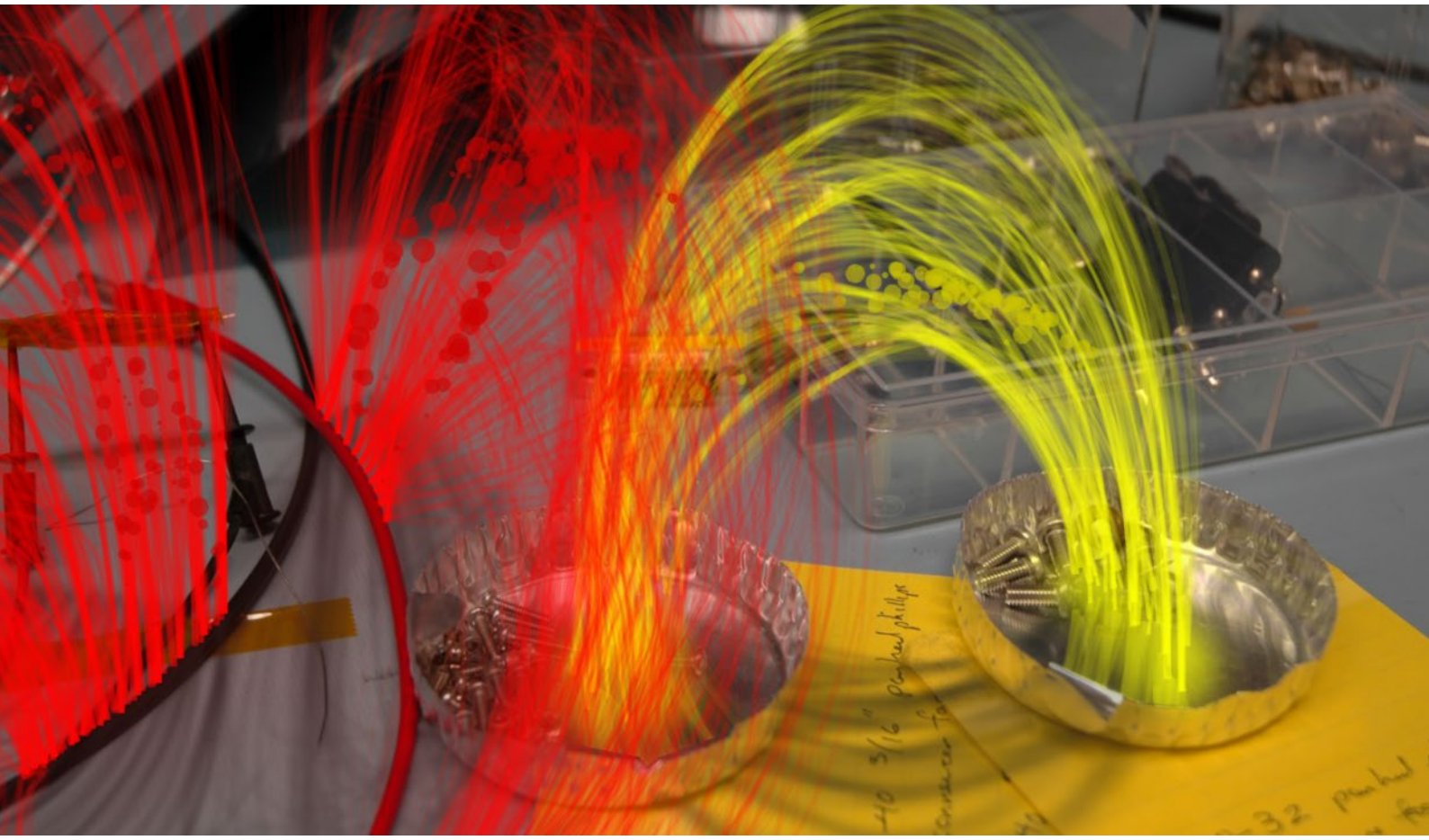
The Unseen Potential of Film for Learning

Film's Interest Raising Mechanisms
Explained in Secondary Science and Mathematics Education



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The Unseen Potential of Film for Learning

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Explained in Secondary Science and Mathematics Education

(met een samenvatting in het Nederlands)

Proefschrift

Ter verkrijging van de graad van doctor aan de Universiteit Utrecht op gezag van de rector magnificus, prof.dr. H.R.B.M. Kummeling, ingevolge het besluit van het college voor promoties in het openbaar te verdedigen op [DATUM] des [TIJD] door

Winnifred Wijnker

geboren op 9 mei 1981, te Wijk bij Duurstede

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Permission to publish the still images in this thesis from the film *Magnetic Movie* (2007) by Semiconductor has been granted by Ruth Jarman and Joe Gerhardt.

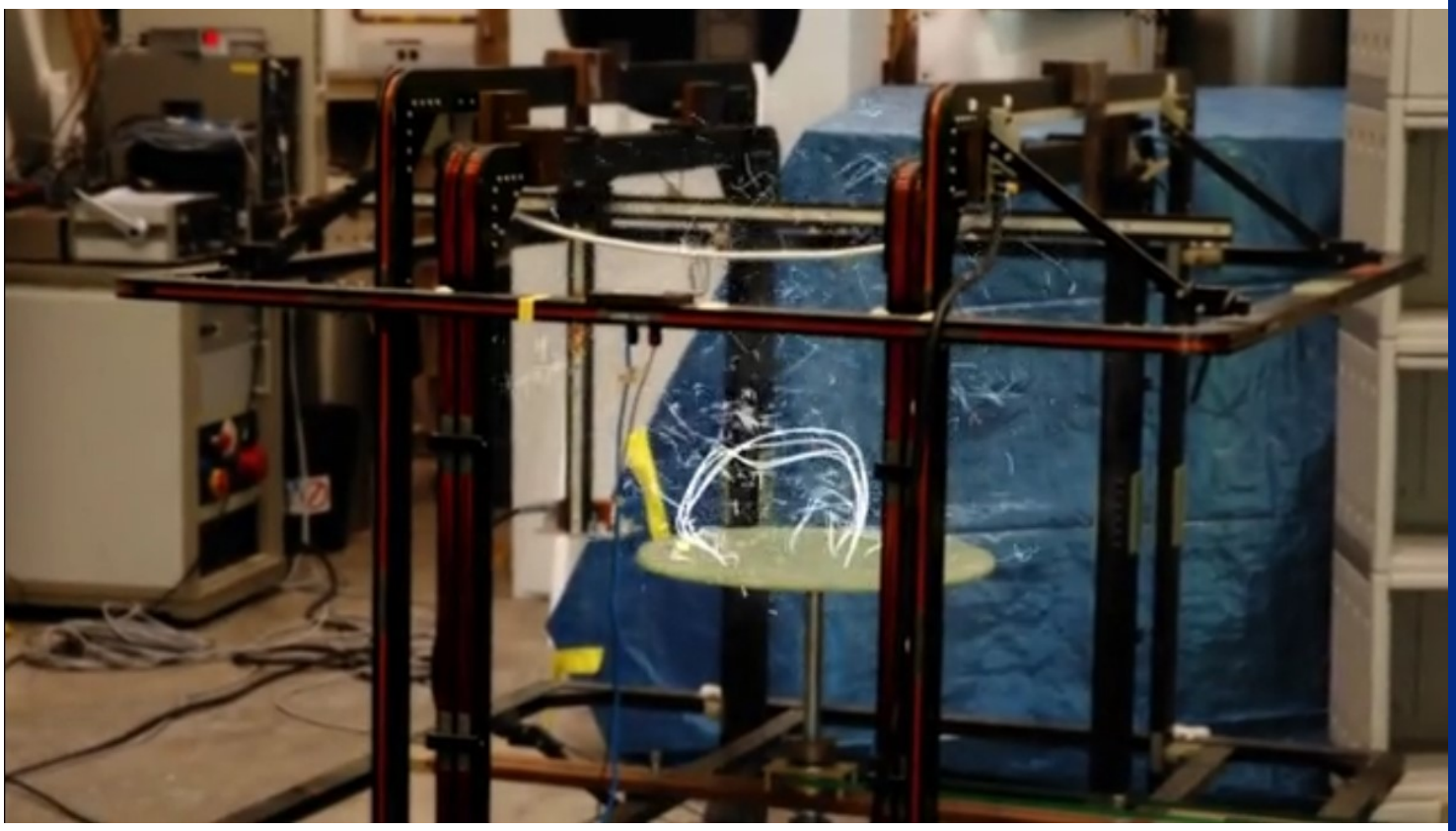
THE UNSEEN POTENTIAL OF FILM FOR LEARNING

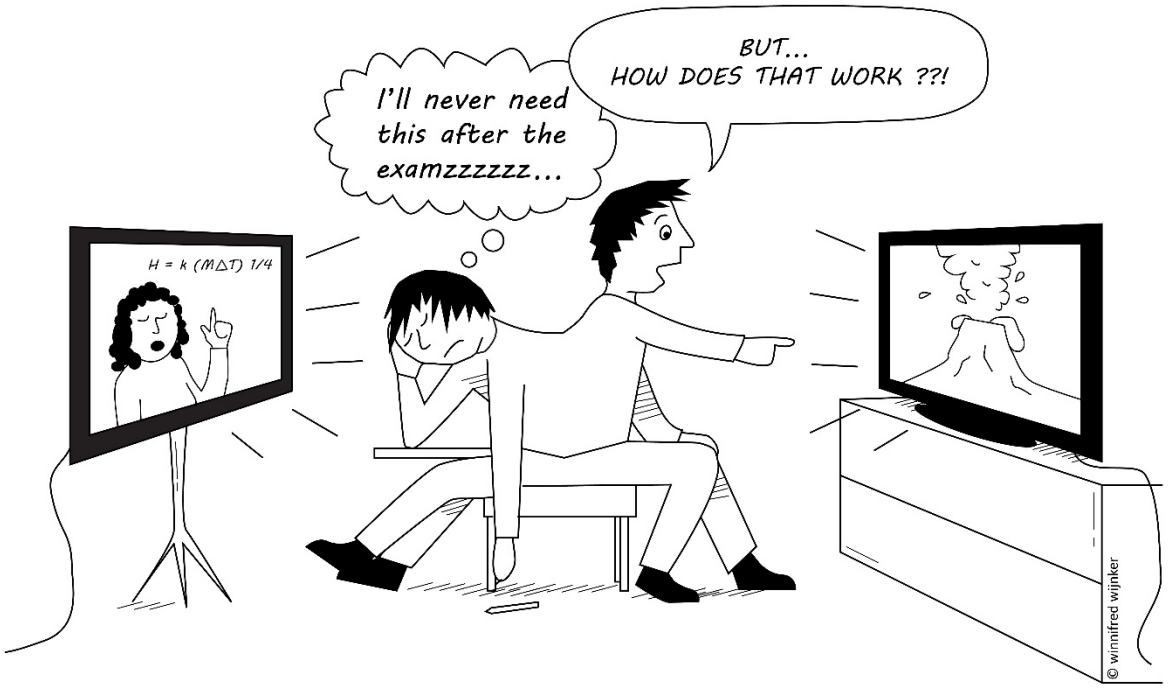
Film's Interest Raising Mechanisms Explained in Science and Mathematics Education

The Missing View from Film Studies

1

General Introduction to the Research Project





If only we had the tools available to interest our pupils in learning...

Introduction

Education is a steady and respected constant in our history. What makes good education, however, is a discussion with no end. In fact, studying this question in research is a learning path in itself. And likewise, what makes good research on education is equally an unending discussion. Education transforms with new insights from research, from practice, and due to social and political forces. The 2020 pandemic outbreak functioned as a top-down force on educational practice to transform, and accelerated what had started to develop bottom up decades before: the digitalization of education.

We can go back as far as the mid-1970s for the introduction of what was called Computer-Assisted Instruction (Mechling et al., 2007). But the widespread use of smartboards in classrooms to replace blackboards and whiteboards, taking off roughly between 2000 and 2010 (Şad, 2012), was a real boost for the development of digital educational materials. With regard to video, smartboards freed classes from unsatisfying television and VCR sets, and online video platforms accessed through smartboards made video an easy-to-use format. The concept of blended learning has been around since about 2001, and is defined as a mix between digital online learning and face-to-face meetings. Blended learning was the standard practice in higher education well before the pandemic outbreak (Bonk & Graham, 2012). Considering new technologies and media in education is a relevant approach when discussing developments in learning, since they are not just carriers of educational content that present content differently: They facilitate new opportunities to engage learners with that content.

At present, in online learning environments as well as in face-to-face meetings, audiovisual media represent a fair amount of the educational content. New opportunities that arise from learning with audiovisual media have been welcomed by educators throughout the decades. Unfortunately, their enthusiasm does not guarantee that these media are also used *optimally*, in the sense that the potential of these media that follows from their specific characteristics are deployed to utilize their full potential. The central premise of this thesis is that the audiovisual medium video is such a non-optimally used medium in education.

To see its full potential, one should consider video from various perspectives, leading to various directions for optimization. Perspectives that are represented in research on videos in education range from the educational sciences and educational psychology to cognitive psychology, each with a different focus leading to different suggestions for optimization. The most prominent perspective in educational practice is that of technology. The technological perspective focuses on the characteristics of video that make it an excellent facilitating tool of online and blended learning. As a technological tool, video can produce a digital document of a recorded instruction, which can be preserved in time, shared online, and replayed at any moment, anywhere. Deploying these characteristics of video, the medium optimizes methods for self-paced and differentiated learning that are of great value to learning in the 21st century. The chaos of transferring rapidly to online teaching during the pandemic outbreak, strengthened this technological perspective even more. But there are some costs to that.

Considering video *only* from the perspective of technology risks that researchers and educators forget that a video does not just present content differently from face-to-face meetings, but that learners also engage with that content differently when presented in a video. Watching presentations from a screen is not the same as experiencing them in real life. Research reports on

demotivated pupils as a result of online-only education in 2020 are numerous (e.g., Meeter et al., 2020), and part of it can be attributed to teachers trying to fit their original course of face-to-face teaching into this imposed online form. In fact, use of video has been criticized right from the moment it made its way into the classroom, as we will see in a bit. To find out how learners engage (differently) with educational content when presented in a video, another perspective is required.

A perspective that so far has been close to absent from the discourse on video in education, is the perspective of media studies, and more specifically that of film studies. Looked upon from this perspective, video is a medium that activates its viewers to anticipate structural developments and hypothesize on resolutions to these developments. It does so by presenting auditive and visual cues that direct the viewers' attention and anticipation (Bordwell, 1985).

It is a perspective that comes naturally to me when considering any kind of audiovisual medium, being trained as a film scholar. Deploying these characteristics of video, the medium does not primarily facilitate methods for knowledge transfer in instruction, but rather it optimizes opportunities for learning aims that are considered key to all learning, but are far too often neglected or not accomplished: raising interest and motivating pupils (Dewey, 1913) – exactly what online learning failed to accomplish during the 2020 pandemic outbreak (Meeter et al., 2020).

The educational potential of film was recognized by teachers as soon as it became available and manageable for use in schools in the early 1920s, and film scholars emphasized the potential of film for education. Wegner (1977) even considered film "[…] the most influential and seductive force available to us to teach, to convince, and to transmit ideas and information […]" (p. 8) precisely because of its mode of audiovisual communication. However throughout the decades, from the few film scholars that did occupy themselves with the educational film, there has been forceful critique on the common format of the educational film: "The first teaching films were visualizations of textbooks. They were dull and boring [...]. Educational films early earned the reputation of being devoid of interest" (McClusky, 1947, p. 375). Thirty years later, nothing much had changed: "Films made for the classroom […] are watched with boredom; minds almost audibly shut against their attempt to teach. Pupils detect the educational film almost immediately, for it is usually characterized by heavy-handed didactics and notable lack of production values" (Wegner, 1977, p. 10). And in the 21st century, still the same critique is expressed: "[The] explicit transmission of content disengages pupils and ignores the strengths of the video format to 'show not tell'" (Thomson et al., 2014, p. 69).

Following these critiques, films and videos made for education lack the power to raise their viewers' interest, whereas fiction films are known to be true interest magnets. Apparently, a clear cut has been made between films made for entertainment, and those for learning, a distinction that is not paralleled in how we use books to teach literature and drama for example (McClusky, 1947). It appeared to me that, while film scholars are primarily occupied with research on fiction films for entertainment, the potential of film and video for raising interest in learning remains underdeveloped. There seems a need to explicitly include the perspective of film studies in the practical as well as the scientific discourse on video in education. This inclusion may offer practical guidance for educational use of video, and an interdisciplinary approach in research. This thesis is an attempt to do so.

Research Scope

Doing research means narrowing down. This thesis is the result of the many choices I made, some at the start, and many along the way. The following offers insight into the motives behind the most prominent choices that determined the scope of research and how these motives led to four concrete research aims.

Motives and aims

At the start of this research project, I had two motives (see Figure 1.1). Firstly, I wanted to offer guidance for educational professionals to optimize video as a tool for raising interest in learning. Many teachers I met early in the project easily saw video's potential to raise interest, but had trouble making informed choices, and I was determined to offer them guidance. However, this was more easily said than done, because what makes up good guidelines? The more clear and concrete the better, so I tried to come up with some general rules. But film making is not like following a recipe. Something may work one time, but the next it may fail because the factors involved in the success are inexhaustive: timing, order, rhythm, framing, lighting, music, acting, et cetera. Yes, all elements that make up an effective video can be analyzed, but the collection of elements does not explain its effectiveness; it merely presents the description of an effective example. And still, a video that was once effective for raising pupils' interest may not succeed the next time, with a different audience and watched in different circumstances. Soon I realized that the clear and concrete guidelines I was hoping to formulate would not meet the teachers' needs.

Rather than offering a recipe for success, I would offer insight into the underlying mechanisms as a means to explain the success. This newly formulated motive led to two concrete research aims: Presenting a structured overview of the current state of video usage in education and the share of interest in it (Chapter 2), and offering worked examples of what works well and what does not when using film and video for raising interest, to guide teachers (Chapter 5).

The second motive of my research project was to make the unheard voice of film studies relevant in the scientific discourse on video in education. As discussed above, there are several

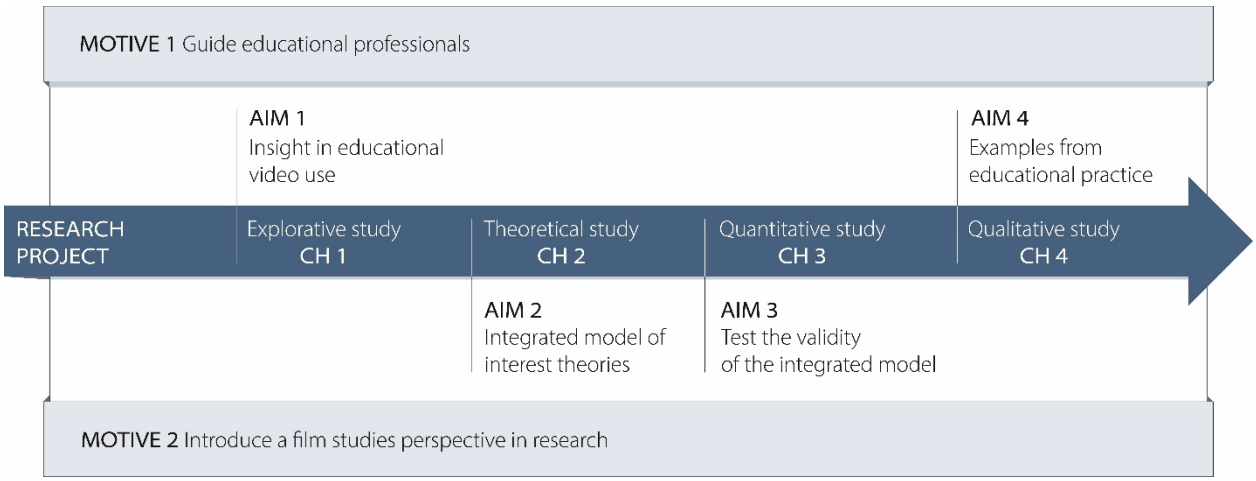


Figure 1.1. Overview motives, aims, and studies within the research project.

disciplines claiming their place in this discourse, but the perspective of film studies is close to absent. Not only do I think that any discourse benefits from multi-perspectivity, I also believe it is a duty of all scientists to make a contribution to any context deemed to be relevant. The context of education is evidently underrepresented in the field of film studies. Being a film scholar myself, working in the field of educational research, I came to realize that a possible cause for this is that film studies is still a relatively young discipline. For a long time it relied on literature and photography studies to formulate theories and analysis approaches of its own (Bordwell, 2010; Tan, 2018a). Only recently, film theorists have begun to empirically study film viewing in a systematic way (e.g., Ildirar & Schwan, 2015). As a consequence, this discipline is still in the process of formulating its own standards for empirical research – which is standard practice in educational research studies. Thus, making the unheard voice of film studies relevant in the scientific discourse dominated by educational research would not only imply a theoretical contribution, but an empirical one as well if we are to come to mutual understanding and agreement.

This motive led to two more aims, as means to open the eyes of both film scholars and educational researchers for the unprecedented opportunities for joint forces: Integrating film theory with theories from educational research in a framework on educational use of video for raising pupils' interest (Chapter 3), and applying this integrated theoretical framework to videos used in educational practice, to test its empirical validity (Chapter 4).

Core Concepts

Doing research in an interdisciplinary team turned out to be no easy task. Differing approaches, standards, and jargon forced everyone in the team to explain what is naturally taken for granted when working within the community of one's own discipline. To come to mutual agreement, we had to make several choices. Now, I will discuss three concepts that lie at the heart of this thesis, to offer a start of mutual understanding between you, the reader, and me, the author.

The first concept is *Interest*. In theorizing and defining interest in Chapter 3, I follow Silvia (2006) and consider interest an emotion, which integrates affect, cognition and motivated action. The relatedness of interest and curiosity has been the topic of a complete special issue of *Educational Psychology Review* in December 2020. And the way we modelled film's interest raising mechanisms in Chapter 3 shows great similarities to Csikszentmihalyi's theory of flow (Csikszentmihalyi, 2014). To make informed choices in how to conceptualize interest in this research project, I took on a functional approach by looking for strong leads to link film theory and theories from educational research.

Being trained as a film scholar, constructivist film theory was my point of departure. Here, perception theories by Popper, Helmholtz, and Gombrich are the central frames of reference to explain viewer activity in terms of inference making and hypothesis-testing (Bordwell, 1985). Prominent film theories on viewers' interest build on that and describe viewers' anticipation of development and closure as the driving mechanism. I sought to find common grounds in education theory, to succeed in an interdisciplinary approach. I found that common ground in emotion theory. A full elaboration of interest as an emotion is presented in Chapter 3. For now, I limit myself to discussing how attention, motivation and flow relate to interest as an emotion.

Following Renninger and Hidi (2016), interest supports motivation and engagement with the object of interest. Emotion theory claims that interest comes with an urge to act (Scherer, 2010).

One aspect of that urge is the willingness to pay attention to it, a second is to spend effort (Renninger & Hidi, 2016). Both interest and flow evolve as a result of evaluations of an event or an object (appraisals) that poses a challenge on the one hand, and the feeling of being able to cope with that challenge on the other. When these appraisals co-exist simultaneously, flow is experienced (Csikszentmihalyi, 2014). When the challenge preludes the coping and coping is delayed, the experience is interest (Tan, 1996).

