목표도 지도서 있는 거랑 같은가요? 애네가 학습했으면 하는 부분이 뭔지…

교　사: 그냥 별로 다르지 않은 것 같은데요.

연구자: 아 제가 이걸 묻는 이유는 제가 궁금해 하는 것이 의도하지 않은 학습들이기 때문에 교사가 의도한 것이 무엇인지를 알고 그것과 다른 것들을 중점적으로 보려고 하거든요 애네가 학습했으면 하는 것들 요목요목 애기해 주실 수 있으세요?

교　사: 전지가 직렬연결일 때가 병렬연결일 때보다 밝다 ,직렬 연결은 전지가 하나 빠지면 불이 꺼지는 것, 병렬 연결은 하나가 빠져도 되는 것, 병렬 연결일 때 하나를 빼도 밝기가 똑같은 것 정도요

연구자: 주로 개념을 획득하는 것이 이번 수업에서의 주 목적이 되겠네요?

교　사: 네.

연구자: 제가 선생님 수업에서 알고 들어가야 되는 것들이 몇 개 있나요? 예를 들어 순서는 이런 식으로 한다거나 특이한 규칙이 있다거나.

교　사: 발표하면 도장주는 거.

연구자: 애들이 그거 되게 받고 싶어한다고 그러셨죠 애들 실험 같은 거 나눠주는 규칙들도 있어요?

교　사: 모둠장이 가져가고 또 모둠장이 걷어오고.

연구자: 참여할 때의 룰도 있어요?

교　사: 없어요 자유롭게 하는 편이에요.

연구자: 선생님 과학시간에 더 지켜야하는 것은 없는 거네요?

교　사: 네 특별히…저는 화장실은 말 안하고 그냥 다녀오라고 하거든요? 아 그리고 동의서는 한 반은 다 가져왔는데 한 반은 00명

밖에 안 가져왔어요.

연구자: 다 가지고 온 반이 몇 반이에요?

교 사: 0반이요

연구자: 0반이 다 가지고 오고 0반이 00명

교 사: 네 더 가지고 오라고 하긴 했는데 늘어봤자 한 두 명 일 것 같아요.

연구자: 애들이 한 반만 가져온 거네요?

교 사: 3분에 2정도?

연구자: 걔네들은 제가 찍으면 안 될 것 같은데 어떡해야 되지 제가 아침에 좀 일찍 가서 선생님한테 명단을 받고 원래 자리는 정해져 있죠?

교 사: 네 원래는 정해져 있는데 0반은 안 낸 애들 따로 앉혀야 될 것 같아요.

연구자: 그럼 제가 일찍 가서 전 시간에 선생님한테 그걸 받아서 모둠 배치를 하도록 할까요?

교 사: 편하신 대로 하세요.

연구자: 총 00명? 00명?

교 사: 00명

연구자: 00명에 00명이면 세 모둠으로만 제가 모으고 나머지 애들 하면 되겠죠? 혹시 제가 지금 받아볼 수는 없죠 선생님이 정리하셔야 되는거죠?

교 사: 네 제가 그냥 서류만 받아가지고.

연구자: 그럼 저희 3,4교시 수업이니까 아침에 일찍 가서 선생님 한테 받아서 애들 체크해서 할게요. 그 날 애들 명렬표랑 서류만 저한테 주시면 제가 체크해서 모둠을 다시 짜놓을게요.

교 사: 네.

Appendix D

The example of transcription of student discourse

(교사의 말이 채 끝나지 않았는데 1번 2번 학생이 일어나고 2번 학생이 실험 도구들을 만지며 시작한다.)

(중략)

(학생1과 학생2이 함께 연결을 하고 있다.)

학생2: 이쪽도 이어 끼워. 아닌데 다시 해보자

학생2: 으자자자자자 아이 손이야. 그렇게 안 해도 돼. 여기만 하면 된다고. 앗, 엉켰다. (전선이 x자로 겹친 것을 보며)

학생1: (소리 내어 웃으며) 하하

학생2: 꼬여버렸어 전류가

학생1: (웃음) 하하

(전선 집게를 빼어 다시 연결함)

학생2: 왜 안 돼지

학생2: 불이 안 들어와요(말을 한 후 옆에 있던 연구자를 바라봄)

학생2: (고개를 갸웃대며 전선을 만지작한다) 왜 이러지?

