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Unintended knowledge learnt in primary science practical lessons

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ABSTRACT

This study explored the different kinds of unintended learning in primary school practical science lessons. In this study, unintended learning has been defined as student learning that was found to occur that was not included in the teachers learning objectives for that specific lesson. A total of 22 lessons, taught by five teachers in Korean primary schools with 10- to 12-year-old students, were audio-and video recorded. 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 learnt. Post-lesson interviews with students and teachers were undertaken. What emerged was that there were three types of knowledge that students learnt unintentionally: factual knowledge gained by phenomenon-based reasoning, conceptual knowledge gained by relation- or model-based reasoning, and procedural knowledge acquired by practice. Most unintended learning found in this study fell into the factual knowledge and only a few cases of conceptual knowledge were found. Cases of both explicit procedural knowledge and implicit procedural knowledge were found. This study is significant in that it suggests how unintended learning in practical work can be facilitated as an educative opportunity for meaningful learning by exploring what and how students learnt.

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Unintended learning; factual knowledge; conceptual knowledge; procedural knowledge; practical work

Introduction

People are always learning and a great deal of this 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 on average about 802 hours per year in lessons (Charbonnier & Truong, 2014). School can be a 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 perceived as a place where the teacher teaches and the students learn. Students' informal learning in school is learning

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that a teacher had not intended as part of that lesson's learning objectives. In this study, we use the term *unintended* to describe students' informal learning in school to distinguish this from informal learning 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 and those outcomes that were, from the teacher's perspective, 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 learnt beliefs or ideologies that were hidden beneath the curriculum or text, whether the teacher was aware of it or not (Apple, 1979). Life in school also requires students to get used to the norms and culture of the school and the expectations of their teachers and, as such, they learn how to behave in the school in general and with the specific teachers who teach them in particular (Jackson, 1990). Unlike the substantial research into students' unintended learning of ideology and culture that has been undertaken there has been surprisingly little that focuses on the unintended learning of knowledge.

What previous research has shown is that that students do learn knowledge that their teachers did not intend (e.g. Hart, Mulhall, Berry, Loughran, & Gunstone, 2000; Shon & Moon, 2011). However, such learning tended to be described negatively and was seen as problematic in that it had the potential to generate scientific misconceptions and/or ineffective lessons. There are a few studies arguing that these unintended learning situations can be utilised as learning opportunities for acquiring scientific knowledge; however, these studies only provided a theoretical discussion and little empirical evidence (Kang, 2006; Lenox, 1985).

This empirical study therefore aimed to explore students' unintended learning 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 provide findings that are unique to science education. Furthermore, focusing on unintended learning in primary school science was seen as providing a richer source of data in that the Korean primary science curriculum has more practical lessons than the secondary science curriculum (Lee, Lee, & Shin, 2011). The aim of this study was to investigate what knowledge students learnt that was unintended by their teacher in primary practical science lessons. The following research questions were used to guide our data analysis and discussion:

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

Literature on students' unintended learning in school

There has been some discussion in the literature on student learning that has not been planned in the curriculum. Generally a 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' (pp. 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 a descriptive curriculum that describes a curriculum as being composed of student experiences. For instance, Hass (1987) defined curriculum as the set of actual experiences that each individual student can have.

Taking these different definitions into account, a curriculum can be considered in terms of three components: (i) designed curriculum, (ii) taught curriculum, and (iii) learnt curriculum. The designed curriculum is sometimes referred to as the intended curriculum whilst the taught curriculum and the learnt curriculum are both alternatively referred to as the actualised curriculum (Nelson, Jacobs, & Cuban, 1992).

There has also been some discussion in the literature about the student learning that can happen between the intended curriculum and the actualised curriculum. Jackson (1990) pointed out that students learnt various things – values, perceptions, and behaviours that were not included in the official curriculum that the teacher taught in the classroom and referred to this as being a 'hidden' curriculum.

Whilst the hidden curriculum refers to what was unintended but nevertheless learnt, the null curriculum refers to what is not taught because it has been excluded from the designed curriculum. 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 the 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 or less important 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 school. 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.

