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Features of and Representational Strategies in Instructional Videos for Primary Science Classes

Joonhyeong Park,[a] Jina Chang,[b] Jisun Park,[c] and Hye-Gyoung Yoon[d]*

[a]*National Institute of Education, Nanyang Technological University, Singapore, Singapore;* [b]*Seoul Seongil Elementary School, Seoul, Republic of Korea;, Ewha Womans University, Seoul, Republic of Korea;* [d]*Chuncheon National University of Education, Chuncheon-si, Gangwon-do, Republic of Korea*

Features of and Representational Strategies in Instructional Videos for Primary Science Classes

Abstract

Utilisation of instructional videos for science teaching has become more widespread due to the expansion of online teaching and learning environments and growing awareness of benefits of videos, such as enabling use of effective multiple representations. With this in mind, this study aimed to examine features of instructional videos for teaching scientific inquiry, a key element of science education, and learners' engagement, a crucial issue in instruction in terms of representational strategies used. We analysed 16 instructional videos for science teaching generated by pre-service teachers. We found that the instructional videos tended to focus on posing a question related to a phenomenon and constructing its explanation conceptually rather than conducting investigations and interpreting the data. It was also found that there were alternations between providing relevant and conceptual resources and affording learners opportunities to answer questions verbally and visually to prompt their engagement. Various representational strategies, such as summarising, comparing, highlighting, sequencing, and presenting vivid phenomena, were also employed for better teaching scientific inquiry as a part of learners' ongoing cognitive activities. Based on the findings, we argue that there is potential for using instructional videos for teaching science, considering representational strategies in terms of scientific inquiry and learners' engagement.

Keywords: Instructional video; scientific inquiry; representational strategies; learners' engagement

Introduction

Using instructional videos in education has greatly increased across formal and informal education in the past decades, particularly with expansions of online learning environments related to the diversification of educational media and resources (Brame, 2016; Zhang et al., 2006). The COVID-19 pandemic also accelerated the prevalence of instructional videos in teaching and learning science. This expansion may also be taking place due to the benefits of instructional videos, which can involve multiple modes of representation including various visualisations (e.g. graphs, animations, diagrams, and written texts) and audio (de Koning et al., 2018). In some cases, teachers have needed to generate instructional videos that can be utilised as a part of online or blended lessons. The attempt to research the creation of instructional videos by pre-service teachers as a way of assessment (Nielsen et al., 2020a) is a result of this trend. Given the growing attention to the potential of using instructional videos, there have been various related studies in educational research. One of the implications in this area has been suggesting guidelines (Brame, 2016; Mayer et al., 2020) for creating effective videos based on theoretical and empirical studies. For example, multimedia learning theory asserts that people learn more successfully using a combination of graphics and verbal communication than they do with graphics and printed text (Mayer, 2009).

However, very few studies have examined the features of instructional videos specialising in science teaching that involve scientific inquiry. For example, Kulgemeyer (2020) examined the effectiveness of videos for science lessons and found that a high explaining-quality video that involves high coherence, summarising, highlighting relevancy, and using analogies and models was more effective than a lower explaining-quality video in understanding conceptual knowledge while there were no significant differences in declarative knowledge. Nielsen et al. (2020b) explored what pre-service teachers were concerned about in producing instructional videos, such as content, engagement, and clarity. Although these studies have suggested significant and meaningful guidelines for generating explanatory videos, involving various structural and compositional elements, there are still further considerations for creating instructional videos for science lessons: Scientific inquiry, which is a crucial aspect of science teaching, and detailed learners' engagement strategies are also essential considerations in creating instructional videos. Since school science aims to develop students' deeper understandings of conceptual and epistemic aspects through experiencing engaged scientific inquiry (Osborne, 2014), instructional videos can also be utilised in alignment with this purpose. This study therefore investigated the features of instructional videos for general science lessons in terms of students' scientific inquiry and their engagement.

Theoretical Background

Teaching inquiry and scientific practices in science classrooms

Scientific inquiry has played a key role in science education for over half a century in relation to what science teaching and learning should look like. As Schwab (1962) noted, 'it is, ironically enough, that science be taught as science' (pp. 4-5), and many science educators and researchers agree that their shapes should be similar to that of science, which can involve various aspects of science such as science, technology, engineering and mathematics (STEM), science, technology and society (STS), and history and philosophy of science (HPS). Considering critiques—such as misunderstandings that lead to a narrow or distorted view of science (Bencze & Alsop, 2009)—of a traditional form of school science from these diverse approaches, teaching scientific inquiry has been reformed from the point of view of the nature of science as teaching scientific practices that involve both social practices and social dimension of science to provide a more authentic view of science to students.

The emergence of emphasising scientific practices has been a crucial aspect of this reform that involves social practices in developing models and constructing data, alongside the discussion that rebuts the basic assumptions of logical positivism, such as a significant distinction between observation and theory, in the philosophy of science (Duschl, 2008). In stressing the sociology of science, epistemic understanding of science has also been highlighted, given that scientific knowledge constructions have been regarded as tentative consensuses among scientist communities over the course of history and numerous debates and discussions over time in the history of science (Hodson, 2008). In this regard, students have been encouraged to experience epistemic characteristics of science as social practices through model-based inquiry, including generating, testing, and revising within discussions (Windschitl et al., 2008) or argumentation (Berland, 2010).

Scientific practices in science education generally not only involve internal elements of science, which were illustrated above, but they also can involve social dimensions of science, which are related to mutual impacts between science and outside of science (Abd-El-Khalick, 2012). Research in this area has claimed that students need to be encouraged to actively participate in scientific practices that involve issues related to science that are more approachable for them so that they can learn how science has an impact on our society and vice versa (Hodson, 1999). For example, students can start participating in discourses about socioscientific issues (SSIs) involving global problems that show the relationship between science and our society (Lee et al., 2013). They can then take sociopolitical actions as responsible citizens to contribute to the sustainability of societies (Bencze, Sperling & Carter, 2012; Hodson, 2003). Hodson (2008) advocated that these kinds of practices can improve students' capacity to take appropriate actions on the matter of social and environmental concerns, which can be one of the goals of science education. This can be even seen as an effort for social justice and an additional step where students can raise questions to critique established knowledge to show that it should not necessarily be taken for granted (Moje, 2007). This broader meaning of scientific practices, which requires a variety of aspects of the nature of science, also can allow students to connect their learning of scientific practices and the real world (Erduran & Dagher, 2014).

Although there have been considerable efforts to involve these various aspects of the nature of science, as mentioned above, teaching scientific practices in science classrooms still tend to highlight the importance of the material or physical worlds (Loving, 1991), which are a crucial part of science and are deeply related to how we understand nature, which is about epistemology, and what we understand as nature, which is about ontology (Tang, 2022). This is not to say that students should only learn science through inquiry into nature or physical worlds but that a variety of pedagogical approaches, including social practices, can be done with or based on them to be more authentic. Settlage and Southerland (2012) suggested that students can learn inquiry into natural phenomena with sufficient support at the beginning stage of learning the nature of science from a cultural perspective. The reason for this is that it is difficult for students to understand complexity of scientific inquiry at first and that not all students can understand unique features of scientific inquiry. Once students attain the capability to carry out inquiry into natural phenomena as a culture of science based on teachers' careful guidance, they will be able to carry out inquiry in more diverse ways, including open-ended inquiry towards authentic scientific practices (Erduran & Dagher, 2014) and social justice (Barton & Upadhyay, 2010).