Two concepts that need a joint discussion are *Film* and *Video.* Educational practice speaks of videos, while film theory prefers film. In bringing together the vocabulary of both worlds into a single discourse, I chose to reserve the term film for the theoretical conceptualization of the medium, and video for the actual material used in classrooms. In this thesis, film is only used as a concrete carrier of audiovisual material when it refers to a feature length film, like a fiction film or documentary – the kinds we watch in film theatres and cinemas.

A fourth and final concept that deserves some elaboration is *Film and video for learning*. Intentionally I do not speak of educational videos. All audiovisual media with a predefined non-interactive structure communicate by the language of film. Videos made for entertainment may be used for learning purposes just as well as videos intentionally made to educate can have entertaining value. The function of a film or video is more dependent on how it is used than on how and why it is made. As is discussed at the end of Chapter 5, how pupils perceive a video is likely to be dependent on the viewing context and the teacher's introduction.

Research Context

The context chosen for this research project reflects the focus of the research institute, the Freudenthal Institute at Utrecht University, that offered a home for my research project. However, this context has not been chosen arbitrarily. Secondary science and mathematics education struggle a great deal to motivate pupils for real engagement (Savelsbergh et al., 2016). This makes it relevant to inquire the potential of film for raising pupils' interest in science and mathematics classrooms. Consequently, all videos used in the subsequent studies treat science and mathematics topics. The studies in this research project were conducted in pre-university education classrooms (followed by the 15% highest performing pupils in Dutch secondary education). The classrooms were taught by ten different science, mathematics, chemistry and biology teachers. In total, 410 pupils aged 13–18 years participated in the studies.

Even though the findings of our studies are specific for the educational contexts described above, I believe that, through theoretical generalization, these findings have the potential to be made applicable to a broader context. The results are formulated in such a way that they go beyond the educational contexts at stake.

Research Overview

The research project presented in this thesis consisted of four subsequent studies. In the study described in **Chapter 2**, we performed explorative research to describe how videos are being used in secondary science and mathematics education in the Netherlands. Starting the research project with an open mind offered the opportunity to explore rather than imply and infer the strategy of teachers when using video. Getting to know the topic within the intended context then could reveal unforeseen factors involved, and offer grounds for the exact focus of the studies that

were yet to follow. The research question leading this study was: *Which video characteristics can be expected to help achieve which teacher aims?* We inquired the aims of seven secondary science teachers, the characteristics of the 13 videos they chose for these aims, and how their pupils (N = 233) perceived the videos with regard to the teacher aims. We conducted teacher interviews, did video analyses, and used pre-and post-viewing pupil questionnaires to perform case studies, and finally a cross-case analysis.

Our findings gave grounds to specify the focus of our next study on constructing a model that integrates theories from educational psychology and film studies on interest. **Chapter 3** presents the model and the theoretical study that lay at its basis. As argued above, we considered interest as an emotion and sought to find parallels between both fields of research. The model describes Film's Interest Raising Mechanisms (the so-called FIRM model) based on pupil-viewers' appraisals. Additionally, we further refined a method for analyzing videos in relation to these appraisals, and a system to operationalize the analysis to determine a video's potential interestingness.

Next, we set up an empirical study to validate the model, which is described in **Chapter 4**. This study included four videos that were used in six secondary science and mathematics classrooms (one video per classroom), with a total of 151 pupils. In this study, we tested the following hypotheses:

1. *Pupils' appraisals of a video's characteristics predict the pupils' interest in the video;*
2. *Pupils' interest in the video predicts the development of pupils' interest in the educational content of the video;*
3. *Pupils' appraisals of a video's characteristics predict the pupils' development of interest in the educational content of the video indirectly via their interest in the video;*

We used pre- and post-viewing pupil questionnaires to perform a path analysis with structural equation modelling.

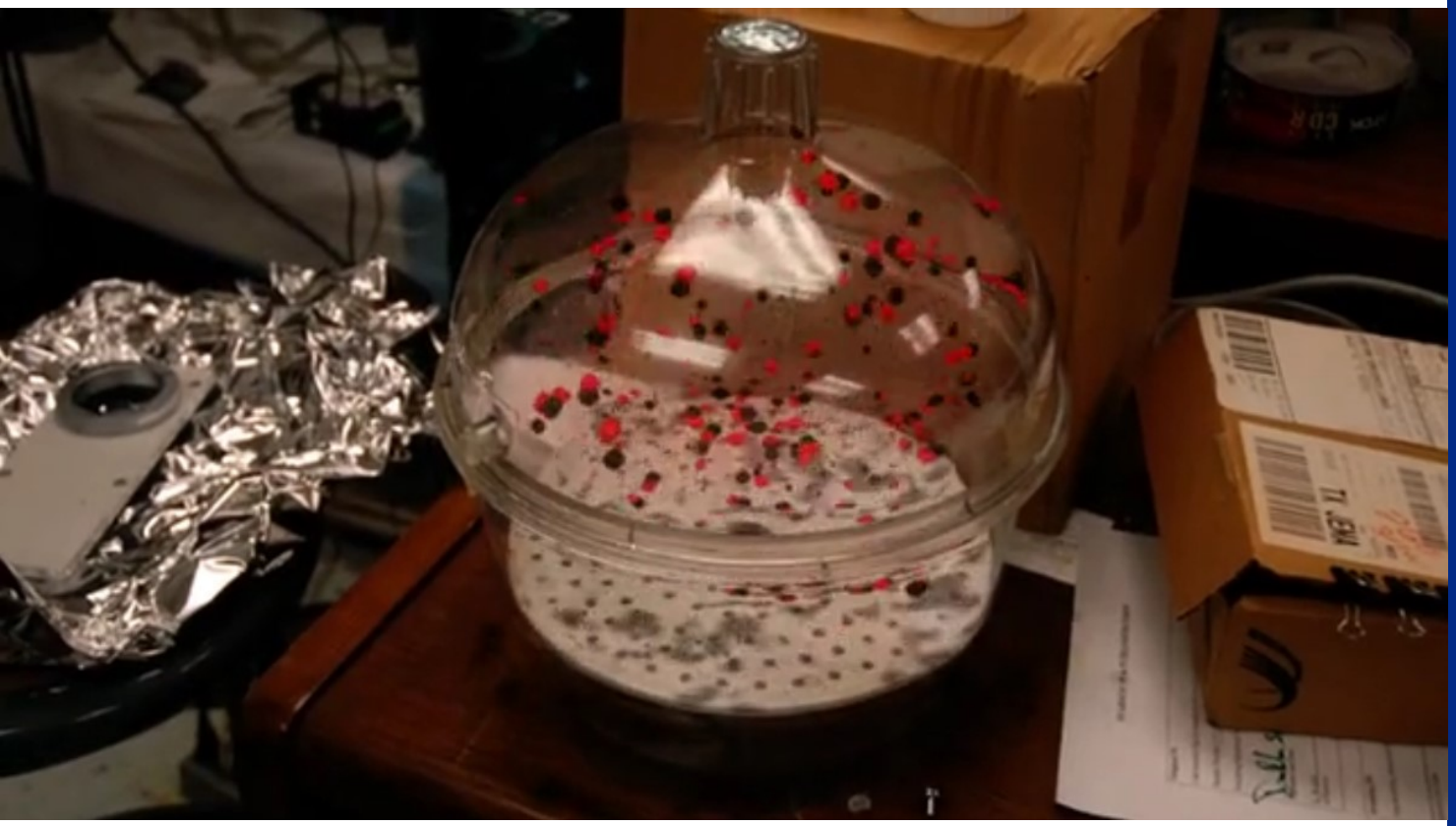
Finally, we performed an empirical study described in **Chapter 5** with the aim to explain, and so to better understand, the mechanisms underlying the FIRM model. The research question leading this study was: *How do pupils' appraisals of video characteristics relate to their interest and to the development of their interest in the video?* We evaluated the use of five videos in seven secondary science and mathematics classrooms (again one video per classroom), with a total of 177 pupils. We used post-viewing pupil questionnaires and did video analyses to perform case studies, and finally a cross-case analysis. This study resulted in four themes that each describe an aspect of the relationship between appraisals and interest. From these themes we formulated three questions that may guide educational professionals when using videos to raise interest in learning.

The closing **Chapter 6** summarizes the research and discusses its main findings, as well as the limitations and suggestions for future research. The added value of an interdisciplinary approach, including the multiple perspectives that co-exist in the discourse on video in education, is discussed conjunctly. The thesis concludes with recommendations for educational professionals who want to get the most out of using films and videos for raising pupils' interest in learning.

Educational Videos from a Film Theory Perspective

Relating Teacher Aims to Video Characteristics

2



Wijnker, W., Bakker, A., van Gog, T., & Drijvers, P. (2019). Educational videos from a film theory perspective: Relating teacher aims to video characteristics. *British Journal of Educational Technology, 50*(6), 3175–3197.

Abstract

Teachers are increasingly using video in their lessons, with various aims (e.g., to raise pupils' levels of conceptual knowledge or interest). Videos that can be used for educational purposes are numerous, ranging from instruction videos to fiction films. Such videos have different characteristics, for example regarding the amount and structure of information, and the audio-visual presentation. However, guidelines on which video characteristics can help to achieve specific teacher aims are lacking. As a first step towards composing such guidelines, we added a film theory perspective to educational research on videos. The study included seven science teachers, 13 videos, and 233 pupils (aged 13–18 years). We used teacher interviews, video analyses, pupil questionnaires and a cross-case analysis connecting all the data. Data analysis followed a grounded theory approach, including open and axial coding to structure the data, and the constant comparative method to interconnect them. The results showed that videos that posed questions were associated with an increase in pupils' interest, and that highly informative videos with authoritative speakers were associated with an increase in pupils self-reported conceptual knowledge gains. Moreover, teachers often did not have explicit aims for using a particular video, and they selected and used videos in their lessons intuitively. Stimulating teachers to use videos in a more aim oriented way may make video usage more effective. From these findings, we developed a framework to assist teachers in selecting or making videos that match their aims, and a model of possible connections between teacher aims and film types as a first step towards guidelines for teachers using educational videos.

Introduction

Audio-visual media such as video are increasingly taking a prominent role in (online) education worldwide (Thomson et al., 2014). Videos are popular with both teachers and pupils. Teachers often search for videos on online platforms, such as YouTube Edu, Khan Academy and (in the Netherlands) Wiskunde Academie (which translates to Math Academy).[1] However, in educational research and practice one question keeps returning in the debate on video usage: What makes a good educational video? (Hobbs, 2006; McClusky, 1947; Schwartz & Hartman, 2007; Thomson et al., 2014). This question is not new: From the 1920s on, film has been used for educational purposes. As soon as films and projectors became affordable and operable for the general public, film made its way into the classroom (Masson, 2012). Yet, after 100 years of teaching with this medium, the question of what makes a good educational video still remains largely unanswered.

What educational videos look like varies greatly: they range from knowledge clips (e.g., instruction about Newton's Laws), and how-to videos (e.g., demonstration of how to graph linear equations), to live registrations (e.g., registration of chemical experiments), documentaries or fiction films (e.g. a dramatized narration of the discovery of penicillin). Teachers' aims for using educational videos also vary, and range from instruction or raising interest, to illustrating classroom instruction or generating input for discussion (Schwartz & Hartman, 2007; Hansch et al., 2015). However, it is unclear what a video should look like to help achieve a particular teacher aim (Schwartz & Hartman, 2007; Thomson et al., 2014). Because guidelines are lacking, teachers have no choice but to go by intuition and experience when using videos for education, making videos' effectiveness uncertain. More research is needed to help teachers make or select videos that meet their educational aims (Schwartz & Hartman, 2007).

Educational Sciences and Video

Previous research on educational videos has mainly been conducted from an educational sciences or cognitive psychology perspective. These studies focus on factors such as efficient process- ing of audio-visual information (Clark & Paivio, 1991; Kester & Van Merriënboer, 2013; Mayer, 2014; Muller, 2008; Sweller et al., 2011), and learning in online environments (Bergmann & Sams, 2012; Kay, 2012; Scagnoli, Choo, & Tian, in press; Van der Zee et al., 2017). Most of these studies share a focus on increasing the learner's level of conceptual or procedural knowledge. Only a few studies investigated the diversity of teacher aims that could be achieved with video (Schwartz & Hartman, 2007; Baggaley, 2013; Hansch et al., 2015). Coming from the field of educational sciences, studies that investigate teacher aims give elaborate aim descriptions (e.g., Schwartz & Hartman, 2007; cf. Table 2.1). Besides this, some studies attempt to describe kinds of videos that connect to these aims (e.g., Koumi, 2006). However, these contributions remain insufficient to formulate guidelines, because the video characteristics are not researched sufficiently. In their paper, Schwartz and Hartman (2007) even call for more research on educational videos to enable describing effective mechanisms that connect video characteristics and teacher aims. We argue here that adopting a film theory perspective can

1 https://www.youtube.com/edu; http://www.khanacademy.org; http://www.wiskundeacademie.nl.

Table 2.1
Categories of Teacher Aims and Corresponding Video Examples, Based on Schwartz and Hartman (2007, p. 338)

Teacher aims	Sub aims	Description	Video examples
Doing	Attitude Skills	Learning attitudes and skills from presented human behaviour	Modelling, identification, demonstration, step-by-step
Engaging	Contextualize Interest	Preparing to learn through creating contexts and developing interests	Ad, trailer, trigger, narrative, anchor
Saying	Explanations Facts	Learning verbal or declarative knowledge	Association, chronicle, analogy, commentary, expository
Seeing	Discernment Familiarity	Learning to notice discernment and to recognize something new	Tour, portrayal, point of view, simulation, highlighting

contribute valuable insights for research on educational videos and thereby, ultimately, help develop guidelines for educational use of videos.

Film Studies and Educational Video

In the field of film studies, videos are analysed systematically by looking closely at what characterizes them. The two main factors that are taken into account in such video analyses are the flow of information and the audio-visual presentation of that information. The first, referred to as the formal system, defines how information is selected, composed, and coloured; the second, referred to as the stylistic system, defines how information is audio-visually presented in mise-en-scène, cinematography, editing, and sound. The interfering formal and stylistic systems together shape the video's *film form* (Bordwell et al., 2017), which is typically categorized in terms of *genre* (Altman, 1998). Genres can help viewers a great deal in trying to make sense of what is presented, because they are based on filmic conventions that direct viewer expectations (Bordwell, 1985). To give an example of a well-known fiction film genre, we recognize a Romantic Comedy by the use of soft tone colours, emotional music, and many close-ups. These characteristics guide the viewer into anticipating the typical romantic comedy story to develop of a single (wo-)man searching and finding a partner.

The educational film can be seen as a genre, cueing the viewer to anticipate the treatment of some educational content that is to be learned. Educational content may range from quantum physics to psychology, and learning may involve more than gaining conceptual knowledge. Film genres are general descriptions of typical structures. To categorize educational films with respect to their variety, we propose not only to look at what binds them, but also at what distinguishes them from each other.

Through making analyses of the formal and stylistic systems of many educational films, McClusky (1947) defined no less than 11 types of films in the educational film genre (see Table 2.2). In addition, he described the educational context in which these videos could be used, giving a lead to connect video characteristics to teacher aims. Film analysis of video

Table 2.2
Film Types in Educational Videos, Based on McClusky (1947, pp. 374–378)

Film type	Video description
Discursive	Systematic treatment of a topic for introduction, summary or background material
Dramatic	As narrative film type, but more emotionally loaded
Drill	Repetitive series of actions that are to be copied by the viewer
Emulative	Shows how to perform an act or skill, or shows patterns of behaviour
Evidential	Record of (scientific) data for study or analysis
Factual	Encyclopaedic presentation of an event or topic for conveying information
Incentive	Activates to develop character, attitudes, morale, and emotional response
Narrative	Tells a story based on fiction or fact to inform or to give an account of events
Problematic	Sets a problem for discussion and supplies data for thinking
Rhythmic	Artistic effects that are to evoke esthetical reactions within the viewer
Therapeutic	As rhythmic film type, but for the treatment of psychoneurotic patients

characteristics and the descriptions of the educational film types together provided the framework we used to describe the educational videos in our study.

Connecting frameworks from the educational sciences and film studies will help make a first step towards developing guidelines for relating teacher aims to video characteristics. To this goal, we performed an exploratory study on videos in science education researching the question: Which video characteristics can be expected to help achieve which teacher aims? To answer this question, we gathered data following three research questions: (RQ1) What aims do teachers have when using videos in their lessons? (RQ2) What are characteristics of the videos that teachers select for their aims? (RQ3) How do pupils evaluate the selected videos in relation to the teacher aims?

Method

Participants

Seven science teachers in Dutch secondary education participated in our study: four male and three female, aged 33–52 years (M = 43.43, SD = 6.91), with 6–17 years of teaching experience (M = 10.86, SD = 3.83). The teachers formed the team of a pre-university education[2] science programme at one school in the Netherlands, which consisted of one mathematics, two biology, two chemistry and two physics teachers. A total of 233 pupils participated in this study (48% male, 52% female), aged 13–18 years, divided over 14 classes (one 9th grade class, and thirteen 11th grade classes).

Procedure

The study included all classroom videos that the teachers had already planned to use in the school year 2016–2017, in the pre-university programme or in regular school classes. Videos used in online learning environments were not included in the study because watching these videos was not mandatory. This added up to 14 videos in total: one teacher used one video, five teachers used two videos and one teacher used three videos. One video was produced by the teacher himself (*Lieke and the drum*), the other videos were selected by the teachers from various online platforms. Each video was evaluated in the classroom in subgroups ranging from

2 The highest level of secondary education in the Netherlands.

23 to 49 pupils, which added up to 447 valid evaluations in total. For each video use we identified the aims the teacher had with its use through interviews (RQ1), analysed the video characteristics (RQ2), and conducted pupil evaluations through questionnaires (RQ3). Together these three types of data made up a single video case, adding up to14 video cases in our study. To address the main research question, the video cases were used for a cross-case analysis (Borman et al., 2006).

Instruments

Teacher Interviews

The teachers were asked to explicate their motivation for using the videos in semi-structured interviews performed by the first author. Structured open questions asked were: "Why do you use video in your lesson?", "What is the function of the video in your lesson?", "What should the video bring about in your pupils?", and "Why do you want this to be brought about in your pupils?". The responses were summarized for each video afterwards.

Pupil Questionnaires

The pupils were asked to fill in a video-specific five-statement questionnaire with a five-point Likert scale (I don't agree at all—I totally agree, see Figure 2.1), in order to investigate whether pupils' perceptions of the video corresponded with the aims the teacher intended to achieve. We composed a different questionnaire for each video to match the aims of the teacher for that specific video, for example: The questionnaire statement "I can give examples of chemical industry" was composed to match the teacher aim of introducing real-life contexts in which chemical industry can be found. The statement "I want to learn more about the subject" was composed to match the teacher aim of raising pupils' motivation. We asked the teachers to check whether the statements indeed reflected their aims. In some cases, it was necessary to adjust the statements to better match the aims of the teachers. The pupils were informed about the research project at the start of the class by the first author. The teachers delivered the lesson as planned with their own introduction of the video. The questionnaires were filled in just before watching a video (pre-viewing) and directly afterwards (post-viewing). The pre- and post-viewing questionnaires for one video both consisted of the same five statements, so that pre- and post-viewing outcomes could be compared.

Data Analysis

We started by analysing the data that resulted from the first three research questions (Phase 1 in Figure 2.2). Next, we gathered and connected the three sources of data for each video case by a cross-case analysis to answer the main research question (Phase 2 in Figure 2.2).

Teacher Aims

To answer RQ1, we analysed the teacher responses. Initial answers of the teachers were somewhat vague, such as "To have a nice start" or "To elaborate on the theory" or "To show a nice example." Asking them to explain their answers resulted in more elaborate replies, such as

Figure 2.1. Five-point Likert scale presentation in the pupil questionnaires.

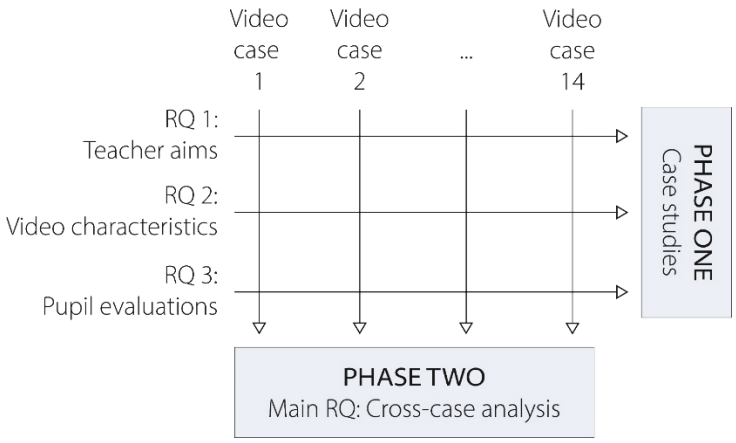


Figure 2.2. Phases in the data analysis.

"I want to show them examples of how the theory can be applied to real life contexts, to get them excited about the topic." In the interviews, the teachers said they had difficulties explicating their motivation for using videos because they had not given it much thought before, not even when selecting the videos.

We used open coding to analyse the teacher responses (Boeije, 2010). In the process of open coding, we summarized and grouped the teacher responses to see if any similarities emerged in the responses. This led to initial categories that we used for axial coding (Boeije, 2010), to connect the teacher responses bottom up to more formal categories. We found that the categories distinguished in the model by Schwartz and Hartman (2007) for designing video for learning and assessment best matched the aims of the teachers in our study (see Table 2.1). Subsequently, we coded all summarized teacher responses using the categories from this model (see Appendix 2A). Most teachers had multiple aims for using a single video. The coding of the summarized teacher responses was conducted by the first author and an independent researcher; 41 out of 42 teacher responses were coded identically, which equals a 97% agreement and a near perfect inter-rater reliability between the two researchers (κ = .97). One case was discussed until consensus was reached.

Video Characteristics

To answer RQ2, we analysed the videos' characteristics following the method of Bordwell *et al.* (2017) to describe the flow of information and the audio-visual presentation of that information. This involved for example: what information was given in what scene, how that information was provided (in audio or visually, in images or in text), and what the image of the video looked like (e.g., animation or live action, camera movements, framing). For each video, we summarized the results in a video description (see Appendix 2B for an example). The descriptions were used in the data analysis to code the videos as film types (see Appendix 2C) following McClusky (1947; see Table 2.2), and in the cross-case analysis (see below).

The film types are not exclusive in nature, meaning that one video could be classified as more than one type of film (McClusky, 1947). However, we treated the film types Discursive, Factual and Evidential as being mutually exclusive. These categories primarily refer to the amount of information that is given and together represent a sliding scale ranging from elaborate discursive explications at one end, to bare evidential recordings at the other. Factual films are positioned in between. Therefore, all videos were coded as one of these three film types. Most videos were

assigned two or three film types. We specified the degree to which each film type was represented in the videos, by adding the code *strong* to the film types that were clearly present in the videos, and *weak* to the film types that were only slightly present. The coding of the film types was conducted by the first author and an independent researcher on the three exclusive categories (Discursive, Factual and Evidential). Twelve out of 13 videos were coded identically, which equals a 92% agreement and an excellent inter-rater reliability between the two researchers ($\kappa = .80$). One case was discussed until consensus was reached. The coding of the other video type categories was conducted by the first author and checked by an independent researcher. There was consensus about all video types that were assigned to the videos.

