INSTRUCTIONAL EXPLANATIONS OF VIDEO LECTURES

IN HIGHLY RATED MOOCs

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Instructional explanations (IEs) are a teacher's deliberate contribution to learning. They are designed and communicated to convey, structure, and convince learning content as well as to respond to an actual or anticipated questions or perceived puzzlement. The purpose of this study is to explore the characteristics of IEs in highly rated MOOC video lectures. Based on the user review scores of the MOOC portals and MOOC providers, 12 MOOCs were selected for this study. A study rubric with 2 layers (i.e., purpose and instance of IEs) was developed by integrating previous studies and then revised after a pilot study. An observation method with momentary time sampling (MTS) was used to capture lecturers' IE instances at every 10 seconds. Over 37 hours of MOOC videos were coded resulting in 13,524 total codes.

The results show that the most frequent IE category was Justification, followed by Familiarizing and Scaffolding. The frequencies were significantly different by subject area and video production type. Five themes of 3-code IE patterns were generated based on the sequential analysis. In unit lectures, IEs at the beginning and ending rely

heavily on Scaffolding and Motivating explanations compared to the remaining lecture portions.

Three main findings of this study are: (1) evidence to validate the observation rubric of this study, (2) five themes of IE patterns, and (3) detailed information on opening and closing IE patterns of unit lectures. In addition, various examples of IE patterns are presented and discussed in detail.

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CHAPTER 1: INTRODUCTION

Background and Problem Statement

Great teachers have existed before technology was adopted in classrooms, before the idea of instructional design was advocated, and even before the school existed. Some teachers are admired because of their noble character and others are admired because of their enthusiasm with their students. In particular, some teachers present such rich explanations for a difficult content that any student can understand easily and concentrate on a task, whereas others unfortunately just provide simple and poor explanations. What makes this difference? This study began with this basic question.

The topics of this study are not new. In fact, research papers have proliferated from the 1980s (Leinhardt & Steele, 2005). The topics, 'great teachers' or 'effective teachers' have been discussed among the scholars of teacher education, and 'good instructional explanation' was a sub-topic of 'effective teachers.' Also, 'pedagogical content knowledge' has been an essential component of instructional explanations (Ball et al., 2008; Shulman, 1986; Sullivan, 2008). An effective teacher is not just a charismatic and silver-tongued teacher; teachers must be experts in the subject matter that they teach.

Recently, researchers have conducted empirical studies in the viewpoint that instructional explanations (IEs) should be investigated in combination with learners' cognitive process (e.g., Maclellan, 2015; Sánchez et al., 2009). Those investigating learners' mental model have proposed several solutions to improve IEs. Their suggestions appear instructivists' answers to the idea of constructivists' scaffolding. When learners face a complicated learning topic in a college-level class, it is highly probable that learners will experience confusions and misconceptions. Learners tend to have an erroneous belief like "I understand it!" even though they actually do not (Charalambous et al., 2011).

Webb et al. (2006) suggested that instructors should encourage learners to actively process given IEs to avoid this erroneous belief. Jucks et al. (2007) pointed out that learners' mental model is different from that of experts. Instructors should avoid the 'expert mistake' and deliver rich explanations that can be easily understood by novice learners. Calin-Jageman and Ratner (2005) also stressed the importance of learners' mental model. Without well-designed IEs, users tend to face *impasse* and lose the chance to correct their mental model (Kendeou & van den Broek, 2007). In sum, IEs should play a role of correction and completeness so that learners can overcome mental passivity (Berthold & Renkl, 2010; Cho & Jonassen, 2012).

Although empirical studies have mainly focused on learners' mental model, IEs consist of many other different components. Think of a college-level lecture. First of all, a learning topic will be presented before providing those scaffolding explanations. If the concept or idea is hard to understand, a lecturer will deliver rich explanations such as analogies or examples to ensure students' thorough understanding. Lecturers deliver not only explanations for understanding, but also explanations for justifying and persuading the truth of the learning content. One of the examples is the proof process of a theorem in mathematics. Historical stories or anecdotes are another example. In addition, lecturers stimulate learners' curiosity, point out the importance of the topic in the knowledgebase and real life, and express their personal feelings related to the content from time to time. In college-level courses, we see every day that lecturers do perform all of these activities in one session.

Many researchers have analyzed instructional explanations in order to find the components of IE (e.g., Dagher & Cossman, 1992; Geelan, 2013; Leinhardt, 2001; Norris et al., 2005). There are also other researchers who have attempted to evaluate the quality of instructors' IEs using their rubrics (e.g., Charalambous et al., 2011; Sevian & Gonsalves, 2008). Treagust and Harrison's (2000) research is an influential example. They analyzed Richard Feynman's (1994) physics lectures to the general public, and summarized five IE components. A decade later, Norris and colleagues (2005) and Leinhardt (2001) proposed theoretical frameworks on IE model.

Back to my initial question, I was curious why an effective teacher's explanations are so easy to understand. What makes the difference between great and poor explanations? In search of the answers to the question, I paid attention to instructional explanations. I have learned that IEs should be designed in consideration of learners' mental model. I also have acknowledged the variety of IE components. After the review of the literature regarding IE rubrics, I have developed an observation rubric by integrating previous studies. It is time to determine characteristics of effective teachers' IEs using my rubric. Now, where can I find 'effective' teachers? How can one define a teacher is effective? Recently emerged online learning environment, MOOC can provide solutions to these questions.

MOOC is the acronym of Massive Open Online Course. MOOCs have significantly grown since 2008 and the total number of users is over 81 million (Bonk et al., 2018; Moe, 2015). About 16,300 courses have been offered by more than 950 educational institutions as of December 2020 (Shah, 2020b). The majority of MOOCs are college-level courses and most of them are presented in the format of lecture videos (Ruipérez-Valiente et al., 2020; Sokolik, 2015). Most MOOCs are freely accessible as long as you sign up a MOOC provider. They charge relatively inexpensive cost only when you are seeking a certificate (Belleflamme & Jacqmin, 2016). Now, researchers no longer have to find or record lecture videos; they can observe and code existing MOOC lectures.

One of the best ways to find effective teachers is asking learners about their teachers. How do you like your teacher's explanations? Were the teacher's explanations helpful for you to understand the topics? Do you feel you have learned a lot in this course? I could ask those questions to students of various courses. The limitation of this data collection method is that it takes extensive time and effort. Alternatively, I can easily gather similar information in MOOCs. In addition, since MOOCs have been grown to a pervasive and important online learning platform, it is valuable to analyze MOOC lectures and provide MOOC lecturers and developers with insights on IEs.

Still, this question remains unanswered: How do you find effective lecturers in MOOC? Some MOOC providers such as Coursera, edX, and Udemy allow users to rate their courses, and these review scores are publicly accessible. Also, some MOOC portals such as Class Central and Course Talk provide the same function. Individual learners' comments are accessible by anyone, too. In this study, I adopted learners' course review scores as the criterion for determining effective lecturers. Although the online rating function may be inferior to a well-designed survey in reliability and validity, this might be the most feasible and practical method to find effective MOOC lecturers.

Purpose of the Study and Research Questions

The purpose of this study is to determine the characteristics of IEs in highly rated MOOC video lectures. Patterns and sequences of effective IEs have been investigated as well as frequencies and durations. Below are explanations of the research questions of this study.

RQ1. What are the components of an effective Instructional Explanations (IE) in MOOCs?

RQ1.1 How often is each type of IEs used in MOOCs?

I developed a new observation rubric by integrating existing rubrics and revised it after a pilot test. Momentary time sampling was implemented as the data collection method while watching MOOC lectures. One IE instance of the rubric was marked at the end of every 10 seconds. I observed 12 courses for at least 3 hours for each, so the total time intervals are at least 12,960. Using the data, the overall frequency and proportion of each IE instance were computed. Previous studies revealed only which IE instances were used in a lecture and did not count the frequencies or durations (e.g., Dagher & Cossman, 1992; Geelan, 2013; Sevian & Gonsalves, 2008). Other studies conducted discourse analysis of instructors and produced qualitative data (e.g., Charalambous et al., 2011; Inoue, 2009; Lachner & Nückles, 2016). Compared to the previous studies, this quantitative research yields more in-depth understanding of effective IEs.

RQ1.2 How are IEs different among subjects (math/CS vs. natural science vs. humanities/social science) in MOOCs?

In this research, 12 highly rated MOOC courses were selected for observation. Four of them are mathematics and computer science courses, four of them are natural science courses such as physics, astronomy, biology, and geology, and four of them are social science and humanities courses such as economics, psychology, history, and philosophy. All are in college-level courses. I expect that differences in IEs will probably exist among these three subjects. Based on my teaching and learning experience, I noticed differences among subjects. Certain IE instances will be more frequently used and presented in longer duration in a specific subject. In this research question, I discover the differences among subjects in terms of frequency and duration of certain IE instances.

RQ1.3 How are IEs different among video production types (Studio vs. Tablet vs. Classroom) in MOOCs?

In the history of MOOC, cMOOCs, xMOOCs, and pMOOCs have been advocated based on connectivist, instructivist, and constructivist viewpoints, respectively (Bonk et al., 2018; Reeves & Bonk, 2015). The majority of current MOOCs are categorized as xMOOC (Allen & Seaman, 2016) and the 12 courses in this research are all xMOOCs. Course materials of xMOOCs mainly consist of recorded lectures, educational videos, and other online resources (Ross et al., 2014). In the preliminary search, I have found there are three types of lecture videos. One is the classroom lecture recording, which is the recording of a live face-to-face classroom lecture. The other two are the studio or tablet presentation, which shows either a lecturer presenting in a recording studio or tablet presentations. I discover the differences in the three types of lecture videos in terms of frequency and duration of IE instances.

RQ2. What are the typical patterns of an IE sequence in MOOCs?

Gagne's (1962) nine events and Reigeluth's (1999) elaboration theory are exemplary instructional design theories to help sequencing IE instances. Likewise, we can expect that effective instructional explanations may have typical sequences. Based on the preliminary research and observations in the pilot study, I assume that an effective lecturer must have established her/his own sequence of IEs. The sequence must have been kept revised as the lecturer has been getting experienced, receiving students' feedback, having chances of observing other lecturers, and learning suggestions of instructional design theories. This study explores the sequences of effective instructors' IEs and reveals exemplary patterns.

RQ3. How are the different types of IEs used in unit MOOC lectures?

In traditional colleges, one unit lecture is usually 50-75 minutes long. On the contrary, most MOOC videos are divided into shorter clips in order not to lose learners' attention (Guo et al., 2014; Hew, 2018) even if the videos are simple conversion of live classroom lectures. In the present study, a unit lecture is equivalent to an individual lecture video, and IE components were examined by the unit lecture. What kind of IE components are mostly used at the beginning and ending of unit lectures? How long are opening IEs presented before an instructor starts to deal with the main learning topic? How long are closing IEs presented after completing explanations of the main learning content? The quantitative results investigate how IEs are changing as a lecture begins, continues, and ends.

Significance of the Study

First, this study helps us step closer to recognize effective IEs. Prior studies have investigated various IE components, but most of the research outcomes were qualitative data. In this study, using the momentary time sampling, I coded lecturers' IEs at every 10 seconds and yielded more than 13,500 data. New observation rubric, frequency, and patterns of IE sequences are the results of this study. I hope this information gives insights to future research regarding IEs.

Second, I hope this study can draw attention to instructional explanations, particularly where xMOOCs are rapidly growing. Although there are various efforts to overcome traditional lecture-style instructions, the market has chosen xMOOCs over cMOOCs or pMOOCs. Considering lecture videos take a large part in an xMOOC content, there is a growing need to research lectures and instructional explanations. The present study reveals how variety of instructional explanations are employed by effective MOOC lecturers in order to help learners to thoroughly understand.

Third, outcomes of this study may be useful for MOOC lecturers and instructional designers. As the MOOC landscape is expanding, more professors and instructional designers are newly joining in this open online environment (Shah, 2019, 2020b). The observation and analysis results of this study should prove beneficial for those who are seeking better solutions in planning, designing, developing, and delivering a new MOOC.

CHAPTER 2: LITERATURE REVIEW

In this chapter, three relevant areas of previous research will be reviewed: (1) instructional explanations (IEs), (2) observation rubrics, and (3) massive open online courses (MOOCs). In the first section, the theoretical background and effectiveness of IEs will be examined. I will also review recent empirical studies that have examined IEs in combination with learners' mental model and mental passivity. In the second section, I will analyze existing rubrics that have been used to observe and evaluate teachers' IEs. The observation rubric in Table 1 is the outcome of the literature review in this section. Finally, in the third section, I will detail the origin, characteristics, types of MOOCs, and empirical studies on MOOC video lectures.

Instructional Explanations

Theoretical Background

Leinhardt (1997, 2001) defines that instructional explanations are "the teachers' and texts' contributions to learning. These explanations are designed specifically for communication of a particular aspect of subject matter knowledge; they are designed to teach" (p. 223). Instructional explanations convey, structure, convince, and demonstrate learning content; model questioning and explaining in the discipline; respond to an actual or anticipated query or perceived puzzlement (Leinhardt, 2001, 2010). Instructional explanations can be categorized into three types: (1) verbal, (2) visual, and

(3) discussion (Geelan, 2012). Verbal explanations are presented in the form of lecture or demonstration of learning content. Verbal explanations can be accompanied with visual diagrams and demonstrations. Also, explanations can be collaboratively generated in a classroom discussion. This literature review will mainly focus on verbal and visual types of explanations because the present study analyzes xMOOC videos in which live classroom discussions are limited.

Wittwer and Renkl (2008) reviewed various empirical studies and proposed four general guidelines for designing instructional explanations (IEs): IEs should: (1) be adapted to the learner's knowledge prerequisites, (2) focus on concepts and principles, (3) be integrated into learner's ongoing cognitive activities, and (4) not replace learners' knowledge-construction activities. In sum, Wittwer and Renkl suggested that IEs should be tailored considering an individual learner's prior knowledge. They also recommended that instructors should develop approaches to comprehend learners' understanding levels. Wittwer and Renkl also argued that IEs alone are not effective and should be examined in combination with learners and learning environments. For the same reason, constructivist perspectives emphasized student learning and interaction (Jonassen, 1999). Such trends toward learner-centered instruction shifted researchers' attention away from teacher's activities (Geelan, 2012).

Similar but Different Topics

Instructional Design and Instructional Explanations

Instructional design can be defined in a broad viewpoint or a narrow viewpoint. In a broad viewpoint, instructional design is defined as "a systematic process that is employed to develop education and training programs in a consistent and reliable fashion" (Reiser & Dempsey, 2007, p. 11). According to this definition, instructional design is similar to instructional systems development (ISD). ISD covers all the systemic and systematic process of producing a training with the model ADDIE, one of the most popular ISD models (Zemke & Rossett, 2002), whereas IEs focus on an instructor's activities before and during a classroom lecture (Leinhardt, 2001).

In a narrow viewpoint, instructional design is called instructional design (ID) theories and mainly focuses on task and learner analysis and content design (Reigeluth, 1983). For example, Reigeluth's (1999) Elaboration Theory suggests providing learning content from simple to complex and general to detail. Merrill's (1983) Component Display Theory helps designers to analyze and display learning content in two dimensions: (1) type of content and (2) performance.

We will discuss in detail later that IEs basically have two facets: *design* and *delivery*. In a nutshell, effective teachers prepare and rehearse a lecture beforehand (*design*), then deliver the content effectively like a great actor (*delivery*). The first difference of ID and IE is that ID theories are robust tools for one of the two facets of IEs: *design*. However, *delivery* is another realm like a talented script writer is not necessarily a talented actor. Second, ID theories prescribe whichever methods that are deemed to be effective for a specific learning situation such as discussion, group project, and/or problem-solving as well as lecture. IEs are mainly in the form of a lecture in a classroom. Research on IEs does not argue that other methods are inferior, but it just focuses on how to best implement IEs.

Disciplinary Explanations and Instructional Explanations

Instructional explanations are different from disciplinary explanations (Geelan, 2012; Treagust & Harrison, 1999). For instance, Treagust and Harrison (1999) compared science explanation and science teaching explanation. Science explanations are strictly theory and evidence-driven, and described in correct scientific terminology. In contrast, science teaching explanations are less rigorous, and often use rich and creative metaphors, analogies, and models. Science teaching explanations are uniquely created by teacher's pedagogical content knowledge, and stimulate student mental models so that they can construct the content and process. The difference can be analogized to a distinction between explanation and understanding. Strasser (1985) identified explanation as the 'natural science' and understanding as the 'human science.' Whereas science explanation is in the realm of natural science, science teaching explanation pursues human understanding.

Classroom Management and Instructional Explanations

Usually, new teachers and student teachers are concerned about classroom management. Even though a teacher has a great lesson plan, no one can effectively teach if the class is not reasonably ready to learn. Therefore, it is argued that all the teachers need to learn about classroom management strategies first (Berliner, 1988; Evertson & Weinstein, 2013).

However, other researchers (Emmer & Stough, 2001; Shulman, 1992) claim that if an effective teacher presents something compelling and interesting for students to learn, then classroom management will not be necessary because of students' intrinsic motivation and curiosity. Most of all, one of the top guidelines of classroom management strategies is to make learning engaging because if a teacher is not equipped with well-designed content and does not deliver it effectively, no classroom management strategies will work (Simonsen et al., 2008).

Effectiveness of Instructional Explanations

Early studies on instructional explanations attempted to compare the effects of different types of IEs. For instance, in VanLehn et al. (2003) study, forty-two high school students participated in sessions with two expert tutors on the subject of physics. The tutoring sessions mainly consisted of lectures although the tutors were very experienced and well prepared. During the lecture, types of explanations were coded by researchers. After the posttests, the results showed that different types of IEs did not make difference in learning outcomes. Similarly, in the research of Chi et al. (2001), a passage regarding heart functioning was presented, and eleven college students and tutors were asked to maintain a dialogue about it. After the dialogue session, the students solved a set of questions involving both shallow and deep learning. The researchers found that there was no correlation between tutorial explanations and deep learning. Furthermore, learning was not impaired when tutorial explanations were removed. Chi and her colleagues' study implied that students' learning outcomes did not differ from tutor-generated explanations but from a different process.

Additional studies have been conducted to discover the effects of different types of instructional explanations. It has long been debated whether only one best solution should be presented for a mathematical problem or whether multiple solutions are better for learners. Große and Renkl (2006) tested the effectiveness of presenting more than one solution methods for mathematical problems. In their 2 x 3 factorial design, multiple solution methods and uniform solution methods were compared in three different settings of instructional support (i.e., none, self-explanations, and instructional explanations). The results showed that multiple solution methods were superior in all three conditions, and no interaction effect was observed.

Meanwhile, Schworm and Renkl (2006) showed that IEs can even be undesirable for certain learners. They compared the effectiveness of self-explanations (SEs) and IEs for mathematics student teachers. The results showed that SEs had favorable effects on learning outcomes. In contrast, IEs decreased the student teachers' SE activities and also their learning outcomes. Interestingly, the student teachers 'subjectively' perceived that they best learned with IEs, whereas the learning outcome was measured 'objectively' higher in SE mode. The researchers concluded that IEs reduced learners' efforts in generating explanations, and consequently hampered learning outcomes (Schworm & Renkl, 2006).

It is not surprising that IEs alone are not always effective. That is why traditional lecture-style instruction has been criticized, and learner participation and knowledge construction have been emphasized (Jonassen, 1999). Recent studies have turned their attention to explore IEs in consideration with learners.

Inoue (2009) observed and analyzed 34 novice teachers' rehearsals. It is obvious that every instructor prepares for a class by designing instruction, developing learning materials, and/or practicing IEs. However, it is not an easy task for a novice teacher to give conceptually rich and meaningful explanations. One way to improve novice teachers' pedagogical content knowledge (PCK) and the quality of their explanations is to rehearse and fine-tune their IEs like actors or musicians rehearse before performing in front of audiences.

In the qualitative research by Inoue (2009), interesting observation results included: (a) "Most of the presenters failed to consider possible confusions and misconceptions that elementary school students may have" (p. 51), (b) "Most of them failed to take advantage of various essential educational opportunities that emerged in their presentations for discussing important assumptions that underlie the representations and rationale that they used" (p. 51), and (c) "It was impossible to describe a linear, simple formula for the ways their PCK interacted and influenced weaknesses of the explanations at the deep level. (…) the step-by-step deconstructions of their actions and utterances appeared to be the only way to give a meaningful valuation of the explanations" (p. 51).

Inoue's (2009) study implies that IEs have two facets: *design* and *delivery*. One of the main activities, when a teacher prepares for an instruction, is instructional design. This can be analogized to writing a script for a play. Like an entertaining play requires an entertaining script, appealing IEs require an appealing instructional design. However, there is a big difference between actors' acting and teachers' delivery. Acting follows the script and focuses on dramatic expressions of the script, whereas teacher's delivery keeps adding or omitting instructional components while interacting with learners (Griggs, 2001). Effective teachers are good at fine-tuning and self-feedback process during the delivery (Ozmen, 2011). Stodolsky (1988) referred to this as "teacher's reconfiguration of activity structures."

The research by van de Pol and Elbers (2013) is a seminal example of the nature of teacher's delivery. They analyzed 22 preservice teachers' lessons in terms of teachers' delivery and student learning. Regarding teachers' delivery, they focused on the 'contingency.' The Contingency Shift Principle is (1) increase control by providing answers or explanations when students fail, and (2) decrease control by asking open questions when students succeed. The results showed that if students' entry understanding level is low, contingent support was effective for student learning. More importantly, they found that teachers tended to overestimate students' understanding. The preservice teachers did not provide enough increased control even when students were not fully understanding the content. In effect, teachers usually have a hard time in deciding what to tell and not tell. They have to make decisions every moment by carefully sensing learners' reactions (Ozmen, 2011).