Both the hidden curriculum and the null curriculum give us an indication that there are more possible opportunities for students to learn than has been planned in the designed curriculum. Students might, for example, learn about the naïve inductivist model of science or that scientific knowledge is objective both from the method in which practical work is performed and/or the way scientific concepts are presented (Hodson, 1996). Furthermore, examples and/or descriptions of scientists in textbooks can influence students' image of scientists, such as giving the idea that scientists are male, wear glasses, and dress in white lab coats (She, 1995). As these beliefs are hidden beneath the curriculum or textbook, a teacher might not know that there is such a belief in the curriculum or textbook. Students might learn norms and culture from the procedures they are taught as, for example, how to get praise or avoid punishment from the teacher's responses (Jackson, 1990). In addition, students may learn content that was unintended by their teacher, and it may either be related or unrelated to the intended learning. For example, a student can incidentally learn the collocations that their 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). Whilst unintended learning can and does occur during intended learning, there is no evidence to suggest that the occurrence of the former is strongly coupled with the occurrence of the latter.

Method

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 1). The list of teachers that researchers could access was prepared and five teachers were selected to ask to participate. When selecting the teachers, we 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 we could access, the observed lessons were taught only by teachers who had less than 10 years' classroom teaching experience. It was expected that observing multiple cases of lessons from a variety of school achievement levels and teacher types and both male and female teachers would help to make the results of this study generalisable as possible.

Context of research settings

Korean science lessons have a unique cultural and historical context that distinguishes them from other countries (Leem & Kim, 2013). As indicated in our previous study that explored how unintended learning took place in Korean primary practical lessons (Park, Song, & Abrahams, 2016), 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. For these reasons, Korean primary school teachers should use the textbook in their lessons (Ryu, Choi, & Kim, 2014).

Yang, Kim, and Cho (2007) showed that most practical lessons in Korean primary schools were highly 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 was mostly aimed at the acquisition of declarative knowledge with less emphasis being given to inquiry (Yang et al., 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

Table 1. Overview of teacher participants.

School	School achievement[a]	Teacher	Teacher type	Student grade (age)	Teachers' teaching experience (years)
A	Low	Mr Lay	Classroom teacher	5th grade (10–11-year-old)	6
B	High	Mrs Yuna	Science subject teacher	5th grade (10–11-year-old)	5
C	Middle	Mr Sun	Classroom teacher	5th grade (10–11-year-old)	4
D	Middle	Mrs Rose	Science subject teacher	6th grade (11–12-year-old)	7
E	Low	Mr June	Science subject teacher	6th grade (11–12-year-old)	4

Note: Pseudonyms are used for the names of the schools and for all participants in this study.
[a]The achievement was categorised based on the school ranking of the national assessment in 2011.

Table 2. Overview of the observed lessons.

Teacher	Class	Observed lesson	Contents of practical task
Mr Lay	1	4 lessons	Electric circuits: conductor, parallel and series circuits
Mrs Yuna	2	4 lessons	Electric circuits: parallel and 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. The number of student participants.

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

actually arranged were more or less the same as those in the textbook and the guidebook for teachers. Only one lesson by Mr Sun was slightly different from the text book in that he decided to make a microscope slide with a leaf instead of using the ready-made slide that the textbooks and guidebook suggested. All the practical work that teachers planned was either for verification of knowledge or followed a discovery-based approach with step-by-step instructions from the teachers.

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 and it was therefore possible to observe lessons in two different classes that Mrs Yuna and Mr June taught. Four of Mrs Yuna's lessons were observed, which consisted of two lessons each from two different classes and a further eight of Mr June's lessons were observed, which consisted of four lessons each from two different classes. Twenty-two lessons were observed in total over a five-month period from March 2014 to July 2014. Each teacher's lessons were observed consecutively, meaning that no lesson came in between the lessons that were observed. The overview of the observed lessons from each teacher is presented in Table 2.

The student participants were Grades 5 and 6 students whose age ranged from 10 to 12 years. A total of 149 students consented to participate in this study. Table 3 shows the number of student participants from each teacher's class.