Pupil Evaluations

To answer RQ3, we calculated the mean outcomes on each statement for each video (based on answers from 19–45 pupils per statement per video). We then compared the outcomes of the pre- and post-viewing questionnaires for each statement of each video to calculate the mean difference. This informed us about the influence pupils perceived from the video regarding the aims of the teacher. We calculated the mean outcomes for each teacher aim category over the mean outcomes of all statements used for all videos regarding that teacher aim, to set the standard for each teacher aim category. Evaluation outcomes of each statement were then compared to this overall mean, determining whether the statement showed an outcome above or below average on that teacher aim category.[3] Given the diversity of questionnaire questions and the small number of pupils per questionnaire, we present only descriptive statistics. Hence, any reported differences should be treated as such.

Cross-Case Analysis

To answer the main research question, the first author used the rich data of each video case to formulate conjectures about how the video characteristics might be related to the teacher aims. In a cross-case analysis we applied the constant comparative method (Boeije, 2010), com- paring video cases to identify similarities and differences. Cases that were found to be similar were grouped to identify properties specific to these groups of cases. The properties consisted of data from at least two of the three data sets (teacher aims, video characteristics, pupil evaluations). From these properties, we formulated conjectures for each group of video cases, for example: “Videos that are used to achieve the aim of Engaging present examples of real-life situations or phenomena.” This conjecture involves teacher aim and video characteristics data. Another example is: “Videos that deal with environmental issues score above average on the aim of Engaging-contextualize.” This conjecture involves data from all three data sets. After a generative round, 15 conjectures were formulated. We then continued with an assessment round to see whether the conjectures would be confirmed for all video cases in the study.

3 Two teachers used the same video (Dr Quantum —Double slit experiment) for two separate modules (CERN excursion and Grenoble excursion). In our study, we treated the double use of this video as two distinct cases. These teachers were interviewed together, and they jointly reported on the teacher questionnaire because they had also jointly selected the video. For the pupil evaluations, we used questionnaires with the same five statements for both cases. The video was evaluated with two different groups of pupils and resulted in different outcomes.

Results

Teacher Aims

With respect to RQ1 on teacher aims, the most frequently reported teacher aims were Engaging and Saying (Table 2.3). In responses coded as Engaging, teachers mentioned wanting to generate pupils' interest in the subject of the module, wanting to introduce the subject of the module and activate prior knowledge, or wanting to present examples or situations as concrete and relevant contexts for the subject. In Saying responses, teachers mentioned wanting to raise the level of conceptual knowledge. Two teacher responses were coded as Doing, with teachers wanting pupils to learn how to perform a task. One teacher response was coded as Seeing, with the teacher wanting pupils to notice a new phenomenon (see Table 2.3).[4]

Video Characteristics

With respect to RQ2 on video characteristics, the videos were quite diverse. For example, there were as many animation videos as live action videos, and about as many videos using quick camera movements and fast editing as unexciting videos.

Table 2.4 shows that by far most videos were coded Discursive, providing plenty of information. In total, eight videos were coded as Problematic. Five of these videos posed questions to bridge the gap to the next scene, and the questions posed were answered immediately in the following scene (coded as Weak). The other three posed questions that were leading for the further development of the video (coded as Strong).[5]

Pupil Evaluations

With respect to RQ3 on pupil evaluations, Table 2.5 shows that, for all videos taken together, the mean difference between pre and post viewing outcomes was lowest for the aim of Engaging-interest. The mean difference is highest for the aim of Saying-explanations, closely followed by Saying-facts.[6]

Cross-Case Analysis

With respect to the main research question, two conjectures were confirmed: (1) Videos that were coded as Problematic-Strong film type scored above average on the aim of Engaging, and

Table 2.3
Number of Teacher Responses per Teacher Aim

Teacher aim	Times mentioned	Sub aim	Times
Doing	2	Attitude	0
		Skills	2
Engaging	16	Contextualize	9
		Interest	7
Saying	17	Explanations	9
		Facts	8
Seeing	1	Discernment	1
		Familiarity	0

4 The summarized teachers' responses categorized as teacher aims are presented in Appendix 2A and 2B.
5 The videos categorized in film types are presented in Appendix 2B.
6 Appendices 2D-2F present specified data on the separate statements.

Table 2.4
Number of Videos per Film Type

Film type	Strong	Weak	Sum
Discursive	11	-	11
Evidential	1	-	1
Factual	2	-	2
Emulative	0	4	4
Incentive	3	0	3
Narrative	1	3	4
Problematic	3	5	8

Note. Strong = clearly present. Weak = slightly present

(2) Videos that scored above average on the aim of Saying-explanations were coded as Discursive film type. T, the other conjectures were rejected because they did not hold true for all video cases. Below, we discuss for both confirmed conjectures how the data involved can be related.[7]

Eight videos in our study posed questions or problems and were coded as Problematic film type. In five of these videos' questions were used rhetorically to propel the story or argument: The question was asked only to be immediately answered in the following scene. However, three videos posed or raised genuine questions that became leading for the direction of the story (*Het Klokhuis: Figure it out! Earth*; *Het Klokhuis: Molecular cooking*; *NOAA Ocean acidification—The other carbon dioxide problem*). In these last three videos, the questions became the starting point of a quest for answers, and the videos were coded as Problematic-Strong film type. Problematic-Strong videos showed a difference between pre- and post-viewing outcomes above average on the aim of Engaging-interest, whereas Problematic-Weak and videos not coded Problematic showed outcomes on or below average. We found no link between Problematic videos and the aim of Engaging-contextualize.

Saying-explanations was the most frequently found teacher aim in our study. Three videos in our study showed post-viewing outcomes and a difference between pre- and post-viewing

Table 2.5
Overall Mean Outcomes of the Pupil Evaluations per Teacher Aim

Teacher aim	Mean post viewing score (SD for videos)	Mean Δ pre and post viewing score (SD for videos)	#video	#statem	#pupils
Doing-attitude	- (-)	- (-)	0	-	-
Doing-skills	3.8 (0.08)	0.5 (0.38)	2	5	44
Engaging-contextualize	3.6 (0.58)	0.4 (0.33)	9	21	298
Engaging-interest	3.7 (0.29)	0.1 (0.11)	7	13	195
Saying-explanations	3.9 (0.76)	1.2 (0.76)	9	17	295
Saying-facts	3.9 (0.58)	1.1 (0.80)	8	11	267
Seeing-discernment	3.2 (-)	0.3 (-)	1	1	27
Seeing-familiarity	- (-)	- (-)	0	-	-

Note. #video = number of videos; #statem = number of statements; #pupils = number of pupils

7 The data referred to below can be found in Appendices 2D, 2E and 2F.

outcomes above average on Saying-explanations (*Dr Quantum—Double slit experiment*; *Ted Edu: Why do honeybees love hexagons?*; *Antifungal drugs: Mayor types and functions*).[8] All three videos, giving plenty of information, were coded as Discursive film type. All videos used for Saying-explanations that gave little information (Evidential or Factual film type) had post-viewing outcomes below average (*Lieke and the drum*; *Heart rhythm dance*). However, there were also two videos used for the aim of Saying-explanations, that were coded as Discursive film type, but showed outcomes comparable to the outcomes of the Factual and Evidential videos (*Het Klokhuis: Figure it out! Earth; Chemistry at work*). Taking a closer look at the characteristics of the Discursive videos used for Saying- explanations shed light on this variation.

All three discursive videos that showed post-viewing outcomes and a difference between pre- and post-viewing outcomes above average on the aim of Saying-explanations were animations. But they were animated at not quite the same level of complexity. *Dr Quantum— Double slit experiment* was the most complex animation video, showing many different camera angles, camera movements, and a moving and talking presenter. This video was produced by professional film- makers. The videos *Antifungal drugs: Mayor types and functions* and *Ted Edu: Why do honeybees love hexagons?* were noncomplex animated videos, showing mainly static images that illustrate spoken information provided in a voiceover. Unlike the two noncomplex videos, the professionally produced video furthermore used exciting music and sound effects to enliven the video. The professional video showed the biggest influence on the pupils' evaluations of Saying-explanations aims of all, both on post-viewing outcomes and difference between pre- and post-viewing out- comes. A potential (speculative) explanation for this might be that pupils took the profession- ally produced video more seriously, assuming it came from an authoritative speaker.

What most discursive videos had in common is that the information is given by an all-knowing presenter. In our study *Het Klokhuis: Figure it out! Earth* and *Het Klokhuis: Molecular cooking* were the only exceptions to this rule. On the contrary, in these videos a naïve presenter functioned to raise questions and to take the viewer on a quest for answers. Similar to the presumed effect of professionally produced videos, the pupils might have taken all-knowing presenters as more authoritative speakers. This might explain the lower outcomes of the discursive video *Het Klokhuis: Figure it out! Earth* for Saying-explanations.

The video *Chemistry at work* was only one of the components that were used by the teacher to achieve the aim of Saying-explanations, and thus could not fully achieve the aim of Saying-explanations on its own. This might explain the lower outcomes of the discursive video *Chemistry at work* for Saying-explanations.

To summarise: Problematic videos were associated with the aim of Engaging-interest as assessed by pupils' self-reports, but only if genuine problems or questions were raised that functioned to lead the direction of the story. Discursive videos were associated with the aim of Saying-explanations as assessed by pupils' self-reports, but only when the information was presented by an authoritative speaker.

8 The video *Dr Quantum—Double slit experiment* forms an exception when used in the module Grenoble excursion. This exception might be explained by the fact that the outcomes on the pre-viewing questionnaire in the Grenoble excursion were already high, leaving little space for improvement.

Discussion

The central goal of our study was to introduce film theory in research on educational videos to make a first step towards the development of guidelines that relate teacher aims to video characteristics. To this goal, we explored in educational practice both the aims teachers try to achieve, and what characterizes the videos they use. We found that, first, the majority of the teachers used videos to raise pupils' levels of conceptual knowledge or interest, in this study referred to as Saying aims and Engaging aims (RQ1). Second, most videos used were highly informative, in this study referred to as Discursive film type (RQ2). Third, using videos was associated with an increase in pupils' self-perceived conceptual knowledge and minor results regarding raising interest (RQ3). And fourth, videos that posed questions that were leading for the direction of the story were associated with raising pupils' interest, and highly informative videos with authoritative speakers were associated with an increase in pupils' self-perceived conceptual knowledge (main RQ).

The most found teacher aims in our study were Saying and Engaging aims (RQ1). However, the teachers had difficulties explaining why they used a video, and how they expected the video would meet their aims. For our study, the teachers made an effort to substantiate their choices concerning video usage. In the discussion of the results with the teachers, they said to find it quite illuminating and useful for future video use to see their aims so clearly categorized. This indicated that guidelines would be very much welcomed by teachers. The fact that teachers intuitively selected videos and were hardly aware of the aims they wanted to achieve furthermore indicated that guidelines are not only welcomed but also needed, if teachers want to use video effectively to achieve educational aims.

As a first step towards guidelines for teachers, we developed the framework represented in Figure 2.3. This framework can assist teachers in selecting or making videos that match their aims, though it needs to be empirically tested. See Appendix 2G for an example of an application of this framework.

The large number of discursive videos we found in our study (RQ2) relates to the type of videos that are most commonly found on online educational video platforms. These videos look alike because makers of educational videos presumably imitate each other's videos, and because they are easy to make. Teachers probably recognize these kinds of videos as being educational and might prefer them over alternatives because of this. To help teachers find other possible video types that may better match their aims, we redesigned the model of Schwartz and Hartman (2007), and replaced the initial intuitively chosen video examples with the film types of McClusky (1947) we used in our study (see Figure 2.4). The results of our study only show indications for the rightfully presumed connection between the aim of Saying-Explanations and the Discursive film type, and between Engaging-Interest and the Problematic film type. However, based on the descriptions of the film types in McClusky (1947), we can presume that more possible connections could be made, as are presented in grey in Figure 2.4. Further research is needed to justify these other presumed possible connections between teacher aims and film types. Again, we consider this only a first step towards guidelines for teachers.

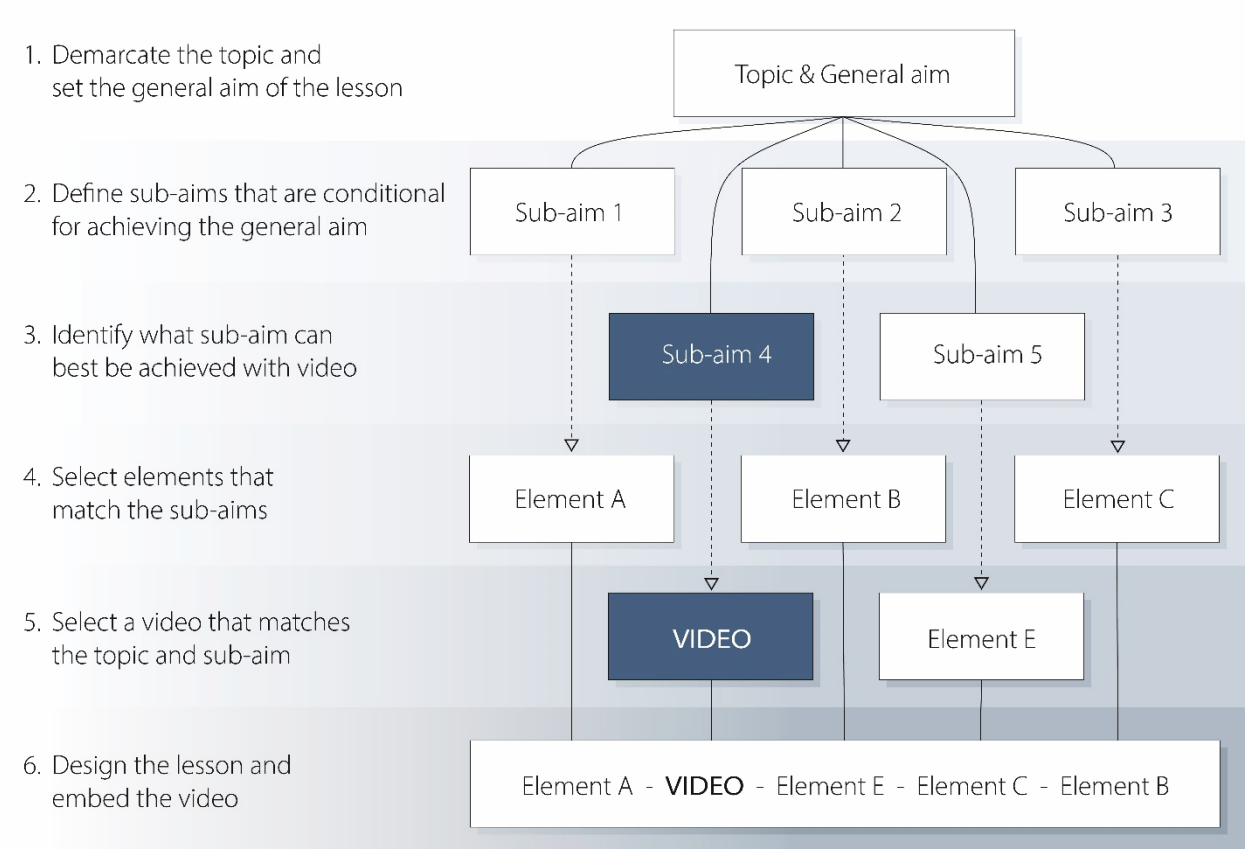


Figure 2.3. Assisting framework for educators to select or make videos that match their aims.

There are some limitations to our research. First, our study showed that pupils felt that discursive videos raised their levels of conceptual knowledge. However, we did not assess whether the videos influenced the pupils' actual knowledge levels. It is important to do so in future studies, because perceived (lack of) knowledge gains may not always correspond to actual (lack of) knowledge gains (cf. Muller, 2008).

Second, our study showed only minor changes in the pupils' self-reported interest. This is in line with previous research indicating that pupil interest is hard to influence with a single intervention. In addition, the degree to which an intervention influences pupil interest is difficult to measure accurately (Hidi & Renninger, 2006). We therefore regarded even small differences between pre- and post-viewing outcomes for this aim category as cues to further investigate the aim of raising interest in the cross-case analysis. The pre-viewing levels of interest in our study were already high. In future studies, it would be recommendable to include videos that can be expected to show more variance regarding pupils' initial interest.

Further (intervention) research is needed to better understand how video characteristics may function to achieve teacher aims. Our study shows that teachers are primarily interested in using videos for the Saying and Engaging aims. Therefore, further research on educational videos could initially concentrate on these two aims. However, subsequently broadening the scope of educational video to other possible film types is important, as it may lead to better utilization of the potential of the video medium. Film theory offers a way to describe this potential; the possible connections between teacher aims and film types presented in Figure 2.4 can be used as a starting point.

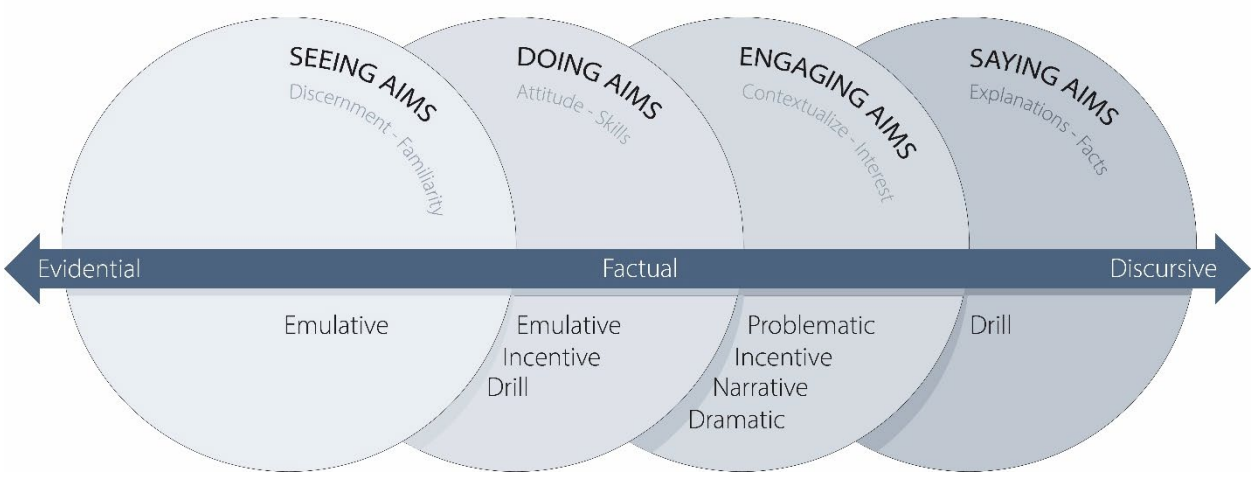


Figure 2.4. Model of presumed possible connections between teacher aims and film types, with use of Schwartz and Hartman (2007, p. 338) and McClusky (1947). The teacher aims (grey circles) with presumably related inclusive film types attached (below in black) are positioned indicatively on the sliding scale of exclusive film types (black horizontal bar).

In our study, we used the perspective of film studies as a complement to educational sciences to describe the characteristics of the educational videos. With film theory one can analyse how characteristics of videos might influence pupils' perception of educational videos in great detail. Relating theories from these two fields of science opens up possibilities to formulate the needed guidelines for making and using videos in education.

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Statements on Conflict of Interest, Open Data and Ethics

There is no conflict of interest in the reported work. The data of our project is in the process of being made permanently accessible through the Data Archiving and Networked Services (DANS) of the joint institute of the Royal Netherlands Academy of Arts and Sciences (KNAW) and the Netherlands Organisation for Scientific Research (NWO), at https://dans.knaw.nl/en. Pupil and teacher data collection and handling was complied with local ethical guidelines regarding collection and storage of data involving human subjects. The pupil data was collected anonymously, the teacher data was anonymized after data collection, and all data was stored on a secured server behind a password.