IEs in Considering Learners' Mental Model and Mental Passivity

In the previous section, it was discussed that design and delivery are two main facets of IEs. To improve the *design* aspect of IEs, researchers suggested considering learners' mental model. For the *delivery* aspect, researchers focused on the mental passivity of learners.

Learners' Mental Model

In Calin-Jageman and Ratner's (2005) study, two conditions were compared with a control group. In one condition, kindergarteners explained expert's answers (Explain-Expert), and in the other condition, children explained their own answers (Explain-Novice). The control group did not generate explanations (Control). Explain-Expert children showed better performance than the control group. The Explain-Expert group also learned expert's strategy more quickly and used it more frequently than the other groups. Interestingly, Explain-Novice group was not significantly superior to the Control group. In children education, creative thinking has been regarded superior to rote memory (e.g., Bansal, 2020). However, Calin-Jageman and Ratner's (2005) study disputes this flawed belief and shows an example of 'impasse.' When learners detect problems in their mental models but they cannot generate their own explanations to solve them, it is called learners face impasses that they cannot overcome (Sánchez et al., 2009).

Here is another example that learners are discouraged to utter self-explanations when they experience impasse. Kendeou and van den Broek (2007) requested a group of college students to self-explain while reading a text about heart diseases. The research concluded that when learners realized that they did not understand the text, they did not produce explanations to overcome the impasse. Participants seldom produced self-explanations when they realized that they had misunderstood the topic.

For kindergarteners or college students, generating their own explanation would be hard work. Sánchez and colleagues (2009) explained that learners were not always able to recover from an impasse through self-explanation. Besides generating self-explanations, correction of explanations that are problematic and completeness of insufficient explanations are both highly important. Incorrect self-explanations might be beneficial only if they are refuted by an external source of information, such as IEs. Correction and completeness of flawed self-explanations is a potential advantage of IEs (Cho & Jonassen, 2012).

VanLehn et al. (2003) investigated a link between impasses, tutorial explanations, and learning. As was mentioned before, impasses take place whenever a learner recognizes an error and the need for a solution. VanLehn and colleagues revealed that IEs following an impasse fostered learning in the physics lessons, whereas IEs without impasse had no correlation with learning. The researchers noted that IEs were effective when learners did perceive them as a solution to their impasse. In that situation, the students performed in-depth processing of the explanations.

Sánchez et al. (2009) assessed the impact of an IE that explicitly addressed the two components of the mental model repair view, that is, conflict detection and repair. In the first one, a specific aid called "Impasse-trigger" was provided. It was designed to provoke an impasse in learners by hinting a possible misunderstanding or openly pointing out an actual misunderstanding. Regarding the second component, a tailored explanation was provided after the presentation of the impasse-trigger. The experiment group was provided with both impasse-trigger and tailored explanations. In contrast, the control group was provided with only identical explanations (no impasse trigger). The experiment group recalled more correct information, generated more transfer solutions, and showed fewer flawed ideas than the control group. As a result, impasse trigger worked as a conflict detector and tailored explanations worked as a repair. Learners benefited from the combination of the two components.

Acuña et al. (2011) conducted similar research with the comparison of high and low prior knowledge groups. They focused on those kinds of IEs that were provided to clarify or to correct the misunderstanding of learners. The study examined whether interaction effects existed between the kinds of IEs and learners' prior knowledge level. Results showed that low prior knowledge learners scored higher when explanations with indications of their misunderstandings were presented. High prior knowledge learners scored almost equally either with or without the indications. The researchers inferred that low prior knowledge learners had difficulties to grasp core ideas from rough explanations rather than indicated explanations.

Considering all of these empirical studies, IEs are most effective when they are presented right after learners face impasse. Effective IEs help learners to correct and complete self-explanations. The research of Calin-Jageman and Ratner (2005) shows that learning could be discouraged when a problem is presented first and learners are requested to explore self-explanation. Calin-Jageman and Ratner suggested that well-designed IEs should be presented after learner impasse. In the previous section, Effectiveness of Instructional Explanations, I reviewed the early comparison studies of different types of IEs. The results showed no significant difference, but the early studies had limitations that they did not incorporate learner impasse in their research design.

In addition, Berthold and Renkl (2010) claimed that IEs should be equipped with pre-designed impasse such as the impasse-trigger. They showed an example of impasse-trigger by quoting a teacher's explanation: "Usually the people who watch this presentation tend to elaborate a simplified conception of the plate collisions process; thus, probably you only saw that plates collide, so the mountains are formed both in the Andes and in the Himalayas by the same principle. However, there are important differences between the two plate collisions that play a big role in clarifying what plate tectonics is" (Berthold & Renkl, 2010, p. 34). In this explanation, the teacher emphasized possible misunderstanding on plate collisions process without getting any question nor perceiving students' reaction. Berthold and Renkl's (2010) research implied that IEs with rich impasse-triggers would encourage learners to detect a conflict and to actively reconstruct their knowledge.

As a strategy to improve IEs, Jucks et al. (2007) suggested to avoid the 'expert mistake.' They pointed out that experts represented their knowledge in a specific way and, thus, they often did not envision the perspective of a novice learner. Experts tend to fail to distinguish between discipline explanations and instructional explanations, and easily assume that novices are thinking the same way experts do. Therefore, it is important for experts to generate IEs that are suitable for novice learners (Koedinger & Aleven, 2007; Schoenfeld, 2010).

Mental Passivity

When should we provide information and assistance to learners, and when should we ask learners to work on their own and to generate information, ideas, and solutions? Koedinger and Aleven (2007) called this problem the "assistance dilemma," and claimed that the assistance dilemma is one of the fundamental unsolved problems in teachers' delivery.

The research by Webb and her colleagues (2006) may give a hint to solve the assistance dilemma. They suggested that learners' follow-up activity after receiving explanations is the strongest predictor with respect to learning outcomes. The follow-up activity was predicted even stronger than the quality of the explanations themselves. The study results align with the early empirical studies that compared various types of IEs and found no differences. Webb and colleagues' study recommends that instructors should provide IEs and chances for active mental processing one after another.

Another study to minimize learners' mental passivity was conducted by Berthold and Renkl (2010). The researchers attempted to improve the effectiveness of IEs by fostering learners' active mental processing. The three cases in their study entailed an instructional assistance, "focused processing prompts." The focused processing prompts were a text input box on a computer screen that requested learners to summarize central concepts and principles of the learning content. The results showed that the focused processing prompts group generated more elaborated explanations on domain principles and fewer incorrect statements compared to the control group. Also, it turned out that the focused processing prompts were effective particularly for novice learners. In the Berthold and colleagues' (2011) next study, "double-edged effects" of focused processing prompts were examined. Both positive effects for novices and negative effects for prepared learners were observed. That is to say, the focused processing prompts were effective in helping novices generate elaborate explanations but, at the same time, they interfered with more prepared learners. Hence, the "double-edged" was a cautionary statement of these researchers.

Two years later, Roelle and Berthold (2013) paid attention to the lack of prior knowledge and utilized "training" to overcome the lack. Although focused processing was proposed to overcome learners' mental passivity (Berthold & Renkl, 2010), learners often did not engage in focused processing. One of the possible explanations could be that lack of prior knowledge hindered spontaneous focused processing. Therefore, Roelle and Berthold assumed that if prior knowledge was learned beforehand, learners was able to be more engaged in focused processing. The results showed that the focused processing prompts fostered conceptual knowledge for novice learners, whereas the prompts hindered the acquisition of conceptual knowledge for trained learners. The researchers concluded that both prompts and training have advantages and disadvantages.

Summary and Conclusion

In this section, I have reviewed theoretical background, similar but different topics, and effectiveness of instructional explanations. I have also reviewed recent empirical studies that have examined IEs in combination with learners' mental model and mental passivity. In sum, the instructional explanation itself is hardly effective for learning. That issue is one of the main reasons that traditional lecture-style instruction has been criticized, and learner participation and knowledge construction have been emphasized. Recent IE studies have proposed several important solutions considering learner impasses, mental correction and completeness, and mental passivity.

Rubrics for Instructional Explanations

In this section, I will review observation rubrics in various literature that has analyzed and evaluated teachers' instructional explanations. To begin, I present the observation rubric in Table 1 that will be used in this section and the pilot study. Of course, the observation rubric has been created by integrating reviewed literature. I present the rubric in the beginning because it is convenient to evaluate and discuss previous studies by comparing and contrasting with my observation rubric. Also, it is efficient to explain how my observation rubric has been created when reviewing each of the literature. Please note that the rubric presented in the Data Collection section and Appendix A is the final rubric that was revised after the pilot study.

Table 1

Observation Rubric for the Pilot Study

Purposes of IE	Presenting	Justification	Familiarizing	Clarification	Scaffolding	Motivating
IE Instances	Presenting a learning topic	Factual/ statistical	Analogy (metaphors and similes)	Examples/ counterexamples	Connect to prior knowledge	Use a 'hook'/ask questions
	Interpretative explanation	Causal explanation	Anthropomorphisms and teleological statements	Contrast/ distinguish	Ask Questions for learner impasse or	Emphasize/Point out important

				eliciting understandings	things (internal value)
Tautology/ repeating	Narrative explanation	Easy word/terms	Compare Everyday concepts with Scientific concepts	Images/ models/ concept map/graphic organizers	Meta statement (external usability)
	Cite/ quote		Application/ practice	Demonstration	Structuring explanation
					Personal feeling
					Humor

Norris and his colleagues (2005) analyzed various articles regarding instructional explanations in science education and proposed 10 types of IEs by their explanatory function. They are (1) Interpretative, (2) Justification, (3) Descriptive, (4) Causal, (5) Deductive & Nomological, (6) Statistical (inductive), (7) Functional, (8) Explanatory unification (generalization), (9) Pragmatic, and (10) Narrative explanation. While Norris and his colleagues have given insights to IE classification, the 10 types of IEs are not clearly separable. One example is Causal Explanation and Functional Explanation. When we explain a fact by indication of its function, one of the most common mechanisms is cause and effect. For example, when we attempt to explain the function of gravity, we will have to say how every object is pulled by an object of heavy mass. In this case, the object of heavy mass is the cause and pulling is the effect. Another example is Justification Explanation. In effect, justification is an umbrella term of other types of explanations. We commonly employ Deductive, Inductive, Causal, Functional, and/or Narrative Explanations to justify ideas, facts, or theories. Therefore, I classified Justification as a purpose of IE, and listed other types of explanations as instances under the Justification category.

Dagher and Cossman (1992) observed 20 high school science teachers and classified 10 types of IEs. Compared to Norris and colleagues' (2005) classification, Dagher and Cossman's IEs are quite piecemeal and specific. Also, these IEs focus mainly on Familiarizing and Justification of my observation rubric. Again, some IEs are hard to distinguish like Functional Explanation and Genetic Explanation. Both explanations employ historic story telling. Another example is Anthropomorphic Explanation and Teleological Explanation. Both are commonly used when a teacher tries to familiarize a learning topic. Dagher and Cossman presented an example of Anthropomorphic Explanation:

> The water of course wants to occupy that space because the water wants to be, wants to fill all of its available area. And the water is trying to get back in to fill this area is what provides that force. (p. 364)

In this explanation, the teacher attributed water to a purposeful character as well as a human character. The teacher's explanation is hard to classify either Anthropomorphic Explanation or Teleological Explanation. Therefore, I classified both Anthropomorphic and Teleological Explanation as an instance of Familiarizing. Table 2 summarizes Dagher and Cossman's 10 types of IEs and the relationship to my observation rubric.

Table 2

Dagher and Cossman's (1992) 10 Types of IEs and Relationship to the Study Rubric

Instructional Explanation	Short Description	Category in the Study Observation Rubric
Analogical	Relate unfamiliar phenomenon to familiar situation	Familiarizing
Anthropomorphic	Attributing human characteristics	Familiarizing
Teleological	Attributing characteristics with purpose	Familiarizing
Functional	Historic cause and effect	Justification
Genetic	Historic antecedent and consequence	Justification
Mechanical	Physical cause and effect explanation	Justification
Metaphysical	Supernatural agent is identified	Justification
Rational	Evidence of warrant is given	Justification
Practical	How-to, step-by-step explanations	Scaffolding
Tautological	Repeat	Presentation

Treagust and Harrison (2000) analyzed Richard Feynman's lectures. The book "Six Easy Pieces" (Feynman, 1994) is a collection of Feynman's lectures between 1961 and 1963, and contains in-depth explanations for the general public on physics such as atom, energy, gravity, quantum physics, etc. Treagust and Harrison categorized Feynman's explanations by: (a) analogies and metaphors, (b) axioms, (c) anthropomorphic and teleological statements, (d) concepts and examples, and (e) imagination and rotational reason. In Table 3, Treagust and Harrison (2000) distinguished explanation into Scientific Content Explanations and Effective

Pedagogical Content Explanations. It is of note that their Scientific Content Explanations can be comparable to Justification, and Effective Pedagogical Content Explanations can be comparable to Familiarizing of my observation rubric.

Table 3

Treagust and Harrison (2000) Classification of Explanations

Explanation Categories	
Scientific Content Explanations	***Effective Pedagogical Content Explanations***
Deductive-nomological	Human action
Deductive-statistical	Anthropomorphism
Inductive-statistical	Teleology
Complete or comprehensive	Analogy
Causal	Metaphor
Empirical	Vignettes

Sevian and Gonsalves (2008) developed a rubric with 16 activity codes to assess the quality of scientific instructional explanations presented by 32 science graduate students. They gave unprepared explanations in a semester long seminar, and the presentations were recorded for the research purpose. Most of Sevian and Gonsalves's activities are very specific such as Use of pictures, Use of demonstrations, Use of examples, Telling stories, Body language, and Use of media. Sevian and Gonsalves did not collect data in a manner of interval recording. They gave scores for each rubric after watching a whole session. They can be regarded as various instances of Justification, Familiarizing, Clarification, Scaffolding, and Motivating.

Geelan (2013) analyzed 16 high school physics teachers' instructional videos to identify distinctive and general features of IEs. The distinctive IE features are different from specific physics topics, and the general IE features can be observed in general. Table 4 lists Geelan's IE features and their relationship to my observation rubric.

Table 4

Geelan's (2013) IE Features and Their Relationship to the Study Rubric

Distinctive Features of IE	Category in the study rubric	General Features of IE	Category in the study rubric
Storytelling of history of science	Justification	The "move to mathematics" (deliver in symbols and equations format)	Justification
Use of concrete examples	Familiarizing	Storytelling and references to the history of science	Justification
Analogies	Familiarizing	Use of analogies	Familiarize
Link to prior knowledge or experience	Scaffolding	Role of technology	Scaffolding
Demonstration	Scaffolding	Attention to the requirements of success in exams	Motivating
Diagram	Scaffolding	Humor	Motivating
Appeal to the idea or imagination	Motivating		

In addition to studies that have proposed comprehensive rubrics to assess IEs, several studies have attempted to determine specific features of IE. Some studies focused on scaffolding such as learner impasse and misunderstanding (Rittle-Johnson et al., 2017; Sánchez et al., 2009), or a 'hook' to interest students (Baecher et al., 2013). Roelle and Berthold (2016) paid attention to comparison and contrasting features of IE, and Wanzer et al. (2010) conducted the comparison study of instructional and non-instructional humor. Analogy is one of the most frequently researched topics in IE use (Brown & Clement, 1989; Glynn et al., 2007; Nashon, 2004; Thagard, 1992; Wong, 1993). Particularly, Brown and Clement (1989) suggested four factors for successful use of analogies: (1) a useful anchoring conception must exist to bridge an example and the target situation; (2) an analogical connection needs to be explicitly explained; (3) in an interactive teaching environment, students should be engaged in the process of analogical reasoning; and (4) the use of analogy should help students construct a new explanatory model.

Summary and Conclusion

In this section, I have reviewed existing rubrics that have been used to observe and evaluate teachers' IEs. The observation rubric in Table 1 is the outcome of the literature review in this section. I concluded that an IE rubric should have two layers: *Purpose* and *Instance*. Instances are instructors' observable and explicit activities whereas purposes are implicit and inferable intensions of instructors. By distinguishing the two layers, IE instances can be more mutually exclusive and easier to code.

Massive Open Online Courses (MOOCs)

Massive Open Online Courses (MOOCs) emerged from 2008 as the Massachusetts Institute of Technology (MIT) began to share their courses on the Web under the Creative Commons License (Bonk et al., 2015; Creative Commons, 2018). Although many universities and colleges are offering their courses over the internet, not all of them are MOOCs. MOOCs are free for access and charge relatively inexpensive cost only when one is seeking a certificate (Belleflamme & Jacqmin, 2016).

Characteristics of MOOC

MOOC is the acronym of Massive Open Online Course. The characteristics of a MOOC can be more clearly understood by expanding the meaning of Massive, Open, Online, and Course. In the word "Massive," we can infer that the number of learners of a course is large (Bowman, 2012 Summer; Koutropoulos et al., 2012; Stewart, 2013). The massive phenomena cannot be explained without considering the second word, "Open." MOOCs are distributed by MOOC providers. MOOC providers exist beyond the boundary of an educational institution. This means any students in other institutions and lifelong learners can freely access MOOCs. Regardless of a major or degree, a student can earn a certificate for each course from MOOC providers (Schaffert & Geser, 2008).

The third word, "Online," means MOOCs are provided through internet. Therefore, learners can overcome restrictions of place and time, and openly access MOOCs (Kop et al., 2011). Open educational resources (OER) are similar to MOOCs since both have the characteristics of Open and Online (Hylén et al., 2012). The difference is that any open online educational resources can be OER, while MOOC is in the form of an educational course (Morrison, 2013). This is another characteristic of MOOC by the fourth word, "Course." Generally speaking, a MOOC is a course with a certificate if a student completes one-semester long learning materials, tests, and assignments.

Small Private Online Course (SPOC) and Corporate Open Online Course (COOC) are variations of MOOC that share the characteristics of Online and Course. SPOC is a tailor-made MOOC for on-campus students. Only on-campus students can enroll a SPOC; it, hence, is not massive. However, blended learning and flipped classroom learning can be implemented in SPOC. COOCs are open online courses for corporate learners. Companies can reduce the cost for education since many MOOC providers also deliver COOCs, and their platforms and courses have already been developed (Bonk, Lee, Reeves, & Reynolds, 2015, 2018; Kolowich, 2013).

cMOOCs, xMOOCs, and pMOOCs

MOOCs can be classified in three types: cMOOCs, xMOOCs, and pMOOCs (Bonk et al., 2018; Reeves & Bonk, 2015). cMOOCs grew out of Siemens and Downes' theory of learning called connectivism (Downes, 2012; Siemens, 2005). Connectivism views learning similar to a computer network composed of nodes and links. cMOOCs emphasize collaboration and sharing by connecting people in a context of self-directed learning. Open online learning environments like MOOCs enable networked approach rather than predetermined curriculum-driven learning (Downes, 2012; Morrison, 2013). Wikipedia and Stack overflow are two online examples of how connectivism works in a network environment (Bruff et al., 2013). In the Wikipedia, knowledge is being built and kept up-to-date by conversations and contributions of many users. In the Stat Overflow, users' answers are evaluated and the best answer to a question takes the top place by programmers' votes (Kop et al., 2011). Although cMOOCs were the first to appear and have been grounded in educational theory, they take only a small part of the overall MOOC landscape (Caulfield, 2013).

xMOOCs emerged in 2011 and their formats were quite different from cMOOCs (Morrison, 2013; Sokolik, 2015). Stanford University was the pioneer in the field of xMOOCs. xMOOCs are a sort of online versions of traditional classroom courses, and their approaches are more instructionist rather than connectivist (Chang et al., 2015). The course design is mostly linear and instructor-driven, so xMOOC learners are content consumers rather than collaborators or contributors (Middleton, 2014). The course materials of xMOOCs mainly consist of recorded lectures, educational videos, and other online resources (Ross et al., 2014). Before MOOCs have been widely received, the OpenCourseWare played a more prominent online resource role. Professors uploaded syllabi, handouts, videos, and so on to share with other professors

(Hollands & Tirthali, 2014). These online resources did not replace their courses in colleges. However, in 2007, a Stanford professor Andrew Ng shared his course titled Machine Learning in a complete one-semester course format (Ng & Widom, 2014). The main course materials were lecture videos and tablet recordings of instructional videos.

pMOOC model began to emerge from 2013 (Reeves & Bonk, 2015). Contrary to the passive learning style of xMOOC, pMOOC emphasizes learner participation in project based learning. pMOOC participants complete a project or address a problem through online collaboration. For instance, preservice or inservice teachers may work together to produce OER for themselves and other teachers (Bonk et al., 2018).

cMOOCs and pMOOCs focused on how people learn and emphasized learner participation, engagement, and collaboration. However, cMOOCs were not accepted in the MOOC market. pMOOCs emerged several years ago and it is still too early to evaluate their success. xMOOCs have focused on delivery and learner achievement. Professors who are effective at classroom lectures just give instructional explanations in front of cameras without changing their teaching habits. The strength of xMOOCs is that they have lower barriers to entry for suppliers, in other words, professors.

Empirical Research on Video Lectures in MOOCs

Many researchers have investigated learner engagement in different types of video lectures. Some have used server log data and others have performed experimental research. Guo, Kim, and Rubin (2014) analyzed over 127,000 students' server log data of four edX courses. They defined 'engagement time' as the length of a video watching session and compared the engagement time by the types of videos. They found that videos with instructor(s) were more engaging than slides only and that engagement time is longer in tablet drawing presentations than in PowerPoint slides or code screencasts. Ozan and Ozarslan (2016) analyzed about 3,000 students' 18,144 video events using the server log data. The research revealed that learners tended to complete watching interview-style videos compared to talking-head style or presentation-style video lectures. However, they did not provide the average length of each type of videos, so the length and type of videos were probably compounded.