학생1: 불이 안 들어와

학생2: (갑자기 집게달린 전선을 빼고 전지의 +,− 방향을 바꾸며) 아! 이렇게 해야 해 (교과서 그림을 힐끗봄)

학생1: 아~

학생2: 이렇게 해야 해

학생1: 그림 봤을 때

연구자: 방금 왜 그렇게 했어?

학생2: (연구자의 질문을 못 들었는지 계속 회로를 만지고 있음) 왜 안 되지?

연구자: 방금 왜 그렇게 했는지 물어봐도 돼?

학생2: 네. (고개를 들어 연구자를 보며) 한쪽 방향으로 흘러야 하는데 거꾸로 끼워서요. 그래도 전류는 흘러야 하는데…….

학생1: (회로를 가리키며) 했더니 안 들어왔어요.

학생2: 왜 안되지? 원래 불 나와야 하는데……. (전구를 전선 집게에서 빼며) 전기가 없어서 그런가?

학생1: 이상해. 왜 안되지?

(학생2이 전구를 소켓에서 빼서 직접 전선에 연결해본다)

학생2: 전지가 이상하지 않다면…….(가위에서 전선을 빼어 다시 연결한다)

학생3: 너네 꺼 불 안 켜져?

학생3: 어~ 조금 들어온다. 전류가 너무 적은건가?

학생2: (가위를 다시 연결하며) 이번엔 한번 이쪽에 껴보자

교 사: (가위를 다시 빼서 실험 쟁반에 놓으며) 아직 실험하지 마세요. 여기 불 들어와요?

학생1: 네

교 사: (학생3, 4를 바라보며) 여기 불 들어와요?

학생3: 아니요

학생2: (계속 회로를 만지며) 전기가 별로 없나봐요. 전자의 이동이 별로 없나봐

학생1: (전구를 손으로 가리키며) 아주 조금

교 사: (학생2, 4의 회로를 봐주면서) 이것도 안 들어와?

(교사의 말이 들리자, 학생1과 2이 2,4,를 본다)

학생2: (학생4를 바라보며) 그러니깐 스위치를 우리에게 넘기시지

학생4: (학생2에게 손을 내밀며) 전구 줘봐

(학생2은 본인들 전기회로에서 전구를 빼서 준다)

(학생4는 2에게서 건네받은 전구를 낀다)

학생2: 회로를 잘못 연결 한 거 아니면, 전지 아님 전구가 이상한거야. 전지를 바꿔서 해봐야지 전지를…….

교 사: (학생3, 4의 회로를 손으로 잡으며) 아니야 잠깐만 기다려봐

학생2: (자리에서 일어나 학생3, 4쪽을 고개를 쭉 빼서 보며 이야기 한다) 아니 플라스틱에.(안 들림)

교사: (계속 도와주며) 기다려 보세요. 기다려 보세요. 연결했어? 여기에 스위치 (무언가 해주고 앞으로 간다)

(중략)

교 사: 2반. 손 머리. 선생님은 가위나 나무젓가락이나 플라스틱 숟가락이나 연결하라는 말을 안했었는데 만지는 사람이 있어. 선생님 설명을 들어야지 우리가 같이 실험을 해보고 다 성공할 수 있어. 알겠지? 손 머리인데 손 머리 안한 사람도 있어요. 실험할 때는 여러분들이 스스로 하게 시간을 줄 거야. 하지만 지금은 실험을 준비하는 거였어요. 불이 들어오는지 제대로 연결했는지를 실험한 거였어요. 연결이 잘 된 모둠 손들어 보세요. (대부분의 학생들이 손을 드나, 학생3,4,는 손을 들지 않는다. 학생1,2도 손을 들었다) oo(학생2의 이름)이 모둠 불 마지막에 들어왔어요?

학생2: (들었던 손을 내리며) 안 들어와.

학생1: (손을 내리며) 확인을 못했어요.

교 사: 그러면 이따가 선생님이 가서 직접 확인하도록 하겠습니다. (몇몇 학생이 손을 내리고 있자) 손 머리 하고 있어요.