In this regard, we will examine the use of instructional videos to teach scientific inquiry as a starting point of scientific practices, which has become increasingly necessary in online teaching and learning environments and has not yet received much attention in science education research.

Instructional Videos for Science Teaching and Learning

Research in instructional videos has been developing to provide better learning opportunities for students in various educational contexts based on multiple theoretical and empirical backgrounds such as multimedia learning, cognitive load theory, and generative learning theory. Key benefits of instructional videos are that they can utilise various electronic resources involving multiple representations (e.g. actual objects and their motions, realistic scenes, narration, computer graphics, and text) and provide time and location flexibility. One of the primary consensuses in the literature is that instructional videos should be produced considering students' engagement (Brame, 2016; Nielsen et al., 2020b), meaning that these videos should have particular purposes and targeted audiences and the levels of everyday language and mathematisation need to be determined (Kulgemeyer, 2020). Based on this guidance, instructional videos can then be constructed concisely and coherently.

Another main consideration in creating instructional videos is prompting cognitive activity (Brame, 2016; Kulgemeyer, 2020). The intent of instructional videos may generally be to provide comprehensive explanations since it is difficult to directly provide opportunities for students to perform generative activities. Despite the communicative limitation of instructional videos, many studies have suggested including interactive features in instructional videos to allow students to cognitively participate in their learning, even during ongoing explanations (Wittwer & Renkl, 2008). This is the area of instructional videos that this study aims to explore: How to prompt students' cognitive participation actively through instructional videos.

While previous studies in the area of research in instructional videos have focused on instructional explanations (e.g. Kulgemeyer, 2018), attention has rarely been paid to scientific inquiry, which involves conceptual, social, and epistemic aspects of science (Duschl, 2008). Considering that these are the crucial parts of science education as a starting point towards learning the nature of science, scientific inquiry may need to be involved in instructional videos as well. It is not easy to fully achieve inquiry learning through instructional videos since scientific inquiry usually associate learners' embodied participations or acts and their collective discussions (Osborne, 2014), such as manipulating variables using apparatuses or materials and having epistemic discourse: This is an inherent impediment to instructional videos. However, given the benefits of instructional videos and greatly increasing attention to them in online learning environments, it will be worthwhile to delve into their possibilities, focusing on feasible features of scientific inquiry through instructional videos.

Representational Approaches for Instructional Videos

There can be at least two dimensions of representational considerations in creating instructional videos. The first dimension asks about philosophical assumptions about the relationships between objects represented and their representations. In mainstream science education, it has generally been regarded that objects or physical materials can be described through scientific representations. However, there has been growing attention to the alternative perspective, which can be called the ‘non-representational theory’, which posits that we may not be able to properly describe objects or physical materials through the language we use (Fendler, 2014). According to this theory, students who watch representations of instructional videos may have different interpretations since representations may involve subjective aspects that prompt different interactions with the represented ideas. In addition, a similar argument in critique of the mainstream view of science, which is known as scientific realism or naturalism, has been raised in the philosophy of science, as scientific knowledge may be incoherent in describing reality or the physical world (e.g. Price, 2004; Rydenfelt, 2021). This may come from an ontological gap between phenomena and their representations (Roth, 2001). As such, we can think of how to take a stance in representing scientific knowledge through instructional videos related to the first dimension. On the other hand, the second dimension asks how we can organise and provide external representations regarding the effectiveness of instructional purposes. Since this study aims to examine the features that emerged externally in instructional videos, we will mainly foreground the second dimension, which is about structural formations and sequences of the content of instructional videos.

We will illustrate several general principles for creating instructional videos that have been discussed in previous studies, although there are various types of instructional videos (Köse et al., 2021). First, signalling or cueing important or new information may improve learners' attention and enable them to focus on a particular section of content presented (de Koning et al., 2009; Ibrahim et al., 2012). Second, segmenting the videos into smaller parts allows learners to digest new information and make sense of the content (Fiorella & Mayer, 2018). This is related to reducing learners' working memory capacity (Mayer, 2009). Third, coordinating verbal and visual information may improve the learning outcome compared to providing a single mode of representation (Mayer, 2009). Through the use of more than two external representations, learners can achieve a deeper understanding based on the different affordances of each mode (Ainsworth, 2006). Fourth, the utilisation of pausing may be beneficial because it allows learners to structure the content (Merkt et al., 2018). Fifth, dynamic visualisation may be more beneficial in conceptual understanding than static visualisation (Höffler & Leutner, 2007). This is because animated videos give detailed procedures and movements and prompt facilitating mental simulation.

There are further general guidelines for generating instructional videos; however, not much attention has been paid to representational approaches for science teaching that involve scientific inquiry, which need to be considered in producing instructional videos. This is because teaching scientific inquiry through instructional videos may entail features from general instructional videos. This study therefore aims to investigate features of representational strategies in terms of their science teaching and learning contexts.

Research Questions

Given the theoretical background and the purpose of this study, the following specific research questions will guide this study.

(1) What features of instructional videos for primary science classes that are generated by pre-service teachers are aimed at students' scientific inquiry and engagement?

(2) How are representational strategies used in instructional videos for students' scientific inquiry and engagement?

Research Method

Research Context and Data Collection

This study adopted an instrumental case study design (Stake, 2000) to investigate features of instructional videos and uses of representational strategies. The purpose of this study is not to make a claim about the generalised features of instructional videos, but to explore their features and uses of representational strategies through a particular case involving instructional videos for primary science classes produced by 16 pre-service teachers in South Korea. Since teachers will increasingly face dealing with instructional videos in the future, this case allows a useful examination of the features and representational strategies of videos at the beginning stage. Hence, to get deeper understanding of underlying thoughts behind the pre-service teachers' intentions, we collected not only instructional videos and but also their descriptions of the purposes and flow of their videos, their target concepts and contexts, and their intentions or rationales of the flow in terms of their expectations of students' learning. They were asked to generate a 5-minute instructional video that allowed students to become engaged and stimulates their scientific thinking when watching the videos online. They were also informed that a particular target concept should be explained to the primary school students. However, for their creation of these instructional videos, the researchers provided no instructions for them about how to teach science inquiry, although they were able to refer to primary science textbooks, which may have been written with a focus on inquiry activities to reflect the national science curriculum. To prompt the use of a variety of resources, we provided possible modes such as spoken and textual explanations, gestures, figures, graphs, diagrams, symbols, web-based simulation programs (e.g. PheT, http://phet.colorado.edu), apparatuses, and models. Although the researchers recommended some concepts (e.g. heat transfer, weight) for targeting, the pre-service teachers chose the concepts to teach depending on their preferences.

Consequently, nine pre-service teachers targeted heat transfer concepts to create their instructional videos, while four chose the weight concept. Other concepts, such as buoyancy, combustion, and the Mpemba effect, were also selected as target concepts. The average duration of the video was 5 minutes and 1 second: The longest one was 5 minutes and 46 seconds while the shortest one was 3 minutes and 18 seconds.

Analytic Framework

To examine features of the instructional videos, we developed an analytic framework that involved scientific inquiry, pedagogical roles of video, and the use of representational strategies. There have been ample studies regarding instructional videos and scientific explanations; however, it is difficult to find previous studies dealing with the features of instructional videos for teaching scientific inquiry, in particular, focusing on representational strategies. As such, the first two aspects were conceptualised by reviewing the literature, while the last aspect (i.e., representational strategies) was particularly developed in a way that was guided by the emergent research perspective (Given, 2008), which was mostly done using a qualitative method to explore new information or insights. This means that the authors reiterated two processes: (1) General representational considerations were conceptualised by reviewing instructional video studies first and (2) preliminary analysis of data intertwined with the researchers' prior ideas related to instructional videos then provided new representational considerations for teaching science inductively. On the other hand, instructional videos can be discretely segmented as phases that have certain intentions or topics involving particular meanings. We identified them as semantic units and determined the phases as units of analysis. This is similar to discourse analysis that separates discrete discourse into segments as semantic units (Van Dijk, 1981). For instance, providing the learning objective and motivating using an interesting situation involves different intentions and content in a particular instructional video, so they were identified and divided into different phases and were analysed separately.