Experimental studies measured learning outcomes, satisfaction, cognitive load, and/or perceived learning. They also gathered eye-tracking data to measure learner engagement. Taiwanese (Chen & Wu, 2015), Chinese (Pi & Hong, 2016; Wang & Antonenko, 2017), Dutch (van Wermeskerken et al., 2017), and French (Colliot & Jamet, 2018) undergraduate students all showed better engagement in instructor-visible videos. Most studies reported better learning outcomes in instructor-visible videos except for the Dutch research. Van Wermeskerken and colleagues (2017) conjectured that the difficulty of the content and types of learning outcomes (i.e., recall and transfer) could affect the results. Colliot and Jamet (2018) explained the results based on two competing hypotheses: *Social-cue hypothesis* that promotes teacher's presence to increase learner motivation and engagement versus *interference hypothesis* that avoids teacher's presence not to divert learners' attention. Colliot and Jamet recommended instructor-visible videos with the consideration to minimize interference effects.

Regarding the length of lecture videos, researchers recommend chunking into short clips. Ozan and Ozarslan (2016) found that learners tended to completely watch short videos in one session. In Guo and Colleagues' (2014) research, the median engagement time was about 6.5 minutes for 6 to 12-minute videos, whereas it was about 3.5 minutes for 12 to 40-minute videos. Pi and Hong (2016) attempted to measure learners' mental fatigue using the eye-tracking data. Learners started to feel tired at the 10-minute point and reached the peak fatigue at the 22-minute point.

Current Status and Trends of MOOC

In 2020, the total number of MOOC students was 180 million enrolled in about 16,300 courses from more than 950 educational institutions; about 47 million new learners registered for their first MOOC in 2020 (Shah, 2020b). The top four MOOC providers by registered users are: (1) Coursera - 76 million, (2) edX - 35 million, (3) Swayam – 16 million, and (4) Future Learn - 15 million (Shah, 2020a).

These four trends in the MOOC landscape have been reported. First, New types of pedagogical experiments in online distance learning can be found like SPOCs (Small

Private Open Courses), DOCCs (Distributed Open Collaborative Course), and SOOCs (Social Online Open Course or Small Open Online Course) (Altınpulluk, 2016). It is likely that they will evolve to more closely resemble regular online courses with flexible learning pathways. These will provide a range of paid-for services, including learning support on demand, qualitative feedback on assignments, and certification and credits (Yuan & Powell, 2013).

Second, MOOC providers gradually seek ways to make profits (Bowden, 2018). Udacity was the first MOOC provider that stopped providing free certificates from 2014. Instead, Udacity offers a kind of micro-credential, "Nonodegrees" for a fee. Coursera charges for assignment grading and for certificates. In contrast, FutureLearn limits access to courses while the courses are not open. Only edX remains in completely free to access except for those seeking certificates (Shah, 2017).

Third, recently MOOC providers begin to offer courses that on-campus resident students can optionally choose (Cunningham, 2017). MOOCs have been rapidly growing since the OpenCourseWare initiatives of MIT in 2001 and Stanford's first MOOCs in 2011. That is one of the reasons that most of MOOCs are college level courses (Dennis, 2012). Now in the United States, Georgia Tech and MIT allow students to choose MOOC courses; although this does not apply to all the degrees, some students can enroll in a parallel MOOC for a certain on-campus course (Shah, 2018).

Fourth, in spite of the fact that MOOCs were initiated by universities, a key target audience of MOOC providers are lifelong learners. As companies are trying to reduce the cost, MOOCs are widely accepted in the area of corporate education (Chafkin, 2013). More than 500 companies have signed up for the Coursera for Business service by the end of 2017 and edX for Business is now offering courses to 40 companies (Shah, 2018).

Summary and Conclusion

In this section, I have reviewed the origin, characteristics, three different types of MOOCs, empirical studies on MOOC video lectures as well as the current status and trends of MOOC. MOOCs have proliferated during the past decade due to its openness, flexibility, and authenticity in the form of a course. Considering the majority of courses in traditional colleges have the classroom lecture format, it is no surprise that xMOOCs are the dominant format in the MOOC landscape. Now, 180 million students take about 16,300 MOOC courses, and more professors are joining to offer their courses via a MOOC (Shah, 2020b). The findings of the present study can hopefully help future MOOC lecturers and instructional designers to develop more effective MOOC videos.

CHAPTER 3: METHODOLOGY

Research Questions

RQ1. What are the components of an effective Instructional Explanations (IE) in MOOCs?

RQ1.1 How often is each type of IEs used in MOOCs?

RQ1.2 How are IEs different among subjects (math/CS vs. natural science vs. humanities/social science) in MOOCs?

RQ1.3 How are IEs different among video production types (Studio vs. Tablet vs. Classroom) in MOOCs?

RQ2. What are the typical patterns of an IE sequence in MOOCs?

RQ3. How are the different types of IEs used in unit MOOC lectures?

Observation Research

Observational methods have been widely used to evaluate lecturers' IEs (Cummings et al., 2002; Koth et al., 2009; Protheroe, 2002) and are especially useful in tracking changes of lecturers' behavior over time (Van Tassel-Baska et al., 2006). However, many of the existing studies regarding IE are qualitative research such as discourse analysis (e.g., Charalambous et al., 2011; Lachner & Nückles, 2016). Existing quantitative studies have attempted to find out different types of IE components or evaluate the quality of IEs (e.g., Dagher & Cossman, 1992; Geelan, 2013; Sevian & Gonsalves, 2008). The present study used the Momentary Time Sampling (Powell et al., 1975) as an observation method. MOOC lecturers' IEs were recorded at every predetermined moment. This method can overcome the limitation of previous research that has not investigated the sequences and patterns of instructors' IEs (Ary & Suen, 1983).

The Momentary time sampling is one of the *discontinued data collection method* or *interval recording* in observation research. Interval recording has been widely used to observe classroom behaviors, especially in special education and early childhood education (Fiske & Delmolino, 2012). *Continued data collection method* or *duration recording* is known to be less biased because a researcher can record a target behavior's exact duration period (Johnston & Pennypacker, 2009). However, the duration recording has a critical weakness. The recorded durations usually do not match between different observers (Mudford et al., 2009). In other words, inter-observer agreement (IOA) is low, and this is a big threat to the reliability of a study. In addition, the measurement can be inaccurate because coders are getting easily tired in an observation session (Fiske & Delmolino, 2012). Due to the weaknesses of duration recording, interval recording is popular in observation research of behavior recording (Devine et al., 2011).

There are three types of interval recording: (1) whole interval recording (WIR), (2) partial interval recording (PIR), and (3) momentary time sampling (MTS). In the PIR, an observer marks 'yes' if a desired behavior has ever occurred in a predetermined time period, whereas in the WIR, the observer marks 'yes' if a desired behavior has occurred from the beginning to the end of the time period. Because of their nature of measurement methods, WIR tends to underestimate and PIR tends to overestimate the actual frequency (Devine et al., 2011; Lane & Ledford, 2014).

MTS is often regarded inaccurate because it records a target behavior at the predetermined precise moment. MTS may have difficulty in capturing a low-frequency behavior (Saudargas & Zanolli, 1990). However, many researchers recommend MTS over WIR and PIR (Devine et al., 2011; Hanley et al., 2007; Powell et al., 1975; Rapp et al., 2008). For example, Hanley and colleagues' simulation study (2007) tested MTS, WIR, and PIR by comparing the results with the intervals from 5 seconds to 120 seconds. PIR systematically overestimated even in the interval of 10 seconds. The differences of the MTS results in the experiment intervals were less than 5%. In the present study, the sample size is over 13,000. With this amount of data, there is little chance to fail to capture low frequency IE instances.

Research MOOCs

The main purpose of this study is to determine the characteristics of IEs in highly rated MOOC video lectures. This study adopted a realistic approach to the definition of effective lecturers. In this study, the operational definition of an effective lecturer is "the lecturer of a MOOC with significantly high review score(s). The review score should be higher than 4.5 on a scale of 1 to 5 with "1" being very dissatisfied and "5" being very satisfied. The number of reviewers should be more than 30."

I used learners' course rating as a criterion for determining effective lecturers. Assuming that no unanimous consensus exists on effective teachers, learners' satisfaction can be one of the objective and observable criteria. Learner's rating is equivalent to a one-item survey with the 5-point Likert scale: How do you like this online course? - (1) Very dissatisfied, (2) Dissatisfied, (3) Neither dissatisfied nor satisfied, (4) Satisfied, and (5) Very satisfied.

Of course, the respondents of this imaginary survey are convenient sample. The data could have been contaminated by stakeholders such as the MOOC providers, course instructors, or competitors. The high review score of a course does not necessarily mean learners' high satisfaction of the lecturer's IEs. They may have given high scores because the course content was helpful for their career, the overall instructional materials were well organized, or they felt that the discussion forum was highly interactive and the forum organizer was exceptionally attentive. However, if the sample size is big enough, we can accept that the review score is meaningful and reliable. In this study, the minimum sample size is set to 30.

Learners' course ratings were obtained from two sources. First, some MOOC providers have their own user rating systems. In Coursera and Udemy, user ratings for each course are publicly accessible. edX is quite different. edX does not have its own rating system. edX displays Course Talk's user review score. In addition, it appears that course instructors in edX can choose whether they want to reveal user ratings or not. The second source to obtain users' course ratings is MOOC portals such as Course Talk and Class Central. These MOOC portals do not offer their own courses. MOOC portals aggregate all the courses from various MOOC providers, and then provide links to individual courses. Users receive personalized recommendations, manage their progress of different MOOC providers, and write reviews for their courses in these one-stop MOOC portals. For Coursera and Udemy, MOOC portal's review scores are independent from their own review scores, whereas edX's scores are the same as those of Course Talk. Therefore, combining these two data sources can increase the credibility of user ratings.

In the preliminary search, I found there are two types of lecture videos. The first type is the classroom lecture recording, which is a recording of a live face to face classroom lecture. Lecturers give IEs in a natural way with minimal help of instructional design or scripts. The length of most videos is more than 1 hour and interactions with students are also recorded. In this study, students' responses will not be coded in the observation rubric. The second type is the studio/tablet presentation. The videos show either a lecturer presentation in a recording studio or tablet presentations similar to the Khan Academy videos. The course videos are divided into 5 to 10-minute short clips. Usually, simple practices or reading assignments are presented between the short clips. Considering that lecture videos, practice, reading materials, and summative tests are deliberately arranged, we can assume that the whole course was aided by instructional design, and scripts may have been prepared for IEs. There are no student features on these types of videos; therefore, no interaction exists to record.

Research Procedure

First, I listed up top rated courses in the MOOC portals. The Class Central presents straightforward pages titled "Class Central's Top 50 MOOCs of All Time (https://www.class-central.com/report/top-50-moocs-2017-edition/)" and "Best MOOCs of 2017 (https://www.class-central.com/collection/new-moocs-2017)." While the Class Central presents top rated courses regardless of subjects, the Course Talk provides such a list only within subjects (https://www.coursetalk.com/course-advisor). Also, the

Course Talk does not sort the courses by the review score. So, I checked the Course Talk review scores one by one based on the rank of the Class Central.

Second, I gathered individual MOOC providers' review scores one by one based on the rank of the Class Central. The edX displays the review scores of the Course Talk. The Coursera provides its own review scores. Other providers do not have their own rating system, so I just left it blank for the courses from those providers. Among the top 50 courses, only four courses matched my criteria. Most of the courses were rejected because they were how-to courses. Some courses were not included because their reviewers were fewer than 30. I performed additional Web searches using the term "top MOOC courses" and was able to find more potential courses with the help of these pages: The 50 Most Popular MOOCs of All Time (https://www.onlinecoursereport.com/the-50-most-popular-moocs-of-all-time/); Most Popular MOOCs of 2017 on Coursera & edX (https://www.mooclab.club/threads/most-popular-moocs-of-2017-on-coursera-edx.8649/); Coursera Top Rated Courses (https://www.coursera.org/featured/top_rated_courses); 10 Most Popular edX Courses in 2016 (https://blog.edx.org/10-most-popular-courses-edx-courses-in-2016).

Third, I selected four mathematics/computer science (CS) courses, four natural science courses, and four humanities/social science courses based on these four criteria. First, the number of reviewers should be at least 30 in two of the three review scores

(Class Central, Course Talk, and the MOOC provider of the course). Second, the review scores should be over 4.5 out of 5 among two of the three scores. Third, the course's main content should be lecture videos because this study attempts to observe lecturers' recorded videos. Lastly, the course should teach knowledge and concepts, and the main goal of the course should be enhancing learners' understanding of course content because this study focuses on instructional explanations. Thus, I excluded how-to courses such as foreign language, programming, and other practical courses.

The selected 12 courses are listed in Table 5. The course names are all pseudonyms. The number of reviewers and review scores are as of April 1, 2018. The courses have been offered by three MOOC providers and created by 10 institutions. Please note that 9 out of 12 courses come from Coursera. I tried to diversify course providers as much as possible, but this was inevitable considering the Coursera is the top MOOC provider and holds about 40% of the MOOC users.

Table 5

The Ratings of the 12 MOOCs Selected for the Study

			Review Scores (# of reviewers)		
Subject	**Course Name**	**Institution (MOOC provider)**	***Class Central***	***Course Talk***	***Individual MOOC Provider***
Math/CS	Calculus (Math)	Ohio U (Coursera)	4.6★ (46)	5.0★ (3)	4.8★ (4,290)
	Mathematical Thinking (Math)	Stanford (Coursera)	4.4★ (44)	4.7★ (39)	4.8★ (925)

	Computer Science 101 (CS)	U Virginia (Udacity)	4.4★ (68)	4.8★ (34)	N/A
	AI: Learn with data (Statistics/CS)	Stanford (Coursera)	4.8★ (327)	4.8★ (122)	4.9★ (67,220)
Natural science	Geology 101 (Geology)	U Alberta (Coursera)	4.9★ (278)	5.0★ (1)	4.8★ (519)
	Biology 101 (Biology)	MIT (Coursera)	4.7★ (26)	4.9★ (79)	4.9★ (79)
	Solar System (Astronomy)	CalTech (Coursera)	4.9★ (38)	4.9★ (318)	4.9★ (245)
	Einstein's Theory of Relativity (Physics)	Stanford (Coursera)	4.4★ (12)	4.7★ (34)	4.8★ (860)
Humanities /Social science	Psychology of Happiness (Psychology)	UC Berkeley (edX)	4.7★ (31)	4.5★ (111)	4.5★ (111)
	Bible History (Religion history)	Emory (Coursera)	4.9★ (33)	5.0★ (17)	4.7★ (110)
	Financial Economics (Economics)	Columbia (Coursera)	4.9★ (15)	4.9★ (14)	4.9★ (387)
	Utilitarianism (Philosophy)	Harvard (edX)	4.9★ (31)	4.9★ (75)	4.9★ (75)

Pilot Study

Descriptions of the Pilot Study

In the pilot study, six lecturers' IEs have been observed and coded with the instrument of the Momentary Time Sampling (MTS) Form (Appendix B). The interval length was set to 10 seconds and the total observation time was more than 5 hours. Three main purposes of the pilot study are: (1) to determine the optimal time interval of MTS for the main study, (2) to check possible obstacles and unexpected issues, and (3) to validate and improve the observation rubric by examining whether the data show reasonable results. Table 6 is the summary of the observed MOOCs and observation time of each course. The course names in this table are all pseudonyms.

Table 6

The Six MOOCs Selected for the Pilot Study

Subject	Course Name	Video Type	Observation Time	# of intervals
Math/CS	Calculus	studio/tablet presentation	66 min 50 sec	401
	Computer Science 101	studio/tablet presentation	33 min 30 sec	201
Natural Science	Biology 101	Classroom recording	58 min 00 sec	348
	Geology 101	studio presentation	53 min 00 sec	318
Humanities /Social Science	Psychology of Learning*	studio/tablet presentation	47 min 30 sec	285
	Financial Economics	Classroom recording	54 min 30 sec	327
Total			5 h 13 m 20 s	1,880

* The 'Psychology of Learning' course was included in the pilot study, but it was replaced by 'Psychology of Happiness' in the main study because the length of lecture videos was fewer than 3 hours.

Procedures of the Pilot Study

For the pilot study, I chose six MOOCs among the 12 MOOCs that have been selected by the procedures described in the previous section. Two math and computer science courses, two natural science courses, and two social science and humanities courses have been selected. Usually, the topic of Week 1 is the overview of the course, so I observed starting from Week 2 lectures. While watching videos, I entered the most appropriate two-letter code in the MTS form every 10 seconds. Occasionally, I had to pause every 10 seconds and spent time to choose the most appropriate code.

Sometimes, I made notes of what the lecturer just spoke or a brief description of the IE. I reorganized and summarized the notes by each code of the rubric and attached in Appendix C. This serves as an educational purpose of the co-observer and as a reference for my future observation. I planned to observe each course for about 50 minutes, but each course's observation times vary because I did not want to stop until I play all the way to the end of a unit lecture. In the pilot study, I am the only observer, so no inter-observer agreement is reported.

After completing data collection, all the codes were gathered in a big spreadsheet. Descriptive statistics such as frequency and proportion of each code were calculated in the SPSS. In order to check whether 20 seconds rather than 10 seconds can be an acceptable interval of MTS, I compared the data in odd rows and even rows.

Findings of the Pilot Study

The first purpose of this pilot study is to determine the optimal time interval. As was discussed in the Observation Research section regarding the discontinued data collection method, a shorter interval does not necessarily guarantee more accurate results (Hanley et al., 2007; Mudford et al., 2009). An optimal length of interval should be determined considering observers' human error and inter-observer reliability. In the pilot study, I set the time interval as short as 10 seconds. If the results of 10-second and

20-second intervals are not so different, I intended to use the 20-second interval for the main research.

In order to compare the two intervals, I divided all the data into two groups (*n* = 940 each). The Odd group consists of the data that were marked at 00:10, 00:30, 00:50 and so on, and the Even group has the data that were marked at 00:20, 00:40, 01:00, and so on. The comparison results show that 27.4% of Odd and Even group data do not match (*n* = 940). The results imply that for more than 1 out of 4 chances, lecturers change their IE instances within 20 seconds. In observation sessions, I also realized that 20 seconds are too long because lecturers were usually speaking three to six sentences in 20 seconds. Assigning only one IE instance at every 20 seconds seemed for me to lose too much information. Although Table 7 shows that the total proportions of each IE instance appear quite similar between the Odd and Even group, differences are almost twice if the proportions are below 5% in case of CA, JQ, MH, and MP. Therefore, I determined the time interval for MTS as 10 seconds.

Table 7

Comparison of Proportions of Each IE Instance (%, n = 940 in each group)

IE Instance	Odd group	Even group	IE Instance	Odd group	Even group
[CA] Application*	2.6	1.3	[MI] Internal Value	3.0	2.1
[CD] Distinguish/Contrast	2.4	2.7	[MP] Personal Feeling*	1.9	0.5
[CE] Example	19.2	19	[MQ] Use a 'Hook"	4.0	4.9

[FA] Analogy	5.4	4.6	[MS] Structuring Explanation	5.3	3.8
[FE] Easy Words	0.8	0.8	[PI] Interpretative Explanation	11.2	9.9
[JC] Causal Explanation	9.9	10.7	[PP] Presenting a learning topic	7.7	8.9
[JF] Factual Explanation	4.8	5.1	[PR] Repeating	3.2	3.4
[JN] Narrative Explanation	7.0	8.3	[SI] Images/Graphic Organizers	1.8	1.9
[JQ] Quote*	3.2	5.4	[SP] Prior Knowledge	4.0	3.4
[ME] External Usability	0.8	1.1	[SQ] Ask Questions	1.9	2.1
[MH] Humor*	0.2	0.0			

* Indicates large difference between the two groups.

The second purpose of the pilot study is to check possible obstacles and unexpected issues. There are three key lessons that I learned in the pilot study.

1. Local backup of the course videos

All of the 12 MOOCs are accessible for free, but some of them set a time period for taking courses, usually three months. In case I cannot complete observation within the period, or I need to watch again, I have to download all the videos and scripts. Fortunately, the MOOC providers let users easily download videos.

2. Need to check the video length beforehand

Initially, I included the 'Psychology of Learning' course in the 12 MOOCs for the main study. In the pilot study, I began to observe it, but I soon realized that the course length was smaller than 3 hours. When I glimpsed the course in the preliminary search phase, it appeared longer than 3 hours, but it turned out that two-thirds of the content was expert interviews, and the length of lecture videos was about 2 hours. The Psychology of Learning's review scores are over 4.8 from the three MOOC websites, and the number of reviewers is about 40,000 altogether. However, observation results of interview videos will be quite different from those of lecture videos. Therefore, I decided to replace the Psychology of Learning with another course in the main study.

3. References for coding

In the observation process, I occasionally had a hard time to decide the most appropriate code. At that time, I made notes to justify my coding and to remain consistency throughout the observation sessions. Sometimes, I was excited when I found high quality explanations, so I made notes to quote in the Discussion and Conclusion chapter of this dissertation. After finishing the pilot test, I decided to reorganize the notes by each code of the rubric. The notes serve as a reference for my future observation as well as an educational manual for the co-observer.

The last purpose of the pilot study is to validate and improve the observation rubric by examining whether the data show reasonable results. In Table 8, proportions of each IE instance by the six courses are presented.