Appendix 2A: Summarized and coded teacher responses per video

Video title	*Module*	*Teacher responses*	*Teacher aims*
Lieke and the drum	Acoustics	Contextualizing physics theory through a concrete lifeworld context	Engaging-contextualize
		Raised interest for studying a physics phenomenon	Engaging-interest
		Being able to notice a physics phenomenon	Seeing-discernment
		Being able to explain a physics phenomenon	Saying-explanations
Dr Quantum—Double slit experiment	CERN excursion	Being able to explain why the experiment is set up the way it is, and what can be derived from its results	Saying-explanations
		Knowing the difference between the two set-ups	Saying-facts
Het Klokhuis: Figure it out! Earth	Earthquakes	Being able to perform an analysis in research on ground layers	Doing-skills
		Raised interest for knowing how to get from data to result	Engaging-interest
		Being able to explain how ground layers are researched	Saying-explanations
Heart rhythm dance	Electric activation of the heart	Raised interest for studying heart rhythm disorders	Engaging-interest
		Being able to explain what happens during heart rhythm disorders	Saying-explanations
		Introduction to the subject, activation of prior knowledge	Engaging-contextualize
		Knowing what a distorted heart rhythm is.	Saying-facts
NOAA Ocean Acidification—The other carbon dioxide problem	Geochemistry	Contextualizing chemical theory through a socio-scientific problem; introduction to the subject, activation of prior knowledge	Engaging-contextualize
		Raised interest for acidification through beautiful appealing images	Engaging-interest
Chemistry at work	Green chemistry	Contextualizing chemical theory through a concrete industrial context	Engaging-contextualize
		Being able to explain what is dangerous about chemical industry and explaining how green chemistry can become more 'green'	Saying-explanations
		Knowing different chemical processes in chemical industry	Saying-facts
Dr Quantum—Double slit experiment	Grenoble excursion	Being able to explain why the experiment is set up the way it is, and what can be derived from its results	Saying-explanations
		Knowing the difference between the two set-ups	Saying-facts

(*Continues*)

Appendix 2A: Continued

Video title	*Module*	*Teacher responses*	*Teacher aims*
Ted Edu: Why do honeybees love hexagons?	Mathematics and architecture	Raised interest for mathematics in general, and the following task in particular	Engaging-interest
		Being able to explain why hexagons exist in nature	Saying-explanations
Antifungal drugs: Mayor types and functions	Membranes	Contextualizing chemical theory through concrete lifeworld contexts; introduction to the subject, activation of prior knowledge	Engaging-contextualize
		Raised interest for the chemical functioning of antifungal drugs	Engaging-interest
		Being able to explain how specific targeting functions	Saying-explanations
		Knowing what specific targeting is	Saying-facts
ß-Lactams: Mechanisms of action and resistance	Membranes	Being able to explain how penicillin and resistance function	Saying-explanations
		Knowing what antibiotics, penicillin, and resistance are	Saying-facts
Het Klokhuis: Molecular cooking	Molecular gastronomy	Contextualizing chemical theory through concrete examples of molecular gastronomy; introduction to the subject, activation of prior knowledge	Engaging-contextualize
		Raising interest for the subject and for chemistry in general	Engaging-interest
Ted talk: Religions and babies, by Hans Rosling	Sustainable energy	Being able to perform a presentation of results from research	Doing-skills
		Contextualizing theory through a concrete socio-scientific problem	Engaging-contextualize
Welcome at the world heritage site of the Wadden Sea	Texel excursion	Contextualizing ecosystem theory through World Heritage Sites; introduction of the subject, activation of prior knowledge	Engaging-contextualize
		Knowing the World Heritage Site of Texel	Saying-facts
How mussel banks shape the landscape of the Wadden Sea	Texel excursion	Contextualizing ecosystem theory through a concrete context; introduction of the subject, activation of prior knowledge	Engaging-contextualize
		Knowing the function of mussel banks in the ecosystem	Saying-facts

Appendix 2B: Example of video description of Het Klokhuis: Figure it out! Earth in the module earthquakes

Film characteristics	*Description*
Flow of information	The presenter poses questions that arise from the preceding information. The questions are leading for the video's continuation. The viewer is taken on a journey to find the answers
Audio-visual presentation	
Mise-en-scène	On location, unformal young enthusiastic adult as presenter, presenter turning directly to the viewers by looking into the camera, presenter takes the position of the naïve viewer
Cinematography	Handheld frequently moving camera, multiple perspectives, quick zooms in the shot
Editing	Short shots, fast editing, intermissive clips
Sound	Energizing exciting music, repeated sound of the explosion
Film type(s)	*Description*
Discursive—strong	Treatment of conducting ground research with sonar
Emulative	Shows how to perform an experiment on ground layers
Problematic—strong	Poses questions that initiate the direction of the video towards finding out what the Earth's core is made of

Appendix 2C: Film types per video

Video title	*Module*	*Film types*	*Description*
Lieke and the drum	Acoustics	Evidential**	Record of (scientific) data for study or analysis
Dr Quantum—Double slit experiment	CERN excursion	Discursive**	Treatment of the execution and findings of an experiment
		Emulative	Shows how to perform an experiment on electrons' behaviours
		Narrative	Describes the course of events of when research on the behaviour of electrons was performed
		Problematic	Poses rhetorical questions to propel the story
Het Klokhuis: Figure it out! Earth	Earthquakes	Discursive**	Treatment of conducting ground research with sonar
		Emulative	Shows how to perform an experiment on ground layers
		Problematic**	Poses questions that initiate the direction of the video towards finding out what the Earth's core is made of
Heart rhythm dance	Electric activation of the heart	Factual**	Shows and names variations in malfunctions of the heart
NOAA Ocean acidification—The other carbon dioxide problem	Geochemistry	Discursive**	Treatment of the issue of Pteropods dissolving; treatment of the process of acidification; explanation of how the research on acidification is performed, and the mayor results
		Incentive**	Tries to convince the audience of the impact of acidification on all life
		Narrative	Describes the course of events in conducting research on acidification
		Problematic**	Poses questions that initiate the direction of the video; raises the urgent problem of human life being threatened by acidification, invites discussion
Chemistry at work	Green chemistry	Discursive**	Treatment of process in factory
Dr Quantum—Double slit experiment	Grenoble excursion	Discursive**	Treatment of the execution and findings of an experiment
		Emulative	Shows how to perform an experiment on electrons' behaviour
		Narrative	Describes the course of events for when research on the behaviour of electrons was performed
		Problematic	Poses rhetorical questions to propel the story
Ted Edu: Why do honeybees love hexagons?	Mathematics and architecture	Discursive**	Treatment of a phenomenon in nature
		Narrative**	Describes a fictional story of how bees came to make hexagonal structures in hives
		Problematic	Poses rhetorical questions to propel the story
Antifungal drugs: Mayor types and functions	Membranes	Discursive**	Treatment of the topic of fungi, and explanation of functioning
		Problematic	Poses rhetorical questions to propel the story
ß-Lactams: Mechanisms of action and resistance	Membranes	Discursive**	Treatment of the functioning of ß-Lactams

(*Continues*)

Appendix 2C: Continued

Video title	*Module*	*Film types*	*Description*
Het Klokhuis: Molecular cooking	Molecular gastronomy	Discursive**	Treatment of the concept of molecular gastronomy
		Emulative	Shows how to make use of chemical processes in cooking
		Problematic**	Poses questions that initiate the direction of the video towards finding ways to use chemical processes in cooking
Ted talk: Religions and babies, by Hans Rosling	Sustainable energy	Discursive**	Treatment of research results and conclusions
		Incentive**	Tries to convince the audience of the idea that there is a relation between income and the Earth's population growth
		Problematic	Poses rhetorical questions to propel the story
Welcome at the world heritage site of the Wadden Sea	Texel excursion	Factual**	Shows and names different World Heritage sites, and the Waddenzee in particular
		Incentive**	Tries to convince the audience of the beauty of World Heritage Sites, and the importance of protection
How mussel banks shape the landscape of the Wadden Sea	Texel excursion	Discursive**	Treatment of mussel banks in the Waddenzee

Note. ** = Coded as Strong.

Appendix 2D Mean outcomes of the student evaluations for the teacher aims per video

Video title	*Module*	*Teacher aims*	*Mean post viewing score*	*Mean Δ pre and post viewing score*	*#stud*
Lieke and the drum	Acoustics	Engaging-contextualize	3.2	0.4	27
		Engaging-interest	3.9*	0.1	
		Engaging-interest	3.9*	0.0	
		Seeing-discernment	3.2	0.3	
		Saying-explanations	2.7	0.4	
Dr Quantum—Double slit experiment	CERN excursion	Saying-explanations	4.7*	2.5*	34
		Saying-explanations	4.7*	2.3*	
		Saying-explanations	4.6*	2.3*	
		Saying-facts	4.8*	2.4*	
		Saying-facts	4.0*	0.4	
Het Klokhuis: Figure it out! Earth	Earthquakes	Doing-skills	3.8	0.9*	25
		Doing-skills	3.7	1.0*	
		Engaging-interest	3.8*	0.2*	
		Saying-explanations	4.2*	0.8	
		Saying-explanations	3.6	0.6	
Heart rhythm dance	Electric activation of the heart	Engaging-interest	4.2*	0.1	49
		Engaging-interest	4.1*	0.1	
		Engaging-contextualize	4.1*	0.0	
		Saying-explanations	3.4	0.4	
		Saying-facts	3.7	0.4	
NOAA Ocean acidification—The other carbon dioxide problem	Geochemistry	Engaging-contextualize	4.1*	0.6*	26
		Engaging-contextualize	4.2*	0.5*	
		Engaging-contextualize	3.4	0.6*	
		Engaging-contextualize	4.4*	0.8*	
		Engaging-interest	3.5	0.2*	
Chemistry at work	Green chemistry	Engaging-contextualize	3.6	0.8*	43
		Engaging-contextualize	3.6	1.2*	
		Saying-explanations	2.7	−0.1	
		Saying-explanations	2.3	0.3	
		Saying-facts	3.4	1.5*	
Dr Quantum—Double slit experiment	Grenoble excursion	Saying-explanations	4.5*	1.5*	45
		Saying-explanations	4.4*	0.5	
		Saying-explanations	4.4*	1.4*	
		Saying-facts	4.8*	1.9*	
		Saying-facts	3.2	0.4	

(*Continues*)

Appendix 2D: Continued

Video title	*Module*	*Teacher aims*	*Mean post viewing score*	*Mean Δ pre and post viewing score*	*#stud*
Ted Edu: Why do honeybees love hexagons?	Mathematics and architecture	Engaging-interest	3.8*	0.0	18
		Engaging-interest	3.7	−0.1	
		Engaging-interest	3.6	0.1	
		Saying-explanations	4.8*	1.8*	
		Saying-explanations	3.6	1.2	
Antifungal drugs: Mayor types and functions	Membranes	Engaging-contextualize	4.1*	0.3	27
		Engaging-contextualize	3.6	0.4	
		Engaging-interest	4.0*	0.1	
		Saying-explanations	4.0*	1.6*	
		Saying-facts	4.3*	0.5	
ß-Lactams: Mechanisms of action and resistance	Membranes	Saying-explanations	4.0*	1.3*	27
		Saying-explanations	3.8	0.8	
		Saying-facts	4.3*	0.3	
		Saying-facts	3.9	0.4	
		Saying-facts	4.4*	0.3	
Het Klokhuis: Molecular cooking	Molecular gastronomy	Engaging-contextualize	3.2	0.6*	23
		Engaging-contextualize	3.4	0.6*	
		Engaging-interest	3.4	0.3*	
		Engaging-interest	3.3	0.2*	
		Engaging-interest	3.2	0.3*	
Ted talk: Religions and babies, Hans Rosling	Sustainable energy	Doing-skills	3.9*	0.4	19
		Doing-skills	3.8	0.1	
		Doing-skills	3.8	0.1	
		Engaging-contextualize	4.2*	0.2	
		Engaging-contextualize	4.7*	−0.3	
Welcome at the world heritage site of the Wadden Sea	Texel excursion	Engaging-contextualize	3.3	0.5*	42
		Engaging-contextualize	3.3	0.0	
		Engaging-contextualize	3.2	0.2	
		Engaging-contextualize	2.4	0.2	
		Saying-facts	3.0	1.6*	
How mussel banks shape the landscape of the Wadden Sea	Texel excursion	Engaging-contextualize	3.1	0.0	42
		Engaging-contextualize	3.1	0.0	
		Engaging-contextualize	2.6	0.1	
		Saying-facts	3.2	2.5*	
		Saying-facts	3.5	1.5*	

Note. #stud = Number of students; * = Above overall average of this category (see Table 5).

Appendix 2E: Mean outcomes of all videos used for the aim of saying-explanations

Video title	*Film type*	*Mean post viewing score on Saying-explanations*	*Mean Δ pre and post viewing score on Saying-explanations*	*#statem*
Lieke and the drum	Evidential	2.7	0.4	1
Dr Quantum—Double slit experiment (CERN excursion)	Discursive	4.7*	2.4*	3
Het Klokhuis: Figure it out! Earth	Discursive	3.9	0.7	2
Heart rhythm dance	Factual	3.4	0.4	1
Chemistry at work	Discursive	2.5	0.1	2
Dr Quantum—Double slit experiment (Grenoble excursion)	Discursive	4.4*	1.1	3
Ted Edu: Why do honeybees love hexagons?	Discursive	4.2*	1.5*	2
Antifungal drugs: Mayor types and functions	Discursive	4.0*	1.6*	1
ß-Lactams: Mechanisms of action and resistance	Discursive	3.9	1.1	2

Note. #statem = Number of statements calculated in the mean; * = Above overall average of this category (see Table 5).

Appendix 2F: Mean outcomes of all videos used for the aim of engaging-interest

Video title	*Problematic film type*	*Mean post viewing score on Engaging-interest*	*Mean Δ pre and post viewing score on Engaging-interest*	*#statem*
Lieke and the drum	–	3.9*	0.1	2
Dr Quantum—Double slit experiment (CERN excursion)	Weak	–	–	0
Het Klokhuis: Figure it out! Earth	Strong	3.8*	0.2*	1
Heart rhythm dance	–	4.1*	0.0	2
NOAA Ocean acidification—The other carbon dioxide problem	Strong	3.5	0.2*	1
Dr Quantum—Double slit experiment (Grenoble excursion)	Weak	–	–	0
Ted Edu: Why do honeybees love hexagons?	Weak	3.7	0.0	3
Antifungal drugs: Mayor types and functions	Weak	4.0*	0.1	1
Het Klokhuis: Molecular cooking	Strong	3.3	0.3*	3
Ted talk: Religions and babies, by Hans Rosling	Weak	–	–	0

Note. #statem = Number of statements calculated in the mean; * = Above overall average of this category (see Table 5); ** = Coded as Strong.

Appendix 2G: Example of using the assisting framework for educators to select or make videos that match their aims

Phases		*Example*
1.	Demarcate the topic and set the general aim of the entire lesson	The general aim is to raise the students' knowledge level on the topic of Acidification
2.	Define sub aims that are conditional to achieving the general aim	a.Getting students introduced to the topic of Acidification b.Motivating students to engage with the ecological problem of ocean acidification c.Activating students' prior knowledge on chemical processes d.Instructing new content on acidification e.Having students engage with the chemical processes involved in acidification f.Evaluation and reflection
3.	Identify what sub aim(s) can best be met with video	Motivating students to engage with the ecological problem of ocean acidification (Engaging-interest and Engaging-contextualize)
4.	Select elements that match the sub aims	a.Introductory talk by the teacher b.Watching a video that illustrates the problem of ocean acidification c.Recapture of previous lessons on chemical processes d.Teacher instruction on acidification processes e.Student experiment assignment f.Evaluation of the experiments in a group discussion
5.	Select a video that matches the topic and sub aim	Factual-Problematic/Narrative/Dramatic/Incentive video (see Figure 4): *NOAA ocean acidification—The other carbon dioxide problem*
6.	Design the lesson and embed the video	Introduce the video as a socio-scientific issue in which acidification plays a key role—Watch the video—Recapture main points made in the video in a group discussion. Refer to: To who or what is ocean acidification a problem? What causes acidification to happen? Can you describe the subsequent steps in process? What are possible future consequences of ocean acidification? What can be done to stop the oceans of acidifying? Resume with classroom teacher instruction

Film as the Engine for Learning

3

A Model to Assess Film's Interest Raising Potential

Wijnker, W., Tan, E. S., Bakker, A., Van Gog, T. J. M., & Drijvers, P. (in press). Film as the engine for learning: A model to assess the potential of film to raise interest. *Projections*.

Abstract

Film has been used for education ever since educators recognized its powerful potential for learning. But its educational application has been criticized throughout the decades for underuse of the distinctive potential of film: to raise interest. To understand more fully film's potential for learning, we propose a dynamic model of viewer interest and its underlying cognitive and emotional mechanisms (FIRM model). In addition, we present an analysis method for assessing the interestingness of films in learning contexts. Our model marries interest theories from cognitive film theory and educational psychology, and captures the dynamics of interestingness across a film as depending on a balance between Challenge posed and Coping potential provided.

Introduction

As soon as films and projectors became affordable and manageable for the general public in the early 1940s, film started to make its way into the classroom (Masson, 2012). Numerous films have been produced and used with the intention to contribute to education ever since, and audio-visual material is becoming more prominent in education with online learning taking off worldwide (Thomson et al., 2014).

From the early years on, educators recognized the medium's powerful potential to show the world outside the classroom, and to raise pupils' interest for its phenomena. Classical theories of learning in education and current empirical research in educational science have supported the notion that interest stimulates learning (resp. Dewey, 1913; Akkerman & Bakker, 2019). So, there are ample reasons to believe that film could be a valuable tool to raise interest in learning contexts.

However, films intentionally produced for educational purposes (educational films) have been heavily criticized by film theorists, in particular the underuse of film's interest raising potential (Champoux, 1999; McClusky, 1947; Porcher, 1975; Thomson et al., 2014; Wegner, 1977; Wijnker et al., 2019). In practice the majority of educational films emphasize instruction and reproduction, typically putting talking heads on display (Hansch et al., 2015). At present, new approaches to teaching are wanted that more effectively stimulate learning, such as inquiry learning and context-based learning (Savelsbergh et al., 2016). Uneasiness with such approaches implemented in new digital learning environments causes teachers to return to habits of knowledge transfer that were default long ago (Niederhauser & Lindstrom, 2018). In the process, the relevant potential of film is overlooked, especially to overcome boredom and to stimulate learning.

Film theorists' critique of educational film is accompanied by their argument that film can be more beneficial for education than has become obvious. They have made it plausible that film is exceptionally suitable for raising viewers' interest while watching and have analysed film features that stimulate interest (Tan, 1996). But research from this field is predominantly focused on the fiction film; the use of film as an interest engine for learning in education has been neglected. In contrast to film theory, educational psychology research has abundantly shown that interest is a key condition for learning. Research on film in this field, though, is narrowed predominantly to the subcategory of educational films, notably instruction films. Educators could select a much larger supply of films for classroom use if they would avail of a general account of how films raise interest and stimulate learning.

This article attempts to marry film theory to educational psychology in order to fully identify the film's potential for raising pupils' interest at the service of learning. First, insights from film theory and educational psychology on interest are combined in a dynamic model accounting for pupil-viewers' interest in films (FIRM model). This model is the basis for an analysis method for assessing any film's interest raising potential for learning. Next, we demonstrate how the FIRM model and the analysis method may function as a starting point to select and produce better films for education. Our argument starts with an introduction into the theoretical conceptualization of interest in film studies and educational psychology.

Theoretical Conceptualizations of Interest as an Emotion

The word interest comes from *inter-esse*, which translates into *to be in between* (Akkerman, 2017; Latour, 1987). Interest refers to a relationship that evolves between a subject and an object (Krapp, 1999). We consider the relationship an emotional one, following Frijda (2009): Emotions "[…] are states characterized by occurrent motives to establish, maintain, or change subject-object relationships." (p. 268). Interest as an emotion in learning involves a motivation in pupils to strengthen their relationship with an educational object. To understand the motivational force of interest (Renninger & Hidi, 2016), we need to dwell on what an emotion is.

All living organisms from bacteria to humans exhibit directed and purposeful relations with objects in the world around them. Individual organisms strive towards optimal relations with objects in their environment. For example, love, friendship or harmony are optimal relations with intimate others. Relations are optimized as "concerns", desired end states of striving, such as a physically nurturing environment, physical well-being, preservation, safety, equality, and belonging. When meeting with obstacles or support to concerns, this is signalled internally as negative or positive affect. Affect is an elementary response signalling pleasure or pain. Affect motivates relational action, namely the continuation or intensification of on-going action versus stopping it and circumventing the obstacle. We can say that the main function of affect and emotion is to change relations between a subject and an object through action (Blakemore & Veuilleumier, 2017; Frijda, 2007)**.** For the sake of readability, we will from here on speak of "action" brief meaning relational action.

There is a considerable variety of psychological approaches to emotion, emphasising different conceptualisations of cognitive regulation of affect and action.[1] The Component Process Model of emotion (Scherer, 2010), see Figure 3.1, integrates most conceptualisations into a modular emotion response model. Together the three modules or components of emotion act as an adaptive mechanism for coping with events that are relevant to an individual's life. Modules operate in sequence, in principle.

In the first module, appraisal consists of evaluations of emoting events that are met, in terms of concerns. For example, the appraisal of loss involves the negative evaluation of an obstacle to the concern of preservation, and a threat is negatively evaluated as an obstacle to safety. The appraisal of goal attainment involves the positive evaluation of support to the concern of self-efficacy. Different emotions have different appraisals. Sadness is associated with an appraisal of loss, fear with one of threat, and happiness with one of goal attainment.
In the second module, appraisals lead to changes in action readiness and motivation, as well as to embodied physiological responses and motor expressions. The latter can be understood as supporting action and motivation for action. For example, the appraisal of loss leads to the action readiness of regaining the object, and the so-called "visceral" perceptions of one's bodily reactions, like an increased heartbeat. The appraisal of threat leads to flee, freeze or fight, the physiological response of adrenaline production and visceral perception of physiological arousal; and goal attainment to mobilizing undirected positive energy.

1 We mention in particular basic emotion theory (Ekman, 1984), dimensional models (Russell, 1980; Plutchik, 1991), constructivist theories (Schachter & Singer 1962; Barrett 2013) and appraisal theory (Arnold, 1960; Lazarus, 1991; Frijda, 2007).

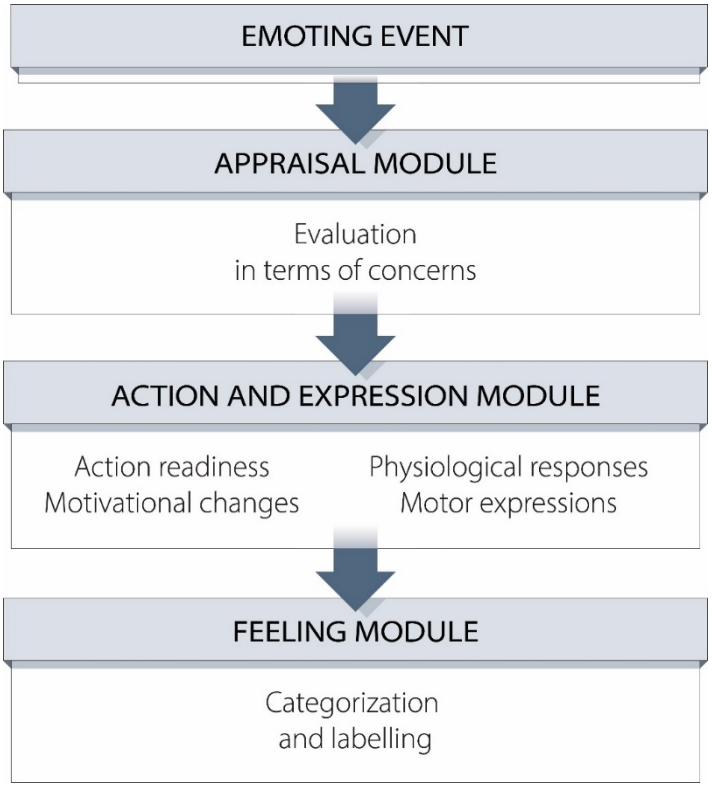


Figure 3.1. The Component Process Model (CPM) of emotion, based on Scherer (2010, p. 50)

The first two modules cover psychological responses that are not necessarily represented in consciousness. The third module renders appraisal and action-motivation aware to the emoting subject. The emotion is categorized and labelled, resulting in emotional awareness, or feeling, of appraisals, expressions and action readiness. The emotion that develops from loss is then recognized and categorized as sadness, that developing from threat as fear, and that from goal attainment as happiness.

The Component Process Model elucidates the motivational force of emotions. According to Klaus A. Scherer (2010) emotion can be distinguished from other states of mind or body. When a situation is *appraised relevant* for the person's needs, goals or values, some *action readiness* i.e., preparedness to act in one or another way is necessarily induced. We add to this account of motivational force the distinctive feature of *control precedence* (Frijda, 1986; 2007; Moors et al., 2017). This feature of action readiness in emotion refers to the priority that action tendencies assume over currently ongoing attention, thought and behaviour. Action tendencies are therefore notoriously difficult to resist.

"Interest" usually refers to a more or less permanent disposition of individuals to be attracted by certain topics. However, it is also the name for an emotion regulating the relationship between a subject and an object in a more or less delimited episode. Andreas Krapp (1999) defined interest episodically, namely as an emotion, referring to it as a motivational state. Paul J. Silvia (2006) conceptualized interest more completely as an emotion according to the Component Process Model of emotion. The typical appraisal for interest according to Silvia consists of two elements: novelty and coping potential (see CPM module 1). Novelty refers to people's perceptions in the stimulus event of features such as

"new, ambiguous, complex, obscure, uncertain, mysterious, contradictory, unexpected or otherwise not understood" (Silvia, 2006, p. 57). Coping potential refers to whether people "can understand the ambiguous event" (Silvia, 2006, p. 57), in other words an estimation of the "likelihood that the poorly understood event will become coherent and clear" (Silvia, 2006, p. 58). Interest reaches positive levels when both the appraised novelty and the estimation of successful dealing with it are sufficient.