Scientific Inquiry and Pedagogical Roles in Instructional Videos

To develop the analytic framework, we categorised sub-components of scientific inquiry, which has also traditionally been called the 'scientific method', and pedagogical roles guided by previous studies in science education and educational video research. First, given the context of dealing with instructional videos in relation to their feasibility, we re-categorised scientific inquiry into posing a question, planning and conducting an investigation, interpreting data, and constructing an explanation, for the primary school science level. In this re-categorisation, we viewed instructional videos as those that would typically be utilised by individual students in online environments, but that can be employed as the first part of teaching and learning scientific inquiry in general science classrooms aimed at teaching scientific practices.

Also, in accordance with the encouraging conditions of instructional explanations in classrooms theorised by Wittwer and Renkl (2008), we drew the pedagogical roles of videos into *activating and focusing* and *affording participation*. The first pedagogical role, activating and focusing (AF), is about conveying certain target content and providing relevant resources to support and facilitate learning. Since prior knowledge and experience play a role as resources for further learning (Chi et al., 2001), there is a need to use familiar subject matter and/or previous learning content. In addition, the target concepts should be conceptually explained with those of foundations (Perry, 2000). Affording participation (AP) is viewed as providing opportunities for the audience to cognitively engage in learning through instructional videos. We considered that asking a question and giving temporal and spatial spaces (Mayer, 2009) to respond to the question in a video affords students' cognitive activities when watching instructional videos. Even though this cannot assure students' participation, we assumed that it can partially work since there have been reports that pop-up questions in instructional videos improved learners' conceptual understanding regardless of answering correctly (Haagsman et al., 2020) and that pausing in instructional videos may be favourable in places learners are structuring the content (Merkt et al., 2018). Only phases that involved allowing a certain amount of time to respond and intentions illustrated in the video descriptions were classified as AP.

We integrated these two analytic aspects together as shown in Table 1. The descriptions of each cell stem from detailed content of scientific inquiry in the literature and were classified by pedagogical role.

Table 1. Analytic framework of scientific inquiry and pedagogical roles

Scientific inquiry	Pedagogical roles	Description
QUE	AF	- Provide everyday experience and/or prior knowledge related to what learners will study

		- Provide learning objectives or pose a question for learning
	AP	- Question about learners' experience related to the posed question - Encourage learners to answer the question
INVES	AF	- Introduce the use of apparatus and the process of investigation - Provide reasons of experimental design
	AP	- Ask the roles of apparatus - Question about how to design an investigation or alternate the design
DATA	AF	- Illustrate the result of the investigation or the observed phenomenon - Interpret the results related to the target concept
	AP	- Encourage learners to interpret data
EXPLN	AF	- Explain the mechanism of the phenomenon or answer the key question
	AP	- Ask students about the concept or the mechanism of the observed phenomena - Let learners apply the learnt concept for other examples

**Note*. Scientific inquiry: QUE—posing a question, INVES—planning and conducting an investigation, DATA—interpreting data, EXPLN—constructing an explanation; Pedagogical roles: AF—activating and focusing, AP—affording participation

Representational Strategies

To analyse instructional videos, we conceptualised representational strategies, which involve how multiple representations are utilised to involve certain purposes (i.e., summarising, comparing, highlighting, sequencing, emphasising, overlapping multiple levels, presenting vivid phenomena, blanking, and delaying), both deductively and inductively. The conceptualisation was informed by literature on instructional videos and supplemented by the repeated process of extracting representational features and their categorisations considering the context of teaching scientific inquiry. We also agreed that if a phase of video had multiple purposes, it then can involve more than two strategies.

From previous studies of instructional videos, we first identified the basic components of representational strategies as signalling, segmenting, and weeding (de Koning et al., 2009;

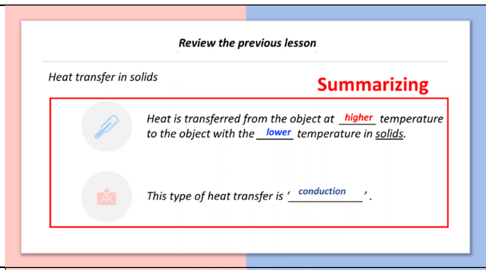
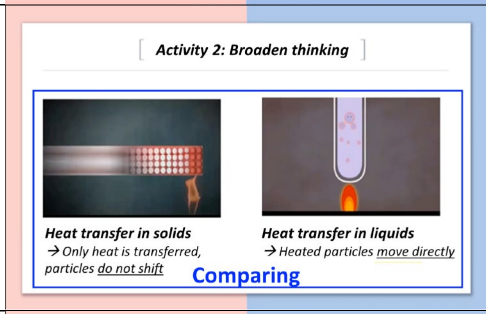
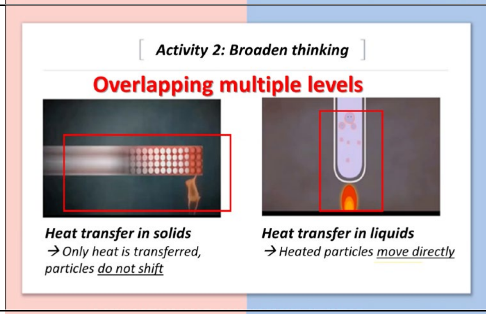
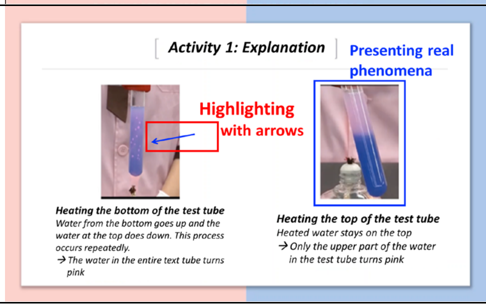
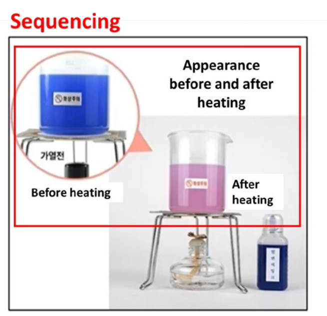
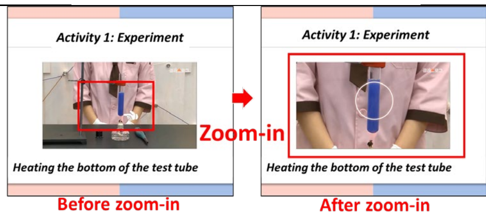
Ibrahim et al., 2012) and revised the classification based on the corpus of data. For example, signalling or cueing, which is representing the main ideas of an instructional video (Ibrahim et al., 2012), was subdivided as *summarising*, *comparing*, and *highlighting* during the preliminary analysis of data. Summarising is structurally presenting a key concept and descriptions by the use of texts, figures, and graphs. Comparing is contrastively presenting more than two things, such as variables and contrast concepts, using different colours and/or fonts, section divisions, pictures, and diagrams. Highlighting is indicating a certain point, including the purpose of observation, using, for example, arrows, points, underlines, and labelling, so that it can be explicitly seen and focused on by learners. The three sub-categories have a common purpose, which is illustrating main ideas, but they have distinctive characteristics. This may be the reason that in science teaching there are various variables, comparative concepts, and scientific terms and a mechanism of the phenomenon being examined. As such, instructional videos for science teaching may involve those aspects more precisely so that they can convey the concrete ideas of the science content. Segmenting is about comprising parts of a video with information that is relevant to making clear a particular intention, which is a crucial component in conveying information more accessibly (Fiorella & Mayer, 2018; Mayer, 2009). We incorporated this component as phases, which are units of analysis. Weeding is eliminating irrelevant information in constructing a video (Mayer et al., 2001). The participants were guided by the time limitation of 5 minutes in place of involving this component in the foreground of the analysis.