Table 8

Proportions of IE Instances by the Course (%, total = 100%)

		Biology (*n* = 348)	Geology (*n* = 318)	CS (*n* = 201)	Calculus (*n* = 401)	Psychology (*n* = 285)	Economics (*n* = 327)	Total (*n* = 1,880)	
Clarification	CA			**4.9**	0.7	1.9	1.5	1.9	
	CD	4.9	1.1	1.9	1.9	1.5	0.7	2.6	
	CE	12.4	12.4	11.2	**36.0**	**3.4**	14.2	19.1	
	CV							0.0	23.5
Familiarizing	FA	1.5	1.5	2.6	4.1	**13.9**		5.0	
	FE	2.2	0.4	0.7			0.4	0.8	
	FH							0.0	5.8
Justification	JC	6.4	8.6	7.5	**15.7**	**2.2**	7.9	10.3	
	JF	0.7	4.1	0.4		**9.7**	**8.2**	4.9	
	JN	7.9	**17.2**	0.7		7.5	2.6	7.7	
	JQ	**7.1**	**7.5**	0.4		1.9	3.4	4.3	27.2
Motivating	ME	0.4			0.7	0.4	3.0	1.0	
	MH	0.4						0.1	
	MI	1.9	1.1	1.5	1.9	0.7	4.9	2.6	
	MP	1.9	1.9		0.4	0.7	0.7	1.2	
	MQ	5.2	2.6		6.0	3.4	3.7	4.5	
	MS	3.0	1.5	0.4	1.1	4.1	**11.2**	4.5	13.8
Presenting	PI	7.5	6.4	10.1	7.5	9.0	9.0	10.5	
	PP	9.0	8.6	4.9	5.6	5.2	5.6	8.3	
	PR	3.7	2.6	0.4	4.1	3.7	0.7	3.3	22.1
Scaffolding	SD							0.0	
	SI	1.1	1.5	0.4	**5.6**			1.8	
	SP	6.7	0.4	1.5	5.6	0.7	2.2	3.7	
	SQ	3.0		0.7	3.0	1.1	1.5	2.0	7.5

Here are brief discussions on the findings of the pilot study.

1. Some IE instances such as CV (Compare everyday concepts with scientific concepts), FH (Anthropomorphisms and teleological statements), and SD (Demonstration) was not marked at all. MH (Humor) takes only 0.1% of the total lecture hours. These IE instances have been combined with another one in the revised rubric.

2. Some IE instances occur more frequently in a specific subject than another. For example, CE (Examples) is observed about 3 times as frequently in Calculus as in the other courses. Since mathematics teaches abstract concepts, perhaps the lecturer referred to examples more often. Another example is that frequency of JQ (quote) of natural science is much higher than that of the other courses. In the two science courses, both lecturers spent long time to tell stories about 16th to 19th century scholars and theories. Please recall one of the research questions, RQ 1.2: How are IEs different among subjects (math/CS vs. natural science vs. humanities/social science). The results of the pilot study assure that the RQ 1.2 is worth to challenge.

Changes Made after the Pilot Study

Based on the findings and my personal experience of the pilot study, the observation rubric has been revised. The biggest change is that the two categories of the purpose layer, Familiarizing and Clarification, have been combined into one category: Familiarizing. It is quite difficult to differentiate the two purposes; The IE instances in familiarizing and Clarification are used when a lecturer aims to help learners effectively understand the content. In observation sessions, I realized that the IE instances of the two purposes were used in turn to explain a single topic. Thus, I reexamined each instance and reorganized them. Counterexample has been combined to FD

(Contrast/distinguish), and FA (Analogy) and FE (Examples) are now more clearly separated.

Second, PI (interpretative explanation) has been divided into PI (interpretative explanation on the learning topic) and FI (interpretative explanation while presenting analogy, example, or narrative) according to the context where it occurs. In the pilot study, I noticed a lot of times that a lecturer provided interpretative explanations while presenting an analogy, examples, or narratives as well as right after presenting a learning topic (PP). Previous studies (Dagher & Cossman, 1992; Norris et al., 2005; Treagust & Harrison, 2000) did not distinguish interpretative explanations by the context. However, I have decided to separate them because in that way we can better understand instructional explanations and it will be beneficial for MOOC lecturers to improve their lectures.

Third, SI (presenting images/models/concept map/graphic organizers) and SD (demonstration) have been removed from the rubric. In multimedia environment like MOOC, these instructional media are not presented by themselves. Rather, lecturers keep giving verbal explanations over such media. In studio/tablet presentation videos, various types of instructional media are presented from the beginning to the end of a lecture. Consequently, I have decided to focus on verbal explanations.

In Table 9, changes from the original to the revised rubric are summarized. The final observation rubric is presented in Appendix A.

Table 9

Summary of Changes on the Rubric Components After the Pilot Study

New or revised IE instance	Old components	Brief description
Familiarizing	Familiarizing and Clarification	Integration of the two categories
[PI] Interpretative explanation	Part of [PI] Interpretative explanation	Created the new code [FI] [PI] is coded only for interpretative explanation of a learning topic
[JH] History of theories	New. Part of [JN] Narrative explanation and [JQ] cite/quote	[JN]: personal experience, story, anecdote, etc. [JH]: past scholars' quote; old and false theories; quote/cite; meaning and influence of old theories
[FA] Analogy	[FA]-Analogy and [FH]-Anthropomorphisms	Integration of the two
[FE] Examples	Name change of [CE]-Examples	[CE] minus counterexample
[FD] Contrast/distinguish/ counterexamples	Name change of [CD]-Distinguish	[CD] plus counterexample
[FW] Easy word/terms	[FE]-Easy word [CV]-compare Everyday concepts with Scientific concepts	Integration of the two
[FI] Interpretative explanation in analogy, example, or narrative	New. Part of [PI]-Interpretative explanation	[FI] is coded while presenting analogy, example, or narratives
[SE] Scaffolding explanations	New. Part of [MS]-Structuring IE Part of [MI]-Important Points	Emphasize important points of the topic; Study guide; Overview the structure of explanations; Wrap-up of previous explanations
[MP] Personal feeling	[MP]-Personal feeling [MH]-Humor	Only 1 frequency of [MH]; Combined to [MP]
[MN] Introduction to the next topic	New. Part of [MS] -Structuring IE	[MN]-Introduction to the next topic at the END of the lecture
Removed	[SI]-images/graphic organizers [SD]-demonstration	In multimedia environment, other verbal explanations are presented over these media.

Data Collection

The observation rubric is presented in the Appendix A. The rubric has two layers: IE Purpose and Instance. As mentioned earlier, Instances are instructors' observable and explicit activities, whereas Purposes are implicit and inferable intensions of instructors. By distinguishing the two layers, IE instances can be more mutually exclusive and easier to code. Table 10 shows the details of the purposes and instances of the final rubric.

Table 10

Details of the Observation Rubric for the Main Study

Purposes and Instances	Details
Presenting	***IEs for delivering the learning topic***
[PP] Presenting a learning topic	Present a learning topic without additional explanation
[PI] Interpretative explanation on the learning topic	Present the learning topic in different words or provide more details about the learning topic
[PR] Tautology/repeating	Simply repeat the learning topic Cf. Wrap-up -> [SE]
Justification	***IEs for soliciting learners to accept that it is true***
[JF] Factual/statistical explanation	Provide facts or statistical results
[JC] Causal explanation	Explain cause-effect relationships or rational, logical reasons from key axioms; give logical explanation in solving mathematical equations
[JN] Narrative explanation	Present personal experience, story, anecdote, etc.; provide a background knowledge
[JH] History of theory	Present old and false theories, and meaning and influence of old theories; quote/cite of old scholars
Familiarizing	***IEs for familiarizing learners to unfamiliar concepts/ideas***
[FA] analogy	Use analogy such as metaphors, similes, teleological statement, or anthropomorphisms
[FE] Examples/concrete situation	List examples of the learning topic; present an example problem in math; programming examples; concrete situation

[FD] Contrast/distinguish/ counterexamples	Contrast, compare, and distinguish the similarities and differences. Present counterexamples
[FW] Easy word/terms	Explanation on academic/unfamiliar terms; Interpret the scientific jargon/terms into everyday words
[FI] Interpretative explanations	Explain the meaning or relationships to the topic of the analogy/example/narrative while presenting analogy [FA], example [FE], or narrative [JN][JH]
Scaffolding	***IEs for building learners' mental model***
[SP] Connect to prior knowledge	Remind previous learning topic or connect to learner's prior knowledge
[SQ] Question for scaffolding	Ask a question for learners to face impasse or to elicit their understandings after some previous explanations Cf. questions without enough explanations -> [MQ]
[SE] Scaffolding explanations	Emphasize important points of the topic; Study guide; Overview the structure of explanations; Wrap-up of previous explanations
[SA] Application/practice	Present application or practice to overcome mental passivity; must require learners' active processing
Motivating	***IEs to motivate learners to engage/be curious/keep working on the course***
[MQ] Use a 'hook'/question for curiosity	Ask questions or use a 'hook' to raise curiosity and interest before providing enough explanations; ask learner attention
[ME] Benefit/usability	State the (external) benefit/usability of the topic
[MP] Personal feeling	Express personal feeling on the topic
[MN] Introduction to the next topic	Provide overview/raise curiosity of the next topic at the END of the lecture

Appendix B shows the momentary time sampling recording form. Using the rubric, MOOC lecturers' IEs were marked at every 10 seconds. I observed at least 3 hours for each course.

Procedures of data collection

The data collection procedures are similar to that of the pilot study. First, I arbitrarily chose one of the 12 courses. Once I completed observing one course, I moved to another one. There is no rationale in the sequence of course observation. I just chose consecutive courses in different subject areas. For example, once I watched a math/CS course, I observed a humanities/sociology or natural science course for the next one. Usually, the topic of Week 1 is the overview of the course, so I observed starting from Week 2 lectures.

While watching videos, I entered the most appropriate two-letter code in the MTS form every 10 seconds. Occasionally, I had to pause every 10 seconds and spent time to choose the most appropriate code. When necessary, I rewound the lecture video, reconsidered my codes, and revised to more appropriate codes. In many cases, I made notes of what the lecturer just spoke or a brief description of the IE. In this way, I was able to justify my codes and figure out the reason I marked that specific code. All the MOOC videos provided supplementary transcripts on the side of lecture videos. Most of the time, I turned on subtitles and they were quite helpful.

The total running time of lecture videos is 37 hours 34 minutes, but I did not log the actual observation hours. I estimate that at the beginning of observation, it took 5 times longer in observation. In other words, it took about 5 hours to observe and code a 1 hour lecture video. As I am getting experienced, it took about 3 hours for a 1 hour MOOC video.

Data Analysis

In this study, two-letter code was marked every 10 seconds, so all the collected data are nominal type and sequential. In order to summarize the data, descriptive statistics such as frequency and rate were presented. In order to find patterns of sequences and to compare different groups, sequence analysis (Fasang & Liao, 2014; Gabadinho et al., 2010) was applied using the statistics package R. In Table 11, data analysis methods for each of the research questions are summarized.

Table 11

Summary of Data Analysis Methods

Research Question	Data Analysis Method
1. What are the components of an effective IEs in MOOCs?	
1.1 How often is each type of IEs used in MOOCs?	Descriptive statistics of total observation data (Frequency/rate)
1.2. How are IEs different among subjects (math/CS vs. natural science vs. humanities/social science) in MOOCs?	Comparison of frequency and rate of each IE instance
1.3 How are IEs different among video production types (Studio vs. Tablet vs. Classroom) in MOOCs?	Comparison of frequency and rate of each IE instance
2. What are the typical patterns of an IE sequence in MOOCs?	Descriptive statistics (Frequency/rate) Sequence Analysis using R.
3. How are the different types of IEs used in one-unit MOOC lecture?	Descriptive statistics (Frequency/rate) Sequence Index Plot of unit lectures

Reliability Test

Another coder observed the MOOC videos and coded IE instances in addition to the researcher. The second coder has a masters' degree in Instructional Systems Technology and has more than five years of experience of instructional design for college level online courses. The coder has been trained by coding IE instances together with the researcher for about 10 hours. Then, the coder independently coded total three courses. The courses have been selected randomly from each of the three subject areas. The total duration of the videos that the second coder observed is 1 hour 53 minutes (Number of codes: 680 = 5.0% of the total observation hours).

The result shows an overall agreement of 76.1% and Cohen's (1968) Kappa coefficient of 0.73 ($z=67.7$, $p < .001$), which indicates Substantial agreement (Landis & Koch, 1977). Two major discrepancies were observed. First, there is an issue involving PP and SE codes. It was not clear how to distinguish "presenting a main topic" (PP) from "overview of instructional explanations" (SE), particularly at the beginning of a lecture. The second issue is related to FI and FE/FD codes. It appears that familiarizing explanations using examples (FE) and comparison (FD) can be confused with interpretative explanations (FI). To avoid this discrepancy, careful attention to IE instances is needed in logging the observation rubrics.

Terms in This Study

- IE Code: 20 IE instances in the rubric. IE component and IE instance are also used interchangeably (See Appendix A and C).

- IE Category: Five categories of the IE purpose layer – *Presenting, Justification, Familiarizing, Scaffolding*, and *Motivating*.

- Subjects: Three subject areas of the observed MOOCs - math/computer science (*MCS*), natural science (*Sci*), and humanities/social science (*HuSo*)

- Video production types: Three types of MOOC videos:

  - Studio recording (*Studio*) - No audience; Recording in a studio with or without a whiteboard; Abundant of background images/videos while the lecturer is speaking.

  - Tablet presentation (*Tablet*) – No audience. Main screen is teacher's PPT presentation or electronic tablet writing. Limited background images/videos.

  - Classroom lecture (*Classroom*) – Student presence. Recording actual classroom lectures. A typical college classroom lecture is long (60 to 90 minutes), so videos are cut to 3 or 4 clips. However, they tend to be longer than the lecture videos of Studio or Tablet type.

- Unit lecture: individual lecture video.

It is important to point out that a typical MOOC course consists of dozens of separate lecture videos. One of the observed MOOCs contained more than 200 short videos, which is unusual. The durations of these video lectures vary; usually 5 to 15 minutes, but much shorter and longer ones also exist.

CHAPTER 4: RESULTS

This chapter describes results from statistical analyses for these research questions:

- RQ1. What are the components of an effective Instructional Explanations (IE) in MOOCs?
    - RQ1.1 How often is each type of IEs used in MOOCs?
    - RQ1.2. How are IEs different among subjects (math/CS vs. natural science vs. humanities/social science) in MOOCs?
    - RQ1.3. How are IEs different among video production types (Studio vs. Tablet vs. Classroom) in MOOCs?
- RQ2 What are the typical patterns of an IE sequence in MOOCs?
- RQ3 How are the different types of IEs used in unit MOOC lectures?

In RQ1, descriptive data and comparison results are presented. The statistical results are frequency of IE components and comparison data of IE categories among three subjects and three video production types. In RQ2, the patterns of 3-code IE sequences are mainly explored. In RQ3, changing patterns of IEs are examined at the beginning and ending of individual MOOC lecture videos. The most frequent opening and closing 2-code patterns are also presented.

Descriptive Data

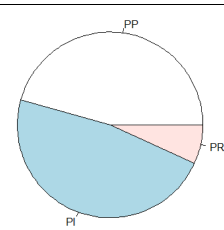
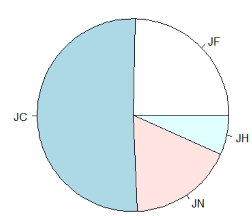
Frequency of IE Codes

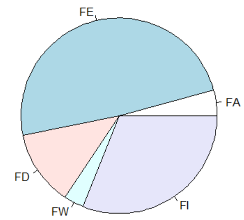
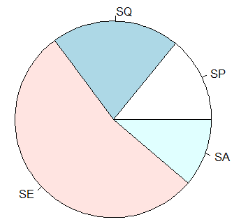
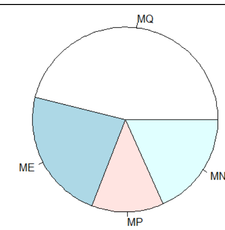
RQ1.1 How often is each type of IEs used in MOOCs?

As described in the previous chapter, 12 MOOC courses were observed for average 3.13 hours per course. One of 20 IE codes was marked at every 10 seconds. Total number of codes are 13,524 (= 135,240 seconds = 2,254 minutes = 37 hours 34 minutes). Table 12 summarizes frequency and proportion of the 20 codes.

Table 12

Frequency and Proportion of the 20 Codes

Category	Code	n	%	
Presenting n=2254 **16.7%**	PP	1030	7.6%	
	PI	1070	7.9%	
	PR	154	1.1%	
Justification n=4314 **31.9%**	JF	1062	7.9%	
	JC	2202	16.3%	
	JN	761	5.6%	
	JH	289	2.1%	
Familiarizing n=3282	FA	139	1.0%	
	FE	1606	11.9%	

24.3%	FD	412	3.0%	
	FW	107	0.8%	
	FI	1018	7.5%	
Scaffolding n=2965 **21.9%**	SP	418	3.1%	
	SQ	623	4.6%	
	SE	1593	11.8%	
	SA	331	2.4%	
Motivating n=709 **5.2%**	MQ	327	2.4%	
	ME	163	1.2%	
	MP	89	0.7%	
	MN	130	1.0%	
		13524	100%	

Among the five categories, Justification was most frequently used (31.9%) followed by Familiarizing (24,3%), Scaffolding (21,9%), and Presenting (16.7%). Motivating was least frequently used (5.2%).

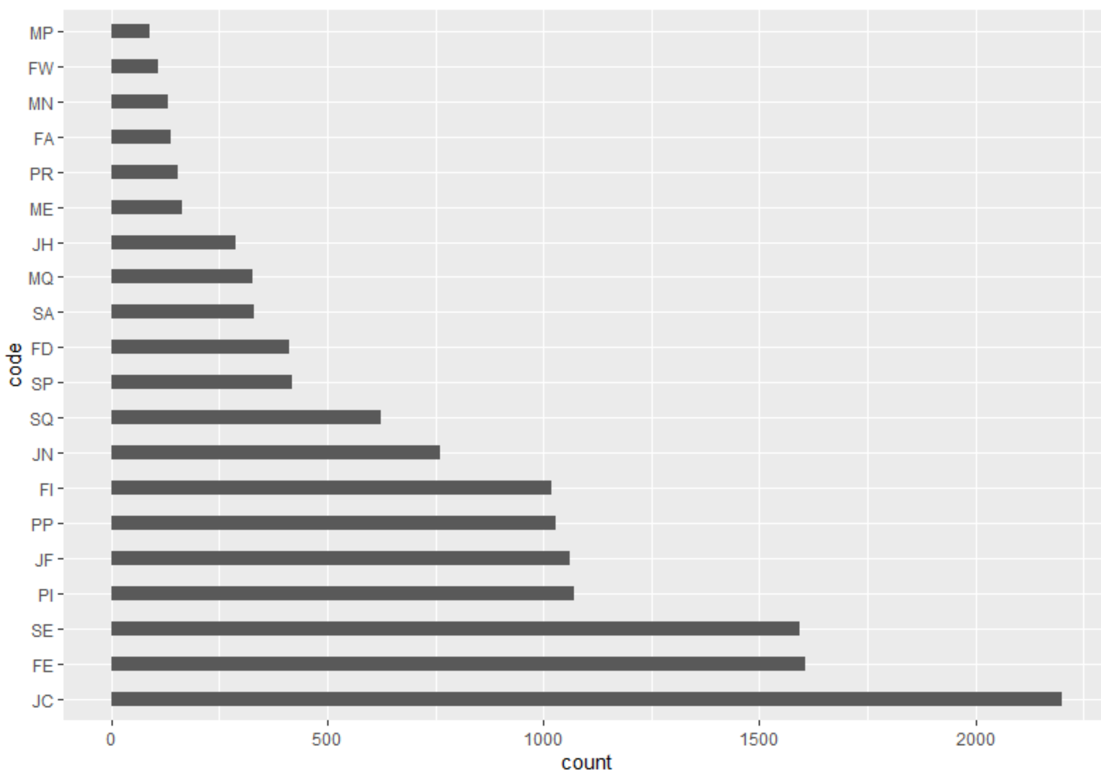
In each category, the most dominant IE code took about 50%; PI (47.5%) in Presenting, JC (51.0%) in Justification, FE (48.9%) in Familiarizing, SE (53.7%) in Scaffolding, and MQ (46.1%) in Motivating.

The frequencies of the 20 IE codes are orderly presented in Figure 1. Among the 20 IE codes, top 3 most frequent codes were JC (Causal explanation, 16.3%), FE (Example/concrete situation, 11.9%), and SE (Scaffolding explanation, 11.8%). Top 3 least frequent codes were MP (Personal feeling, 0.7%), FW (Easy word/terms, 0.8%), and

MN (Introduction to the next topic, 1.0%). In other words, for a 10-minute MOOC lecture video, an average MOOC lecturer would spend about 1m 40s in providing causal explanation (JC); 1m 10s in providing examples (FE); 1m10s in overviewing the following explanations, emphasizing important points, and wrapping up (SE).