학생2: (시선은 학생2를 향하고 있는 듯하나 특정 누군가에게 말을 건네고 있는 것 같지 않고 혼잣말인 것 같다.) 전지가 이상한 거 같아. 전기가 없거나

교 사: 선생님이 여러 가지 물체를 더 나누어 줄 거야. 하나씩 바꿔가면서 끼워보도록 합니다. 먼저 하기 전에 예상을 할 거예요. (중략) 왜 손 내렸지? 선생님 말 잘 듣고 잘 따라해야지 다 같이 실험을 많이 해볼 수 있으니깐. 일단 선생님한테 물건 다 받고 실험관찰 다 쓰고 선생님이 시작하면, 그 담에 만집니다. 알겠지?

학생들: 네

교 사: 모둠에서 oo자리 2번들 다 나오세요. (물건 나눠줌)

학생2: 스위치가... 스위치...

학생4: 스위치가 이상한가?

학생2: 스위치 빼고 한번 해보자. 스위치에 이상이 있나..

학생2: (학생1이 뭔가 빼자. 학생1에게) 그걸 왜빼

학생2: 안그래도 시간 없어서 빨리해봐야 하는데

(학생4가 전선을 전구에 연결해보고 있음)

학생2: 안돼.

학생2: 와 됐다. 됐다. 됐다.

학생2: 스위치의 문제네

(학생4가 앞으로 나가서 스위치가 망가졌다고 말하고 새 거를 받아옴)

(6조로 교사가 옴)

교 사: 아까 전에 불이 켜지는 전구 뭐였어요?

학생2: 불이 켜지는 거요?

교 사: 응

학생2: 이거요. 아까 바꿨었는데. 이거 전지를 바꿨더니 안됐어요.

교 사: (전지끼우개에서 전지를 빼며) 원래 켜지는 전지는 뭐였어?

학생2: 검은색이요.

교 사: (전지를 들며) 요거였어?

학생2: (다른 전지를 가리키며) 아니 요거요

(학생2이 가리킨 전지를 전지끼우개에 집어넣으며)

교 사: 한번 해보겠습니다. 들어와요? 안 들어와?

(학생2이 전구를 유심히 들여다본다. 모든 실험기구는 학생2 앞에 놓여 있다. 학생1을 몸을 학생2쪽으로 돌린 채 보고만 있다.)

학생2: 스위치가 이상한 거 같애요. 스위치 빼고 했더니..(계속 전구와 전선 연결된 부분을 유심히 보며 이야기 한다)

(교사는 전지와 전선을 연결하고 있다. 학생1은 그 모습을 보고 있다.)

교 사: 전구 한번. 불 들어오니? 안 들어와?

(학생2의 손에 있던 전구와 전지를 교사가 집어 들고 다시 연결을 확인 한다)

학생2: 아니오

교 사: 된다.

학생2: 되요?

교 사: 불들어오지? 스위치 줘보세요. 잠깐만

학생2: 스위치에 연결하세요?

교 사: 스위치에 연결하면...

교 사: 스위치 눌러봐.

학생4: (교사가 스위치 누르라고 한지 10초 후) 그래도 안켜져

학생2: 스위치 때문에

교 사: 그러면 스위치 빼고 하겠습니다.

교 사: 전선하나 더 줘보세요.

교 사: (전선을 연결해주며) 전선 하나 더 연결해서 물체를 여기다 연결하는 거야. (불이 안 들어오자 회로를 계속 만진다) 잠깐만, 불이 안 들어오네.

학생2: (전지 끼우개를 가리키며) 요거. 요게 이렇게 돼 있어요. 스프링이 제대로 안 끼워져 있어요

(교사가 전지를 빼서 스프링을 몇 번 만지고 전지를 끼운다. 끼운 후 펜치로 스프링을 몇 번 죄어 준다. 다시 전지를 빼서 손으로 스프링을 만지작 한 후 전지를 넣는다. 다시 전지를 빼서 스프링을 만지고 전지를 넣는다.)