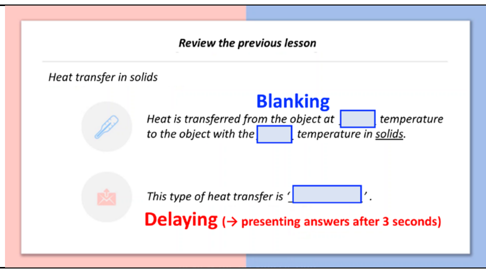
In addition, representational strategies were also deductively and inductively categorised. These strategies, which may be deeply related to the context or nature of science teaching, which tends to postulate that students learn and practice science by means of natural phenomena, were categorised from the corpus of data: *sequencing*, *emphasising*, *overlapping multiple levels*, and *presenting vivid phenomena*. Thus, the strategies were related to involving observations of scientific phenomena with a certain focus or elaboration of the mechanism of the phenomenon. Sequencing presents a temporally sequenced phenomenon to illustrate the main ideas that involve the time flow of the phenomenon, for example, showing the changes in heating water. Emphasising is providing information that facilitates visual observation of a particular phenomenon by zooming in and out, slowing down or speeding up the time scaling, and repeating. Showing a closer and slower view of the boiling phenomenon is an example of this strategy. Overlapping multiple levels is providing more than two levels of representation from the macroscopic, microscopic, and symbolic levels. Since just observing a phenomenon cannot show a mechanism that is mostly invisible, there is a need to provide both observable and unobservable entities together in explaining scientific concepts (Ainsworth, 2006; Gilbert & Treagust, 2009; Park et al., 2020). Presenting vivid phenomena involves showing nature and phenomena without the aid of computer graphics to allow students to make sense of the phenomena.

On the other hand, *Blanking* and *Delaying* were determined to be other representational strategies from the corpus of the data. Blanking is retaining purposive partial or total blanks in videos. Delaying is pausing or slowing down the progress of a video. These strategies were utilised either separately or together. Presenting a key sentence of an instructional video without keywords, or blanking, and waiting for a moment, or delaying, to find the answer is a case where the two are utilised simultaneously. Table 2 is a summary of representational strategies for instructional videos, including examples that were exacted from the data collected.

Table 2. Representational strategies for instructional videos

Representational strategy	Description	Example

Summarising	Summarising and presenting key content and descriptions using texts, figures, and graphs	
Comparing	Comparing and concurrently presenting more than two things using different colours and/or fonts, section divisions, pictures, and diagrams	
Overlapping multiple levels	Overlapping multiple levels of representation (macroscopic, microscopic, and symbolic) simultaneously	
Highlighting	Highlighting and indicating a certain point so that it is explicitly seen by learners using arrows, points, underlines, labels, and other indications	
Presenting vivid phenomena	Showing pictures or video clips to provide everyday life and scientific phenomena vividly	
Sequencing	Presenting a temporally sequenced phenomenon to demonstrate the process of a phenomenon or an event	
Emphasising	Emphasising and providing details of a particular phenomenon by zooming in and out, adjusting time scale, and repeating	

<table>
<tr><td>Blanking</td><td>Creating intended partial or total blanks</td><td rowspan="2">
</td></tr>
<tr><td>Delaying</td><td>Intentionally slowing down or pausing the progress of a video</td></tr>
</table>

Data Analysis

The analysis was performed in two steps: The first step involved quantitative analysis in understanding the instructional videos in terms of components’ distribution (RQ1), while we drew qualitative features based on the first analysis as the second (RQ2). First, we analysed 16 instructional videos and their descriptions guided by the developed analytic framework that involves three aspects: scientific inquiry, pedagogical role, and representational strategy. We identified phases of the instructional videos and classified the phases into sub-categories of scientific inquiry and pedagogical role, excluding the durations that were irrelevant to content such as greetings and rhetoric. We also analysed what representational strategies were utilised in each phase. For the analysis, the four authors of this study first independently carried out the analysis on two exemplary videos and discussed until reaching a consensus. Afterwards, forming two groups of two authors each, half of 16 instructional videos was analysed together to preserve the reliability of the analysis. For this, we utilised a web-based video analysis program, V-note, as shown in Figure 1. The upper line of this figure indicates the time flow, and the left side of the column consisted of eight sub-categories encompassing one of four scientific inquiry and one of two pedagogical roles. Each block in Figure 1 is a phase, and the identified representational strategies are shown as small coloured circles on the right-hand side of each block.

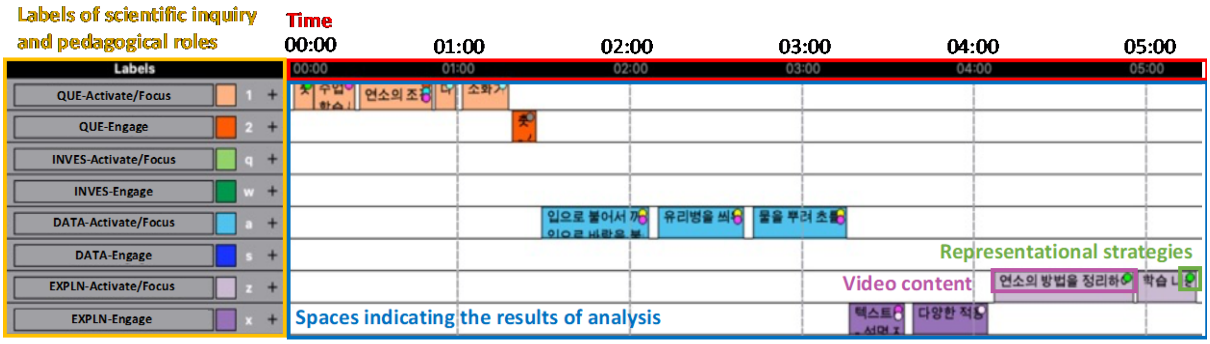


Figure 1. A screenshot of analysis using a web-based analysis program

For the second step, based on the quantitative features of the videos in terms of the distribution, we qualitatively analysed the features of the instructional videos using the constant comparison method and memo-writing (Charmaz, 2014) aligned with the emergent design. We also documented them focusing on the two selected videos created by YM and HJ (pseudonyms) to illustrate and highlight the features of representational strategies related to the students' scientific inquiry and engagement. These two videos were selected as showing the best contrast on the following three criteria: the number of phases, the sub-categories of scientific inquiry, and the appropriateness of the use of representational strategies.

Responding to RQ1: What features of instructional videos for primary science classes that are generated by pre-service teachers are aimed at students' scientific inquiry and engagement?

To determine the features of the instructional videos in terms of students' scientific inquiry and engagement, we quantitatively analysed the data and obtained its descriptive analysis results as shown in Table 3. There were 216 phases in the 16 instructional videos and the average number of phases in each instructional video was 14.7. The highest number of phases in a single video was 26 while the smallest number was 5.