Figure 1

Frequency Chart of the 20 Codes

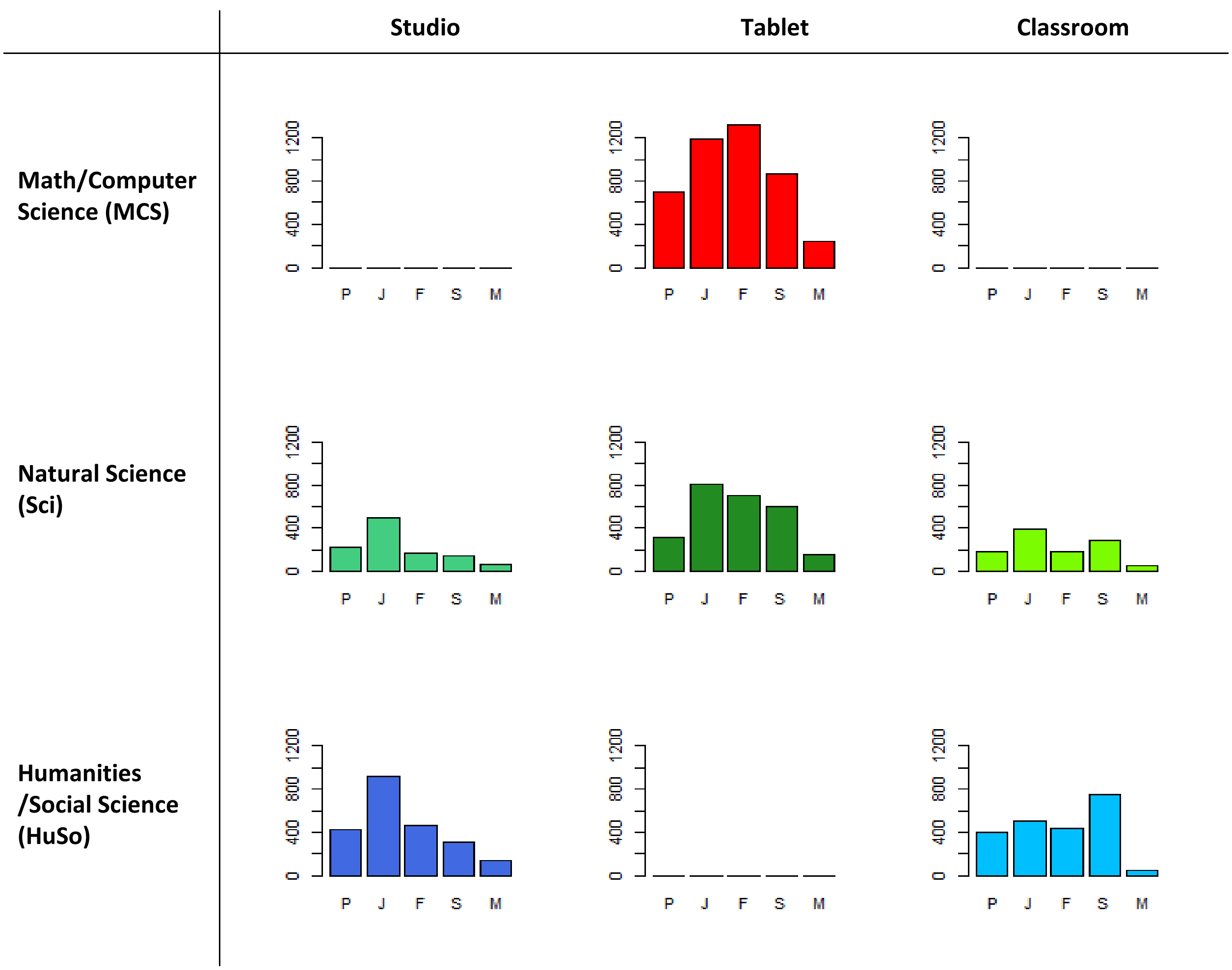


IE Code Distribution Among Three Subjects and Three Video Production Types

Figure 2 shows how the five categories are differently distributed among three subjects and three video production types of this study. Natural science (Sci) courses were delivered in all three production types. All four math/computer science (MCS) courses utilized only tablet presentation, whereas humanities/social science (HuSo) courses did not use tablet presentation.

Figure 2

Comparison of Five Categories Among Three Subjects and Three Video Production Types



It is visually noticeable that Familiarizing was the most frequent in MCS and Justification was the most frequent in Sci. Among the three production types, Justification was the most frequent in Studio type, and Scaffolding was relatively the most frequent in Classroom type. In the next two sections, frequencies and statistical significance will be presented in detail.

Comparison of Three Subjects

RQ1.2. How are IEs different among subjects (math/CS vs. natural science vs. humanities/social science) in MOOCs?

Table 13 shows frequency of five categories in three subject areas. A Chi-square test of independence was performed to examine the relation between category and subject. The relation between these variables was significant, X^2 (df = 8, N = 13,524) = 199.89, $p < .001$.

Table 13

Frequency and Percentage of Five Categories in Three Subjects

	Presenting		Justification		Familiarizing		Scaffolding		Motivating		Total	
Math/CS	696	16.1%	1184	27.5%	**1318**	**30.6%**	869	20.2%	243	5.6%	4310	100%
Natural Science	725	15.1%	**1697**	**35.5%**	1056	22.1%	1030	21.5%	278	5.8%	4786	100%
Humanities/Social Science	833	18.8%	**1433**	**32.4%**	908	20.5%	1066	24.1%	188	4.2%	4428	100%

Note: In case squared standardized Pearson residuals are greater than 9.0, the cells are colored.
Blue: significantly greater number is observed than expected.
Red: significantly smaller number is observed than expected.

Bold: the biggest number in each subject area.

It was found that the most frequently used category was different by subject areas. Familiarizing was the most frequent category in MCS, whereas Justification was the most frequent category in Sci and HuSo. Though Justification was the most frequent in HuSo, the Chi-square test indicated that Presenting and Scaffolding were significantly frequent in HuSo compared to the other two subject areas.

In order to investigate different uses of IE codes by subject areas, detailed analyses were performed in IE code level. In particular, Justification was the most frequently used category both in Sci and HuSo. Then, is there any difference in specific IE code use? In Table 14, JC (Causal explanation, 50.0%) was the most frequent code in Sci, whereas JF (Factual/Statistical explanation, 44.1%) in Huso. Moreover, JC (18.2%) in HuSo was the third frequent code next to JN (Narrative explanation, 29.0%). Notably, JC in MCS took 92.3% and was extremely dominant. That is to say, other justification explanations except for JC were rarely used in MCS.

Table 14

Frequency and Proportion of Justification Category in Three Subjects

	JF		JC		JN		JH		Total	
Math/CS	32	2.7%	**1093**	**92.3%**	47	4.0%	12	1.0%	1184	100%
Natural Science	398	23.5%	**848**	**50.0%**	298	17.6%	153	9.0%	1697	100%
Humanities/Social Science	**632**	**44.1%**	261	18.2%	416	29.0%	124	8.7%	1433	100%

Bold: the highest frequency in each subject area.

Comparison of Three Video Production Types

RQ1.3. How are IEs different among video production types (Studio vs. Tablet vs. Classroom) in MOOCs?

Table 15 shows frequency of five categories in three video production types. A chi-square test of independence was performed to examine the relation between category and production type. The relation between these variables was significant, X^2 (df = 8, N = 13,524) = 641.08, p < .001.

Table 15

Frequency of Five Categories in Three Video Production Types

	Presenting		Justification		Familiarizing		Scaffolding		Motivating		Total	
Studio	650	19.3%	**1419**	**42.2%**	640	19.0%	452	13.4%	203	6.0%	3364	100%
Tablet	1010	14.6%	1998	28.9%	**2026**	**29.3%**	1466	21.2%	405	5.9%	6905	100%
Classroom	594	18.2%	897	27.6%	616	18.9%	**1047**	**32.2%**	101	3.1%	3255	100%

Note: In case squared standardized Pearson residuals are greater than 9.0, the two greatest cells are colored.

Blue: significantly greater number is observed than expected.

Red: significantly smaller number is observed than expected.

Bold: the biggest number in each video production type.

Different from the Table 13, Table 15 shows that the video production types were unevenly distributed. The total number of tablet type was twice bigger than the other two types. Thus, a Chi-square test of Independence resulted in that the majority of squared standardized Pearson residuals were greater than 9.0. In Table 15, the two greatest squared standardized Pearson residuals are colored in each type. Bold numbers are simply the biggest number in each video production types.

It was notable that the most frequently used category was all different by production type. Justification was the most frequent category in Studio type, Familiarizing in Tablet type, and Scaffolding in Classroom type. The red cells - Scaffolding in Studio type, Justification in Table type, and Familiarizing in Classroom type were not the least frequent category; they were significantly less frequent category compared to the other two production types based on the Chi-square test.

Extra care is required in interpreting this result. As was shown in Figure 2, video production type and subject areas are compounded. Nearly 3/4 of Tablet types are MCS courses; Studio and Classroom types include only Sci and HuSo courses. This issue will be discussed in detail in the next chapter.

IE Patterns

RQ2 What are the typical patterns of an IE sequence in MOOCs?

In the previous section, results focused on the occurrence of individual IE category and code. In this section, sequence of IE codes is of interest in order to explore typical IE patterns of efficient MOOC lecturers.

Analysis Method

In order to investigate sequence of IE codes, sequential analysis has been performed (Bakeman & Gottman, 1986). The basic algorithm of sequential analysis is to search 2 to 5-code patterns from a string of sequential codes. To avoid repeating the same code in a row, consecutive serial events were merged. For example, assume the following is a series of IE codes (total 11 codes):

PP, PP, PP, PI, SE, SE, MQ, MQ, MQ, FE, FE

Duplicate events are deleted as follows:

PP, ~~PP, PP~~, PI, SE, ~~SE,~~ MQ, ~~MQ, MQ~~, FE, ~~FE~~

Then only these non-consecutive codes remain as follows:

PP, PI, SE, MQ, FE

As a result, total 5 codes (not 11 codes) are used to generate these patterns:

- 2-code patterns: PP>PI, PI>SE, SE>MQ, MQ>FE
- 3-code patterns: PP>PI>SE, PI>SE>MQ, SE>MQ>FE

- 4-code patterns: PP>PI>SE>MQ, PI>SE>MQ>FE

In the previous section, the total number of single IE codes were 13,524. After deleting duplicate consecutive codes, total 5,635 of 2-code patterns were obtained. The total number of 3-, 4-, and 5-code patterns were 5,395, 5,155, and 4,916, respectively.

Most Frequent Patterns

Table 16 shows top 20 of 2- to 5-code patterns. The most frequent 2-code pattern is PP>PI which is about 4.3% of the total 5,635 and the next one is FE>FI (3.1%). The most frequent 3-code pattern is PP>PI>FE which is about 1.1%.

Table 16

Frequency of Top 20 Patterns (2-, 3-, 4- and 5-Code Patterns)

	2	N	3	N	4	N	5	N
1	PP>PI	245	PP>PI>FE	58	SQ>SA>SQ>SA	25	SQ>SA>SE>SQ>SA	17
2	FE>FI	175	PP>PI>PP	46	PP>PI>PP>PI	22	SQ>SA>SQ>SA>SE	13
3	SE>PP	135	PP>PI>SE	46	FE>FI>FE>FI	21	SA>SE>SQ>SA>SE	12
4	FI>SE	106	SE>PP>PI	44	SA>SE>SQ>SA	21	SQ>SA>SQ>SA>SQ	12
5	JC>SE	103	FE>FI>SE	43	SQ>SA>SE>SQ	19	SA>SQ>SA>SQ>SA	11
6	SE>FE	103	FE>FI>FE	41	PP>PI>FE>FI	17	SE>SQ>SA>SQ>SA	11
7	PP>FE	100	PI>PP>PI	39	SA>SQ>SA>SE	14	JC>SQ>JC>SQ>JC	9
8	PI>FE	99	SE>FE>FI	36	SE>SQ>SA>SE	14	SE>SQ>SA>SE>SQ	9
9	JC>FI	90	JN>JF>FI	34	PI>PP>PI>FE	13	SA>SE>SQ>SA>SQ	8
10	PI>SE	89	SQ>SA>SE	32	SA>SQ>SA>SQ	12	SA>SQ>SA>SE>SQ	8
11	JF>FI	86	FE>JC>FI	30	SE>PP>PI>SE	12	SQ>JC>SQ>JC>SQ	8
12	JN>JF	84	FI>FE>FI	30	SQ>JC>SQ>JC	12	FE>FI>FE>FI>FE	7
13	PP>JF	83	JC>SQ>JC	30	FE>JC>FI>SE	11	FI>FE>FI>FE>FI	7
14	FE>JC	82	PI>FE>FI	29	FI>FE>FI>FE	11	JN>JF>FI>JN>JF	7
15	SE>JC	81	SA>SE>SQ	27	JF>FI>JN>JF	11	PP>PI>PP>PI>FE	7
16	SQ>JC	79	SE>SQ>SA	27	SE>SQ>SA>SQ	11	FE>FI>FE>FI>SE	6

17	FE>SE	75	SA>SQ>SA	26	JC>SQ>JC>SQ	10	JN>JF>JN>JF>FI	6
18	PP>JC	75	SQ>SA>SQ	26	JF>JN>JF>FI	10	PP>PI>SE>PP>PI	6
19	PI>PP	72	JC>FI>SE	25	JN>JF>JN>JF	10	SE>PP>PI>PP>PI	6
20	SE>SQ	70	SE>JC>SE	25	FE>FI>SE>FE	9	FE>JF>FE>JF>FE	5

In Search of Valid 3-Code Patterns

In sum, the sequential analysis revealed that: (1) the top 20 2-code patterns were used about 1 to 4% each, and (2) as patterns became longer (3-, 4-, and 5-code patterns) no dominant pattern was found. All of the 3+ patterns were less than 1% except for the most frequent 3-code pattern PP>PI>FE. These low frequencies perhaps discourage practical use of 3+ code patterns of this study. That is the first reason that I will show a loose overview of IE patterns in this section.

The second reason is that the conditional probabilities of 2-code patterns are high enough to give attention. Conditional probability is the likelihood of an event based on the occurrence of a previous event (See Frick et al., 2021). For example, the simple probability of PP>PI pattern is 4%, but the conditional probability of P(PI|PP) is 245 / 752 = 32.6%. This means that once PP occurred, the probability of the occurrence of PI as a next event is 32.6%. In other words, once an instructor presents a main topic (PP), interpretative explanations (PI) follow right after PP in one out of three cases. These high conditional probabilities of 2-code patterns support the usefulness of the five themes of 3-code patterns.

The third reason is that the variations of IE patterns are extremely common in real life. Even if an effective instructor attempts to stick to an exemplary IE pattern, actual IE patterns in classes would be quite different by adding, omitting, and/or repeating specific codes (Griggs, 2001; Ozmen, 2011; Stodolsky, 1988). As shown in Table 16, counting 'exact' match distinguishes all the variations of similar patterns. Sticking to exact matches has the risk to underestimate and easily lose important information of the sequential analysis results.

Therefore, in Figure 3, the five themes of 3-code patterns are presented as a loose overview of IE patterns. These are different from the top 20 3-code patterns in Table 16. Here is the method how the five themes have been generated:

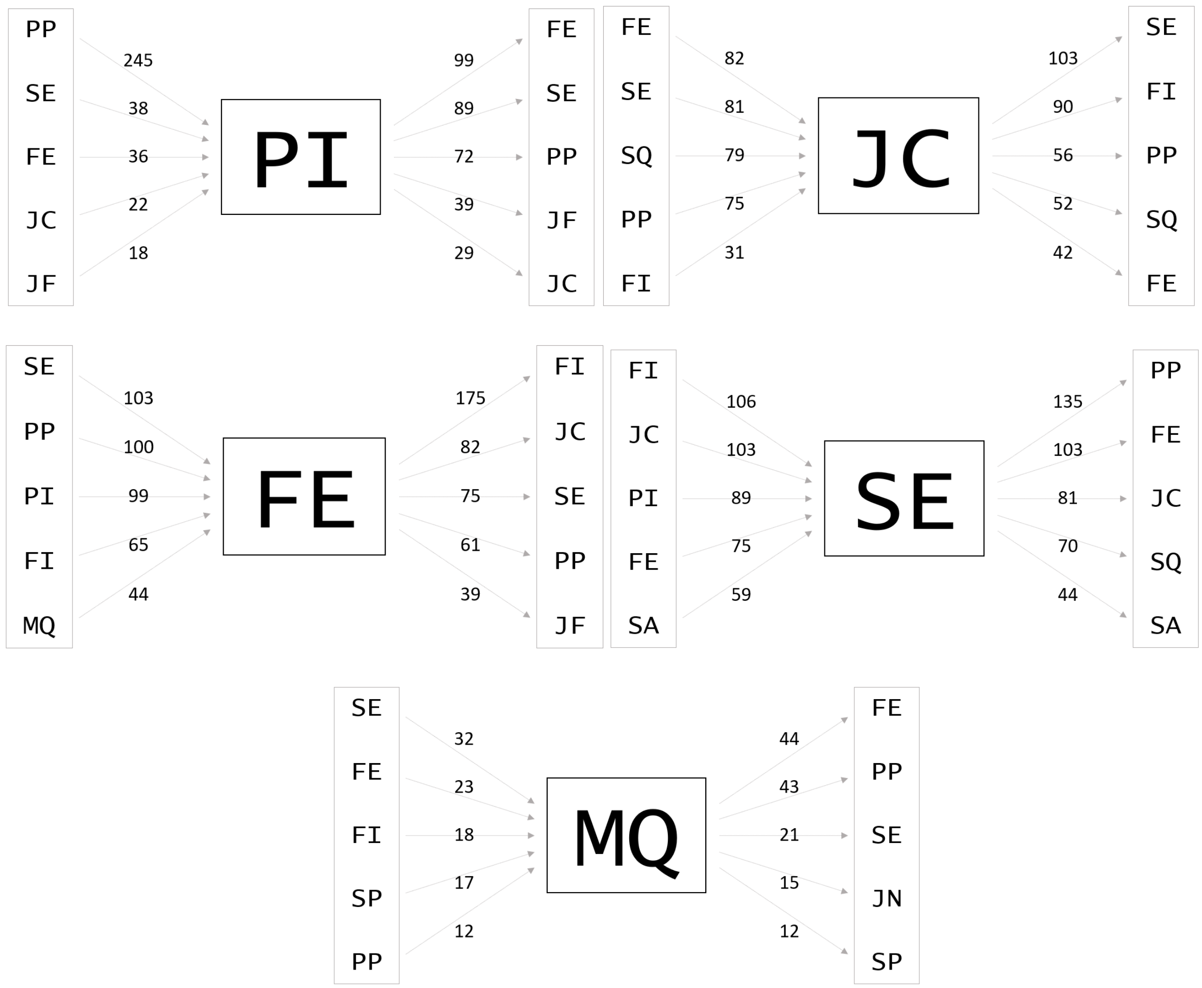
1. Five main codes have been selected from the five categories. Each main code is the most frequently used code from each category.

2. Based on the frequency of 2-code patterns, top 5 codes that come *before and after* the main code have been listed.

3. The frequencies of 2-code patterns have been denoted on the arrows.

Figure 3

Five Themes of 3-Code Patterns



Note: the numbers in the figure are the frequencies of individual 2-code patterns.

Here is how to read the figure. For example, please focus on the main code PI of the first figure. The figure shows that the frequency of PP>PI and PI>FE pattern is 245 and 99, respectively. Please note that the figure does not necessarily mean that the exact PP>PI>FE pattern is the most frequent. Again, the frequencies in figure 3 are all based on 2-code patterns. However, PP>PI>FE pattern is worth attention because this 3-code combination is generated based on the two separate top 2-code patterns: PP>PI and

PI>FE. Although we see only 58 cases of 3-code pattern of PP>PI>FE in Table 16, we can assume that a lot of variations rooted on this IE sequence exist such as PP>PI>SE (46 cases – replaced FE with SE) and PP>FE>FI (23 cases – omitted PI). Detailed discussion on the five themes will be presented in Chapter 5. The discussion will include variations/extensions of each theme and examples of IE sequences from the MOOC lectures.

Sequence Analysis in Unit Lectures

RQ3 How are the different types of IEs used in unit MOOC lectures?

A unit lecture refers to an individual lecture video of a course. It is important to point out that a typical MOOC course consists of dozens of separate lecture videos. The durations of these video lectures vary; usually 5 to 15 minutes, but much shorter and longer ones also exist. Each lecture video in MOOCs is a complete short lecture. In other words, in a unit lecture, a lecturer begins with opening words, provides instructional explanations on main topic(s), then finishes with closing words. This is also true for classroom recordings which are the results of cutting a long (60-75 minutes) classroom recording.

In this section, we will see sequences of IE components as time flows. Main questions are: How are IE components increasing or decreasing as a lecture progresses? What IE components are mostly used at the beginning and ending of unit lectures?

To answer the questions, total 13,524 observed IE codes were grouped by unit lecture. Total number of unit lectures was 240, and the average length of unit lectures was 9.40 minutes (minimum: 1.48 and maximum 29.15). In order to find how IE components were changing as lecture progresses, the first and the last 3 minutes of unit lectures were analyzed. Among the 240 unit lectures, those lectures that are less than 6 minutes have been excluded in this analysis because if a unit lecture is too short, the 3-minute slice includes both beginning and ending parts of the lecture. As a result, total 176 unit lectures were analyzed. The distribution of the 176 unit lectures among three subject areas and three video production types are presented in Table 17.

Table 17

Descriptive Data of the Unit Lectures Longer Than 6 Minutes (Frequency and Mean Length)

	Studio	Tablet	Classroom	Total	Mean length of unit lectures (in minutes)
Math/CS	.	50	.	50	11.3
Natural Science	17	34	15	66	11.9
Humanities/ Social Science	34	.	26	60	10.9
Total	51	84	41	176	
Mean length of unit lectures (in minutes)	9.7	11.9	12.6		

Beginning of Unit Lectures

Figure 4 shows how the five categories of IEs are changing as lecture flows for the first 3 minutes (=18 codes). Scaffolding and Motivating are sharply decreasing, whereas Justification and Familiarizing are increasing as lecture progresses.

Figure 4

State Distribution Plot of IE Sequences for the First 3 Minutes (n=176).