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 1). In this section, we describe each data source and how the data were collected.

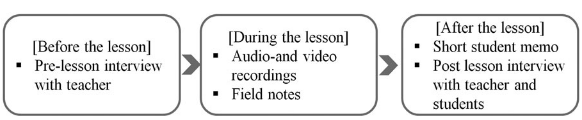

Figure 1. The process of data collection.

Pre-lesson interviews

Pre-lesson interviews were carried out with the teachers to ascertain details of the lessons to be observed. It was decided to undertake pre-lesson interviews because the objectives and tasks that teachers have planned can, albeit infrequently, 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, if needed, to clarify something that the 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 the learning objectives the 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 – with only the exception to this being part of Mr Sun's lesson.

Researcher: Please tell me about your lesson plan
Mr. Sun: (Students) will learn the structure of leaves. Microscopes are prepared and guidebook for teachers says that it would be desirable to do practical work with ready-made slides but I didn't prepare it in order to make our own whether it is successful or not.
Mr. Sun: [With showing the workbook he already wrote expected answers] After observing without prejudice, I am planning to correct what is wrong.

Although Mr Sun planned a lesson that was slightly different to that presented in the guidebook for teachers, he wrote the expected answers that the guidebook suggested and planned to correct his students' misconception based on this. 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.

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 of 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' small group 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 audio-recorded conversations to confirm if learning had occurred and, if so, what they had learnt and how they had learnt it.

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.

Short student memos after lesson and post-lesson interviews

After a class, students were asked to write a short memo about what they had learnt in the lesson. The learning that students wrote about in these memos was used to pick up on unintended learning in the audio and video recordings. Most of these short memos were about the intended learning but there were a few instances of learning that the teacher did not intend within that lesson. These data were also one of the complementary data sources used to confirm the unintended learning from the video.

The transcription of this example is as follows: 'I learnt that there is a magnetic field when electricity flows through the wire and I learnt 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 learnt. Teachers were asked to reflect on their lessons with the aim of determining which aspects of the observed learning had been intended.

Data processing

The collected data were organized to identify occurrences of unintended learning. The data processing for identifying occurrences of unintended learning was as follows. Firstly, each pre-lesson interview with a teacher was transcribed to identify the learning objectives of the lesson. The teacher's 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 learnt something that was not included in the teacher's learning objectives for that lesson and, at the same time, students reflected on this experience by mentioning the experience or doing some action because of this experience. Once discourse or behaviour was initially identified that appeared to be student learning that was unintended by the teacher the audio and video recordings were revisited several times and checked against that teacher's stated learning 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 triangulate and confirm the selected unintended learning episodes. In addition, we checked whether

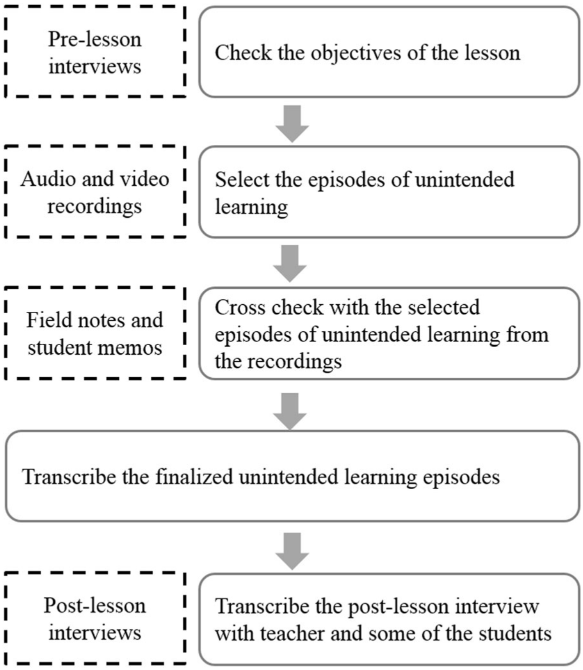

Figure 2. Data processing procedure.