Table 3 The feature distribution of the instructional videos

Pedagogical roles		QUE (%)	INVES (%)	DATA (%)	EXPLN (%)	Total (%)
Activating and focusing	Number of phases	63 (29.2)	16 (7.4)	35 (16.2)	60 (27.8)	174 (80.6)
	Average	3.9	1.5	2.5	3.6	11.0
	Max	6	3	6	12	20
	Min	1	0	0	1	5
Affording participation	Number of phases	19 (8.8)	2 (0.9)	4 (1.9)	17 (7.9)	42 (19.6)
	Average	2.6	1.0	1.3	2.1	3.7
	Max	5	1	2	5	6
	Min	0	0	0	0	0
Sum	Number of phases	82 (37.8)	18 (8.8)	39 (18.0)	77 (35.5)	216 (100.0)
	Average	6.6	2.5	3.8	5.8	14.7
	Max	14	3	7	17	26
	Min	1	0	0	1	5

* *n* = number of phases, (*n*) = percentage. 16 instructional videos were analysed. ‘Average’ indicates the average number of phases per instructional video. ‘Max’ and ‘Min’ indicate the number of phases of the instructional video corresponding to the sub-categories. For example, among 16 instructional videos, the video with the highest number of phases in activating and focusing had 20 phases, while the video with the lowest number had 5 phases, as shown in the fourth and fifth rows of the total column.

More Phases in QUE and EXPLN Than in INVES and DATA

There were more phases that emerged in QUE and EXPLN scientific inquiry than there were INVES and DATA in the instructional videos. The percentage of phases that were QUE and EXPLN were 37.8% and 35.5%, respectively, while the percentage of INVES and DATA phases were 8.8% and 18.0%, respectively. In particular, all instructional videos involved phases of QUE and EXPLN, as shown by the minimum numbers of QUE and EXPLN being 1; however, four instructional videos did not contain any phases of INVES and/or DATA. This distributive result may indicate that the instructional videos made by the pre-service teachers were more focused on conceptual explanations than epistemic aspects of scientific inquiry, such as conducting investigations and interpreting the data.

More Activating and Focusing and Fewer Affording Participation

More phases (174 of 216) appeared in AF than in AP (42), as shown in Table 3, which is a gap of more than four times. In particular, QUE and EXPLN mostly involved these two pedagogical roles, while INVES and DATA mostly involved the AF pedagogical role. This may mean that the pre-service teachers were concerned with learners' engagement more in QUE and EXPLN science inquiry than in INVES and DATA. Some videos showed alternation between the two pedagogical functions, mainly in QUE and EXPLN components, which will be discussed in the two representative cases.

Responding to RQ2: How are representational strategies used in instructional videos for students' scientific inquiry and engagement?

Based on the analysis, we found two contrasting cases to highlight the utilisation of representational strategies among 16 instruction videos. Case 1 had a simple pattern and fewer phases in using representational strategies involving only the QUE and EXPLN scientific inquiry, while Case 2 involved a dynamic use of representational strategies involving all the scientific inquiry. The topic of both the cases was heat transfer: Case 1 involved two types of heat transfer, conduction and convection, while Case 2 was only focused on convection. We will explore the use of representational strategies in the two contrasting cases, considering in particular scientific inquiry and learners' engagement.

Case 1: A Simple Instructional Video Case With Fewer Phases

In Case 1, YM, who is a pre-service teacher, created an instructional video for primary students about heat transfer focusing on conduction and convection. His instructional video introduced these two types of heat transfer in three states of matter: solids, liquids, and gases. This video only contained AF phases and not AP phases and comprised QUE and EXPLN scientific inquiry as shown in Figure 2 and Table 4. The duration of this video was 4 minutes and 55 seconds, and it consisted of five phases, which was the smallest number among the 16 instructional videos.

Figure 2. A screenshot of the analysis of Case 1

Table 4. The content flow and the use of representational strategies in Case 1

Phase [time]	Scientific inquiry and pedagogical roles	Content	Representational strategies
P1 [00:01-00:48]	QUE-AF	Introducing heat transfer in everyday life	Summarising: Cases of heat transfer
P2 [00:49-01:00]	QUE-AF	Presenting types of heat transfer	-
P3 [01:05-02:32]	QUE-AF	Explaining the process of conduction in solids	Sequencing: Showing the process of conduction using stop motion Emphasising: Repeatedly playing the stop-motion clip Overlapping multiple levels: Overlapping macro- and micro-level views of the phenomenon to explain the process
P4 [02:34-03:50]	EXPLN-AF	Explaining the process of convection in liquids	Comparing: Explaining how heat transfer differs in solids and liquids Sequencing: Showing the process of conduction using stop motion (See Figure 3) Emphasising: Repeatedly playing the stop-motion clip Overlapping multiple levels: Overlapping macro- and micro-level views of the phenomenon to explain the process
P5	EXPLN-AF	Explaining the process of convection in gases	Comparing: Explaining how heat transfer differs and is similar in liquids and gases

[03:53-04:26]			Sequencing: Showing the process of conduction by stop motion Emphasising: Repeatedly playing the stop-motion clip Overlapping multiple levels: Overlapping macro- and micro-level views of the phenomenon to explain the process

Note. Scientific inquiry: QUE—Posing a question, EXPLN—constructing an explanation; Pedagogical roles: AF—activating and focusing

Elaborating for AF but No Use of Representational Strategies for AP

This video started by introducing everyday experiences that involve being hot or cold (P1) and discussed multiple types of heat transfer using only spoken language (P2), as shown in Table 4. The video was created in stop motion to describe conduction and convection in terms of the movement of particles, as the video creator's intention was to provide explanations and resources to help learners understand an observable phenomenon and the unobservable parts of its mechanism, as noted in his description:

> I want to both provide information on the experiment intuitively and show the particulate nature of matter. I expect that learners will better understand the experiments if they are familiar with both the visible phenomena and the invisible mechanisms. … I did my best to represent them in ways that are easy to understand using stop-motion clips. (Excerpt 1 from YM's description in Lines 3-5)

As shown in Figure 3, small red and blue pieces of paper were used to represent heated and cooled particles and their movements during the heating of liquids and the process of convection was explained in terms of the particle view. This particular visual information indeed involved incorrect ideas about the convection in liquids, although this was not the focus of analysis. This phase involved overlapping both micro- and macro-levels together in stop motion and voice over (overlapping multiple levels). It also provided changes in the number of heated and cooled particles and their locations during heating as time passed (sequencing) which would allow students to focus on what changes in the heated water from the particulate perspective. This simulation of convection can be beneficial in helping learners to understand what happens in the phenomenon. Stop motion was also repeatedly shown to emphasise the process of heat transfer in liquids (emphasising). Since there were two types of heat transfer involving three states of matter, this video also compared the differences and similarities among them, as shown in Table 4 (comparing). These representational strategies were utilised for AF; however, there was no use of AP to help with learners' engagement.