Some attempts have been undertaken to operationalize and measure interest (e.g., Silvia, 2005; Cañas-Bajo et al., 2019). Jose Cañas-Bajo et al. (2019) measured interest in real time, by having participants mark their interest using press buttons while viewing a film. Silvia demonstrated in a number of experiments that appraised novelty-complexity of test stimuli (poems, picture, geographical shapes) and estimated ability to understand these were predictors of interest. Interest can be called an epistemic emotion, as it arises in the pursuit of knowledge goals (Brun et al., 2008, as cited in Vogl et al., 2020). Understanding and knowing are the emotional concerns that are satisfied in interest. Silvia (2006) distinguishes as functions of interest first, to engage the person in the situation and to motivate exploration and learning, and second to provide for diversity of experience.

Interest is for action just like other emotions, say anger or fear. The affective mechanism underlying interest is the dopamine-based seeking system that produces "eager forward-directed and investigatory activities" in response to expected stimulation and reward, according to Carrol E. Izard (1977).[2] A general action readiness produced when an event is appraised as interesting (that is, positively appraised as both novel and comprehensible) is an inclination to invest attention and effort in it (CPM module 2). The action readiness is reflected in the facial expression of interest, which is characterised by raised eyebrows and a slight smile. Boredom in contrast, shows in drooping eyelids and tilted head (see, e.g., Keltner et al., 2019). More specifically Silvia mentions inclinations to explore the environment and to elaborate or persist in a difficult task. Most specifically, interest-driven deep and persistent cognitive elaboration of educational texts have in empirical studies been found effective for memory and comprehension (Silvia, 2006). Finally, the experience of interest reflects the mobilisation of resources and the positive estimation of comprehensibility (CPM module 3). It is a positive feeling, despite the uncertainty that is characteristically appraised in the event.[3]

In sum, when interest is conceptualized as an emotion, we can understand why it has motivating force. A positive evaluation of novelty balanced with coping potential instigates a readiness to spend resources on exploration, elaboration, and persistent engagement with the

2 Izard's view of interest as an emotion motivating exploratory action has been supported in current biopsychological research. See for example Jaak Panksepp (2005) who distinguished basic neuro-affective systems in mammals associated with panic, fear and rage. The "seeking system" deals with expectancy and wanting.

3 "At the experiential level interest is the feeling of being engaged, caught-up, fascinated, and curious. There is a feeling of wanting to investigate, become involved, or extend or expand the self by incorporating new information and having new experiences with the person or object that has stimulated the interest. In intense interest or excitement, the person feels animated and enlivened. It is this enlivenment that guarantees the association between interest and cognitive or motor activity. Even when relatively immobile the interested or excited person has the feeling that he is 'alive and active'" (Izard, 1977, p. 216). The positive feeling has also been documented in Panksepp's neuro-biological studies: "The seeking system is an energizing, hedonically positive functional system of the brain […] which has been further developed into a dopamine-centred "wanting" or "incentive salience" model [in recent neuropsychological studies]." (Panksepp, 2005, p. 46).

stimulus. Because emoted, the whole person is involved in the readiness concerned, and the feeling of being interested is predominantly positive.

Film theory and educational psychology research have dealt with interest as an emotion in different but overlapping ways. The two fields of research have given us leads to describe the specific appraisals involved in interesting films and in interesting learning activities that can explain films' potential to raise interest in learning contexts.

Interest as Conceptualized in Educational Psychology and Film Theory

Studies on interest in educational psychology provide empirical evidence for the link between interest and learning (Akkerman & Bakker, 2019; Dewey, 1913). Positive effects of interest have been shown on education outcomes such as task value perceived by pupils, academic achievements, and time spent on tasks (Hidi, 2006; Patrick et al., 2011; Renninger & Hidi 2016; Tobias, 1994). Beside interest for educational contents, interest in learning for its own sake is a valued goal of education in general. Overall, experiencing interest is pleasant in itself, regardless of the goal one is pursuing (Renninger & Hidi, 2016).

Educational psychology follows the conceptualization of interest introduced above. Interest as an emotion in the context of learning is characterized as a balance between the appraisals of novelty-complexity and coping potential or comprehensibility (Silvia, 2008; CPM module 1). Novelty-complexity is appraised in educational content that is new to the learners that is, not encountered before, or not in the current way, so that there is something to explore and to discover. The appraisal of comprehensibility on the other hand involves the learners' beliefs that although not able to grasp it entirely yet, they will be in the end. Comprehensibility is the prospect or anticipation of comprehension. The balance between novelty-complexity and anticipated comprehension fuels interest at any moment throughout engagement with the object.

Interest experienced in an educational context gives rise to the action tendency of knowledge seeking, or the willingness to pay attention and put effort in comprehending the novel-complex content, and thus relational engagement with the content (Krapp, 1999; Renninger & Hidi, 2016; CPM module 2). This can take various forms dependent on the learning objective. For example, in a chemistry course about molecular cooking the learning objective could be to familiarize pupils with concepts of chemical processes and their occurrence in the real world. Interested learners are willing to put effort in finding cues that relate to their prior knowledge in order to link new information to what is already known (Schiefele, 1991). Relating the learning objective to a familiar context, such as daily cooking, makes it easier for pupils to find relatable cues. Reaching understanding and gaining new knowledge as the rewarding outcome evokes satisfaction and raised self-efficacy, and stimulates further and future engagement (Hidi, 2006; Patrick et al., 2011; Renninger & Hidi, 2016; Tobias, 1994); the pupils' interest for the educational content develops (CPM module 3). Investments made increase the value of getting to know and understand the new content further.

While educational psychology follows emotion theory in conceptualizing pupil interest in learning contexts, cognitive film theory follows emotion theory in conceptualizing viewer interest as an appraisal-driven emotion. Film theory has attempted to account for film viewers' interest using characteristics of the medium, in particular the narrative film. Films

are studied as narrative discourses that evoke a complete story-world by piecemeal narration of events (Bordwell, 1985).

Ed Tan (1996; 2008; 2018a; 2018b) proposed a theoretical account of film-viewer interest as the emotional response to narration in the fiction film. The viewer's task is to construct the complete story-world from presented pieces. While the presentation is in progress, the viewer's appraisal of interest consists of anticipatory rather than definitive evaluations. Evaluations target the prospect of complex developments, of actions and their outcomes, and uncertainties about these (CPM module 1). Anticipatory appraisals are induced early in the film, when the initial status quo (all is clear in the fictional world) is interrupted. Viewers anticipate that the discourse will come to a closure (all is clear again). Anticipated reward consists not only of prospects of closure, but also of satisfactory outcomes that the final story-world will offer (Tan, 1996). For example, the discourse of *Het Klokhuis: Moleculair Koken* a Dutch informative film about molecular cooking starts with a familiar listing of food and cooking methods we use daily (all is clear). Next, an unusual duo appears, a cook and a chemist, to explore new ways of cooking (complex developments and mission are set). The film takes the viewer through the preparation of a three-course molecular menu and ends with the satisfactory closure of the presenter eating a tasty new desert (mission completed, all is clear again).

A balance between appraisals of complex developments in the film's story or discourse on the one hand, and prospects of the film's rewarding closure on the other motivate the viewer's activity. It consists of constant building of hypotheses about what will happen next, and what happened before the point where the film took off. Hypotheses are refined or rejected in favour of new ones (Bordwell, 1985) (CPM module 2). Cumulated attention and effort spent in the activities can be called investments. Interest is a dynamic response, because investments tend to grow over time, while also prospects of complex development and rewarding closure change from one moment in the film to another. In the example of the film on molecular cooking, from the start viewer activity is motivated by the presenter posing a challenging as well as promising a claim to viewers: We can make better and tastier recipes by analysing the chemical processes in cooking. Viewers are challenged to finding and evaluating grounding arguments for that claim in the film's proceedings, encouraged by the prospect of seeing actual chemically synthesized dishes. Viewers' hypotheses about what will happen next are also directed by announcing the preparation of a menu.

A proper balance between steadily growing investment and ditto anticipated return pushes interest to the maximum, and makes film viewing a self-reinforcing mechanism. Following increases of investments and prospects of reward, also experienced interest builds up in intensity (CPM module 3), until the closure of the film is taking place and the final (re)solution is presented. At this point viewers' interest starts to drop, and so does the motivation to act (Tan 1996). In our molecular cooking film example, every prepared dish functions as a reward, as partial proof for the claim that whole meals can be cooked molecularly. The finalization of one dish cues interest in the next, and its particular method. Presented with the final dish viewers are left with the question what possible other methods could be applied for cooking.

Tan's (1996; 2008) account of interest applies to narrative fiction films. In narrative films, viewers action tendencies aim to anticipate story world events ("How will this story end?").

Obviously and as hinted in the cooking film example, films used in learning contexts include non-narrative film forms as well, such as associational (displaying related images, sounds or events), categorical (displaying concepts and instances of theses), and rhetorical (displaying an argument) (Bordwell et al., 2017). In associational films, the aim of the action tendency is to engage in free association, and to bring together seemingly unrelated images, sounds and events ("What do these images, sounds and events mean, what do they tell me?"). In categorical films, it is induction (finding a category encompassing instances) or deduction (generating exemplifying instances for a category). In rhetorical films like our molecular cooking film example, the aim is to check and validate an argument ("Is this true?").

Thus, appraisal of complex developments balanced by anticipated closure and reward, and the tendency to spending attention and efforts in comprehension accompanied by embodied responses, are consciously labelled as the feeling of interest and a desire to know the outcomes of the story.

Integration of Theories on Interest

Summarizing the similarities between the two theories on interest, they both construct interest as an emotion. Appraisals are akin: from the perspective of educational psychology, interest is likely to be raised if learning objectives 1. are novel and complex, and 2. make the pupils feel capable of comprehension. From the perspective of cognitive film theory interest is likely raised if films 1. present prospects of complex developments, and 2. raise confidence in the discourse guiding viewers to a rewarding closure. Both perspectives posit a balance between appraisals of 1. *Challenge* (novelty and complexity; complex developments) and 2. *Coping potential* (anticipated comprehension; anticipated rewarding closure) as key to raising interest (see Conclusion and discussion for relatedness to Flow theory). Concerning action tendencies, both perspectives similarly describe a readiness to invest *effort and attention* in the object of interest. Finally, both theories point at a self-reinforcing mechanism of investments resulting from these action tendencies.

An Integrated Model of Interestingness

Films provoke emotions in their viewers, such as enjoyment, fear, amusement and interest. Any film can be evaluated as to its potential to provoke a certain emotion. In experimental psychological aesthetics numerous studies have used expert analyses of art works as measures of interestingness (Haanstra et al., 2013). These measures predict actual interest of untrained viewers, e.g., measured by looking times (Berlyne, 1974; Cupchik & Gebotys, 1990; Silvia, 2006). Film analysts for example reviewers, can evaluate the degree to which a horror film may frighten its target audience, or the degree to which a comedy can amuse an audience. The potential of films to make their viewers interested can likewise be evaluated. Reviewers routinely report how interesting ("boring", "exciting", etc.) a film is. What is evaluated is the "interestingness" of a film (Krapp, 1999; Silvia, 2008). Assessment of a film's emotion potential is usually based on implicit judgements using intuitive norms and categories from analytic experience. The purpose of distinguishing interestingness from viewers' experiences is to enable the identification of film characteristics that potentially make interest rise.

We believe that the integrated theory of interest in film viewing can be employed in an explicit analysis model of the interestingness of films. Analysing interestingness involves a shift of perspective from the viewer to the film, from the viewer's appraisal to the features of

the film. A film's interestingness, that is its potential to provoke interest, when properly evaluated by an analyst, is predictive of the *interest* actual viewers experience. More in particular, highly interesting films should raise stronger action readiness in target viewers. That is, their motivations and tendencies to invest effort and attention in comprehension should be higher than if they would watch a less interesting film.

Figure 3.2 summarizes a model of interestingness based on the combined film-theoretical and educational psychology perspectives on interest. In our model, a film's interestingness depends on the balance between on the one hand, the challenge it offers to viewers and on the other, the coping potential it affords viewers. The higher the challenge AND the coping potential, the more interesting the film is. The model explains the mechanism underlying interest raising films in learning contexts and specifies the variables that need to be analysed or measured.

Important parallels should be noted between appraisals of interest by actual viewers, and analytic evaluations of interestingness. Challenge and coping potential feature in both. However, challenge and coping potential as appraised by actual viewers are intuitive judgements, while the analytic assessments of challenge and coping potential are based on explicit structural analyses of the film's form and presentation of contents.[4] As is good practice in the domain of education, teachers evaluate and judge any kind of educational material be it a book, a game or a film before presenting it in class or using it as a reference.

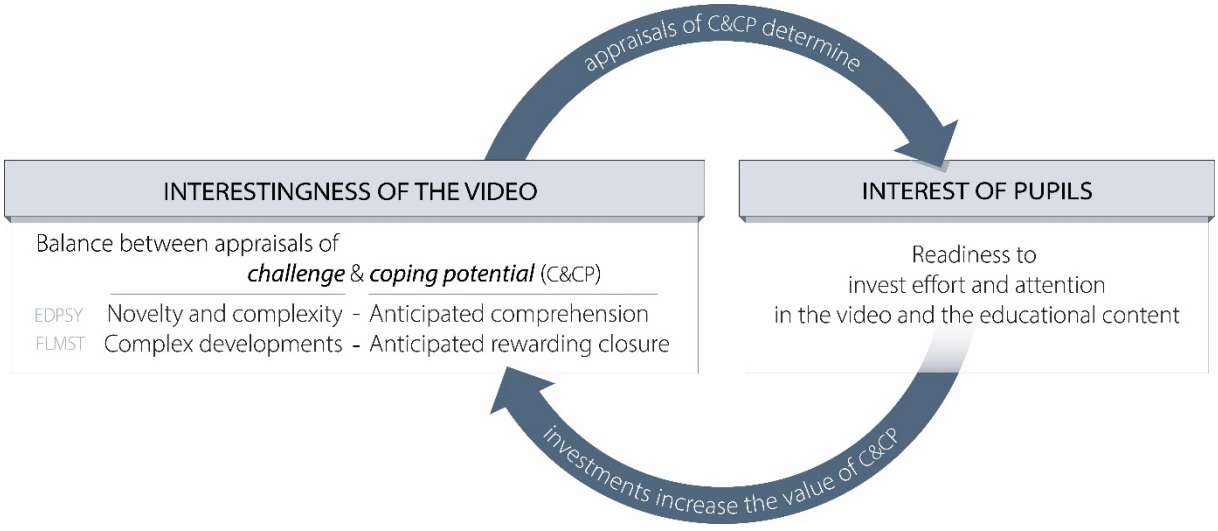


Figure 3.2. Model of film's interest raising mechanisms (FIRM model). This model describes how film raises interest in learning contexts. The interestingness of a film reflected in the film's balance between challenge and coping potential predicts the potential interest of the pupil-viewers reflected in their motivation to engage with the educational content. Pupils' actual investments reflect their interest development. Investments made increase the value pupils attribute to the appraisals and may result in further interest development.

4 It may be helpful here to be reminded of the role of expert analyses in psychological accounts of language use or music. Untrained persons can have strong intuitions and judgements on the grammaticality of sentences, or the harmony in a melody, but it needs expert linguist and musical analyses to get at accounts of the intuitions. Likewise, untrained film viewers do not avail of the explicit norms and structural categories that experts can show underlie implicit appraisals.

In any case the teachers will keep their pupils in mind while forming their judgement, as do the expert analysts in our study. The analysis of interestingness is not the analyst's own emotional appraisal, but the analyst's anticipations of appraisals made by viewers in actual viewing. In what follows, we take on the perspective of the analyst, and illustrate the use of norms and categories in film analysis for each film form to assess interestingness.

Well-Made Films for Learning

The specific contents that represent the challenge and coping potential balanced along the course of the film are film form specific. The film forms distinguished by cognitive film theory (Bordwell et al., 2017) can all be found in films used in learning contexts. The appraisal of interestingness varies over the forms. Table 3.1 exposes challenges typically posed, and rewards or coping potential offered by the four most common forms. For example, narrative films evoke the action tendency of pursuit and anticipation of story world knowledge filling causal gaps in the discourse. This action tendency is evoked if challenging narrative or story-world complications are balanced with the prospect of any resolutions to these complications.

Another example: categorical films evoke the search for concepts that categorize presented instances, if the presentation of uncategorized instances is balanced with the prospect of learning how to categorize them (inductive challenge).

Table 3.1
Interest components as substantiated in the film categories identified by David Bordwell et al. (2017)

		Film category			
		Narrative film	Associational film	Categorical film	Rhetorical film
Appraisals	Challenge	Story world complications	Complexity, ambiguity	Induction: uncategorized instances Deduction: unexplained concepts	Ungrounded claim
	Coping potential	Story world resolution	Affective experience	Instances and their categories; Concepts and their instances	Grounded claim
Action tendency	Affectively charged readiness to spend effort and attention	(Causal) Elaboration and anticipation of story world events	Free association	Induction: seeking to find categorizing concepts Deduction: seeking to find exemplifying instances	Check and possible validation of an argument

To determine what balance in the structure of films makes a film interesting in learning contexts, we can look at films that fail to raise interest. Complexities in the development of the film can on the one hand be too high and the prospect of a satisfactory closure too distant,

which results in confusion and frustration. On the other, complexity can be too low, and closure too obvious. Then the viewer can already tell all further developments and the ending.

The resulting emotion is boredom. Whether or not the balance is appropriate to raise interest, is largely dependent on a good match between the complexity level of the film and the competence level of the pupil-viewers. Obviously, the competence level of pupil-viewers regards especially prior knowledge of subject matter and topics. Films used in learning contexts present tough challenges in view of pupils' available competence, while promising pupil-viewers closure or understanding that is valued.

We propose that well-made films for learning contexts balance challenges and coping potential all along the way. That is, they exhibit an optimal balance at every consecutive moment of the serial presentation that films constitute. Well-made films signal to viewers from the start that a rewarding comprehensible film will be offered by steadily feeding the viewers' coping potential with new information, but delay the presentation of definitive rewarding outcomes till the end (Tan, 1996).

The properties of balanced challenges and reward, and delayed of final reward of well-made films sustain maximal interestingness. They lead us to propose the following two claims on well-made films for learning:

1. *The film delivers on promise*. An optimal balance between challenge and coping potential during the film maximizes interest throughout, and builds up increasing anticipations of closure and comprehension. At some point, the challenge must be traded for rewarding full comprehension. We refer to the moment when the challenge meets with full coping, as the *moment of closure*. In our molecular cooking film, the claim made by the presenter at the onset of the film about the possibility of making new molecular recipes poses a rhetorical challenge (i.e., an ungrounded claim) to the viewers: it is possible to molecularly cook a full dish. This challenge is met in the end when the dish is shown in reality. In this film there is a clear moment of closure. When there is no moment of closure pupil-viewers will be left confused and frustrated. Subsequently, the positioning of that moment of closure is responsible for the strength and scope of the film's interestingness. This brings us to the second claim;
2. *Interestingness increases across the film.* An increase of interestingness from start to end overcomes habituation of pupil-viewer activities and efforts with time. This claim implies an early introduction of a first challenge, and that during the film outcomes are only piecemeal presented and elaborated by the viewer, which leads to a steady increase of coping potential until it fully meets the challenge at the moment of closure. In our molecular cooking film, the final dish served at the end is the crown to creation of in-between-courses. Positioning the moment of closure early in the film would render the remaining of the film dull and boring. Whereas signaling to pupil-viewers from the start that a rewarding comprehensible film will be offered – the moment of closure is on its way! – but delaying the presentation of a final rewarding outcome, interestingness is pushed to its maximum.

At the basis of these claims lies a general assumption: *The challenge and coping potential represented in the film are nontrivial*. Challenges that are not perceived as worth the effort of coping, are not interesting even if optimally balanced with piecemeal provided coping potential. The same accounts for cues that are not regarded by viewers as adding to their

coping potential. In addition, interestingness of films for learning has upper and lower limits set by pupils' prior competence. Any film is well-made only with respect to its audience's competences. What is maximally challenging to one audience can be too easy for another; what seems promising to one, may seem undoable to another.

Analyzing Films for Learning as to Interestingness

Our model of interestingness can be made operational in film analysis. Next, we present a method for an expert's evaluation of how well-made a film is. Evaluation consists of analyzing the course of challenge and coping potential of the film moment by moment. This course reveals the balancing of challenge and coping potential, the moment of closure, if any (claim 1), and its positioning in time (claim 2). The method of analysis entails scoring challenge and coping potential as variables. Note that, as explained previously, it is not any empirical viewers' appraisal that is scored, but an analyst's judgment of balance, challenge and coping potential as revealed by the film's structure. The analyst's expertise needs to cover the subject matter of the film, the targeted pupils' available knowledge of the subject matter, and the structuring of film discourses.

Balance between challenge and coping potential: The primary focus of the analyst is to identify all challenges present in the film, with respect to the intended viewers. Challenges of different film forms (see Table 3.1) can be found within one film. Next the analyst identifies all cues in the consecutive moments of a film that can help viewers to cope with the challenges.

Scoring challenge: Using one's expertise all identified challenges are assessed on a numerical scale. The score reflects the weighing of the challenge's novelty and complexity level, as can be expected to be experienced by the intended viewers (see Conclusion and discussion section for our remarks on objective scaling). The analyst needs to distinguish between main and secondary challenges. Main challenges stretch over the entire course of the film, whereas secondary challenges are only present in one or several scenes. Because challenges that stretch over a longer period of time require more effort from viewers to cope with, main challenges are assigned double the value of secondary challenges. The analyst assesses how a challenge once introduced builds up over consecutive moments, and when it has been fully presented. In a well-made film the challenge's score remains at its maximal level until full closure. As soon as a challenge is answered, its score is set to zero (see Figure 3.3 – Challenge). In the case of multiple presented challenges, the analyst sums the scores related to different challenges for each moment in the film. We refer to this as Cumulative challenge (see Figure 3.6 – Cumulative challenge).

Scoring coping potential: Coping potential is assessed on a equivalent numerical scale. Each cue is assigned a score that results from the analyst's weighing of its value for coping with the related challenge. The score builds up to reach its maximum at full presentation of the cue.

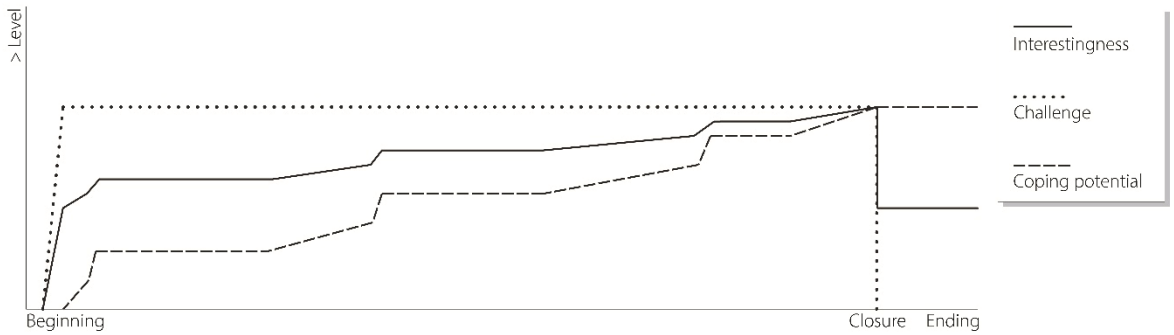


Figure 3.3. Course of challenge, coping potential and interestingness of a single main challenge film.