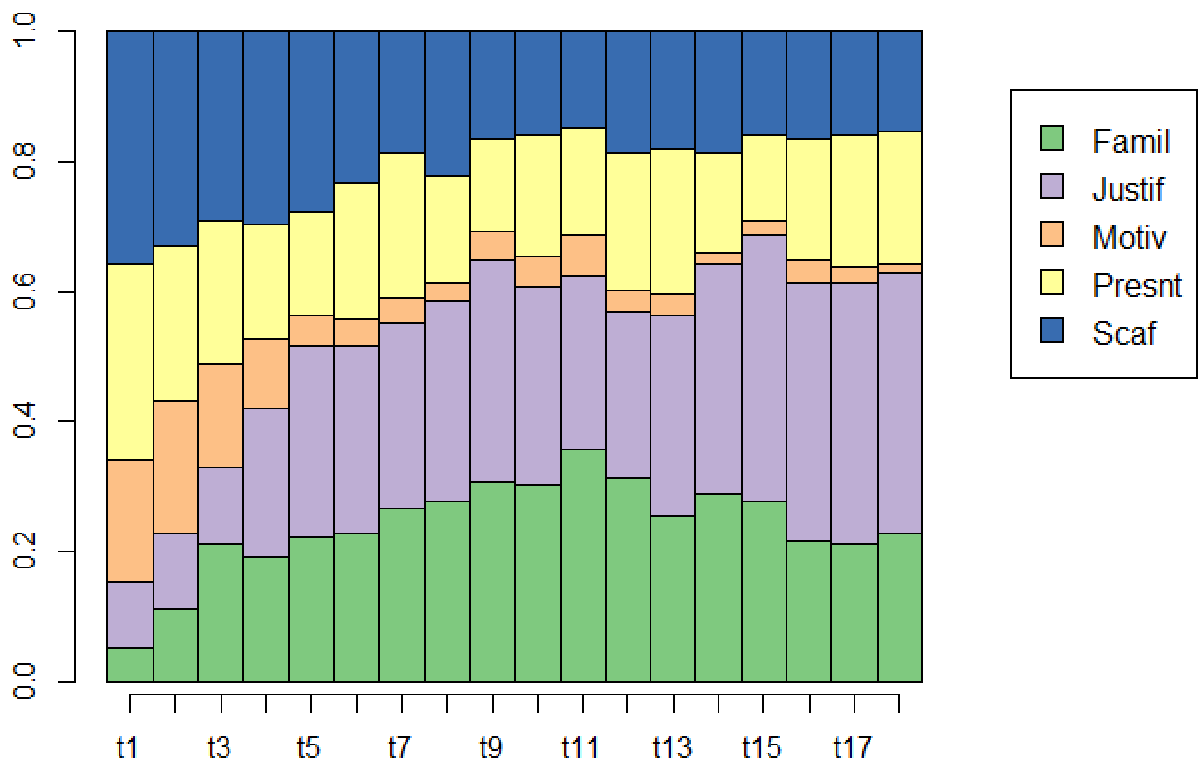


Table 18 compares frequencies at the beginning (t=1) and after 3 minutes (t=18). The sum of Scaffolding and Motivating is 55% at the beginning. It means that about 55% of unit lectures begin with either scaffolding or motivating explanations, whereas the use of those two categories after 3 minutes is decreased to 16%. The second most frequent category at the beginning is Presenting (30%). We see that 30% of unit lectures begin without warming up or opening words.

Table 18

Frequency of Five Categories at the Beginning (t1) and After 3 Minutes (t18)

	t1		t18	
Scaffolding	63	36%	27	15%
Presenting	53	30%	36	20%
Motivating	33	19%	2	1%
Justification	18	10%	71	40%
Familiarizing	9	5%	40	23%
Total	176	100%	176	100%

In order to identify exact IE codes at the beginning, the most frequent IE codes have been examined. Table 19 shows that more than 90% of unit lectures begin with one of the top 5 IE codes. Lecturers tend to begin a unit by presenting a main topic (PP), connecting to prior knowledge (SP), using a 'hook,' or questioning for curiosity (MQ), overviewing the structure of the following explanations (SE), or providing narrative explanations (JN).

Table 19

Top 5 IE Codes at the Beginning

Codes (t = 1)	n	%

PP	53	30%
SP	42	24%
MQ	31	18%
SE	19	11%
JN	15	9%
Total	157	90.9% (of all 176 cases)

Table 20 shows 10 mostly used 2-code opening patterns. The top 5 codes in the second place are highlighted in the table. It is no wonder that all of the first-place codes are the top 5 codes. In addition, 9 out of 11 second-place codes are the top 4 codes except for JN. It is inferred that at the beginning of a lecture, top 5 IE instances are used regardless of an order, and the top 5 IE instances consist of the majority of opening words.

Table 20

Top 10 Opening Patterns (Total = 176)

	Pattern	n
1	SP>MQ	12
	SP>SE	12
3	PP>PI	11
4	SP>PP	10
5	MQ>SE	9
	PP>FE	9
7	MQ>PP	8
	PP>SP	8
9	JN>PP	7
10	PP>SE	6
	SE>SP	6

Note: top 5 opening IE codes in the second place are highlighted.

Ending of Unit Lectures

Figure 5 shows how the five categories of IEs are changing as lecture flows for the last 3 minutes (=18 codes). As MOOC lectures are approaching to an end, Scaffolding and Motivating are sharply increasing, whereas Presenting, Justification, and Familiarizing are all decreasing.

Figure 5

State Distribution Plot of IE Sequences for the Last 3 Minutes (n=176).

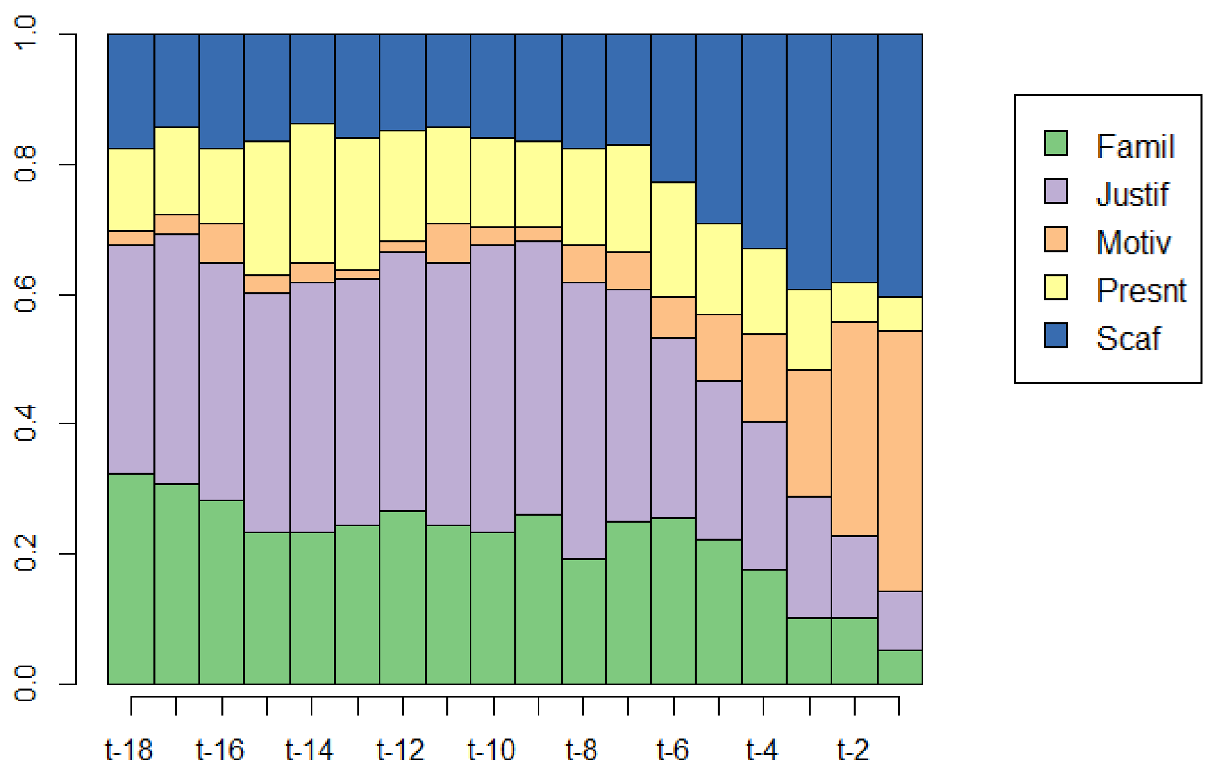


Table 21 compares frequencies at 3 minutes before ending (t= -18) and at the end (t= -1). The sum of Scaffolding and Motivating is 80% at the end. It means that about

80% of unit lectures close with either scaffolding or motivating explanations, whereas the use of those two categories 3 minutes ago is only 20%.

Table 21

Frequency of Five Categories at 3 minutes Before Ending (t-18) and at the End (t-1)

	t-18		t-1	
Scaffolding	31	18%	71	40%
Presenting	22	13%	9	5%
Motivating	4	2%	71	40%
Justification	62	35%	16	9%
Familiarizing	57	32%	9	5%
Total	176	100%	176	100%

In order to identify exact IE codes at the end, the most frequent IE codes have been examined. Table 22 shows that about 80% of unit lectures close with one of the top 5 IE codes. Lecturers tend to close a unit by introducing the next topic (MN), wrapping up or emphasizing important points (SE), providing practice questions (SA), pointing benefit/usability (ME), or asking questions for curiosity (MQ).

Table 22

Top 5 IE Codes at the End

Codes (t = -1)	**n**	**%**
MN	45	26%
SE	37	21%
SA	32	18%
ME	15	9%

MQ	8	5%
Total	134	77.8% (of all 176 cases)

Table 23 shows 10 mostly used 2-code closing patterns. This time, it is no wonder that the top 5 codes dominantly appear at the second places, so I want to focus on the first places (highlighted). Only 3 out of the top 5 closing codes are found in the first places. The other two codes, MN and SA, occur only at the last places and hardly used in other places.

Table 23

Top 10 Closing Patterns (Total = 176)

	Pattern	n
1	SE>MN	22
2	SE>SA	14
3	FI>SE	10
4	JF>SE	6
5	MQ>SA	5
	PI>SE	5
	SE>MQ	5
8	ME>MN	4
	SE>ME	4
10	JC>SE	3
	JF>FI	3
	PP>SA	3
	PP>SE	3
	SQ>MN	3

Note: top 5 closing IE codes in the first place are highlighted.

CHAPTER 5: DISCUSSION

This chapter discusses evaluation of the study rubric and statistical results of the observation data. In addition, exemplary instructional explanation (IE) patterns and particular IE patterns at the beginning and ending of unit lectures will be discussed.

Frequency of IE Codes

Evaluation of the Study Rubric

The results show that Justification is most frequently used (31.9%) followed by Familiarizing (24,3%), Scaffolding (21,9%), and Presenting (16.7%). Motivating is least frequently used (5.2%) among the five categories. Among the 20 IE codes, Top 3 most frequent codes are JC (16.3%), FE (11.9%), and SE (11.8%). Top 3 least frequent codes are MP (0.7%), FW (0.8%), and MN (1.0%).

It is noteworthy that all 20 IE codes have been observed although their frequencies are uneven. This is a supporting evidence for the validity of the study observation rubric that has been newly developed for this research. Table 24 summarizes relationships of the study rubric and other researchers' rubrics that were discussed in the literature review chapter.

Table 24

Comparison of Study Rubric and Previous Research Rubrics

		Dagher & Cossman (1992)	Treagust & Harrison (2000)	Geelan (2013)	Others
Presenting	**PP**		Axiom		
	PI		Complete or comprehensive		Interpretative (Norris et al., 2005)
	PR	Tautological			
Justification	**JF**	Rational	Deductive-statistical Inductive-statistical		
	JC	Mechanical	Causal	Deliver in symbols and equations format	Causal (Norris et al., 2005)
	JN	Metaphysical	Deductive-nomological Empirical Vignettes		Narrative (Norris et al., 2005)
	JH	Functional Genetic		Storytelling of history of science	
Familiarizing	**FA**	Analogical Anthropomorphic Teleological	Human action Anthropomorphism Teleology Analogy Metaphor	Analogies	Analogy (Brown & Clement, 1989; Glynn et al., 2007; Nashon, 2004; Thagard, 1992; Wong, 1993)
	FE	Practical		Concrete examples Demonstration Diagram	
	FD				Comparison and contrast (Roelle & Berthold, 2016)
	FW				
	FI		Complete or comprehensive		Explanatory unification (Norris et al., 2005)
Scaffolding	**SP**			Link to prior knowledge/experience	
	SQ				Learner impasse and misunderstanding (Rittle-Johnson et

				al., 2017; Sánchez et al., 2009)
	SE			
	SA			
Motivating	**MQ**	Imagination	Appeal to the idea or imagination	'hook' to interest students (Baecher et al., 2013)
	ME		Attention to the requirements of success in exams	
	MP		Humor	Humor (Wanzer et al., 2010)
	MN			

Table 24 above shows that almost all the IE codes are closely related to previous studies except for these 4 codes: FW, SE, SA, and MN. Particularly, FW (Easy word/terms) and MN (Introduction to the next topic) are the second and the third least frequent codes. For the future revision of the study rubric, perhaps it is reasonable to combine FW into PI and FI since interpretative explanations can include explanations on academic and unfamiliar terms.

Although the frequency of MN is quite low, this is an important IE instance because introducing and raising curiosity of the next topic motivates learners to keep working on next MOOC videos. Compared to traditional face-to-face teaching, the length of MOOC videos is relatively short. Students prefer MOOC videos that are less than 15 minutes (Berg et al., 2014). In a large-scale study that used data from 6.9 million video watch sessions, Guo et al. (2014) recommends that the length of MOOC videos should be less than 6 minutes. Considering that MOOC lectures are divided into short videos, it is understandable that MN is more frequently presented than in traditional lectures. Additionally, it is reasonable to newly add MN code which was not covered in previous rubric research.

In the rubrics of previous research, SA (Application/practice) has not been counted. One reason would be those studies focused only instructors' instructional explanations to come up with their rubrics. In my pilot study, some MOOC videos' production type was classroom recording, and those videos included learners' participation. In addition, some MOOC lecture videos provided pop-up quizzes so that learners needed to pause and answer the quiz. Thus, SA code had to be added to capture those instances.

Lastly, no previous studies proposed an IE instance compatible with SE (Scaffolding explanation). Interestingly, SE is one of the top 3 frequent codes in this study (11.8%). Scaffolding explanation helps learners to build their own mental model while watching MOOC videos by instructors' overviewing the structure of the following long explanations, wrapping up previous long explanations, emphasizing important points of the topic, and providing study guide. My impression in observing a variety MOOC videos is that SE is an essential IE code for an effective instructor. Various use of SE will be discussed in detail in the following section, Noteworthy IE Patterns and Examples – Five Themes.

Discussion on Frequency of IE Codes

It was not expected that the frequency of 20 IE codes would be even, but the difference was quite noticeable. I will discuss mainly on the top 3 most frequent codes (JC, FE, and SE) and the top 3 least frequent codes (MP, FW, and MN).

Top 3 most frequent codes: JC, FE, and SE

JC is presented to provide causal explanations typically after presenting an example (FE), scaffolding explanation (SE), question for scaffolding (SQ), or a learning topic (PP). Causal explanation is one of effective explanation methods to justify that a statement is true. By listening to casual explanations, learners take time to think over the learning topic and easily understand the statement (Maxwell, 2004; Montanero & Lucero, 2011). Considering the nature of causal explanation, it delivers for longer time than any other IE instances. In the following example in Table 25, the instructor presents proof of a theorem. This example shows why causal explanations are presented for a long time.

Table 25

Example of Long JC Use

[PP] *Presenting a main topic >* ***[SE]*** *Scaffolding explanation (Study guide; overview of the following explanations) >* ***[JC]*** *Causal Explanation*

	Code	Instructional explanation
1	PP	(theorem iv), if a divides b and b divides c, then a divides c. And this is under the assumption b non-zero.
2	SE	Okay, you prove all of these by going back to the definition of divisibility.

3	SE	What I'm going to do is just, I'll give you, I'll prove two of them as examples. Let me just pick number (iv). Let's prove (iv), that's this one here. All the proofs are essentially the same idea.
4	JC	If a divides b, and b divides c, then that means there are integers d and e, Such that b = da, and c = eb.
5	JC	That's the definition of divisibility, in which case c = d times e times a
6	JC	which again, by the definition of divisibility, means a divides c. Let me do one more, let me do (vi).
7	JC	Okay, so a divides b so that means, since a divides b, it means there is a d, Such that b = da,
8	JC	in which case taking absolute values, absolute value b equals absolute value d times absolute value a.
9	JC	And since b is non-zero we know that the absolute value of d will have to be greater or equal to 1. (JC continues…)

Note: the numbers in the first column stands for both order and time. Each row contains instructional explanation for 10 seconds.
Source: Mathematical Thinking. video ID-Thk9-02

Table 26 compares top 3 IE codes in terms of total frequency and the number of disconnected occurrences. Although JC is the most frequent IE code, its occurrence is relatively low. This means that causal explanation (JC) tends to be continuously presented for a long time compared to FE and SE. We see the example of lengthy JC above. In addition, the average time of continuous presentation of JC is almost twice longer than the other two codes. The following table shows that once JC is presented, it takes average 45 seconds until an instructor changes to a different IE, whereas FE and SE takes average 20-25 seconds. This is another evidence that causal explanations are typically presented for a long time.

Table 26

Comparison of Total Frequency and the Number of Disconnected Occurrences

	JC	FE	SE

Frequency	2202	1606	1593
# of disconnected occurrence	487	641	763
Avg. time (second)	45.2	25.1	20.9

The frequencies of FE and SE are smaller than that of JC, but their disconnected occurrences are much higher. This means FE and SE tend to be presented shortly but frequently. FE is followed by FI in the majority cases. Once an example (FE) is presented, interpretative explanations of the example (FI) typically follow. Scaffolding explanations (SE) play a transitional role. Before moving to a different topic, instructors usually wrap up previous explanations, emphasize important points, and introduce the next topic. It is obvious that this kind of explanation would be short but occur frequently.

Top 3 least frequent codes: MP, MN, and FW

MP is marked when an instructor expresses personal feeling/preference or gives a joke. In this research, MP appears only 89 times (0.7%) among the 13,524 codes. Although humor and intimacy has been emphasized as a trait of a good teacher (e.g., Baker & Taylor, 2012), it is surprising that MP is rarely used. One reason would be that the lectures are videotaped. Instructors might be nervous in front of a camera and teach with formal language, whereas they maybe enjoy informal talking in a classroom.

If we think about it from a different angle, the result suggests that an effective instructor is not necessarily a funny or friendly person. Such result appears contradictory to previous studies that suggested instructor humor as one of the main factors for effective MOOCs (Hew, 2016, 2018). First, these studies claimed that four main engagement factors were (1) problem-centric learning, (2) active learning supported by timely feedback, (3) helpful course resources, and (4) instructor attributes such as enthusiasm or humor. Among them, instructor attributes took about 10% of the factors (Hew, 2018).

Second, the scope of Hew's research and that of the present study are different. Hew's studies analyzed learners' reviews on the MOOCs that they enrolled in, whereas I coded moments of instructors' explanations. Learners' comments in Hew's studies are related to the overall evaluation on the whole course, whereas the frequency data reported in my study reflects the proportion of instructors' specific IE instance use.

Third, in Hew's studies, the exact factor name related to humor was "instructor passion, humor" (Hew, 2018, p. 19). This factor is quite different from the MP code. MP is marked at the moment when an instructor utters personal feeling or gives a joke. Instructor's passion and enthusiasm are instructors' *attributes* that learners can appreciate after completing the course but can be hardly captured by MP code because they are not instructional *explanations*.

In sum, the study results are not contradictory to previous research. I also witnessed instructors' passion and enthusiasm in various instructional explanations. The sparseness of MP does not necessarily mean that the instructor is lacking in passion or enthusiasm.

In the study rubric, MN is defined as 'introduction to the next topic at the *end* of the lecture.' MN has been marked only at the end of a unit lecture, and perhaps that is the biggest reason that MN is one of the least frequent codes. However, the analysis of unit lectures casts light on this minor code MN: the result shows that 26% of unit lectures' last code is MN. In other words, MOOC instructors close their lecture by introducing to the next topic in 1 out of 4 cases. This will be discussed in detail in the following section: Sequence Analysis in Unit Lectures.

IE Code Comparison Among Three Subjects and Three Video Production Types

The results show that the most frequently used IE category is different by subject areas. Familiarizing is the most frequent category in math/computer science (MCS), whereas Justification is the most frequent category in natural science (Sci) and humanities/social science (HuSo). The learning topics in math and computer science courses are usually divided into small pieces and instructors show examples rights after presenting a topic. In math courses, a theorem or formula is presented, then an example problem follows. In computer science courses, a programming command is presented, then coding examples follow to show how it is used. That is perhaps one of the reasons that Familiarizing is the most frequent topic in MCS.

As was noted before, Justification (31.9%) was the most frequently used category in overall courses. It is interesting that among the four codes in Justification category, Factual/statistical explanation (JF, 44.1%) was the most frequent in HuSo, whereas Causal explanation (JC, 50.0%) in Sci. Essentially, the natural science field seeks causal explanations. As Dagher and Cossman (1992) indicated, the field's scientific content explanation methods are widely used in teaching, too. In contrast, humanities and social science usually deal with factual phenomena and use causal explanations relatively infrequently.

One remarkable point in the 3x3 comparison of Figure 2 is that MCS uses only tablet presentation. HuSo, on the other hand, uses the other two production types (Studio and Classroom) excluding tablet presentation. In this study the number of courses was only 12 in three subject areas, so it is hard to generalize. Though, this result is consistent with a quantitative research study (Santos-Espino et al., 2016) that analyzed 116 MOOCs. According to Santos-Espino and colleagues (2016), the different video production type is probably linked to cultural factors and intrinsic properties of the content. MCS courses need to show more equations, diagrams, and programming codes, and that leads the instructors to select tablet presentation as an optimal production type.

It is noteworthy that no MOOC video showed only the tablet screen all the time among the six tablet presentation courses: some courses showed instructor and tablet alternatively, and the others showed instructor's head at the corner of the screen. The presence of instructor has been strongly recommended by empirical studies. Presence of instructor can enhance learner attention and engagement (Guo et al., 2014; Kizilcec et al., 2014) and can develop intimate tutoring relationship (Adams et al., 2014). The empirical study by Wang et al. (2020) concludes that presence of an instructor attracts learners' visual attention, and the amount of visual attention is positively linked to learner satisfaction. A recent eye-tracking study suggests that the most effective position of instructor should be on the right side (Zhang et al., 2021). In addition, Chen and his colleagues (2017) investigated how learner emotions are related to the various video production type in MOOCs. The results showed that picture in picture (PIP), text overlay, tablet presentation, screencast, and animation video types can induce positive emotions.