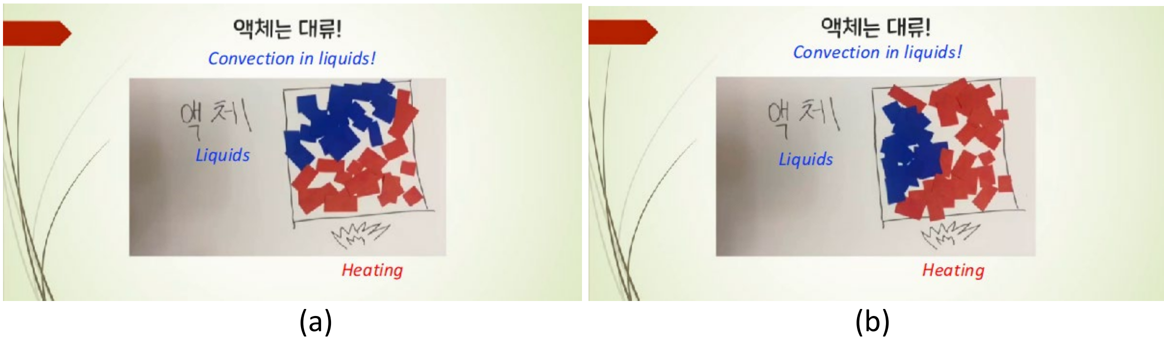


Figure 3. The use of overlapping multiple levels and sequencing representational strategies for explaining in P4: Explaining the process of convection in liquids. (a) initial state (b) later state. Note: The flow of the represented convection is inappropriate considering the heated spot.

Simple Pattern in the Use of Representational Strategies With Fewer Phases

Only five kinds of representational strategies emerged in this video, and four of them (comparing, sequencing, overlapping multiple levels, and emphasising) were utilised repeatedly in phases P3-P5, as shown in Table 4. This similar pattern appearing in one short video may have been too simple to help learners focus on the phenomenon even though stop motion was repeatedly used in an effort to make it easy to understand, although this might be useful for AF. In addition, there were only five phases in the video. This was the smallest number of phases, while the average was 14.7. Applying a target concept to various phenomena has been shown to be more effective in teaching science conceptually (Andrade et al., 2017), and doing this may create more phases; however, this video did not show any epistemic aspects or any relevant examples to situate the learning content into an everyday experience and gave only the conceptual explanation of heat transfer. The use of fewer phases in the video may not provide how we know about the mechanism of convection, indicating that nothing was provided in the epistemic aspect in teaching scientific inquiry.

Case 2: A Dynamic Instructional Video Case With More Phases

In Case 2, HJ planned and made her instructional video to teach the convection concept to a primary science class with the assumption that learners had learnt about conduction in a previous lesson. In contrast to the simplicity of the previous case, as shown in Figure 4, she included both pedagogical roles AF and AP and all the components of scientific inquiry while using a variety of representational strategies and a greater number of phases. The duration of this video was 5 minutes and 28 seconds and consisted of 18 phases, which was more than the average number of phases.

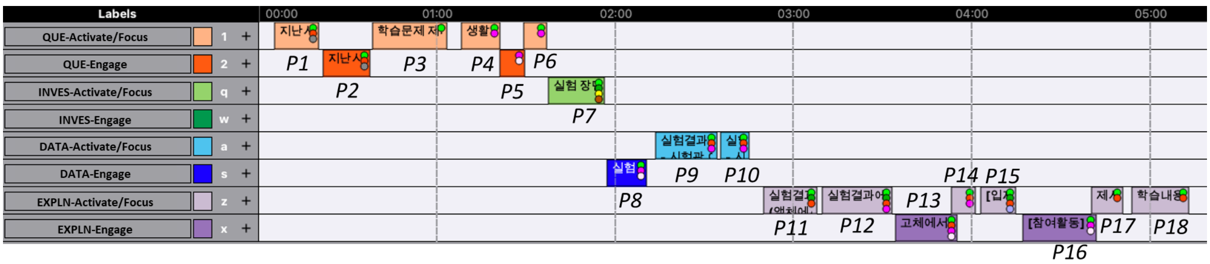


Figure 4. A screenshot of the analysis of Case 2

Table 5. The content flow and the use of representational strategies in Case 2

Phase [time]	Scientific inquiry and pedagogical roles	Content	Representational strategy

P1 [00:05-00:20]	QUE-AF	Recalling previous lessons about heat transfer in solids	Summarising: Providing a summary of the features of heat transfer in solids Highlighting: Colouring the keywords Blanking: Creating blanks for keywords such as 'high/low temperatures' and 'conduction' Delaying: Providing time to find the answers
P2 [00:20-00:36]	QUE-AP	Requesting to provide the blanked (key) word	
P3 [00:38-01:03]	QUE-AF	Providing the learning objectives and the overview	Summarising: Showing the learning objectives using numbering and texts in relation to the previous and the next lessons
P4 [01:06-01:21]	QUE-AF	Motivating using familiar subject matter	Sequencing: Showing the movement of noodles through the video Presenting a vivid phenomenon: Providing the boiling noodle picture and video clip to show an everyday life example of convection Delaying: Providing time to describe the phenomenon based on the observation of the video clip example
P5 [01:21-01:29]	QUE-AP	Questioning to observe and describe the convection phenomenon	
P6 [01:29-01:37]	QUE-AF	Posing the key question for the lesson	
P7 [01:37-01:56]	INVES-AF	Introducing the two experimental designs to observe the feature of convection	Summarising: Showing the two experimental designs to observe the convection phenomenon Comparing: Contrasting the different design of the investigation Highlighting: Labelling the apparatuses for the investigation Sequencing: Providing the before and after colour of thermochromic dye Presenting a vivid phenomenon: Providing the picture of the apparatuses Delaying: Providing time to have a prediction of the results
P8 [01:56-02:12]	INVES-AP	Questioning to predict the results of the two investigations	
P9 [02:13-02:34]	DATA-AF	Presenting the process and results of Investigation 1	Summarising: Showing the summarised investigation results Highlighting: Circling and pointing to highlight the key observable phenomenon where the solution colour is changing Sequencing: Showing the process of colour change caused by heating Emphasising: Zooming in to provide a closer view of the process and repeating the significant process Presenting a vivid phenomenon: Presenting Investigation 2 realistically
P10 [02:35-02:46]	DATA-AF	Presenting the process and results of Investigation 2	
P11 [02:48-03:07]	EXPLN-AF	Introducing the scientific concept 'convection'	Summarising: Presenting the features of convection as a form of heat transfer Comparing: Using different colours to compare the water molecular motions depending on the temperature (i.e., red

			coloured text: higher temperature, blue coloured text: lower temperature) Highlighting: Shading the key term ‘convection’ in yellow colour
P12 [03:09-03:33]	EXPLN-AF	Interpreting the investigation results based on the convection concept	Summarising: Presenting the key results of the two investigations Comparing: Juxtaposing the two different results of the investigations contrastively Highlighting: Shading the key results in yellow colour Sequencing: Showing the two investigations results using two cropped videos Presenting a vivid phenomenon: Presenting Investigations 1 and 2 realistically Overlapping multiple levels: Adding microscopic movements of the water molecules on the realistic experimental videos, which are at a macroscopic level
P13 [03:34-03:54]	EXPLN-AP	Recalling the conduction concept	Summarising: Providing the summarised features of the conduction in solids Comparing: Explaining the differences between convection and conduction Presenting a vivid phenomenon: Showing the investigation results of conduction Delaying: Providing time to answer the question about the differences between convection and conduction
P14 [03:55-04:00]	EXPLN-AF	Questioning the differences between convection and conduction	
P15 [04:02-04:13]	EXPLN-AF	Distinguishing the differences between convection and conduction	Summarising: Providing the features of the concepts in text Comparing: Juxtaposing the processes of convection and conduction Sequencing: Showing the processes of convection and conduction using animated videos Highlighting: Shading the different explanations between convection and conduction Overlapping multiple levels: Presenting both microscopic movements of the particles and macroscopic phenomena
P16 [04:15-04:39]	EXPLN-AP	Adapting the convention concept to another context	Presenting a vivid phenomenon: Showing the picture of the tea being heated Blanking: Creating a blank for visualising how tea leaves in water will move when the water is heated Delaying: Providing a temporal opportunity to visualise how tea leaves in water will move when the water is heated
P17 [04:40-04:52]	EXPLN-AF	Visualising the process of convection	Summarising: Providing a visualised explanation of the convection of the tea leaves