there were any missed episodes from the second step that had been noted in either the field notes and/or the students' memos. If missed one was identified, the audio and video data was re-examined to confirm whether it included that unintended learning episode and, if it did, it was included. Fourthly, the finalized episodes of unintended learning were transcribed. In order to determine the nature of the unintended learning, we transcribed the selected episodes' audio data of the discourse between teachers and students, discourse amongst students, and behaviour of the teacher and students. In addition to unintended learning episodes, the post-lesson interview with the teacher and some of the students were also transcribed. Figure 2 shows how data were processed. The main data sources for analysis were transcriptions of unintended learning episodes from the audio and video data and transcription of post-lesson interviews.

It should be noted that the duration of the unintended learning episodes observed in this study varied, with those in Mrs Yuna's lessons, which were typical of those in other teachers' lessons, ranging from 30 seconds to 5 minutes.

Data analysis

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 behaviours.

For 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, for better reliability, two more lessons were analysed by one of the researchers and an invited science education researcher. The number of unintended learning that the invited science education researcher analysed in these two lessons was larger than what the researcher analysed. Whilst all of the unintended learning episodes identified by the researcher were also identified by the invited science education researcher, the latter also identified a number of additional episodes that she thought were examples of unintended learning. However, on further analysis, all of these additional episodes of unintended learning were discarded as, in each case, it was not possible to ascertain that these were not the teachers' intended learning outcomes. For instance, the invited researcher mentioned that students seemed to learn how to negotiate with their different opinions. However, as we cannot tell whether they learnt it in this lesson it is difficult to consider it as unintended learning in this study. The researcher and the invited researcher, through discussion, agreed not to include the ambiguous unintended learning in this study. Three more lessons were analysed independently and total agreement was found in all three cases after which the researcher analysed the rest of the data.

Coding for knowledge and reasoning of unintended learning

Identified examples of unintended learning were coded for knowledge that students learnt and for reasoning that students engaged.

Knowledge can be categorised in various ways. Ryle (1949) categorised knowledge as propositional knowledge and procedural knowledge. In an educational context, Bloom's taxonomy of knowledge has been widely used for learning goals. Krathwohl (2002) developed a revised Bloom's taxonomy and categorised 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: Conceptual connections between the facts that students observed and their prior knowledge
- Procedural knowledge: Empirical knowledge that students learn about how to do things

The reasoning students used in their unintended learning was also analysed. 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' behaviours, discourse, and type of knowledge acquired, we were able to infer what cognitive process they used. The epistemic reasoning framework that Driver, Leach, Millar, and Scott (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 categorised 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 recognised as provisional and problematic.

Based on the definition of knowledge and reasoning explained above, each example of unintended learning identified was analysed and Table 4 shows how it was analysed.

The transcription in Table 4 shows that students learnt 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 5 shows another example of coding for conceptual knowledge. The students whose discussion is shown in Table 5 learnt 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 4. Examples of coding for factual knowledge and phenomenon-based reasoning.

[Part of the transcription of Mr Lay's lesson on 3 July 2014]	
S1: Press the battery. It doesn't work.	
S1: Is this because the 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 learnt that the 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 5. Examples of coding for conceptual knowledge and model-based reasoning.

[Part of the transcription of Mr Lay's lesson on 3 July 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 learnt that the compass needle moved towards the battery because of the magnetic field.
Type of knowledge	Conceptual knowledge
Type of reasoning	Model-based reasoning

Table 6. Examples of coding for procedural knowledge by practice.

[Part of transcription of Mr Lay's lesson on 3 July 2014] 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. (Ellipsis) 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 learnt that pressing the battery's connections to the circuit wires firmly made the battery connect when initially the circuit did not work well because of poor electrical connections.
Type of knowledge	Procedural knowledge

Table 6 shows another example of coding for procedural knowledge by practice. Students whose discussion is shown in Table 6 learnt that pressing a battery made it connect when the circuit did not work well. About 10 minutes after the lesson started, the students learnt how to make the circuit work by pressing the battery by observing what their teacher did for them and then afterwards applied this procedural knowledge.