Noteworthy IE Patterns and Examples – Five Themes

For the research question 2: *What are the typical patterns of an IE sequence in MOOCs*, sequences of IE codes have been investigated and typical 3-code patterns have been presented in terms of five themes in Chapter 4. In this section, in order to promote practical use of IE instances, exemplary IE patterns and examples will be discussed in detail.

The results show that: (1) the top 25 2-code patterns are used about 1 to 4% each, and (2) as patterns get longer (3-, 4-, and 5-code patterns) no dominant pattern is found. The most frequent 3-code pattern `PP>PI>FE` takes 1.1% and others are all less than 1%.

Why do we have no dominant IE patterns? The most plausible reason would be that variations of IE patterns are extremely common in real life. Even if an effective instructor attempts to stick to an exemplary IE pattern, actual IE patterns in classes would be quite different by adding, omitting, and/or repeating specific codes. Griggs (2001) compare teachers' delivery with Actors' acting. Acting follows the script and focuses on dramatic expressions of the script, whereas teacher's delivery keeps adding or omitting instructional components while interacting with learners (Griggs, 2001). Effective teachers are good at fine-tuning and self-feedback process during the delivery (Ozmen, 2011). Stodolsky (1988) referred to this as "teacher's reconfiguration of activity structures." Therefore, I argue that we need to look through variations of IE patterns, not to stick to the exact formation of patterns only. Of course, the five themes of 3-code patterns in Chapter 4 will be our guiding light.

Theme 1: PI (Interpretative Explanation on the Main Topic)

PP>PI>FE>FI is one of the most common patterns in explaining a main topic. The basic form of this pattern is PP>FE and two types of interpretative explanations, PI and FI are following PP and FE, respectively. This pattern is consistent with those instructional theories that propose generalities-example micro sequencing (Reigeluth & Keller, 2009; Van Patten et al., 1986). Table 27 is an example of the PP>PI>FE>FI pattern. At first, the instructor presents the main topic, *len* command and adds interpretative explanations on the len command. Then, he shows programming example of the len command, and adds detailed explanations on the example.

Table 27

Theme 1: PP>PI>FE>FI Pattern

***[PP]** Presenting a main topic > **[PI]** Interpretative explanation > **[FE]** Example > **[FI]** interpretative explanation on the example*

1	PP	I want to introduce one other operator that works on lists, and that's the len operator. Len is short for length, and we use len like this: [The instructor writes on the tablet]
2	PI	it looks like a procedure call. We pass into len the object that we want to know the length of that can be a list. Len actually works for many things other than lists. It also works for strings. It works for any object that's a collection of things, and the output from len is the number of elements in the input.
3	FE	For example, the result of len applied to the list 0, 1 is 2, since there are 2 elements in the list. The result of applying len to this list is also 2.
4	FI	It looks like there are many more elements here, but len is only counting the outer elements. If 1 of the elements of a list is a list, it doesn't matter how many elements that list contains. It only contributes 1 to the length of the original list, so the result of this call would also be 2.
5		We can also use len on a string, and the output will be the number of characters in the string. In this case the string Udacity has 7 characters, so the output is 7.

Source: Computer Science 101. video ID-CS11-10

An extended pattern is *SE*>PP>PI>FE>FI>*SE*, which adds each SE at the beginning to overview the following long explanations, and at the end of PP>PI>FE>FI to wrap up the whole explanations of the topic. Sometimes, FD (i.e., contrast, distinguish, counterexample) is added between FE and FI to provide more rich and compelling explanations like PP>PI>FE>FD>FI.

Another variation is an inverted pattern such as FE>FI>PP>PI. When FE is provided before PP, the preceding example works like a hook to stimulate learners' curiosity. In the following example in Table 28, the instructor shows a picture of mountain top in Hawai'i Volcanoes National Park to describe caldera and its edge. Then he explains connections of this picture with Olympus Mons in Mars. Next, he presents the main topic, 'active volcano.' Finally, learners realize instructor's implication of showing Hawaiian mountain in Earth while explaining craters in Mars.

Table 28

Theme 1: FE>FI>PP>PI Pattern

[FE] *Example >* ***[FI]*** *interpretative explanation on the example* ***> [PP]*** *Presenting a main topic >* ***[PI]*** *Interpretative explanation*

1	FE	But in any case, what do you see? If you can very carefully make out this is the edge of the main Caldera around here. There it is. You can see the edge down here really well. I'm outlining that,
2		there's a nice hotel The Volcano House Hotel, you can stay at. The edge of that cold air goes right to here. There's another smaller Caldera that has collapsed inside of it.
3		There's another Caldera, this is where all the steam is coming from. There's another caldera inside there. And in fact if you were to go to this Volcanoes National Park right now,
4		you're not even allowed to go on this section because this has become not just a caldera but there's actually a lava lake inside here, which they don't let you to get up close in seeing; which is just devastating to me because I would love to see a real lava lake.

5	FI	But this looks a lot like that picture of the top of Olympus Mons that we saw before.
6		It had craters, craters within craters, craters to the sides of craters. These are the sorts of analogies, in addition to the fact that Olympus Mons is at the top of the mountain.
7	PP	These are the sorts of analogies that make you pretty clear in this case that you are looking at the summit of a at least once active volcano.
7	PI	And in fact you're not looking at the summit of any once active volcano, you're looking at the largest volcano anywhere in the solar system, the largest mountain anywhere in the solar system.

Source: Solar System. video ID-Ast1-09

Another variation is to add JF (i.e., factual/statistical explanation) and FI (i.e., interpretative explanation on the fact) between PP and PI like PP>JF>FI>PI. The following example in Table 29 orderly presents a main topic, related research, interpretative explanation on the research, and interpretative explanation on how the research is related to the topic.

Table 29

Theme 1: PP>JF>FI>PI Pattern

[PP] *Presenting a main topic >* ***[JF]*** *Fact/research results >* ***[FI]*** *Interpretative explanation of the research >* ***[PI]*** *interpretative explanation on the topic*

1	PP	The first is that there's growing literature that we are all born with what's called a, a "set point" for happiness, that part of happiness is genetically determined.
2	JF	And this is work that comes from the field of behavior genetics, and it shows that identical twins are much, much more similar in their happiness levels, than are fraternal twins.
3	FI	So, this suggests that happiness is heritable; it is passed down through our families, and
4		so, a large portion, about 50% of happiness is genetically determined.
5	PI	So, that leads some researchers to conclude that maybe it is futile, or kind of not very worthwhile to try to change our happiness levels, because it's partly genetic.

Source: Psychology of Happiness. video ID-Hpy1-06

Theme 2: JC (Causal Explanation)

JC is most frequently used after FE, and when it accompanies FE, FE>JC>SE, FE>JC>FI and FE>FI>JC are the most typical patterns. Table 30 is an example of FE>JC>SE pattern. In the middle of explaining the Coriolis effect, the instructor presents an example of merry-go-round, then explains how the Coriolis effect works. After this, he provides an additional scaffolding explanation by emphasizing an important point.

Table 30

Theme 2: FE>JC>SE Pattern

[FE] *Example >* ***[JC]*** *Causal explanation >* ***[SE]*** *Scaffolding explanation (Emphasize important points)*

1	FE	To understand the Coriolis effect, imagine you're standing in the middle of a merry-go-round or a carousel with a friend standing directly across from you. If the merry-go-round is stationary, you can throw a ball directly at your friend and it will reach them.
2		However, if the merry-go-round is rotating, a direct throw will miss. Even though the path of the ball does not change, the position of your friend in space has moved.
3	JC	From their perspective, it appears that the ball's movement has been deflected from a straight trajectory.
4		Similarly, as the earth rotates, the path that the winds are moving around the surface of the earth appear to be deflected.
5	SE	However, and this is the tricky part, the direction in which the winds appear to be deflected depends on which hemisphere you're in. Let's consider how this works.

Source: Geology 101. video ID-Mtn3-01

FE>JC>FI and FE>FI>JC patterns are mainly used in mathematics courses when presenting an example problem (FE), solving the problem to show why (JC), then providing interpretative explanations on the example problem. One variation is FE>*SE*>JC>FI, which is an addition of scaffolding explanation (SE) that overviews how the example problem will be solved.

SQ (i.e., Question for scaffolding) is a remarkable IE instance that comes before or after JC. Berthold and Renkl (2010) claim that IEs should be equipped with pre-designed impasse such as the impasse-trigger, and well-designed IEs should be presented after learner impasse (Calin-Jageman & Ratner, 2005). In the MOOC videos, I observed that instructors utilized a variety of SQ. The lecturers ask questions to intentionally trigger learner impasse, and contrast facts so that learners can detect conflicts. The example in Table 31 shows continuous use of SQ>JC.

Table 31

Theme 2: Repeated SQ>JC Pattern

[SQ] *Question for scaffolding (learner impasse) >* ***[JC]*** *Causal explanation*

1	SQ	How would you know whether it was the DNA that went in or the protein that went in? You'd have to-- STUDENT: Use biochemistry to separate them and inject each individually?
2	JC	I could use biochemistry to purify the protein component and the DNA component.
3	SQ	And then how do I get them into the cell? The virus is this insidious device that can inject whatever it needs to into the cell. It's a living, working mechanism.
4	JC	The minute you grind this thing up to separate the protein and the DNA, it now doesn't actually work. So how am I going to get into the cell? It's an idea.
5	SQ	We purify and try each component. But I don't know how to make it work, then. It's broken. What else can I do? STUDENT: Add fluorescence to either just protein or just DNA.
6	JC	If I could fluorescently tag just the protein, and see if the fluorescent label goes in, or fluorescently tag the DNA and see if it goes in.

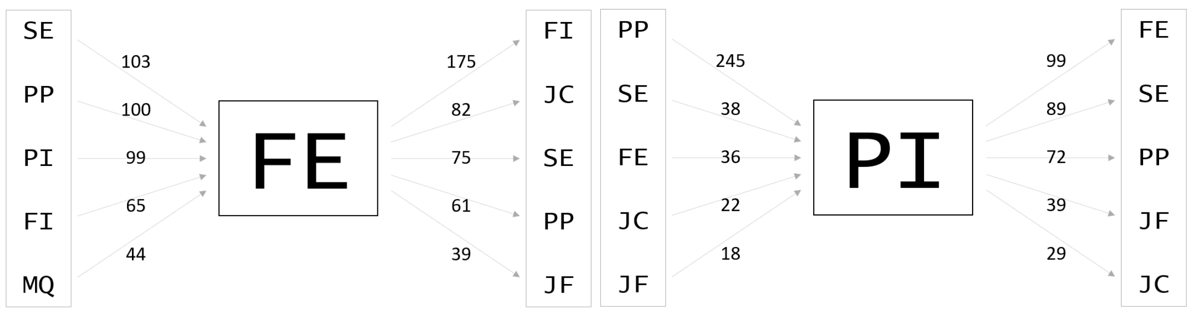
Source: Biology 101. video ID-Bio10-03

Theme 3: FE (Examples/Concrete Situation)

FE is typically used after SE or PP and before FI or JC. It is of note that FE>FI connection is very strong. Figure 6, a part of the Figure 3, shows that FE>FI is far more frequent than any other FE>□□ patterns. We can check similar strong connection of PP>PI pattern compared to other □□>PI patterns. The importance of interpretative explanation is confirmed in these cases, too.

Figure 6

Strong Connections of PP-PI and FE-FI



Besides the PP>PI>FE>FI pattern in Theme 1, SE>FE>FI pattern is also widely used. In this pattern, before providing an example, scaffolding explanation (SE) is presented to overview the following long explanations. In this way, SE helps learners figure out why the next example is presented at this time. Table 32 is an example of the SE>FE>FI pattern.

Table 32

Theme 3: SE>FE>FI Pattern

***[SE]** Scaffolding explanation > **[FE]** Example > **[FI]** Explanation on the example*

1	SE	In order to motivate the discussion of neural networks, let me start by showing you a few examples of machine learning problems where we need to learn complex non-linear hypotheses.
2	FE	Consider a supervised learning classification problem where you have a training set like this. If you want to apply logistic regression to this problem, one thing you could do is apply logistic regression with a lot of nonlinear features like that.
3		So here, g as usual is the sigmoid function, and we can include lots of polynomial terms like these. And, if you include enough polynomial terms then, you know, maybe you can get a hypothesis that separates the positive and negative examples.
4	FI	This particular method works well when you have only, say, two features - x1 and x2 - because you can then include all those polynomial terms of x1 and x2.

Source: AI: Learn with data. video ID-ML4-01

Theme 4: SE (Scaffolding Explanation)

Scaffolding explanations (SE) help learners to build their own mental model and prevent learners from getting lost while an instructor is explaining (Mehdian, 2009; Reiser, 2004; Safadi & Rababah, 2012). In the observation results, SE is typically used after FI and JC to wrap up previous long explanations, to provide study guide, and to emphasize important points of the topic. Also, SE is typically presented before PP and FE to overview the structure of the following long explanations. The following example in Table 33 shows how different types of SE's are used in consecutive order.

Table 33

Theme 4: JF>SE>PP Pattern

***[JF]** Factual Explanation > **[SE]** Scaffolding explanations > **[PP]** presenting a main topic*

1	JF	currency promises to pay, gold. There is a pyramid all the way, all the way up.
2	SE	*[Study Guide]* This image, I think, will be, will be helpful in a minute, but I'm going to let it just percolate there for a little bit.
3		*[Wrap up]* So this hierarchy is a qualitative hierarchy. Right? We're moving on a credit to money axis here. Credit to money, more moneyness as we go up. Okay?
4		*[Wrap up]* And more quantity. So quality is here and quantity is here, is the, is the way this image works.

5		*[Overview of following IE]* I introduced that pyramid for the forthcoming reason. To now add a third dimension. Right? We started with financial instruments, financial institutions.
6		*[Overview of following IE]* Now what I want to emphasize about the monetary system using this diagram, is its dynamism. Okay?
7	PP	That it is a fluctuating system. It's changing all the time. Okay?

Source: Financial Economics. video ID-Eco1-04

SE>PP>SE>FD is a noteworthy pattern to explain a new topic. In the following example in Table 34, the instructor presents overview of the following explanations at first. Then he presents the main topic 'differentiable,' and mentions an important point. Finally, he gives richer explanation by contrasting with the 'continuity on an interval.' This pattern is similar to the SE>FE>FI pattern in Theme 3. In both patterns, scaffolding explanation is presented before long explanations in order to encourage leaners to be prepared for a new topic and to prevent learners from getting lost.

Table 34

Theme 4: SE>PP>SE>FD Pattern

[SE]** Scaffolding explanation (Overview of the following explanations) >* ***[PP] *Main topic >* ***[SE]*** *Scaffolding explanation (Important point) >* ***[FD]*** *Compare/contrast*

1	SE	Now, think back to when we were talking about continuity last week. We started out with a definition of continuity at a single point
2		and then we expanded that definition to be continuity on a whole interval. We played the same game with the derivative. Here we go.
3	PP	If the derivative of f exists at x, whenever x is between a and b, but not at a, or at b, we won't worry about that, just whenever x is between a and b. And if this happens, then, we say that f is differentiable on the interval (a,b).
4	SE	So, as a little bit of a warning here, this is not a point. This is an interval. It's all the numbers between a and b, not including a, not including b.
5	FD	Now, contrast this with continuity, when we talked about continuity on an interval, I also had separate definitions for continuity and closed intervals or half-open intervals.

Source: Calculus. video ID-Cal4-01

Theme 5: MQ (Use a Hook / Question for Curiosity)

In regard to the IE code MQ, MQ>FE>PP and MQ>PP are the most typical patterns. Before presenting a new topic, asking motivating questions raises learners' curiosity and attention (Keller & Suzuki, 2004; Keller, 2008). These patterns have been observed occasionally but not very often in this study. Please note that the four IE codes in Motivating category (MQ, ME, MP, MN) are only 5.2% and MQ takes 2.4% of all the codes.

MQ is usually presented at the beginning of unit lectures. This will be discussed in the next section, Sequence Analysis in Unit Lectures. In this section, examples of MQ use in the middle and at the end of explanations will be presented. The example in Table 35 shows how MQ is presented in combination with SQ. After wrapping up previous explanations, the instructor uses a hook with the words "extraordinarily important." After reminding prior knowledge, he delivers well-designed learner impasse with the words, "misconception," "might be tricked," and "not true."

Table 35

Theme 5: SE-MQ-SP-SQ Pattern

***[SE]** Scaffolding explanation (Wrap up) > **[MQ]** Raise curiosity > **[SP]** Remind prior knowledge > **[SQ]** Learner impasse*

1	SE	So, this will be our definition for the square root function. The square root of x is the nonnegative number which squares to x.
2	MQ	There's one particular place where this plays out and it's extraordinarily important. So, let's take a look at that now.

3	SP	We've got our definition. The squared of x is the nonnegative number which squares to x.
4	SQ	Now, there's one popular misconception that comes up because of this definition. So, in light of the definition of the square root, right,
5		the square root of a number being the nonnegative number which squares the number to the radical, you might be tricked into thinking that the square root of x squared is x. That's not true and let's see why.

Source: Calculus. video ID-Cal2-04

At the end of a unit lecture, MN (introduction to the next topic) is usually used, but some lectures conclude with MQ. Closing with MQ appears quite enjoyable, while closing with MN seems mundane. Table 36 is an example of closing with MQ. The instructor suddenly changes tone and tells a different story. This appears a kind of a plot twist, and it raises learners' curiosity to the next topic. In addition, the instructor intrigues learners by using the word "dramatic" in the final sentence.

Table 36

Theme 5: Use of MQ at the End of a Unit Lecture

1	MQ	If you only look at the southern highlands of Mars, it does look a lot like the moon, but there are places on Mars where you could have looked, where you would have seen a very different story.
2		And even when you look at the highlands of Mars you see some things that are not precisely moon-like. I showed you, for example, these craters.
3		These craters are not as distinct as these smaller craters. And what they look like is that they have been eroded. They haven't eroded away completely.
4		They certainly haven't eroded away as much as they would have on the Earth. But there's a hint even from these very first images, that perhaps Mars is not entirely moon-like, and something more interesting might be going on.
5		We'll see some dramatic evidence that, that's true over the next few lectures.

Source: Solar System. video ID-Ast1-07

Sequence Analysis in Unit Lectures

It is easily assumed that instructors usually do not cut to the chase and explain a main topic from the beginning of a class. Likewise, instructors usually do not finish their explanations abruptly at the end. We are familiar with opening and closing words of an instruction, and we know that those words are specifically presented mainly at the beginning and ending of a lecture. it is obvious that the IE patterns at the beginning and ending would be different from the majority of other IE patterns.

With regard to the beginning and ending of unit lectures, in this study, I attempted to find out more detailed information based on data. What kind of IE codes are mostly used at the beginning and ending of unit lectures? How are the opening and closing IE codes increasing or decreasing as a lecture continues? How long are opening IE codes presented before an instructor starts to deal with the main learning topic, and how long are closing IE codes presented after completing explanations of the main learning content?

The two state distribution plots in Chapter 4 (Figure 4 and 5) show distinct increase and decrease of 5 IE categories. In addition, Table 37 shows exceptional characteristics of the beginning and ending of a unit lecture. In overall MOOC lectures, Justification and Familiarizing takes about 56%, but their portions are 15% or less at the beginning and ending. It is astonishing that the proportions of Motivating are considerably high at the beginning and ending, whereas it takes only 5% of total lecture.

Table 37

Comparison of Five Categories (Total vs. Beginning vs. Ending)

	Total	Beginning (t = 1)	Ending (t = -1)
Justification	32%	10%	9%
Familiarizing	24%	5%	5%
Scaffolding	22%	36%	40%
Presenting	17%	30%	5%
Motivating	5%	19%	40%
Total	100%	100%	100%

In the state distribution plot for the first 3 minutes (Figure 4), the proportions of Scaffolding and Motivating are relatively high at the beginning, and their portions are decreasing as lectures progress. Scaffolding is moderately decreasing and becomes flat after 60 seconds. Motivating is steeply decreasing and seldom appears after 40 seconds. In the state distribution plot for the last 3 minutes (Figure 5), the proportions of Scaffolding and Motivating are increasing as a lecture comes to an end. Scaffolding is moderately increasing from 60 seconds before the end. Motivating is steeply increasing from 50 seconds before the end.

In sum, it is inferred that the IE codes at the beginning and ending of unit lectures are different from those in the remaining time frame. It is the two IE categories, Scaffolding and Motivating that are mostly used at the beginning and ending, and their average presentation time is 40 to 60 seconds.

The results align with various teaching guides for higher education. A number of teaching guides suggest that Instructors should begin a class with questions for curiosity and summary of the previous class so that students have the time necessary to connect ideas and build larger conceptual understandings (Lang, 2016a; Love, 2013; Smith, 2008). Instructional explanations in MOOCs to connect between previous knowledge and current learning content enhance learners' conceptual understanding and context-transfer (Ambrose et al., 2010; Ziegenfuss, 2016). Among the top 5 opening IE codes, SP, MQ, and SE are related to the practical guides.

Here are two examples of opening patterns in Table 38. The first instructor connects prior knowledge to upcoming unit's topic. The second instructor asks questions for curiosity, then introduce forthcoming learning topics.

Table 38

Opening Patterns: SP>PP and MQ>SE

1	SP	Now I'd like to revisit a topic that we talked about a little bit earlier which is the relationship between attachment status and happiness, and I bring this up because we just finished reading about oxytocin.
2	PP	Oxytocin in the brain is typically manufactured communicated and having a significant impact in structures that we call care nurturance circuitry and …

Source: Psychology of Happiness. video ID-Hpy2-05

1	MQ	Glance at any atlas or map of the world that exhibits relief, and it becomes quickly apparent that mountains are nearly everywhere.