			Highlighting: Using coloured arrows to differentiate the motions of heated/cooled particles
P18 [04:54-05:13]	EXPLN-AF	Wrapping up the concept of convection in liquids	Summarising: Providing a verbalised explanation of convection Highlighting: Underlining the key term 'convection'

**Note*. Scientific inquiry: QUE—posing a question, INVES—planning and conducting an investigation, DATA—interpreting data, EXPLN—constructing an explanation; Pedagogical roles: AF— activating and focusing, AP— affording participation

Dynamic Between Activating and Focusing and Affording Participation

The distinct feature of this instructional video compared to the previous case in terms of pedagogical role was the many alternations between AF and AP to support learners' knowledge construction. As shown in Table 5 and Figure 4, the dynamic alternations between AF and AP appeared in the QUE, DATA, and EXPLN scientific inquiry of the instructional video. The learning objectives of this video were understanding and explaining the convection phenomenon.

(a) (b)

Figure 5. The use of blanking and delaying representational strategies for learners' engagement in (a) P1: Recalling previous lessons and (b) P2: Requesting to answer the blanked words.

The video began by recalling the previous lesson's content about heat transfer in solids in a summarising phase (P1) and continued with a request for learners to provide the hidden words (P2) that were the key terms of understanding the concept (Figure 5). In P1, summarising was employed to provide the resources to activate learners' prior knowledge. Within this summary, blanking and delaying were utilised together to afford learners opportunities to find the keywords and check them a little later. The use of these representational strategies was a shift from AF to AP and possibly prompted learners' cognitive engagement. After providing a list of the learning objectives (P3), she introduced a relevant and familiar example of an everyday experience, boiling a noodle soup, using a realistic video clip that could allow learners to focus (P4) and asked the learners to observe and describe the convection phenomenon (P5). Relevant questions while presenting a visual resource that involves a key concept might lead learners to have deeper views of the phenomenon, such as the direction and movement of boiling soup. Based on the review of the learnt concept and introducing the familiar example, a guide question was posed for the lesson (P6). These alternations between AF and AP might be a way of encouraging learners to cognitively participate in the instructional video, rather than providing only the AF pedagogical role as was done in the previous case. Her plan for learners' engagement was explicitly written in her description:

> Through summarising the concept of the previous lesson, I intended for learners to be able to recall the key content. In the introduction section, I presented the learning objectives and designed the video to help learners become motivated and make a link between the everyday phenomenon of boiling noodle soup and the target concept, which was convection. (Excerpt 2 from HJ's description in Lines 8-12)

In a similar vein, we found the other alternations in the EXPLN scientific inquiry in her video. The alternations were providing an interpretation of the convection phenomenon (P11-P12) with a comparison to conduction (P14-P15), asking the differences between them (P13), and drawing the movement direction of the convection (P16). For these alternations, various representational strategies were employed for both AF and AP. One remarkable feature of the use of blanking and delaying here (P16) was request using a gestural mode of representation while the phases of AP were mostly in the verbal mode. This requested visual information is a key part of understanding the convection concept. She arranged an opportunity for learners to draw the line (P16), as shown in Figure 6(a), and she provided a delayed and visualised explanation (P17), as shown in Figure 6(b). It seemed that she encouraged primary school students' embodied engagement within the video to avoid them being passive learners. Her intention was mentioned in her description:

> I created this part to let learners draw the leaves' movements in the boiling pot. I expected this participation to help learners build the concept based on the learnt content. (Excerpt 3 from HJ's description in lines 15-16)

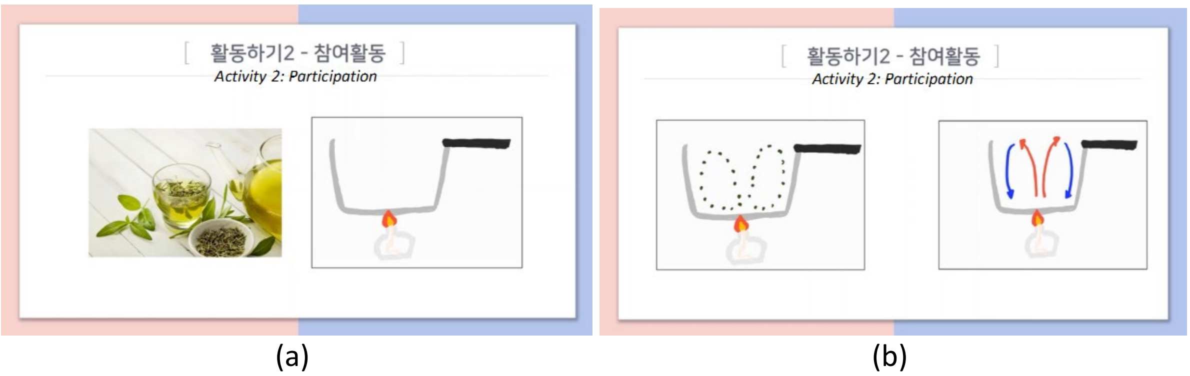


Figure 6. The use of blanking and delaying representational strategies for learners' engagement. (a) P16: Asking to visualise the direction in the convection phenomenon and (b) P17: Providing the visualised answer to the question.

Dynamic Use of Representational Strategies With More Phases

This instructional video comprised all nine types of strategies that were identified in this study multiple times across 18 phases, which exceed the average, which was 14.7. In particular, the utilisation of many representational strategies was appropriate in presenting the key content of the teaching. Phases P12 and P15 of the EXPLN scientific inquiry showed this well. To investigate, thermochromic dye was dissolved in water in the two test tubes that turned pink when the temperature was over 40 °C and blue under 40 °C. There were two investigations conducted: One was heating the top of the test tube and the other was heating the bottom.

In P12, she structurally summarised and visualised the results of the two controlled investigations by contrasting them as shown in Figure 7 (a). In this summary, she inserted and played again the scientific phenomena using cropped videos to emphasise the contrasting results of heating the bottom one turning all the water pink and heating the top one turning only the upper side pink (summarising, comparing, sequencing, and presenting a vivid phenomenon). She also created and added the animated computer graphical effects showing the heated particles going upwards to explain the convection phenomenon (overlapping multiple levels) and highlighted the key differences in the results using yellowed coloured text (highlighting). Elaborative and visualised explanations based on the interpretation of conducted investigations are important in conceptually understanding scientific concepts (Gilbert & Treagust, 2009). While using various representational strategies, she effectively presented the summary by linking the investigations and the mechanism of convection in the context of a transition from DATA to EXPLN scientific inquiry. In P15, she aimed at broadening the current learning content using a comparison with the previous content to highlight the differences between the two phenomena: Heat in solids is mainly transferred by transmission of the particles' vibrations, while heat in liquids is mostly transferred by the particles' movements, which are caused by density differences. For this, she compared and juxtaposed the two processes from the particle view (comparing, sequencing, and overlapping multiple levels) and summarised the main differences using highlighted text (summarising and highlighting) as shown in Figure 7 (b). We found her plan in the description of the video:

It is configured to establish the concept by showing it once again as an image containing a computer graphic of moving liquid particles. The differences between heat transfer in solids and in liquids were intuitively revealed through infographic images rather than experimental images. (Excerpt 4 from HJ’s description in Lines 23-26).