Coping potential scores related to the same challenge are summed over the moments of the film. The analyst assesses the build-up of coping potential scores over the film. When the coping potential level associated with one challenge reached the maximum level of that challenge, a moment of closure is identified (see Figure 3.3 – Challenge and Coping potential).

Note that the coping potential score at the moment of closure is a terminal value; coping potential does not drop after its final value (see Figure 3.4 – Coping potential). Hence, in the case of multiple, sequentially presented challenges, the analyst also sums coping potential scores related to different challenges for each moment, referred to as Cumulative coping potential (see Figure 3.5– Cumulative Coping potential).

Scoring interestingness: As explained above, interestingness depends on the balance of challenge and coping potential. We propose to define the variable interestingness simply as the average of the cumulative scores assigned to challenge and coping potential at any moment of the film's presentation. As a consequence, at the introduction of each new challenge and each cue to cope with that challenge, interestingness rises with half of their scores at any moment. At the closure of each challenge, interestingness drops with half of the challenge's maximum value (see Figures 3.3, 3.4 and 3.5).

Evaluation of well-madeness: Evaluation of a film as well-made involves interpreting the course of challenge and coping potential scores over the consecutive moments of the entire film. First, the balancing of challenge and coping potential over the film is interpreted, as well as the general assumption of nontriviality. Are there moments when challenge is not balanced with coping potential? Is interestingness diminished at these moments? Are challenge and coping potential valuable to the viewers? Second, the course of challenge and coping can be evaluated with the two claims of well-madeness in mind.

Claim 1 is subscribed to by the analyst when summed coping potential scores related to one challenge are at some moment at least equal to the maximal score of that challenge. The analyst takes this to mean that *the film delivers on promise.* It rewards the viewer's anticipations it has provoked and efforts to comprehend the entire discourse in the end. The analyst can interpret on the one hand what cues to the final answer the film provides along the way, and on the other, the cumulation of viewers' attention and efforts from one to the next cue. Both are reflected in the cumulative coping potential curve.

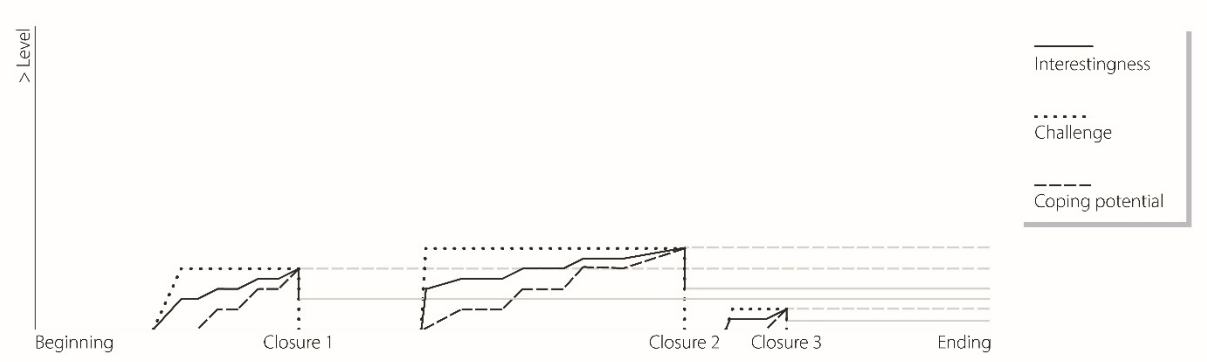


Figure 3.4. Course of challenge, coping potential, and interestingness of a multiple secondary challenge film, with separated lines for coping potential and interestingness related to each challenge. The remaining levels of coping potential and interestingness that result from early challenges are depicted in light grey.

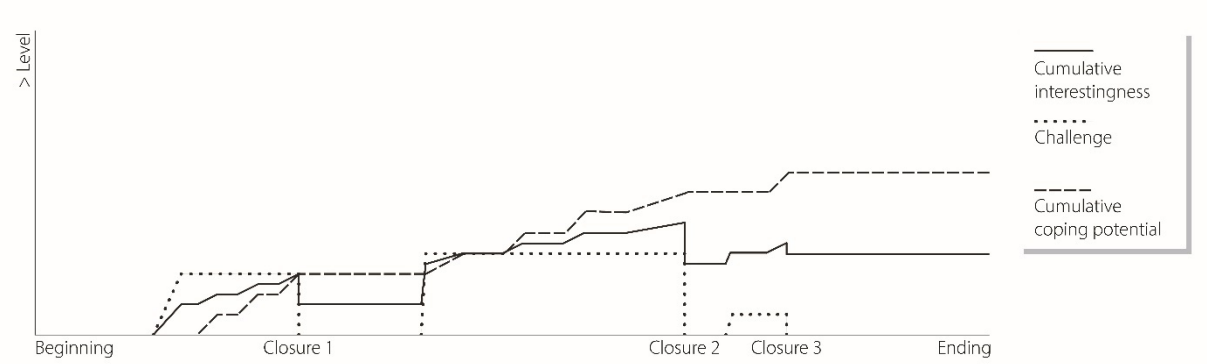


Figure 3.5. Course of challenge, cumulative coping potential, and cumulative interestingness of a multiple secondary challenge film.

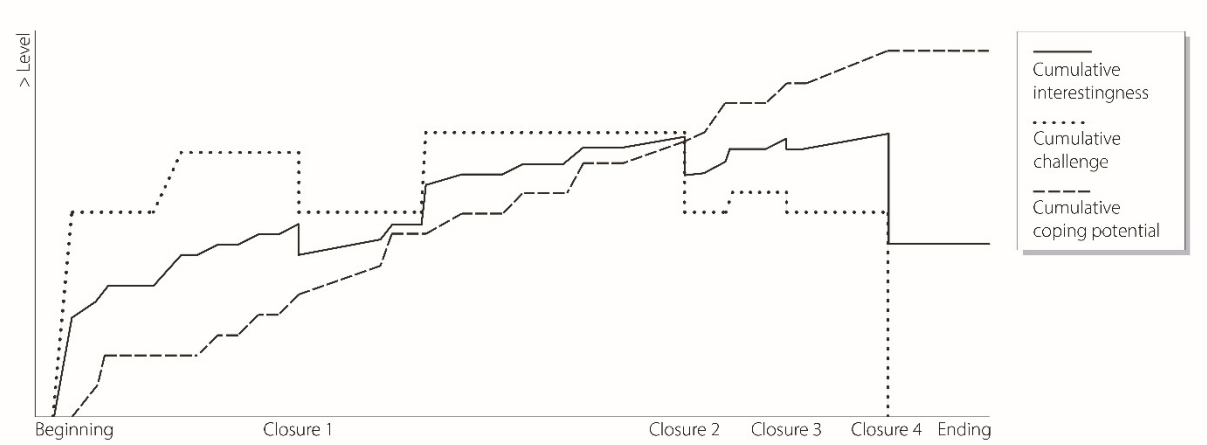


Figure 3.6. Course of cumulative challenge, cumulative coping potential, and cumulative interestingness of a mixed multiple challenge film.

Claim 2 is supported when the way to closure is gradual, so that *interestingness increases across the film*. The analyst may especially consider timing of challenges and whether they are main or secondary. The best designed film qua interestingness has an early introduction of a first challenge and includes multiple challenges of which at least one is a main challenge (see Figure 3.6). Comparing Figures 3.3 and 3.5 it can be seen that early introduction of the first challenge means both early and prolonged development of interestingness. Multiple challenges presented in series (Figure 3.5) have both benefits and costs with regard to interestingness. Interestingness is raised with each new challenge, but only as long as the challenge is not answered. In contrast, the primary challenge (Figure 3.3) can be more potent over a prolonged period. A combination of the two optimizes the development of interestingness (Figure 3.6).

In closing, it should be emphasized that the interestingness curve does not represent a series in time of any absolute ratings of a film's interestingness. It is the trends in the curves that are of interest for analyzing a film's interest raising potential structure. For a fully elaborated analysis, see Appendix 3A: *Analysis of interestingness of* Het Klokhuis: Moleculair Koken.

Conclusion and Discussion

Our presented theories from educational psychology and cognitive film theory both characterize interest as an emotion. Emotions are affectively charged and therefore notoriously difficult to resist. Both theories describe the manifestation of the interest emotion as the tendency for a person to invest in their relationship with the contents of the situation they are in. Emotional tendencies to engage in film viewing drive film viewers to mental and affective activity, anticipating on and seeking for resolutions to challenges that films pose continuously. The main challenge is to understand the complete formal contents of a film, be it the narrative – its events, plot and characters; an associational construct – its complex and ambiguous events; a categorical system – its concepts, instances and relations; or a rhetorical argument – its claims, arguments and warrants. Emotion-driven tendencies to engage in the film's form, bring along learning activities centering on targeted educational contents, be they story events, ambiguous events, concepts and instances or arguments. Because formal relations can be complex and require the use of knowledge of the world or its domains, learning processes can take place. Interest as an emotion fuels the effort invested and enables enjoyment (or rather appreciation) of rewards obtained in the process of learning. Bringing together the two theories lies the basis for our understanding of how film can activate pupil-viewers, and interest them – in a relatively pleasant way – for learning activities.

Based on a conceptual foundation of interest as an emotion, we have proposed a dynamic model for interestingness of films for learning (FIRM model). Moreover, we have formulated two claims on well-made – in the sense of optimally balanced and maximally interesting – films as requirements that can be assessed: 1. The film delivers on promise, that is, all challenges should be met by coping potential, and 2. Interestingness increases across the film, that is, early introduction of the first challenge and delayed presentation of the coping potential. The general assumption underlying these claims is that the challenges and offered coping potential in the film are nontrivial to its viewers. We have demonstrated how a film for learning can be analyzed as to its match with the requirements to well-made films in terms of

interestingness. And we have shown how the analysis can reveal strengths and weaknesses of a film, as well as evaluate its interestingness at any moment of its presentation.

Raised interest, described as a positively appraised balance between challenge and coping potential as we did here, closely relates to the concept of Flow. Flow occurs when there is a balance between perceived challenges and perceived skills (Csikszentmihalyi et al., 2014). Theories of interest and of flow both emphasize a challenge that matches the subject's ability to cope with that challenge. The main difference between the interest balance and the balance of flow is the timing of coping. Flow occurs when challenge and coping coincide completely. There is a perfect and immediate match between challenge and coping or skill. Interest is reached when challenge coincides with the *prospect* of coping. The matching answer to the posed question is anticipated but delayed as yet.

The present study on interestingness of film for learning has some limitations. One limitation on our theoretical model is that in explaining interestingness, it purposefully factors out another variable of film appraisals and qualities, namely enjoyability. We adhere, as some emotion researchers do, to the notion that interest is a positively valanced emotion (e.g., Izard, 1992). However, interest is not identical to enjoyment, since different appraisals are at play (see Silvia, 2008 and Tan, 1996). In our conception, the relational action tendency in interest is a pleasantly tinted desire. This point has also been made in recent conceptualizations of interest. According to Pekrun (2019) the activity in interest-based activity has positive affect to it. Learning out of interest then is pleasant. But it can be argued that enjoyment occurs also independently in the viewing and learning process. For example, every step in the accumulation of coping potential, every piece of the solution or argument may be greeted with pleasure. Thus, there is room for an extended emotional model of learning with enjoyment as an independent factor. A limitation in the requirement profile of well-made films for learning is the lack of numerical scaling of challenge and coping potential. In its present early stage, it relies on an intuitive judgement of the particular analyst. We have high hopes that awaiting scales for interestingness, interrater agreement can be reached on at least the relative size of increment steps between two subsequent analysis units. A final limitation in the analysis is the absence of a grounded way to introduce a priori estimations of challenge and coping potential, thus of interestingness, in targeted audiences. We believe that the problem is far from new. Educators face the task of tweaking educational contents and activities to prior knowledge and competence of their pupils. At least some standardized measures have been developed, such as reading or arithmetic performance classifications. Probably, in other domains any design of learning material relies on experiential knowledge of skilled teachers. There may be ways to use their collective judgements for the analysis of interestingness of films for learning.

In spite of these and other limitations, we expect that the method laid out here can be used to analyse and test a large number of films for learning as to interestingness, possibly resulting in a great many more effective patterns of balanced challenge and coping ability than the linearly rising one that we have proposed and found. A longer list of strengths and weaknesses found in the analysed films will certainly help designers of films for learning purposes to come up with more interesting educational narratives, expositions, documentaries and other films.

In closing, we stress the necessity of more interesting films for learning. Film's powerful potential to show the world outside the classroom, and to raise pupils' interest for phenomena

in this world as was recognized by educators from the 1940s onward, is heavily underused. Pupils grow up seeing films for learning with a general emphasis on instruction and reproduction, concisely spelling out for them what content needs to be remembered. How can we expect pupils to be astonished, moved, surprised by film, if we prime them to search for knowledge and facts? If learning and enjoyment in learning is the primary goal of education, and if educators deem interest to be the key, then this should be reflected in how we teach. We aspire to return to film its full potential as an interest-raising tool for learning. By conducting more empirical studies we will further refine our model and analyses, and we invite other researchers to participate. This way film can finally become what Hart Wegner considered "[…] the most influential and seductive force available to us to teach, to convince, and to transmit ideas and information […]" (1977, 8).

Appendix 3A
Analysis of Interestingness of Het Klokhuis: Moleculair Koken

This film is in actual use in a Dutch chemistry class for sixteen to seventeen-year-olds. The film is an 8.20 min. segment of *Het Klokhuis – Moleculair Koken* (*Molecular Cooking*), a Dutch educational television program for children aged nine to twelve (https://www.hetklokhuis.nl/tv-uitzending/2002/Moleculair-koken with exclusion of the non-documentary parts min. 3.42-5.39, min. 8.20-10.08, and min. 12.07-14.28). The format includes documentary and staged fragments on an educative subject. The segment was selected by a chemistry teacher and only included documentary fragments. Analysis units were subsequent scenes delineated by represented actions in image, sound and spoken comment lines.

Balance between challenge and coping potential: Regarding form, Molecular Cooking is a primarily rhetorical film with categorical elements. Rhetorical form analysis (see Table 3.1, rightmost column) identified as yet ungrounded claims (challenge of rhetorical films), and arguments that ground these claims (coping potential of rhetorical films); Categorical form analysis (see Table 3.1, second column from the right) identified uncategorized instances and unexplained concepts (challenges of categorical films), and categorizing concepts for the instances and exemplifying instances for the concepts (coping potential of associational film). Appendix 3A-1 displays the analysis more fully.

Identifying challenges and coping potential, we found five ungrounded claims of which we indicated one as a main claim (challenge of rhetorical films), two uncategorized instances and eleven unexplained concepts of which we indicated one as a main concept (challenge of categorical films). Keeping in mind the intended viewers, aged nine to twelve, over the course of the film all claims were sufficiently grounded (coping potential of rhetorical films), all uncategorized instances were categorized, and all unexplained concepts were explained (coping potential of associational film). Evaluated for the actual viewers of the Dutch chemistry class, aged sixteen to seventeen, we expect the amount and nature of the cues to deliver redundant coping potential.

Scoring challenge, coping potential and interestingness: The scores we assigned to the challenges and coping potential were made while keeping in mind the intended viewers of the filmmakers (aged nine to twelve). The scores would have been lower for the older actual viewers that have more prior knowledge on the subject matter. We set the maximal challenge value equal to the value that the developing coping potential could meet in the end to reflect our evaluation of the balance between challenge and coping potential that all challenges were sufficiently met by coping potential. The maximal challenge value for each challenge was kept constant until the moment of their closure. Increases in coping potential related to the main challenge scored two points, those in relation to secondary challenges one. Coping potential scores were summed across subsequent analysis units resulting in a running cumulative. Per unit, the mean was calculated of cumulative challenges and coping potentials to score the interestingness of the unit (see Appendix 3A-1). The development of challenge, coping potential and interestingness are summarized in Figure 3.7 (again note that the scores are not anchored in any validated scale, however, the development of challenge, coping potential

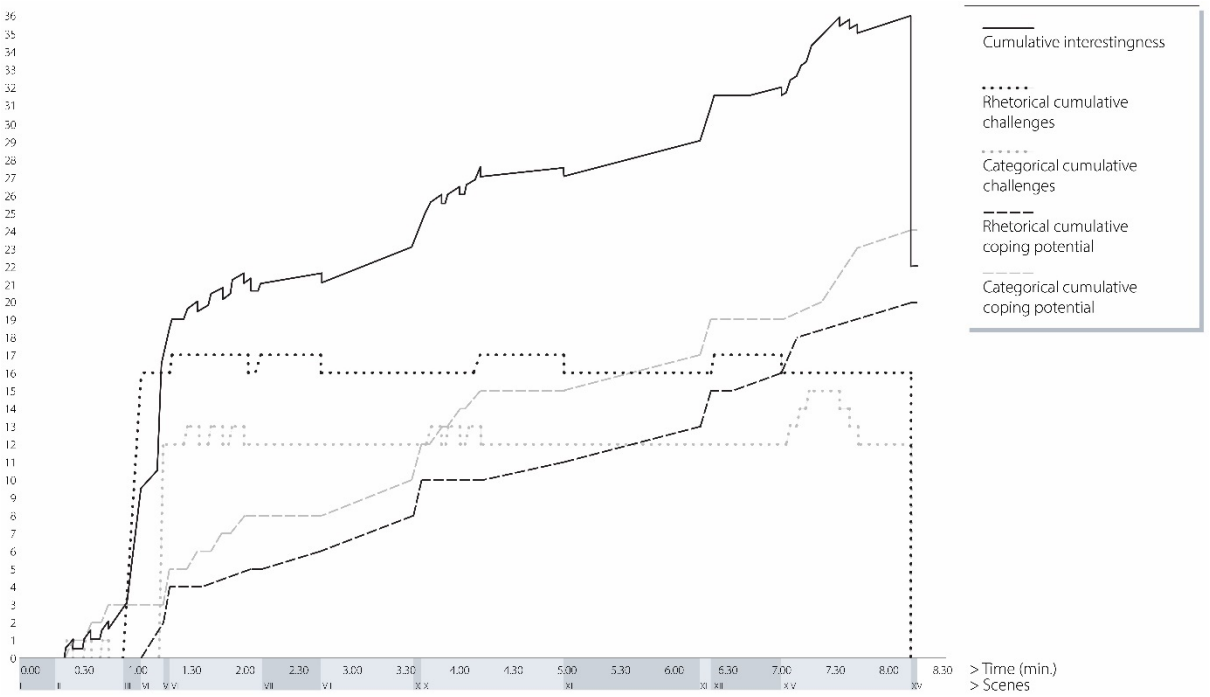


Figure 3.7. Cumulative challenge, cumulative coping potential, and cumulative interestingness of *Het Klokhuis Moleculair Koken*, derived from rhetorical and categorical form analysis.

and interestingness from the film's beginning to end is captured by the course of the scores). Appendices 3A-2 and 3A-3 graphically specify the rhetorical and categorical analyses.

Evaluation of well-madeness: The main challenge of this film presents the prospect of overcoming novelty and complexities related to molecular cooking. This big challenge is initially balanced by only minimal cues for confidence that new dishes will be delivered (positive host and the cooking lab). The coping potential related to the challenge rises with progress in the cooking, and with explanations and demonstrations, making interestingness rise. We found categorical development closely linked with the rhetorical argument by challenges popping up in the process of demonstrating the possibilities of molecular cooking posed by novel terms (e.g., starchy products). The resolution was in demonstrations that each answered part of the rhetorical main challenge. In general, we found the introduction of new challenges to be well-balanced over the course of the film, as were the cues delivering coping potential.

Since coping potential could only be scored as "maximal" and not scaled as an amount, we cannot analytically assess the value of challenge and coping potential in this film – the general assumption underlying the two claims on well-made films for learning. For this one would need objective measures of competence on the subject from some reference group, plus the estimated challenge involved in proving that molecular preparation of a good novel dish according to the same group. However, it can be expected that the younger intended viewers would value the challenges posed in the film higher than the older actual viewers.

Now we evaluate the two claims on well-made film. All claims presented in the film were grounded, all uncategorized instances were categorized, and all unexplained concepts were explained. The film thus met claim one on well-made films by delivering on promise. Claim two on well-made films was also met: interest increased across the film. The main rhetorical

claim was exposed rather early in the film. There were no prominent horizontal lines in the representation of interestingness indicating the development to had come to a pause, and arguments and categories or instances were presented piecemeal. However, there were minor drops after the closure of each secondary challenge. Because the categorical development was closely linked with the rhetorical argument, the closure of each secondary challenge also resulted in a rise of the coping potential related to the main challenge. A drop of the interestingness level at the closure of a secondary challenge never negatively exceeded the level of interestingness that was already reached before the start of that secondary challenge, and due to the relatedness of secondary and main challenges even less than would have been the case with non-related fragmented challenges.

Appendix 3A-1
Film Analysis on Rhetorical and Categorical Elements in the Film Het Klokhuis: Moleculair Koken

Scoring:

- Increase in perceived coping potential (the prospect of meeting the challenge posed) related to main challenges: 2 points, indicated with (+ +);
- Increase in coping potential related to secondary challenges:1 point, indicated with (+);
- The total amount of points assigned to one challenge = maximum value of the challenge = coping potential met in the end, indicated with (-);
- Challenge was assumed to remain fully present until completely resolved or explained.

Note that the cumulative challenge drops one point whenever a secondary challenge is met by the coping potential. See for example Categorical components in scene II: with the introduction of *Unexplained concept 1: Products* the cumulative challenge increases one point, and drops one point with the introduction of the *Exemplifying instances of 1*. The cumulative challenge does not drop when a main challenge is partially met by the coping potential because it is not yet fully met. However, the introduction of related coping potential does cause the cumulative coping potential to rise. See for example Rhetorical components in scene IV: with the introduction of *Prospect of proof for main claim* the cumulative coping potential increases two points (not just one because it is related to a main challenge) while the cumulative challenge remains at 14 points. The cumulative challenge related to the main challenge remains to be stable until the end of scene XIV.