Findings

Factual knowledge gained by phenomenon-based reasoning

The knowledge that students learnt unintentionally in this study was mostly factual knowledge that was based on a description of what they observed. Out of 79 cases of unintended learning, 50 were found to be factual knowledge. This can be inferred as engaging 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.

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 it 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 she was asked whether she was curious about the reason the light bulb got warm, she answered that she was not.

As in Jane's case, this study found that most cases of unintended learning remained at the level of 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 carefully noted here 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. We are 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. The textbook explains that a 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).

There were 25 cases in this study where students were observed to try things that they were curious about and described what they observed. This mostly led to the unintended learning of factual knowledge. Amongst 25 cases of unintended learning that occurred when students tried things that they 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. Jiyeon and her group members were observed to try several things that their 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. 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. Two minutes later, one student suggested that Jiyeon not connect these two battery cases firmly together as they are designed to be connected (making a 'click' when connected correctly) but rather to only touch the plastic sides of the cases to each other and check whether this also can let electricity flow. When they did this series of things there was not much discourse between the group members about what they tried other than descriptions of what they observed.

In another of Mr June's lessons, we observed that Enu was trying to make an electric circuit that was irrelevant to the lesson. 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 localised 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.

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 the 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 level of reasoning (Hogan, Nastasi, & Pressley, 1999). Oh et al. (2007) reported the example that students could have opportunity to expand their knowledge, not limited to intended learning, by asking questions to the 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 amongst Korean students (Park, Martin, & Chu, 2015). This suggests 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.

Conceptual knowledge gained by relation- and model-based reasoning

Some cases where students learnt conceptual knowledge that was unintended by their teacher were also observed. Fourteen cases of unintended learning were found to be conceptual knowledge which was less than the number of occurrences of factual knowledge.

Relation-based reasoning

Five cases of unintended learning were found to be associated with relation-based reasoning. In one of Mrs Rose's lessons, in which her stated learning objectives were for the students to check the acid–base neutralisation by observing colour change when phenolphthalein was added, 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 indicated colour change.

However, they did not see any changes and complained that the colour had not changed to red. Whilst 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 colour change. 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 their teacher is shown below.

Teacher:	Didn't the colour change?
Hyojin:	The colour went away when [I] stirred it.
Teacher:	Right before it was stirred only this part was mixed but now the whole thing is mixed.
	It went back to a non-basic state.
	[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 colour 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 colour changed when she stirred it. When Mrs Rose heard Hyojin's reasoning she provided the reason for this phenomenon's occurrence. 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 a 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 we 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 colour change and the mixing of the liquid.

Sohyun:	What are you doing?
Junho:	Look carefully. [Doing like a magic].
	[Adding sodium hydroxide into the liquid where hydrochloric acid and phenolphthalein had been mixed]
Sohyun:	Isn't this enough to make a colour change?
Junho:	Ta-da!
	[Stirring the test tube where a colour 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 suggests 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.

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 the batteries is removed.

The students in Group 7, however, found that the brightness of light bulb dimmed when one of the 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]
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 the 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 the 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 the electric circuit]

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

From the transcript above it can be seen that 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 was removed. After that, they put 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 for their practical work going 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. The other student said that you cannot figure out how much charge is left in a battery by shaking it. By doing so, they learnt not only the reason for the electric circuit not working well but also that shaking a battery is not the way to check whether the battery is out of charge or not.

Procedural knowledge by practice

In this study, we were 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 in which a slide was made in order to observe the structure of the leaf using a microscope, students learnt 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, in which the teacher's learning objectives were for the students to learn that leaves consist of veins and stomata, did not include learning how to operate a microscope. Indeed, it was observed that the teacher in this lesson and the assistant adjusted the focus of each microscope in each group. The students therefore did not need to adjust the focus of the microscope and the only thing they needed to do was to observe the slides. However, during the practical work the view became out of focus and Jin recalled the method that the assistant used and related what he recalled.