(a) (b)

Figure 7. The use of a variety of representational strategies. (a) P12: Presenting the key contrast results from the two investigational observations while playing the cropped video clips and adding the animated computer graphic to represent the particles’ movements. (b) P15: Contrasting the differences in heat transfer in solids and liquids at the particle level.

Summary and Discussion

Interest in instructional videos in science teaching has been increasing due to expansions of online learning environments and developments of various visualisation resources. However, there have been a lack of studies investigating instructional videos in terms of dealing with scientific inquiry, which are a core element of science education that involve not only scientific knowledge but also how we know and why we believe scientific concepts. Duschl’s (2008) study showed that it is essential to apply epistemic practices in science teaching to get to the core of science where meaningful connections can be made between conceptual knowledge and relevant natural phenomena. On the other hand, learners’ active engagement is another crucial issue in elevating the effectiveness of instructional videos (Brame, 2016). From these necessities, we investigated the features of the instructional videos in terms of scientific inquiry and learners' engagement to draw implications for creating instructional videos for science teaching.

Our results showed that instructional videos in this study were focused more on posing questions and explaining the mechanisms of phenomena posed by the questions than conducting and analysing investigations to draw out results. Overall, there were more attempts to activate prior knowledge and focus on the target concepts through the videos; in particular, this tendency emerged in the phases aimed at conducting and analysing the investigations. These results may indicate that the pre-service teachers were less focused on involving epistemic aspects of scientific inquiry in instructional videos than on conceptual components, although it may be challenging to teach epistemic practices merely through instructional videos. Considering their useful roles in science teaching and their increasing utilisation recently, it would be worthwhile to involve scientific inquiry in instructional videos to encourage learners to make sense of natural phenomena and of how to justify the constructed model (Berland et al., 2015; Osborne, 2014).

To boost students' engagements in teaching scientific inquiry through instructional videos, some videos in this study provided alternations between providing information and affording learners' participation by utilising various representational strategies. For example, as shown in Figure 6, when recalling a previous study and posing a question, the video provided temporal and spatial opportunities for learners to answer the questions and moved a step forward to the subsequent phases. In this process, blanking and delaying, creating intentional blanks to allow learners to answer, were used as a representational strategy to stimulate learners' cognitive activities, including visual and gestural movements, and delayed right answers were provided that could be used by learners as feedback. Since it is crucial that learners have opportunities to join ongoing cognitive activities (Wittwer & Renkl, 2008), prompting questions including conceptual and epistemic aspects for students to answer can be meaningfully effective. In addition, since continuing to use questioning in science teaching to keep learners focused by posing questions, observing phenomena, describing evidence, constructing explanations encourages learners to move forwards to scientific inquiry (Benedict-Chambers et al., 2017), alternations between providing cognitive resources and affording learners opportunities to engage can be beneficial as a part of science teaching.

Various representational strategies, such as summarising, comparing, highlighting, sequencing, presenting vivid phenomena, and overlapping multiple levels, were utilised to achieve the purposes of the instructional videos. Since the use of instructional videos involves multiple representations, strategies for orchestrating various representations for teaching is an important issue in constructing instructional videos, given their constraints and functions (Ainsworth, 2006). In particular, taking into account teaching scientific inquiry, it is crucial to structurally illustrate abstract concepts well while depicting natural phenomena or conducting investigations to prompt learners' observations, inferences, and construction of explanations. This may require more than removing extraneous information for better learning (Mayer et al., 2020). For example, as shown in Figure 7 (a), to effectively present the contrasting results of the two investigations, six types of representational strategies (summarising, comparing, highlighting, sequencing, presenting a vivid phenomenon, and overlapping multiple levels) have been employed together effectively. Using these well-organised phases, the video conceptually compared the differences between heat transfer in solids and heat transfer in liquids using an animated computer graphic to represent the particles' movements. In this example, the successive phases involving effective use of various representational strategies can contribute to learners being able to make a connection between the mechanism of convection and their epistemic understanding of the concept. It may imply that it is important to appropriately utilise representational strategies that are deeply intertwined to involve teaching scientific inquiry as well as encouraging learners' participations.

As discussed in the Theoretical Background section, it is indeed challenging to teach overall features of scientific inquiry through instructional videos due to their inherent limitations. However, instructional videos can still provide opportunities for students to cognitively participate in thinking about conceptual and epistemic aspects of scientific inquiry beyond merely providing information when they are constructed properly following both the general principles (e.g. Brame, 2016; Mayer et al., 2022) of creating instructional videos and the representational strategies identified in this study. For example, instructional videos can be arranged at the beginning stage of lessons and initiate further classroom or small group discussions about the concept to be learnt, how it is related to their everyday life, how they can investigate the concept, how to collect data, how to analyse the data, how to draw a conclusion, how we convince them, and so on. Potentially, students can utilise the conceptual and epistemic understanding that is initiated from the instructional videos in performing social practices as scientific inquiry guided by teachers in actual science classrooms as a way of flipped learning or in discussions on online platforms. These kinds of participation can help them be better able to negotiate and form meanings with their peers and teachers (Wenger, 1998) and move forward to conduct more open-ended scientific inquiry. In addition, the findings of this study can be also utilised in producing instructional videos for the extensive teaching of scientific practices, such in relation to sociology of science. For instance, using instructional videos to raise some approachable scientific issues related to students' everyday lives in ways that use proper representational strategies to illustrate current problems can be a useful way to engage students in the issues and to prompt them to think critically about them.

Although we can see possible merits of instructional videos, there can be further considerations in their careful use beyond the representational strategies of videos. First, students may not be able to understand content solely through the use of instructional videos (Brame, 2016). As we illustrated above, videos can be arranged as a part of lessons that involve students' active learning and practices, such as writing down their thoughts or having discussions with peers, considering the purposes of teaching science, with videos fulfilling specific purposes, such as providing cognitive resources (e.g. relevant scientific ideas, vivid phenomena) with key guiding questions and prompting students' engagement. Giving students feedback on their active learning following instructional videos may enhance their learning more meaningfully (Fiorella & Mayer, 2018). Second, it is also crucial that instructional videos not involve content that may mislead students or reinforce alternative conceptions. When science educators create or select instructional videos, they may need to check whether the content is aligned with a consensus of educational or scientific communities because the visual and verbal representations being provided can be an important resource for students in their future learning (Medina & Suthers, 2013).

Conclusion

In this study, we examined the features of the instructional videos and explored the possibilities they can afford for students' engagement in teaching scientific inquiry through the use of a variety of representational strategies. Even though this exploratory case study drew the findings from the pre-service teachers' video creations who had been not trained to produce instructional videos, we could see advantages of using representational strategies in generating instructional videos for teaching scientific inquiry. These are what this study notably contributed to the current body of knowledge related to instructional video for teaching science, while previous studies have discussed scientific explanations or generic instructional videos. As such, we argue potential for utilising instructional videos for teaching scientific inquiry based on appropriate utilisations of various representational strategies, even beyond those we identified through this study, to encourage learners' cognitive and embodied engagement for their further science learning. We hope that the findings will be useful to science educators who want to create instructional videos or choose appropriate videos involving teaching scientific inquiry and learners' engagement. On the other hand, as a future study, the effectiveness of instructional videos can be empirically examined in terms of learning achievement when teaching and learning scientific practices.

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Ethical Statement

Ethics approval was obtained from the Institutional Review Board of the Chuncheon National University of Education, No. 2021-4.

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