교 사: (학생2에게 건네주며) 끼워서 한번 해봐

학생2: (다시 전지에 전선을 연결하며) 돼야 되는데

학생1: (스위치를 들어 보이며) 왜 안 연결해?

학생2: 안 켜지잖아

교 사: 다 됐어요? 칠판 봅시다. 예상을 들어볼게요.

(교사는 학생들의 예상을 발표시킨다. 학생2은 교사를 보지 않고 전지끼우개를 만지면 바라보고 있다. 옆에 앉은 친구가 교사를 안보고 딴짓하는 학생2을 쳐다본다. 그러나 교사를 보라고 채근하지는 않는다.)

(학생 2명에게 예상을 물어보지만 왜 그렇게 생각했는지는 물어보지 않음. 실험을 시작하라고 함)

교사: 아직 안돼요?

학생4: 선생님 이거 스위치도 안들어와요.

학생4: 전지가 없나봐요.

학생2: (아까부터 전구를 손으로 만지작대며 유심히 보고 있다가) 선생

님, 전구 이거 진공이 여야 되지 않아요?

교 사: (전구를 뺀 소켓에 새 전구를 연결하며) 응

학생2: (교사에게 전구를 보여주며) 근데 여기 구멍이 뚫려 있어요.

교 사: (고개를 낮춰 전구를 본다) 어디?

학생2: (교사에게 전구를 보여주며) 진공이 안돼서 그런 거 같아요. 구멍이 뚫렸어요.

교 사: 아 괜찮아.

학생2: (교사에게 말하는 것 같지만, 교사를 직접 쳐다보고 있지는 않다) 전구에 이상이 있었어요. 역시. 아. 전구에 구멍이 뚫려 있어서 진공이 안 됐구먼.

학생2: (교사가 회로를 만드는 것을 바라보며) 팔라멘트에 공기가 닿구만. 전구에 유리 속을 진공으로 해놨는데 그게 구멍이 나가지고 안됐던 거

교 사: 이것도 안 들어오네. 왜 됐다 안됐다 하지

학생2: 아 그걸 안 끼웠네. 됐다. 안끼워서 그런거였어. 전구에 이상이 있었어요.

교 사: 자. 됐지. 하나 더 연결해서 여기에 연결해봐. 불이 들어오나.

학생2: 네

교사: 클립 먼저해봐.

학생2: 클립은 당연히 되지.

교사: 이제 만지지마, 전구 끼운건. 요거 두 개만 해요.

학생2: 클립은 당연히 되지. 어 안돼지?

교사: 이거 빠졌다. 이건 만지지말고 요것만 해.

학생2: 선생님이 이게 조금밖에 안나와가지고요.

교사: 만지지마!(약간 톤이 높아지면서)

교사: 이게. 현준아. 하다가 빠져 이렇게. 요렇게 물리거든. 그러면 안되겠지? 선생님이 일부러 이렇게 물려놨어. 위로. 그러니깐 이건 만지지 말고 요것만 바꿔서 해봐

학생2: 클립 됐어.

교사: 이걸로 같이 해요.

학생4: 이거 안되요.

교사: 지금 되. 이제

학생4: 근데 이거 스위치 안눌러요?

교사: 응 스위치 안눌러. 지금 이게 안되니깐

교사: 현준아. 뭐가 되는지 알려줘야지. 클립부터 다시해봐 다시 해봐

교사: 다시 보여줘. 이거는 안되니깐 하지 말고

학생1: 은박지 됐어.

학생4: (실험도구를 손을 뻗어 가지고 오려고 함)

(학생1, 2만 하는게 못마땅해서 3, 4가 기분이 상함)

학생2: 어서 해봐. 해봐

학생2: 안하네

학생2: 숟가락 안돼어. 나무젓가락 안됐고

(실험 진행함. 학생3, 4는 본인들꺼를 따로 하려고 앞에 나가서 준비물을 가져옴)

학생4: 우리 유리병 해볼게.

학생2: 유리병?

학생4: 이거 해보라고 있는 거잖아

교사: 잘 되요?

교사: 이거 샤프심 한번 해보자 (샤프심을 가지고 옴)

학생2: 샤프심이요? 샤프심은 산화되가지고. 빛이 처음엔 나긴 하지만.