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

As opposed to Hyun learning procedural knowledge that he can describe to his friends, Jihoon learnt something that he could not describe whilst 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. After several tries, Jihoon exclaimed that he had figured out how to do it.

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 learnt 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 learnt and this can only be acquired by practice (Polanyi, 1967).

Summary and discussion

In this study, we found that students learnt factual knowledge, conceptual knowledge, and procedural knowledge unintentionally (Figure 3, left diagram). These types of knowledge were learnt by means of phenomenon-, relation-, and model-based reasoning.

Factual knowledge gained by phenomenon-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 might be difficult for students to fill in the gap by themselves, it is important to give them an 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 the unintended learning in this study has been associated with phenomenon-based reasoning.

It was 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,

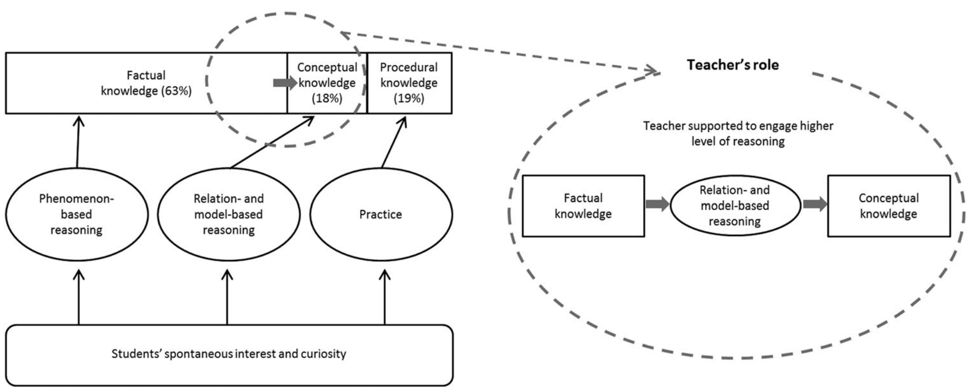

Figure 3. Types of knowledge and reasoning in unintended learning and the teacher's role in unintended learning.

factual knowledge gained by phenomenon-based reasoning might provide opportunities for educative experience in the long term.

Conceptual knowledge gained by relation- and model-based reasoning

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 we 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.

It was found that the students could learn conceptual knowledge by engaging in relation- or model-based reasoning with help from the teacher (Figure 3, right diagram). Several studies also support that a 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 a teacher as a first step and teachers need to find a way to support students' reasoning or learning (Van Es & Sherin, 2002). It means that a 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 by practice

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 were successful in getting results but others were not, although they did exactly the same procedure (Polanyi, 1967). Doing the exactly same procedures does not guarantee obtaining the successful result. Polanyi (1967) said that this difference might, in part, be due to the level of a person's implicit procedural knowledge. Polanyi introduced the idea of tacit knowledge, which consists of things we know without being able to say how we know them, which 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 an opportunity for unintended learning, especially opportunities to learn implicit procedural knowledge.

Implications

Whilst 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 whilst doing practical work. However, current practical science lessons in formal education recommend that teachers do standardised 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 sanitised 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 recognise that students can learn from them by getting through them. Instead of putting a lot of effort into making sanitised practical work, teachers need to put more effort into supporting and facilitating students 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 utilise unintended learning for more learning opportunities, teachers need to be aware that unintended learning can take place and to notice students' unintended learning. Bentley (1995) and Hyun and Marshall (2003) have noted the importance of an unplanned learning opportunity that they argued teachers should seize for teaching within the lesson, which they referred to as a teachable moment. To seize these moments, teachers need to be alert to what students are doing and what they are interested in and the use of video for teacher education can allow teachers to be aware of them. Video analysis that we used in this study can be a useful tool for facilitating teachers to reflect on what they may not be aware of within the lessons and what possible teaching practices they can provide for it (Siry & Martin, 2014).

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. This study is not suggesting 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. We 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 learnt and develop them into models or explanations about these observations.

Note

1. There are two types of teacher who teach science in primary schools in Korea. Homeroom teachers teach science and other subjects. Science subject teachers teach science to all the students in the same grade.

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