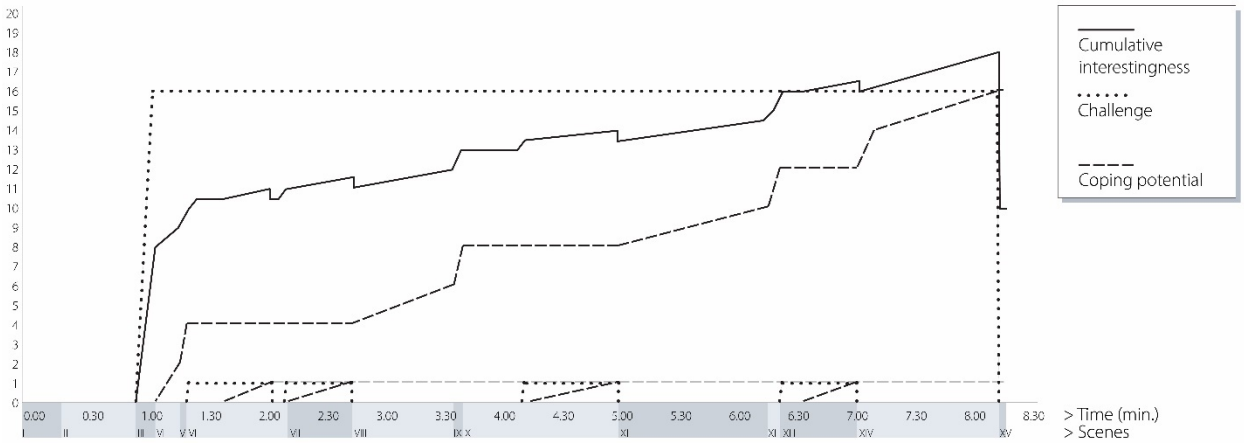
				RHETORICAL COMPONENTS						CATEGORICAL COMPONENTS						OVERALL CUMULATIVE		
Scene	**Time**	**Action and image**	**Lines**	**Challenge**	**Coping potential**	**Points - main in red**	**Cumulative Challenge**	**Cumulative Coping potential**	**Cumulative Interest**	**Challenge**	**Coping potential**	**Points - main in red**	**Cumulative Challenge**	**Cumulative Coping potential**	**Cumulative Interest**	**Challenge**	**Coping potential**	**Interest**
	.00	Het Klokhuis leader					0	0	0				0	0	0	0	0	0
I	.20	Close-ups of pans, knives, bowls, a stove. An empty kitchen. Several products in the front, Bart enters the shot from the left, zoom out.	**Bart:** Food is fantastic. Nature supplies us with endless delicious products.				0	0	0	Unexplained concept 1: Products		(-)	1	0	0.5	1	0	0.5
		Close ups of shrimps, tomatoes and cucumber, apples and pears, ginger and mint, strawberries and grapes.	**B:** Meat, fish, vegetables, fruit, herbs, seeds, nuts.				0	0	0		Exemplifying instances of 1	(+)	0	1	0.5	0	1	0.5
		Back to Bart in the kitchen.	**B:** And then you can do all kinds of things with it in the kitchen:				0	0	0	Unexplained concept 2: Methods of preparation		(-)	1	1	1	1	1	1
		Close ups of stirring sauce in a pan, backing a piece of fish, putting a plate in the oven, chopping asparagus, pouring liquid in a bowl, pouring something steamy in a bowl.	**B:** Cooking, baking, roasting, stewing, cutting, mixing, cooling.				0	0	0		Exemplifying instances of 2	(+)	0	2	1	0	2	1
		Back to Bart in the kitchen.	**B:** Countless recipes have been created over the years.				0	0	0	Unexplained concept 3: Recipes		(-)	1	2	1.5	1	2	1.5
		Bart stands still next to the products that were shown in the close ups.	**B:** From "Babi pangang" to kale stew and from mayonnaise to salt herring. But the question is: Can we still improve those recipes? Or better yet: Can we also come up with new recipes?				0	0	0		Exemplifying instances of 3	(+)	0	3	1.5	0	3	1.5
II	.58	Bart walks towards the camera through a hall way.	**B:** *But of course!* If you research the preparation of food and you look very precisely what happens, you can use that knowledge to cook even better and tastier.	Main claim		(16 -)	16	0	8				0	3	1.5	16	3	9.5
V	.08	Close up of Eke's hands while peeling an orange, zoom out to Bart, Eke and Jan in the kitchen. Close ups of Eke's face, and his hands while cutting chives. Back to Bart, Eke and Jan. Close ups of Jan's face while looking through a microscope, and his hands while placing a new slide underneath it. Back to Bart, Eke and Jan in the kitchen.	**B:** We are going to cook with knowledge and this is a top duo for that: Eke Mariën, top chef and recipe creator, and this is Jan Groenenwold, chemist, food detective at Utrecht University. The cook and the chemist. We are going to make a molecular three-course meal.		Prospect of proof for main claim	(+ +)	16	2	9	Main unexplained concept: Molecular meal		(12 -)	12	3	7.5	28	5	16.5
	.21	Title on the background of the prepared dish	Appetizer: Orange mayonnaise pudding		Prospect of proof for main claim	(+ +)	16	4	10		Exemplifying instance of main	(+ +)	12	5	8.5	28	9	18.5
I	.25	Close up of vinegar being poured into a glass.	**B:** One of the tricks of cooking is of course bringing different ingredients together into a new, tasty combination. But what if the ingredients don't want to mix?	Secondary claim 1		(-)	17	4	10.5	Unexplained concept 4: Ingredients		(-)	13	5	9	30	9	19.5
		Zoom out, Bart pours vinegar in a glass. Bart adds oil to the vinegar.	**B:** Take for example vinegar, here, and sunflower oil.				17	4	10.5		Exemplifying instance of 4	(+)	12	6	9	29	10	19.5
		Close up of oil and vinegar being put together	**B:** Vinegar is a…				17	4	10.5	Uncategorized instance 1: Vinegar		(-)	13	6	9.5	30	10	20
			B: … aqueous ingredient …				17	4	10.5		Categorizing concept 1: Water-based ingredient	(+)	12	7	9.5	29	11	20
			B: … and sunflower oil…				17	4	10.5	Uncategorized instance 2: Sunflower oil		(-)	13	7	10	30	11	20.5
		Resulting in two layers of liquids on top of each other in the glass.	**B:** … an oily ingredient. And watch what happens. They don't want to mix!				17	4	10.5		Categorizing concept 2: Oli-based ingredient	(+)	12	8	10	29	12	20.5

		Bart holding the glass turning to Jan. Jan takes an egg from a box. Close up of Jan breaking the egg on the edge of the glass and adding the egg to the liquids. Jan puts a mixing machine into the glass and starts mixing. Close up of the glass where the ingredients turn into mayonnaise.	**B**: But Jan, how can we still mix these liquids? **Jan:** That is possible, with an egg. You add an egg to the mixture. Then you take a hand blender and put it in.		Proof for secondary claim 1	(+)	16	5	10.5			12	8	10	28	13	20.5
		Close up of Jan explaining. Close-up of the mayonnaise. Jan and Bart sitting next to the mayonnaise, Jan still explaining.	The egg contains molecules, protein molecules. They are very good at protecting the oil droplets that I am mixing. And because they are so well protected, that mayonnaise will no longer fall apart.	Secondary claim 2		(-)	17	5	11			12	8	10	29	13	21
II	.17	Close up of a hand that puts mayonnaise on a glass slide. Close up of hand placing the slide underneath the microscope. Close up of hand turning the wheel of the microscope. Close up of Jan looking through the microscope while explaining. Zoom out, Jan moves away from the microscope, Bart enters the shot from the right and looks through the microscope. Image through the microscope of bubbles moving past each other. Bart moves away from the microscope and looks towards the computer screen in the back displaying the same image of the bubbles. Back to image of the bubbles. Back to Jan and Bart, Jan explains to Bart.	**J:** Look Bart, this is what mayonnaise looks like under the microscope. **B:** Wow, all little balls huh?! **J:** Yes, those are fat drops. You can see them sitting very close together here. They do not flow together like fat and vinegar because there is a layer of protein molecules around them, around those drops.		Proof for secondary claim 2	(+)	16	6	11			12	8	10	28	14	21
III	.39	Close up of hands cutting oranges. Close up of Eke's head while cooking. Close up of flame lighted underneath a pan on a stove. Close up of boiling butter in the pan. Close up of Bart, pan to the left where Eke is standing. Over shoulder of Eke while Bart is listening. Zoom in on Eke pouring juice through a sieve. Close up of measuring glass being filled with juice. Over shoulder of Eke. Close up of Eke knocking mayonnaise in a bowl while Bart pours in the juice. Tilt to Bart's face. Close up of the bowl in which the mayonnaise is being knocked. Close up of three glasses being placed on the kitchen counter. Close up of Eke's hands while putting the mayonnaise into the glasses with a spoon. Eke filling the three glasses. Eke putting the glasses into the microwave. Close up of Eke's finger pressing the microwave's button. Top view of Eke emptying a glass onto a plate. Close up of Eke cutting a cucumber. Top view of Eke placing the cucumber onto the plate, and putting shrimps on the plate. Close up of Eke's hands cutting chives. Top view of Eke scattering the chopped chives on the dish. Bart and Eke standing next to each other in the kitchen. Close up of the plate being placed onto a set table. Zoom out to Bart sitting at the table and Eke standing next to it. Top view of the prepared dish (point of view of Bart). Back to Bart sitting. Bart starts eating, zoom in on Bart. Bart starts eating, looks into the camera. Zoom out, Eke watches Bart eat.	**B:** Eke, what are we going to make? Eke: We're going to make an orange mayonnaise. And um, you normally make mayonnaise with vinegar. And now I use orange juice instead of vinegar, reduced a bit so that it is very concentrated. And then I add orange oil. **B:** You can really see it starting to foam right ?! **E:** Yes, you can see it going. I put it in a small container and then it goes in the microwave. And then you get a lot of heat for a very short time. **B:** Yes. **E:** Then the egg white in the mayonnaise solidifies. And the air that I just punched in, it is trapped inside the egg white, it cannot get out. So then you get a very light mayonnaise cake. It's a new dish. Look Bart: Orange mayonnaise pudding with Dutch shrimps, a little cucumber and… some chives. **B:** Hmmm… What a special combination. Yummy! **E:** Yes, orange and shrimp go really well together.		Proof for main claim	(+ +)	16	8	12		Main categorizing concept: new dish	(+ +)	12	10	11	28	18	23
X	.41	Title on the background of the prepared dish	Main course: Bonded cod		Prospect of proof for main claim	(+ +)	16	10	13		Exemplifying instance of main	(+ +)	12	12	12	28	22	25
	.46	[All rhetorical and categorical elements that are represented in the action or image are also represented in the lines, and categorized there. From here onward, we therefore leave out further analysis on action and the image]	**B:** When cooking, not only the taste is very important, but also the feeling in the mouth.				16	10	13	Unexplained concept 5: Feeling in mouth		(-)	13	12	12.5	29	22	25.5
			B: For example, is something very crunchy? Is something sticky? Are things hard or soft? Is it watery or a bit thicker?				16	10	13		Exemplifying instances of 5	(+)	12	13	12.5	28	23	25.5
			B: With cooking you can influence that feeling very well. And an important trick is binding.				16	10	13	Unexplained concept 6: Bound		(-)	13	13	13	29	23	26

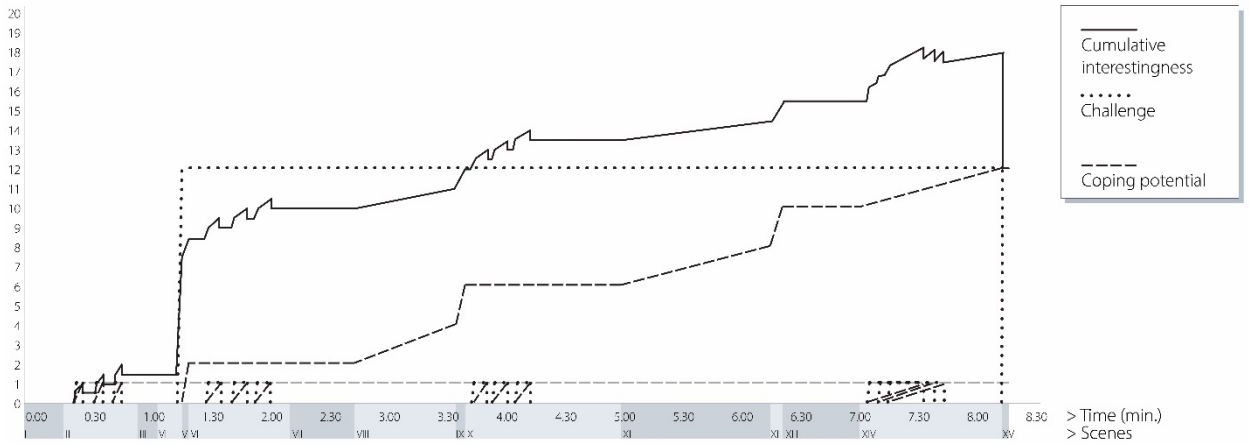
									products									
			B: Because a lot of soups, a lot of sauces like mayonnaise, or desserts like vanilla custard would only taste watery if they were not thickened.			16	10	13		Exemplifying instances of 6	(+)	12	14	13	28	24	26
			B: Well, that binding, that thickening is done with starch. Starch …	Secondary claim 3		(-)	17	10	13.5	Unexplained concept 7: Starchy products		(-)	13	14	13.5	30	24	27
			B: … is very much in seeds, in grains, but also very much in potatoes. I have potato starch here as an example.				17	10	13.5		Exemplifying instances of 7	(+)	12	15	13.5	29	25	27
			B: Jan, how exactly does that starch work? **J:** Starch? Well starch, you know it a bit, it is a bit powdery and those are actually all granules. **J:** These bunches are your starch grains and I now add water. So it is the water molecules. And that can actually move freely through it. This sauce is unbound. **B:** Yes. **J:** Everything can move freely. What happens when you increase the temperature: You put the pan on the fire, you start cooking, the temperature rises. Then those strings go, they get loose. They will unravel like this, whoopie. And all those molecules in between cannot move that freely at all. This is how you actually bind your sauce.		Proof for secondary claim 3	(+)	16	11	13.5				12	15	13.5	28	26	27
I	.06		**E:** Now we are going to make a béchamel sauce with a little herb cheese. Look, I have a very tasty herb cheese here, a spring cheese with all kinds of spring herbs in it and a little paprika. And I will soon stir it through my bechamel. And you make a béchamel on the basis of butter, you melt it, you add some flour, then you cook that flour in the butter, then you actually stir it and then you pour milk in it and that binds, that becomes a bound sauce. And you melt your cheese through it and then you are actually done with your cheese sauce. There you go Bart. This is a piece of cod fillet with the cheese sauce we just made and asparagus on the side. Enjoy your meal. **B:** Thank you, I think that will work. Hmmm. **E:** Approved? **B:** Sure!		Proof for main claim	(+ +)	16	13	14.5		Exemplifying instance of main	(+ +)	12	17	14.5	28	30	29
II	.22	Title on the background of the prepared dish	Dessert: Strange fruit with oil snow		Prospect of proof for main claim	(+ +)	16	15	15.5		Exemplifying instance of main	(+ +)	12	19	15.5	28	34	31
III	.27		**B:** This is liquid nitrogen, minus 196 degrees Celsius, almost 200 degrees below zero! But Jan, how can we cook with that again?	Secondary claim 4		(-)	17	15	16				12	19	15.5	29	34	31.5
			J: Well, because it's so very cold you can freeze things very quickly. We're going to freeze raspberries in that liquid nitrogen, minus 200 degrees. Time to get them out. We've actually made hundreds of mini raspberries now. The structure and shape of the raspberry has completely changed due to the freezing and smashing.		Proof for secondary claim 4	(+)	16	16	16				12	19	15.5	28	35	31.5
IV	.08		**B:** Eke, time for dessert. What are you going to do exactly? **E:** I'm going to make a real molecular dessert. I'm going to prepare something with low pressure ...		Prospect of proof for main claim	(+ +)	16	18	17	Unexplained concept 8: Low pressure preparation		(-)	13	19	16	29	37	33
			E: ... I'm going to prepare something with very high pressure ...				16	18	17	Unexplained concept 9: High pressure preparation		(-)	14	19	16.5	30	37	33.5
			E: … and I'm going to cook something at a very low temperature.				16	18	17	Unexplained concept 10: Low temperature preparation		(-)	15	19	17	31	37	34
			E: Well I use strawberries, which I let get sucked with redcurrant juice in vacuum.				16	18	17		Exemplifying instance of 8	(+)	14	20	17	30	38	34

		E: I use an aerosol that normally contains whipped cream. I empty a carbon dioxide cartridge into it and I also put grapes in it and if you leave that for a while then the carbon dioxide will sit in those grapes and then you get fizzy grapes.			16	18	17	Exemplifying instance of 9	(+)	13	21	17	29	39	34
		E: Then there comes the ultimate one that is with nitrogen I am going to make a foam, or ice I should say, of oil and I flavored that oil with rosemary.			16	18	17	Exemplifying instance of 10	(+)	12	22	17	28	40	34
		[All introduced Categorical concepts in this scene also function as exemplifying instances of the main Categorical challenge]			16	18	17	Exemplifying instances of main	(+ +)	0	24	12	16	42	29
		B: Hmmm. Oh, this is really delicious, you can taste that rosemary, the berry juice, the strawberry. This really is the perfect ending to a molecular dinner Eke! **E:** Awesome. **B:** Hmmm. **E:** Very good, I'm glad you like it. **B:** Definitely!	Proof for main claim	(+ +)	0	20	10			0	24	12	0	44	22
V	.20	Het Klokhuis outro			0	20	10			0	24	12	0	44	22

Appendix 3A-2
Course of Challenge, Coping Potential, and Cumulative Interestingness due to Rhetorical Elements in the Film Het Klokhuis: Moleculair Koken



Appendix 3A-3
Course of Challenge, Coping Potential, and Cumulative Interestingness due to Categorical Elements in the Film Het Klokhuis: Moleculair Koken



Modelling the Mechanisms of Interest Raising Videos in Education

4

An Empirical Validation Study

Wijnker, W., Bakker, A., Schukajlow, S., & Drijvers, P. (submitted-a). *Modelling the mechanisms of interest raising videos in education: An empirical validation study*.

Abstract

Videos are assumed to have the potential to raise interest in educational content. The mechanisms of raising interest, however, have hardly been studied. In this study, we aim to validate the core components of a dynamic model of pupil-viewer interest. The model describes how pupils' interest in a video is the result of their appraisals of video characteristics, and how this interest influences the further development of interest in educational content. The five appraisals in the model represent characteristics of learning material and activities, film and video, and games that have found to potentially raise interest: Novelty and complexity, Comprehensibility, Complex developments, Rewarding closure and Absorption. We empirically tested the use of four videos in six 12th-grade science and mathematics classes (151 pupils). Using path modelling, we analysed the effect of pupils' appraisals of a video on their interest in the video, and subsequently on their interest in the educational content. All five appraisals in the model were significant predictors for the pupils' interest in the video and for their development of interest in the educational content.

Introduction

While the use of film and video in educational contexts is increasing worldwide (Fyfield et al., 2020; Thomson et al., 2014), still little is known about how the use of audio-visual media can contribute to learning processes (Hobbs, 2006; McClusky, 1947; Schwartz & Hartman, 2007; Thomson et al., 2014). Prior research suggests that, in the context of learning, film and video are particularly suitable for raising pupils' interest in educational content and for learning in general (Wijnker et al., in press). In the field of science and mathematics education, raising pupils' interest is one of the core foci of attention in curriculum innovation, because their motivation to learning science subjects is lagging behind other disciplines, in particular in Western countries (Potvin & Hasni, 2014; OECD, 2016). Many educational innovations such as context- or inquiry-based teaching, and IT usage have been proposed as possible motivators, but intervention studies researching the qualities of specific tools are scarce (Schukajlow et al., 2017) and there is little systematic evidence for effectiveness (Savelsbergh et al., 2016). Video might help in remediating the problem of low pupils' interest, but only when made and used knowledgeably.

The scarcity of theory-grounded good practices of video usage in education inspired us explore the practice of video usage in educational contexts (Wijnker et al., 2019), and to investigate the mechanisms underlying films and videos that interest pupils. As part of that investigation, we gathered interest theories from different domains and integrated them in a model (Wijnker et al., in press). We formulated a theoretical basis for our model from general interest theories (Blakemore & Vuilleumier, 2017; Frijda, 2007, 2009; Izard, 1977, 1992; Scherer, 2010; Silvia, 2005, 2006, 2008), and more specifically from interest theories in the field of educational psychology (Akkerman, 2017; Akkerman & Bakker, 2019; Hidi, 2006; Krapp, 1999; Patrick et al., 2011; Renninger & Hidi, 2016; Schiefele, 1991; Tobias, 1994), and from film studies (Bordwell, 1985; Bordwell et al., 2017; Tan, 1996, 2008, 2018; Tan & Visch, 2018). In brief, our model describes how pupils' interest in the video, as a result of their appraisals of video characteristics influences the development of their interest in the educational content. Inspired by Game theory we subsequently added the appraisal of Absorption. The model and the appraisals are explained in the next section.

The aim of this study was to empirically validate the model's core mechanisms and to find leads for whether the appraisals in the model represent predictors for the development of pupils' interest in the video and its content.

In this article, we use the term *film* to refer to any kind of audio-visual medium that has a fixed course of development. This excludes for example games in which the pupil-players manipulate the course of events while playing. It includes any category of film, be it narrative (development of a fictional story), associational (development of connections and relations), categorical (development of categorization) or rhetorical (development of an argument) (Bordwell et al., 2017). It includes life action and animation. In education, teachers often use a short film clip rather than a complete fiction film or documentary, commonly referred to as a *video*. When discussing actual film material in our study we speak of videos, to distinguish it from the general theoretical notion of the film medium.

Theoretical Framework

Interest refers to a relationship that evolves between a subject and an object (Krapp, 1999; Wijnker et al., in press). In the case of watching a video for educational purposes, the subject is the pupil-viewer and the object is the video with its educational content (and may be more specifically the general idea of the video, the approach of the topic, the imaging, the structure, etc.). This interest relationship between a subject and an object is an emotional one (Frijda, 2009). Emotional relationships imply a subject's appraisal (judgement) of the object, which motivates specific actions (Scherer, 2010). With the emotion of interest, the subject's motivated action is to invest more effort on and attention to the object (Silvia, 2006), or – in an educational setting – the willingness to engage with the educational content (Renninger & Hidi, 2016). For as long as the subject is actively engaged with the object, interest might be regarded as a situational emotion, referred to as situational interest. It is assumed that repeated interested engagement may nurture a more sustained interest in the object as well (Renninger & Hidi, 2016).

We applied these theories to our focus on video in education, and formulated an elaborate model (Wijnker et al., in press) of which the core components that we investigate in this study are presented in Figure 4.1. With this model we aim to explain (top left arrow) how pupil-viewers' appraisals of a video determine their interest in the video and their willingness to engage with it and its content. Subsequently, if a video motivates the pupils to action (top right arrow), it may contribute to a more sustained interest in the video's educational content. Indirectly, pupils' positive video appraisals may contribute to their development of interest in the educational content (bottom arrow) via their interest in a video.

Interest theories from the domain of educational psychology and from film studies informed us about the nature of the appraisals that generally evoke interest with pupils and viewers respectively. Both domains similarly describe a balance between a set of two appraisals: Pupils generally positively appraise learning objectives that they characterize as novel or complex, and yet comprehensible (Krapp, 1999; Silvia, 2008). Interested viewers generally positively appraise complex developments presented through film, and the rewarding closure of these developments (Tan, 1996, 2018). The sets of appraisals from the two domains similarly describe a balance between *challenge* (novelty and complexity; complex developments) and *coping potential* (comprehensibility; rewarding closure). The theories describe how interest only increases when these related characteristics are appraised positively, and when a balance between challenge and coping potential is experienced by the pupil-viewers.