교사: 된다. 된다. 샤프심도 되지?

학생2: 샤프심도 팔라멘트같은 역할을 하지만, 공기와 접촉해서 끊어져 버리잖아요.

학생1: (웃음)

학생2: 책에서 봤어.

교사: 아까 선생님이 샤프심 하나를 들고 모둠마다 다니면서 불을 켜봤는데 샤프심은 도체에요 부도체예요?

학생들: 도체

교사: 샤프심도 도체예요. 금속이 아닌데요. 도체야. 샤프심은 뭘로 만들었을까?

학생들: 흑연

교사: 흑연으로 만들었어요. 금속이 아니어도 전기가 흐르는 물체가 있어요. 물을 떠놓고 전기를 흘리면 전기가 흐를까?

학생들: (네. 아니오 섞여 있음)

교사: 물도 전기가 흘러요.

Appendix E

The example of short student memo after lesson

초등학교 6학년 (2)반 (4)모둠 이름:

7월 3일, 오늘 수업에서 새롭게 알게 된 것을 자유롭게 써 주세요

전류가 흐르는 전선에 자기장
이 있는 것을 알았고, 그 전류의
흐름이 바뀌면 나침반이 돌아가는
방향이 바뀐다는 것을 알게
되었다.

Appendix F

The example of transcription of post-lesson interview

연구자: oo아. 이거 무슨 의미로 쓴거야?

학　생: 이거 잘 못 썼어요. 역시 자석이라고 썼어요.

연구자: 역시 자석이라고? 뭐가?

학　생: 역시 자석이 세다.

연구자: 아, 뭐가 센데?

학　생: 자력이요.

연구자: 이거를 쓰게 된 배경? 상황을 좀 설명해 줄래? 이것만 봐선 내가 이해를 못하니까. 너가 이걸 왜 썼는지.

학　생: 저는 그냥 되는 데로 썼습니다.

연구자: 되는 대로? 어, 뭘 되는대?

학　생: 그냥 생각나는 대로 썼습니다.

연구자: 어, 생각나는 대로. 뭐가 생각나는데?

학　생: 왜 이렇게 깊이 말하세요?

연구자: 어, 나는 알아내는 게 직업이니까. 궁금해서. 이게 너가 무슨 생각을 했을지, 왜 이렇게 썼을까가 궁금하니까. 무얼 보고 역시 자석이라고 생각했는지.

학　생: 제가요. 자석이 너무 잘 붙어요.

연구자: 자석? 어떤 게 자석이었어?

학　생: 네? 어, 그냥 아까 현준이가 저기에서 놀고 있었을 때 걔가 자석을 너무 잘 붙여가지고 그게 자력이 세가지고 그렇게 썼어요.

연구자: 누가? 누구?

학　생: 아까 저기서 놀고 있었던.

연구자: 아, 이걸 쓴 게 너희 실험할 때 말고 저기 앉아서 oo이가 장난하는 거 보고. 걔가 무슨 장난했는데? 나 못 봤어.

학　생: 그 뭐지, 동그라면서 그 자력이 좀 센 거 있잖아요.

연구자: 아, 동그란 자석? 이거 네오디늄 자석.

학　생: 네. 제가 하던 거.

연구자: 너가 하던 거? 방금 저기서 한 거?

학　생: 네. 아까 여기서. 그거로요. 너무 잘 놀아서 여기 썼어요.

연구자: 그 놀고 있는 모습 중에서 뭘 보고?

학　생: 그 한 개로 이런 거 같은 거나 이런 거 다 붙는 걸 봐가지고 그래서 썼어요.

연구자: 아, 혹시 그러면 그 자석 있잖아. 그 자석이 그렇게 강한 거를 이전에도 알고 있었어, 아니면 오늘 걔가 노는 걸 보고 혹시 알았어?

학　생: 노는 거요.

연구자: 아, 그 자석은 전에 과학 시간이나 아니면 다른 시간에 써본 적이 없었어?

학　생: 써본 거 같기도 하고 생각이 안 나요.

연구자: 아, 근데 그렇게 강한 거는 몰랐구나.

학　생: 네.

연구자: 오케이. 고마워, oo야.