2	MQ	Mountains occur in three quarters of the world's countries. Mountains can be found on every continent. They can be found in very climate and they can even be found in every ocean. But have you ever considered why mountains are located specifically where they are? How did they get there?
3	SE	In this lesson, we'll explore the physical origins of mountains, theories of mountain building, and how changing ideas of mountains and their genesis have shaped our engagement with them.

Source: Geology 101. video ID-Mtn2-01

With regard to the closing of a lecture, Lang (2016) recommends to wrap up the whole lecture, to emphasize important points, and to connect the learning topics to everyday life. In addition, it is effective when students themselves write down the summary and important points. Desai et al. (2018) stress the importance of introduction to the next topic at the end of a lecture. Among the top 5 closing IE codes, SE, ME, SA, and MN are related to the practical guides.

Here are two example of closing patterns in Table 39. The first instructor summarizes previous explanations, then motivates learners to keep working on the next topic. The second instructor uses a hook to motivate learners to the next topic, then provides a quiz to test themselves.

Table 39

Closing Patterns: SE>MN and MQ>SA

1	SE	So, with these visualizations, I hope that gives you a sense of what's the range of hypothesis functions we can represent
2	SE	using the representation that we have for logistic regression. Now that we know what h(x) can represent,
3	MN	what I'd like to do next in the following video is talk about how to automatically choose the parameters theta so that gives a training set we can automatically fit the parameters to our data.

Source: AI: Learn with data. video ID-ML3-03

1	MQ	But it turns out that understanding biological properties requires understanding things beyond these covalent bonds that draw the atoms as you normally would draw them.
2	MQ	It actually involves understanding non-covalent bonds and other funny forces. So let's try to cover the non-covalent bonds that are important to understanding biology.
3	SA	Do you feel like an expert on bonds yet? To test your understanding, we've got a question for you about polar covalent bonds.

Source: Biology 101. video ID-Bio2-03

Limitations of the Research

This study did not measure learners' achievement or engagement. The observed courses were selected based on MOOC portals' user ratings. Highly rated MOOCs are not necessarily effective for learning. No evidence was provided in this study that the exemplary IE patterns can improve learners' achievement.

This study assumes excellence of instructional explanations delivered by highly rated MOOC instructors. However, highly rated MOOC instructors does not necessarily provide effective instructional explanations. Learners give a rating not only based on instructors' explanations in MOOC videos but also based on learning materials, usefulness of the course, discussion board activities, and so on. User rating is not the best way to determine effective instructional explanations, but without measuring learning outcomes, user rating is perhaps the second best option.

In analyzing IE patterns, only non-consecutive codes were counted regardless of the length of duplicate codes. For example, these two sequences PP>PI>PI> PI>PI>FE and PP>PP>PP>PI>FE>FE>FE were considered as the same PP>PI>FE pattern. Each code in IE patterns represents various length. In this study, no analysis was performed to compare the difference by the code length. I do not have an answer to the question whether there is any difference between short codes and long codes.

A systems approach to instruction needs to consider all the components of MOOC. The focus of this study is a kind of micro-level instructional design theory. Even if a MOOC instructor provides outstanding lecture videos, learning can occur in combination with various useful materials and discussion board activities that encourage learner participation.

Summary of Findings and Suggestions for Future Research

First, an observation rubric for instructional explanations has been newly developed for this study. The rubric is a result of the integration of extensive literature review and has been revised after a pilot test. Still, the rubric needs more validation. I already suggested combining FW into PI and FI. In addition, definitions and examples of each code need to be more clearly documented. I tried to make the 20 codes mutually exclusive as much as possible, but still some ambiguity exists.

One contribution of this study to IE observation rubrics is the discovery of SE and MN code, which were overlooked in previous rubric development research. Considering the short lengths of MOOC videos, closing each video with introduction to the next topic (MN) enhances learners' motivation to keep progressing.

In this chapter, I showed various examples of SE use. In a nutshell, frequent use of scaffolding explanations (SE) dramatically improves an instruction. Preparing for great examples, brilliant analogies, and a plot twist for learner impasse is quite difficult and time consuming. However, overviewing before long explanations, wrapping up after long explanations, emphasizing important points, and providing study guides require only instructors' kind mind and good habit. It is no surprise that SE is one of the top 3 frequent IE codes of the highly rated MOOC instructors. I would suggest a comparison study of highly rated vs. poorly rated courses particularly focused on SE use.

Second, the observation results of this study have generated five themes of IE patterns. Some patterns are quite obvious and commonly used such as PP>PI>FE>FI pattern. Some patterns make IEs exciting and engaging such as FE>FI>PP>PI, SE>FE>FI, and repeated SQ>JC pattern. Highly rated MOOC instructors frequently use those IE patterns, and I was impressed by their versatile and consistent use of explanation patterns. However, we cannot be sure all of their explanations are great. I suggest empirical studies utilizing eye-tracking technology to find out which IE patterns gain or lose learners' engagement.

In addition, I suggest comparison studies that will provide empirical evidence for or against instructional design theories. Merrill's (2002) First Principles of

Instruction help us to consider key instructional *components*, whereas Gagne's (1962) nine events shed light on effective instructional *sequences*. Likewise, instructional design theories provide guidelines and prescriptions. However, it is important to determine if effective MOOC lecturers actually follow the prescriptions. If effective lecturers have established their own explanation sequences, what are the similarities and differences between them and instructional design theories? Typical patterns of IE sequences as a result of observation research could lend insights into micro instructional design theories.

Third, the results have revealed detailed information on opening and closing IE patterns of unit lectures. Scaffolding and Motivating explanations are far more frequently used at the beginning and ending. For the beginning of a lecture, reminding prior knowledge, asking questions for curiosity, and overviewing learning topics help to gain attention and to activate learners' mental model. For the ending of a lecture, wrapping up previous explanations, providing practice questions, connecting to everyday life, and introducing the next topic are desirable ways of closing. Similar to SE, I am sure that small amount of attention to opening and closing words will significantly improve MOOC lectures.

Concluding Thoughts

I heard a story from my friend who attended a Nobel laureate's onsite presentation. He was thrilled that he would learn directly from a maestro of physics. However, the Nobel laureate presented more than 100-page slides; in fact, he literally read the slides from the first page to the end. "It was a good nap!" my friend chuckled.

In Korea, online video lectures for Korean SAT prep are offered by big companies. A handful of most popular instructors have hundreds of thousands of subscribers and earn enormous amount of money every year. This market is very competitive, and a winner takes all. An interview with star instructors inspired me in writing this dissertation. According to the interview (Choo, 2009), thorough knowledge on the content and outstanding delivery are key factors to be a prominent online instructor. Whenever I watch top instructors' lecture videos, I am impressed by their passion as well as teaching skills. In the interview, the star instructor noted, "I have a strong intent to make them understood until the last student."

Similarly, in observation sessions of this study, the highly rated MOOC instructors' explanations were extremely impressive to me, and sometimes I paused and admired with awe. Dr. Brown unfolded amazing stories about Mars, which was regarded an isolated planet with rocks and ice only. Dr. Evans made me deeply engage in the lecture with his energy and enthusiasm. Dr. Ng was extremely effective in helping me to understand an unfamiliar topic, machine learning, by adding a little bit of complexity again and again as his lectures progressed. He was incredibly consistent in keeping his own explanation sequence throughout the whole lecture.

What makes some teachers present such rich explanations so that any student can understand easily and engage in the task? This study was a journey to seek answers to that fundamental question. There are various situations to share one's knowledge not only in MOOCs but also in everyday life. A top salesperson might be requested to share his/her skills and experiences with newly employed salespersons in the company. Any professional might have a chance to present in a local conference. I hope this study is helpful for those whose main job is not teaching. In addition, perhaps it finds valuable uses among present and future MOOC instructors. The findings and recommendations in this study are not panacea for effective instruction; however, I believe they offer fairly quick and relatively simple solutions to dramatically improve one's teaching. In addition, there is one more secret ingredient; the delight that occurs when one's students exclaim that they learned a lot from your lecture. Such delight of teaching fuel the passion to find ways to continue to improve one's teaching.

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APPENDICES

Appendix A: Observation Rubric

PRESENTING	JUSTIFICATION	FAMILIARIZING	SCAFFOLDING	MOTIVATING
[PP] Presenting a learning topic	**[JF]** Factual/statistical explanation	**[FA]** Analogy	**[SP]** Connect to prior knowledge/ Wrap-up	**[MQ]** Use a 'hook'/ question for curiosity
[PI] Interpretative explanation on the learning topic	**[JC]** Causal explanation	**[FE]** Examples/concrete situation	**[SQ]** Question for scaffolding	**[ME]** Benefit/usability
[PR] Tautology/repeating of the learning topic	**[JN]** Narrative explanation	**[FD]** Contrast/distinguish /counterexamples	**[SE]** Scaffolding explanations	**[MP]** Personal feeling
	[JH] History of theories	**[FW]** Easy word/terms	**[SA]** Application/practice	**[MN]** Introduction to the next topic at the END of the lecture
		[FI] Interpretative explanations - while presenting analogy, example, or narrative		

Appendix B: Momentary Time Sampling Form

Course Name and Video ID: ____________________

Coder Name: ______________________________

Video Type: ___________________________________

Date: ____________________________________

Total Observation Time: _______________________

Length of each interval: ____________________

	Interval #									
	1	2	3	4	5	6	7	8	9	10
0_										
1_										
2_										
3_										
4_										
5_										
6_										
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15_										
16_										
17_										
18_										
19_										
20_										

Appendix C: Notes for Each of the IE Instances

PRESENTING

IEs for delivering the learning topic

[PP] Presenting a learning topic

Present a learning topic without additional explanation

- “The atomic composition of life is pretty similar across all living organisms.” (Learning topic)
- “There are three kinds of covalent bonds.” (Learning topic)
- “The basis of plate tectonics is the idea that the Earth's surface is broken into several rigid plates.” (Learning topic)

[PI] Interpretative explanation on the learning topic

Present a learning topic in different words or provide more details about the learning topic

- (Right after presenting a learning topic) “This is covalent bonds. They are shared electron pairs. Shared pairs of electrons. And they are strong.” (More detailed explanation)
- “The solution is to change the definition. Instead of having the square root function be just a number which squares to x, you're going to take it to be the nonnegative number which squares to x.” (Detailed explanation on the definition)

[PR] Tautology/repeating of the learning topic

Simply repeat the learning topic that was previously mentioned

Cf. Wrap-up -> [SE]

JUSTIFICATION

IEs for soliciting learners to accept that it is true

[JF] Factual/statistical explanation

Provide facts or statistical results

- “So, there you see the total size of the balance sheet is, they're $2.8 trillion. By the way, before the crisis it was less than 1 trillion. So when I say that the size of the balance sheet tripled, that's about right. And here's the liability side. So you can see that the liabilities of the Central Bank are about 1 trillion of currency in circulation. That's green pieces of paper." (Provide facts and numbers on a report)

[JC] Causal explanation

Explain cause-effect relationships or rational, logical reasons from key axioms; give logical explanation in solving mathematical equations

- "The problem with the pure money system which is what we've seen, we've seen last time is that when you run your deposits down to zero, you're, you can't make any more purchases." (Cause-effect relationship)
- "Well, k^2 would have to be -16. So, if there were a square root of -16, when I square it, I get back -16. And imagining here that k is some real number. And that means there's three possibilities. Either k is positive, k is zero, or k is negative. If k is positive, then k squared would also be positive because a positive number times a positive number is still positive. But that can't be, because k squared is supposed to be -16. So, this first possibility doesn't happen. Now, if k were zero, then k squared would be zero, but k squared is supposed to be -16. So, k isn't zero. Is k negative? Well then, what's k squared? That would be a negative number times a negative number, and that would still be positive. And that can't be because k squared is supposed to be -16. So, this possibility also doesn't happen." (Logical explanation)

[JN] Narrative explanation

Present personal experience, story, anecdote, etc.; provide a background knowledge

- "I had the opportunity to visit this extraordinary place…" (Personal experience)
- "But this is how it was in the United States before the Fed there was not par clearing, par clearing was created. Par clearing in the payment system in the United States was created by a set of institutions and it is not easy to create this thing, by the way." (Historical story and background knowledge)

Cf. Present history of theories/scholars -> [JH]

[JH] History of theories

Present old and false theories, and meaning and influence of old theories; quote/cite of old scholars

- "For centuries, among the Western intellectuals it was believed that mountains had been cast in their present poses by God, and would remain always and forever that way. Prior to the 1700s for many people in the West it was the Christian Bible, specifically the biblical account creation that really determined how the Earth's past was imagined." (Old theory)
- "And of those, the best known was James Ussher, the Irish Archbishop of Armagh. In the mid 1600s, Ussher calculated the Earth had a beginning date of 9 AM on Monday, October 23rd, 4004 BC. Ussher's incredibly precise beginning date for the Earth had some longevity. It was actually still being printed throughout the English speaking world as late as the early 1800s." (Quote, meaning of the old theory)

- “The discoveries of Mary Anning, an English fossil collector and others, did much to shine light upon ancient ages of monstrous creatures, mammoths and mammals, sea dragons or giant lizards, dinosaurs as they were christened in 1842.” (Meaning and influence of old theory/scholar)

FAMILIARIZING

IEs for familiarizing learners to unfamiliar concepts/ideas

[FA] Analogy

Use analogy such as metaphors, similes, teleological statement, or anthropomorphisms

- “You may have noticed the human phenomenon that when you share with somebody else the sharing is not always equal. We talk sharing, but some people are better sharers than others. It turns out that is also true at the atomic level.” (Metaphor)
- “We're going to use an analogy of the game of pinball to help us understand these two thinking modes.” (Metaphor)
- “Each plate is moving in various directions at rates from one to ten centimeters per year. Now that's as fast as fingernails grow.” (Similes)

[FE] Examples/concrete situation

List examples of the learning topic; present an example problem in Math; programming examples; concrete situation

- “Well, here's an example. Here, I've got the square root of four. And I'm saying the square root of four is two.” (Math problem example)
- “So here's an example, we could create the name, speed of light, and we can assign to it the value of the speed of light in meters per second. So after that assignment, the name speed of light refers to that value.” (Programming example)
- “Okay, say maybe gold just all, just all gold and then it has these deposits on the liability side from let's say two different people so that we have something where we can make a payment person Alpha and person Beta.” (concrete situation)

Cf. give logical explanation in solving mathematical equations -> [JC]
Cf. statements that require learners’ active processing in presenting practice questions/programming examples -> [SA]

[FD] Contrast/distinguish/counterexamples

Contrast, compare, and distinguish the similarities and differences. Present counterexamples

- “These bonds as compared to my 80 kilocalories per mole, these are five kilocalories per mole, just five kilocalories per mole.” (Contrast)

- “That is the price of par. This is the price of one money in terms of another money right now, today. So this is about today, this is about the future.” (Contrast)
- "Ocean plates are thinner, often less than 100 kilometers thick, but denser than the continental plates, which are roughly 150 kilometers to 200 kilometers thick." (Compare)
- “Be careful (…) Let's try to define a function. Just making this stuff up, I'll call the function B(x) for bad. And I'll say that the value of B(x) is some rearrangement of the digits of x.” (Counterexample)
- (After explaining difficulties of learning abstract concepts) “But what about ones like love, zest, or hope? Those are all abstract. Yes they are, but the thing is, these abstract terms are often related to our emotions.” (Counterexample)

[FW] Easy word/terms

Explanation on academic/unfamiliar terms; Interpret the scientific jargon/terms into everyday words

- “The Latin name here referring to yeast is "zyme." The thing that was in yeast was called an "en-zyme." There were en-zymes, something in yeast.” (Explanation on academic/unfamiliar terms)
- "Python is named after Monty Python" (Explanation on academic/unfamiliar terms)
- “Greediness is referred to at the atomic level as electronegativity. That's the technical term for greediness, electronegativity” (Using easy word)

Cf. [PI] is more detailed explanation on the learning topic. [FW] is an explanation on a specific terms.

[FI] Interpretative explanations

Explain the meaning or relationships to the topic while presenting analogy [FA], example [FE], or narrative [JN][JH]

- (After presenting analogy of a pinball for neural system) “In this diffuse mode of thinking, you can look at things broadly from a very different, big-picture perspective. You can make new neural connections traveling along new pathways. You can't focus in as tightly as you often need to, to finalize any kind of problem solving. Or understand the finest aspects of a concept.” (Explain the meaning of the analogy)
- (While presenting an example of the two functions F and G) “This is really quite surprising. f and g don't compute their output in the same way, right? This one is doing something different than this function, and yet, for any input value, f's output value is this, which is the same by expanding out as g(x).” (Explain the meaning of the example)
- (While presenting an example) “You might be tricked into thinking that the square root of x squared is x. That's not true.” (Explain the relationship to the topic of the example)

SCAFFOLDING

IEs for building learners' mental model

[SP] Connect to prior knowledge

Remind previous learning topic or connect to learner’s prior knowledge

- “So, let's take a look at that now. We've got our definition. The squared of x is the nonnegative number which squares to x.” (Remind previous learning topic)
- “In many economics classes you've had, you talk about this and you talk about MD equals MS, money demand equals money supply okay?” (connect to learner’s prior knowledge)

Cf. Wrap-up -> [SE]

[SQ] Question for scaffolding

Ask question for learners to face impasse or to elicit their understandings after some previous explanations

- “You were taking sugars and you were producing carbon dioxide and alcohols. How could this be made to work? Did you need a living organism to do it?” (Learner impasse)
- “Now, there's one popular misconception that comes up because of this definition.” (Learner impasse)
- “Now, how do you relate that to anything?” (Elicit understanding)

Cf. Questions without enough explanations on the topic -> [MQ]

[SE] Scaffolding explanations

Emphasize important points of the topic; Study guide; Overview the structure of explanations; Wrap-up of previous explanations

- “It's not rocket science, but the point is that what has happened in the world is that this model became the dominant one.” (Point out important things)
- "That's it. You should know that. I'm not going to ask you to memorize a lot, but you should know those things." (Study guide)
- “The first section, the next section of the class that we're going to do is thinking about the payment system.” (Overview of the lesson)
- “This is mostly what we're going to focus on-- nothing more than six atoms, six types of atoms. So out of a periodic table of more than 100 elements, you're going to get to know six atoms particularly well.” (Introduce what learners should focus)
- “What we're trying to look at here is, is there a change in the aggregate money supply or in the size of the balance sheet depending on the pattern of payments.” (structuring following explanations while showing an example)
- “All right. That's pretty much it for atomic chemistry. Now, hang onto those principles. Covalent bonds. They're really strong. They don't break at random. We have unequal sharing. Some bonds are polar; some bonds are not.” (Wrap-up previous explanations)

Cf. simple statement to ask learner attention -> [MQ]

[SA] Application/practice

Present application or practice to overcome mental passivity; must require learners’ active processing

- On-screen pop-up quiz
- Application questions between short videos

Cf. simply solving practice questions/programming example -> [FE]

MOTIVATING

IEs to motivate learners to engage/be curious/keep working on the course

[MQ] Use a 'hook'/question for curiosity

Ask questions or use a 'hook' to raise curiosity and interest before providing enough explanations; ask learner attention

- "To understand how science is done, you think about what discoveries meant to the people who were discovering them, and what was so surprising. So put yourself back in the mindset of somebody just before the turn of the 20th century." (Use a hook)
- "I bring you the gecko. The gecko can climb up glass. It can climb this way. Why is the gecko not falling down? Well people thought maybe the gecko has glue on its pads. It does not. What holds the gecko up? The gecko is held up by Van Der Waals forces." (Raise curiosity and interest)
- "Sometimes, you're asked to calculate the domain of a function that's more complicated than, than just the square root of x." (Raise curiosity and motivate challenge)
- "I'm trying to draw your attention to two sorts of issues that arise when we're thinking about banks." (ask learner attention)

Cf. raise curiosity at the END of the lecture -> [MN]
Cf. ask learner's mental activity by presenting a problem -> [SA]

[ME] Benefit/usability

State the (external) benefit/usability of the topic

- "You can do really complicated things with, with functions." (Point out usability/benefit)
- "This example suggests that there's a real richness to this theory" (Point out usability/benefit)
- "The general population needs to understand how this stuff works. Because we need to make some big decisions about how to regulate this new system." (Point out usability/benefit)

[MP] Personal feeling

Express personal feeling on the topic

- "I know it's hard to understand." (Sympathy)
- "I don't like it." (Preference)
- "But boy, I have no clue what's going on. And he's so honest here. It's wonderful." (Acclamation)

- “But I'll tell you-- it doesn't much matter. Because this level of description of life isn't much useful for anything. It's not a very satisfying description.” (Personal evaluation)
- "This is not rocket science, it can be understood. And it's my mission to help people understand it. I think we're in a teaching moment in history where we need to understand this." (motivation and personal feeling)

[MN] Introduction to the next topic

Provide overview/raise curiosity of the next topic at the END of the lecture

- “We're talking about financial globalization. And we're thinking, what does that imply for money and monetary theory? That's what we're trying to do. We're trying to develop monetary theory for the real world. For the real work that's around us now. And the guideposts we're going to use are these great texts of the past” (Introduction the next topic at the end of the lecture)

Cf. Provide overview at the beginning or in the middle of the lesson -> [SE]
Cf. Raise curiosity at the beginning of the lesson -> [MQ]

Curriculum Vitae

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EDUCATION

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Manager of Web Services (Full time Professional Staff) **2006 – Present**

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PUBLICATIONS

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PEER-REVIEWED CONFERENCE PRESENTATIONS

- **Lee, Junghun** (2004). Supporting web-based distance education: Online pedagogical activities help system to enhance student motivation and participation. In the *annual conference of the Association for Educational Communications & Technology (AECT)*.

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- So, H. J., Bardzell, S., & **Lee, Junghun** (2004). Designing interactive web-based instruction. In the *annual conference of the Association for Educational Communications & Technology (AECT).*

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