In the next phase of our research project, we decided to add an insight from game theory to the model. Although, like film studies, game theory focuses on audio-visual media, game players' interest develops quite differently from film viewers' interest. One of the most prominent differences between the two media regards the absence of a fixed discursive structure in games (Costikyan, 2000). Games typically engage players in a narrative *space*, rather than a

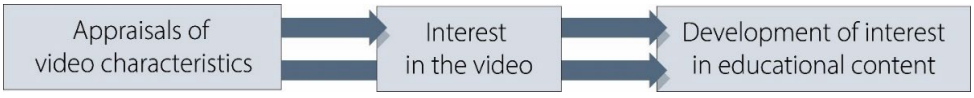


Figure 4.1. Simplified model of film's interest raising mechanisms with pupil-viewers, following Wijnker et al. (in press).

structure like film does (Jenkins, 2004). In film, it is precisely this structure that is responsible for the build-up of the interest raising challenge-coping potential balance (Tan, 1996). Interest theories in game studies do not describe such a balance, but are dominated by the single appraisal of Absorption (immersion, transportation) (e.g., in relation to science education; Barab & Dede, 2007). We included absorption as an appraisal additional to the ones in the original model, resulting in a total of five appraisals.

Hypotheses

The primary aim of our study was to assess the validity of the core components of our model through empirical investigation of pupils' evaluation of videos in multiple classrooms. To meet this aim, we formulated the following hypotheses: 1. Pupils' appraisals of a video's characteristics predict the pupils' interest in the video (top left arrow in Figure 4.1); 2. Pupils' interest in the video predicts the development of pupils' interest in the educational content of the video (top right arrow in Figure 4.1); 3. Pupils' appraisals of a video's characteristics predict the pupils' development of interest in the educational content of the video indirectly via their interest in the video (bottom arrow in Figure 4.1).

We reformulated our hypotheses into measurable terms of direct, indirect and total effects. A direct effect is an effect measured from one variable on the other. An indirect effect is measured from one variable, via a second *mediating* variable, on a third one. The product of the direct effect of the first variable on the second and the second variable on the third, added to the indirect effect of the first variable on the third one, makes up the total effect of the first variable on the third one. This reformulation resulted in four new hypotheses:

1. There are significant direct effects from the pupils' appraisals of the video on their interest in the video (see Figure 4.2, solid lines running from left to right);
2. There is a significant direct effect from the pupils' interest in the video on their development of interest in the educational content (see Figure 4.2, solid line running from top to bottom);
3. There are significant indirect effects from the pupils' appraisals of the videos on their development of interest in the educational content via their interest in the video as a mediator (see Figure 4.2, dashed lines);
4. There are significant total effects from the pupils' appraisals of the video on their development of interest in the educational content (calculated from direct and indirect effects).

This empirical investigation allowed us to identify whether the key appraisals we found in film theory, educational psychology and game theory represent significant predictors for pupils' interests.

Method

In this study, three science videos and one mathematics video were evaluated in six classrooms (one video per classroom). We measured the pupils' appraisals for the videos, their interest in the videos, and their development of interest in the educational content. We used a pre- and post-viewing questionnaire to measure change.

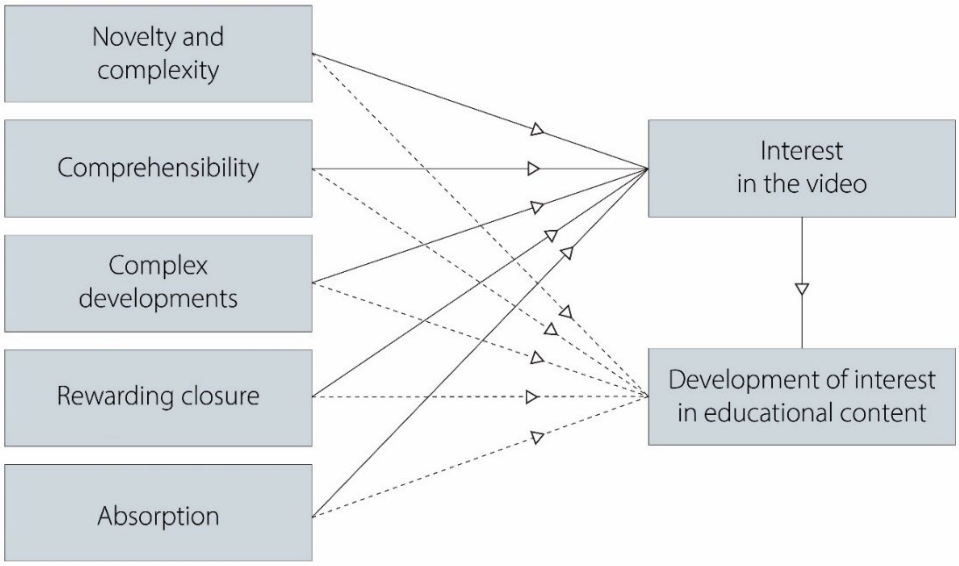


Figure 4.2. Illustration of the expected direct effects (solid lines) and indirect effects (dashed lines) between the variables as formulated in the hypotheses.

Participants

Four science and mathematics teachers (aged 33–59) from four different secondary pre-university schools in the Netherlands that showed interest in evaluating the use of videos in their educational practice took part in our study. We evaluated the video use in six classes that consisted of 12th grade pre-university pupils (aged 16–18). In total, 151 pupils participated in the study of whom 60.3% were female. Data from a seventh class from a fifth teacher was omitted from the study due to irregularities in the procedure (see below).

Procedure and Design

A protocol was formulated to ensure that videos were introduced in the same way in each classroom. To judge treatment fidelity, the first author attended all lessons. The teacher introduced the video, taking into account the researchers' instruction not to make any remarks to direct the pupils' attention while watching the video, and not to interrupt the video or to speak while the pupils were watching. The pupils filled in the pre-viewing questionnaire after the teacher introduction of the video, just before watching the video in a plenary setting. Directly after watching the video the post-viewing questionnaire was filled in by the pupils. After that, the teacher continued the lesson as usual. The treatment was implemented as intended in six classes. In the seventh class, the teacher did not start the video right after the pre-viewing questionnaire was filled in but presented an application first. The data from this class was therefore omitted from the study.

Videos

All teachers selected one video they had planned to use in September–October 2019 to increase their pupils' interest in the content of the lesson (see Table 4.1). The videos were proposed by the teachers themselves, to match their curriculum during the period in which data collection

Table 4.1
Video Cases

Video case	Video title	Duration (min : sec)	Discipline	No. of classes	No. of pupils
1	The inner life of the cell	3:12	Biology	2	51
2	Bubble boy	2:07	Biology	1	31
3	Ehrlich's magic bullet: selective staining	3:03	Chemistry	2	43
4	The Brachistochrone	10:34	Mathematics	1	26

took place. By having the teachers select the videos, we tried to minimize our interference with the natural course of video usage in a classroom setting, and to safeguard the representative design of this study as much as possible (Araujo et al., 2007). Only videos were included that the teachers selected with the aim to increase their pupils' interests for learning. The length of the videos was limited to 12 minutes to minimize diversity in interest development over the different videos due to the time spent on watching. Furthermore, the videos had to be suitable for use without the teacher making any remarks to direct the pupils' attention while watching the video, because this is assumed to interfere with the pupils' course of interest development (Wijnker et al., in press). All teachers selected a video they had used before, so they were familiar with the content and were confident it matched the topic of the lesson. In this study, we use the term *video case* for each video used in one or multiple classrooms.

Pupil Questionnaires

We used a pre- and post-viewing questionnaire to measure pupils' interest in the educational content prior to and directly after watching the video. The procedure we used to define that content was as follows: We asked the teachers to describe a. the topic of the entire course, b. the topic of the lesson in which the video was to be used, and c. the topic of the video. In consultation with the teacher, the researcher formulated a description of the educational content in the questionnaires that would be close to the topic of the lesson (b), but keeping in mind the broader topic of the course (c) and the more specific topic of the video (a). In this way, we tried to keep the description of the content specific and relatable to the video, and at the same time clearly connected to the broader educational content of the course. For example, in the biology course about *DNA and protein synthesis* (a), to introduce the lesson about *Cell processes* (b) the teacher used a video about *Life inside the cell* (c). The description of the educational content we used in the questionnaire was *DNA and processes in the cell*.

The pre-viewing questionnaire consisted of five statements to measure the pupils' interest in the educational content that were taken from validated questionnaires to measure situational interest (Rotgans & Schmidt, 2014). The statements of their situational interest questionnaire (SIQ) were designed to identify change in interest levels and therefore match the aim of our study. The items that were most fit to measure the pupils' interest in the educational content were: "I think [the educational content] is interesting", "I want to know more about [the educational content]", "I enjoy working on [the educational content]", "I expect to master [the educational content] well", and "I am fully focused on this topic, I am not distracted by other things." For each video case, we adjusted the statements to fit the educational content of the video, lesson, and course.

Table 4.2
Statements in the Post-Viewing Questionnaire for Measuring the Model's Appraisals

Statement	Appraisal
I saw, heard or learned something new	Novelty and complexity
I was well able to follow the video	Comprehensibility
I wanted to continue watching the video	Complex developments
The video felt like a whole	Rewarding closure
While watching I felt engaged in the video	Absorption

The post-viewing questionnaire started with the statement: "The video I just saw was interesting" to measure the pupils' interest in the video. Next, the questionnaire measured the pupils' appraisals of the videos' characteristics from our original model, and the added appraisal of Absorption. The items used are represented in Table 4.2. It concluded with the same items as in the pre-viewing questionnaire to measure change in the pupils' interest in the educational content. The items of the questionnaires were accompanied by a 10 cm Visual Analogue Scale (VAS) ranging from *Totally not true* to *Completely true*. The centre of the VAS was indicated with a small gap in the 10 cm line. Still images of the video were placed above the items measuring the appraisals in the post-viewing questionnaire to stimulate the pupils' recall of the video. The pupils' marks on the 10 cm VAS lines were transcoded into one decimal numbers (0.0–10.0).

Statistical Analysis

Data Preparation

To examine the degree of dependence within the classes we calculated the intraclass correlation coefficient (ICC) for interest at pre-test using the statistical program Mplus version 8.3 (Muthén & Muthén, 1998-2018). The ICC was 0.09 for the mean measure of interest in the educational content, meaning that 9% of the observed variance in pupils' mean interest scores is due to systematic between-classroom differences compared to the total variance in mean interest scores. This very low ICC value makes it acceptable to believe that the data was not nested within the classes.

We detected two extreme outliers (Q3: more than 3 box lengths from the hinge) in the measures for all cases taken together using box plotting in SPSS version 26. We compared all values belonging to the pupils that showed the extreme outliers to the other pupils and found strongly deviating values for most of their reports, indicating that they diverge a great deal from the average pupil. We decided to remove them from the dataset.

Within the complete dataset, we missed out on data from two pupils in two different cases in the post-viewing questionnaire for the items measuring Interest in the educational content. Full information maximum likelihood estimation (FIML) in Mplus was used to fill these missing values.

With SPSS, we calculated Cronbach's alpha for the results of the five measures of Interest in the educational content in the pre- and post-viewing questionnaires of all video cases taken together to evaluate their reliability as measures for this variable. Both indicated the internal consistency was high (α_{pre} = .84, α_{post}= .85).

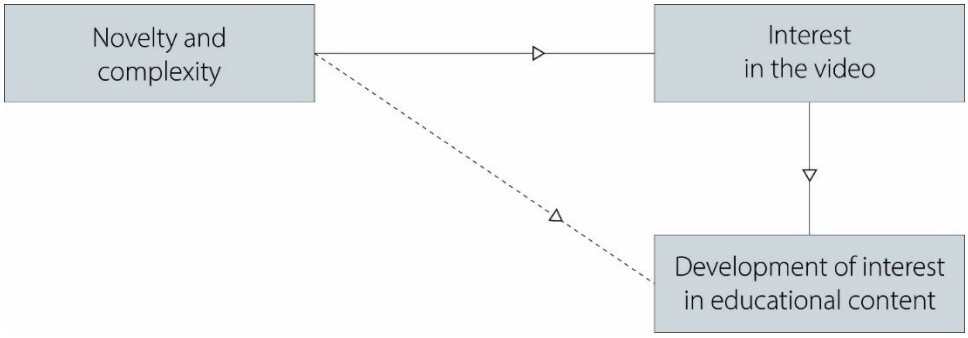


Figure 4.3. Illustration of the expected direct effects (solid lines) and indirect effect (dashed line) in path model 1 (M1), between the independent appraisal variable Novelty and complexity, the mediating dependent variable Interest in the video, and the dependent variable Development of interest in the educational content.

Data Analysis

To test our hypotheses, in Mplus we path modelled the five appraisals as independent variables, and Interest in the video and Development of interest in the educational content both as dependent variables.variables. Given the presumed interaction between appraisals in the interest theories, the appraisals cannot be accounted as unrelated defining factors. This relatedness was confirmed by the high and significant correlations between the appraisal variables we found in our empirical data (see Table 4.4 in the Results section**)**. To account for these correlations, we ran the SEM analysis in Mplus for each appraisal separately. We thus set up five different path models: M1 for Novelty and complexity (see Figure 4.3), M2 for Comprehensibility, M3 for Complex developments, M4 for Rewarding closure, and M5 for Absorption.

Table 4.3

Correlations between Pupils' Interest in the Video and their Development of Interest in the Educational Content, and the Mean Values.

			I.	II.		
Video case	Mean pre-interest in educational content (SD)	Mean Post-interest in educational content (SD)	Mean Δ pre-post interest in educational content (SD)	Mean interest in the video (SD)	*r* between I. and II.	*p* (one-tailed)
1	5.5 (0.2)	5.8 (0.2)	0.3 (0.1)	5.8 (0.3)	0.50	0.000
2	5.8 (0.3)	6.0 (0.3)	0.2 (0.1)	5.5 (0.4)	0.49	0.003
3	5.2 (0.3)	5.5 (0.3)	0.3 (0.1)	4.8 (0.4)	0.34	0.014
4	4.2 (0.4)	5.1 (0.4)	1.0 (0.2)	7.4 (0.3)	0.32	0.058
All	5.3 (0.1)	5.6 (0.1)	0.4 (0.1)	5.7 (0.2)	0.45	0.000

Note. Pearson's *r* was used.

Table 4.4
Correlations Calculated over all Video Cases between Pupils' Appraisals of the Videos, their Interest in the Videos, and their Development of Interest in the Educational Content

Variable	Mean (SD)	1	2	3	4	5	6	7
1. Interest development	0.4 (0.1)	-						
2. Interest in the video	5.7 (0.2)	.45	-					
3. Novelty and complexity	5.3 (0.2)	.40	.35	-				
4. Comprehensibility	5.5 (0.2)	.21	.45	.20	-			
5. Complex developments	5.2 (0.2)	.41	.74	.32	.43	-		
6. Rewarding closure	5.8 (0.2)	.30	.27	.23	.38	.37	-	
7. Absorption	4.9 (0.2)	.38	.71	.35	.35	.74	.27	-

Note. $p < .001$ for all correlations (one-tailed). Pearson's r was used.

Results

Descriptive Analysis

Per video case and for all video cases together, the means and standard deviations of the pupils' interest in the videos were calculated, as well as the mean change in the pupils' interest in the educational content (see Table 4.3). Over all video cases the pupils rated their interest in the videos at 5.7 (SD = 0.2) points, and their mean interest in the content increased with 0.4 (SD = 0.1) points. The overall correlation between Interest in the video and Development of interest in the educational content is .45 ($p < .001$).

Model Fit

The calculated correlation matrix of the variables measured in the current study is presented in Table 4.4. The analysis of the values showed that all the correlations are in the expected direction (all) correlations are positive and significant). Highest correlations were found between Interest in the video and Development of interest in the educational content, Interest in the video and the appraisal of Complex developments, Interest in the video and the appraisal of Absorption, and between the appraisals of Complex developments and Absorption. The model fit for each of the five path models is presented in Table 4.5.

Hypotheses Testing

The aim of our study was to test the validity of the core components of our theoretical model through empirical investigation of multiple videos in actual classrooms. To meet this aim, we set up four hypotheses.

Concerning hypothesis 1, all found estimated effects are significant, indicating that the pupils' appraisals of the video characteristics do indeed predict the pupils' interest in the video (see Figure 4.4). With regard to hypothesis 2, all found estimate effects are significant, indicating that the pupils' interest in the video does indeed predict the development of pupils' interest in the educational content. With regard to hypothesis 3 and 4, for the five path models, the estimated total effects from the appraisals on Development of interest in the educational content ranges between 0.22 and 0.41. Again, all found estimate effects are significant, indicating that the pupils' appraisals of video characteristics do indeed predict the pupils' development of interest in the educational content indirectly via their interest in the video.

Table 4.5
Fit Values for the Five Path Models with Regard to the Variables Interest in the video and Development of Interest in the Educational Content

Path model	Interest in the video		Development of interest in the educational content	
	R^2	p (one-tailed)	R^2	p (one-tailed)
M1 Novelty and complexity	0.12	.009	0.27	.000
M2 Comprehensibility	0.21	.001	0.21	.000
M3 Complex developments	0.54	.000	0.22	.000
M4 Rewarding closure	0.07	.058	0.24	.000
M5 Absorption	0.51	.000	0.21	.000

Note. All path models were saturated with RMSEA=0, CFI=1, Chi-Square p=0.000, SRMR=0.000

Conclusion and Discussion

The lack of insight into the mechanisms underlying pupils' interest development with the use of audio-visual media such as film and video inspired us to set up a theoretical model that describes the mechanisms underlying the interest raising potential of film and video. The aim of this study was to test the validity of the core components of our model. The model was drawn from interest theories stemming from the field of film studies, educational psychology and game theory. It describes pupil-viewers' appraisals of videos viewed in an educational context: Novelty and complexity and Comprehensibility, Complex developments and Rewarding closure, and Absorption. When positively appraised by the pupils, the pupils get interested in the video which stimulates the pupils to further engage with the educational content that the video entails: their interest in the content is raised.

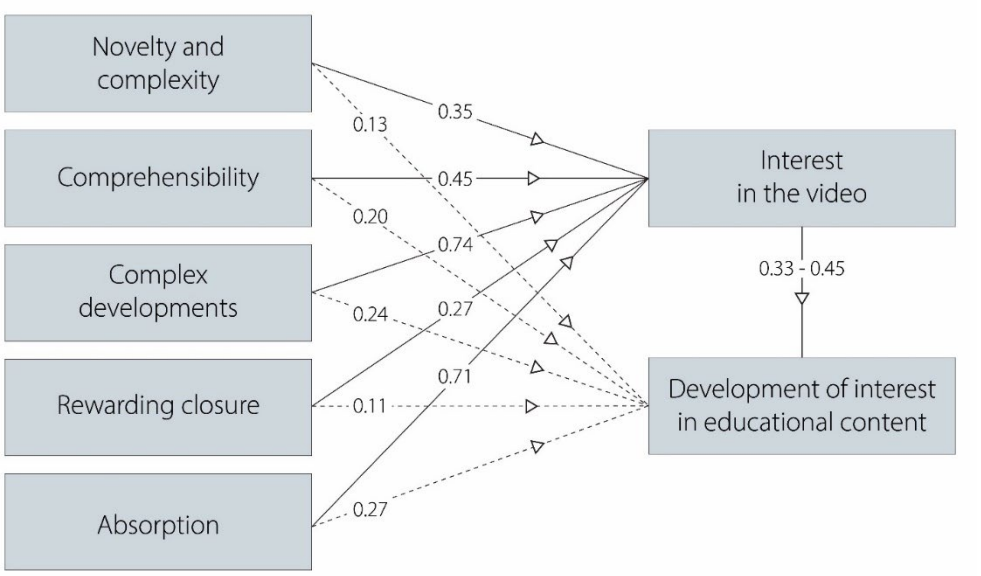


Figure 4.4. Estimated regression values of direct effects (solid lines) and indirect effects (dashed lines) in the hypothesized path models. Note: $p < .001$ for all regression values (one-tailed).

The empirical data gathered for this study and analysed in this article indeed supports the validity of the core components of our model. Regarding our first hypothesis, from the results we conclude that there were significant effects from the pupils' appraisals of the videos on their interest in the videos. Our exploration of the data in the descriptive analysis also showed indications for a confirmation of an interaction effect between the appraisals that are paired in the theories from educational psychology and film studies, on the pupils' interest in the video.

Regarding our second hypothesis, we found a significant effect from the pupils' interest in the video on their development of interest in the educational content. In our descriptive analysis, we also found a significant correlation between the pupils' interest in the videos and their development of interest in the educational content. Similar video ratings (video cases 1-3) were associated with similar results for interest development. The highest rating for interest in the video (video case 4) was associated with a larger interest development than the lower ratings for interest in the video (video cases 1-3; see Table 4.3). These results confirm our belief that our model properly describes the mechanisms underlying videos that help to raise the interest of pupils for educational content, which motivates them to further engage in this content.

Regarding our third and fourth hypotheses, we found significant effects from the pupils' appraisals of the videos on their development of interest in the educational content.

The results of our inquiry showed a strong correlation between the appraisals of Absorption and Complex developments, and they similarly correlate to the pupils' interest in the video. These outcomes allow for at least two different interpretation: First, a video's absorbing power and its complex developments are mutually strengthening film characteristics that have a similar effect on the pupils' interest in a video. Secondly, the items in the questionnaire were measuring the same thing. More research is needed to find out how the appraisal of Absorption relates to the appraisal of Complex developments in film viewing.

The uncertainty about what the items for Absorption and Complex developments in the questionnaire actually measured forms a first limitation of our study. Other than the items we used for measuring situational interest, we do not know of validated questionnaires to measure specific appraisals. We tried to stay close to the interest theories that lie at the heart of our model to formulate the statements for our questionnaires. A future study that validates questionnaires to inquire appraisals would be more than welcome. A second limitation is the scale of the study's set-up with a limited number of videos and pupils. A final limitation is that we were unable to test all components that play a role in the mechanisms described in the original model, which is more elaborated. A prominent missing component in our analysis is the motivated action while watching the video that is directed towards the video's proceedings, rather than after watching and directed towards the educational content. Measuring motivated action towards the video's proceedings implies a constant measure while watching. It is extremely challenging to gather such data without brutally interrupting the flow of the viewing process. There are some promising examples of studies using real time tracking for example with facial expressions (Tan, 2014) or press buttons (Cañas-Bajo et al., 2019) as measures that might be useful in future research on our model.

In sum, we believe that the empirical data gathered in this study gives grounds to validate our model of mechanisms that underlie interest raising videos in learning contexts. In the practice of making videos for educational use, this could be a starting point to formulate the guidelines teachers and film makers are now missing out on. The results of our study indicate that a video

watched in the context of learning is most likely to be found interesting when the video's structural development is complex, yet provides for a rewarding closure; if the content is novel and complex, yet making the pupils feel capable of coping with that novelty and complexity; and if the video is absorbing. The pupils' appraisals of the video are likely to be good predictors of their development of interest in the educational content. Future research is needed to support these possible implications.

Acknowledgements

We want to thank Gitte van Helden for her contribution to the data management.

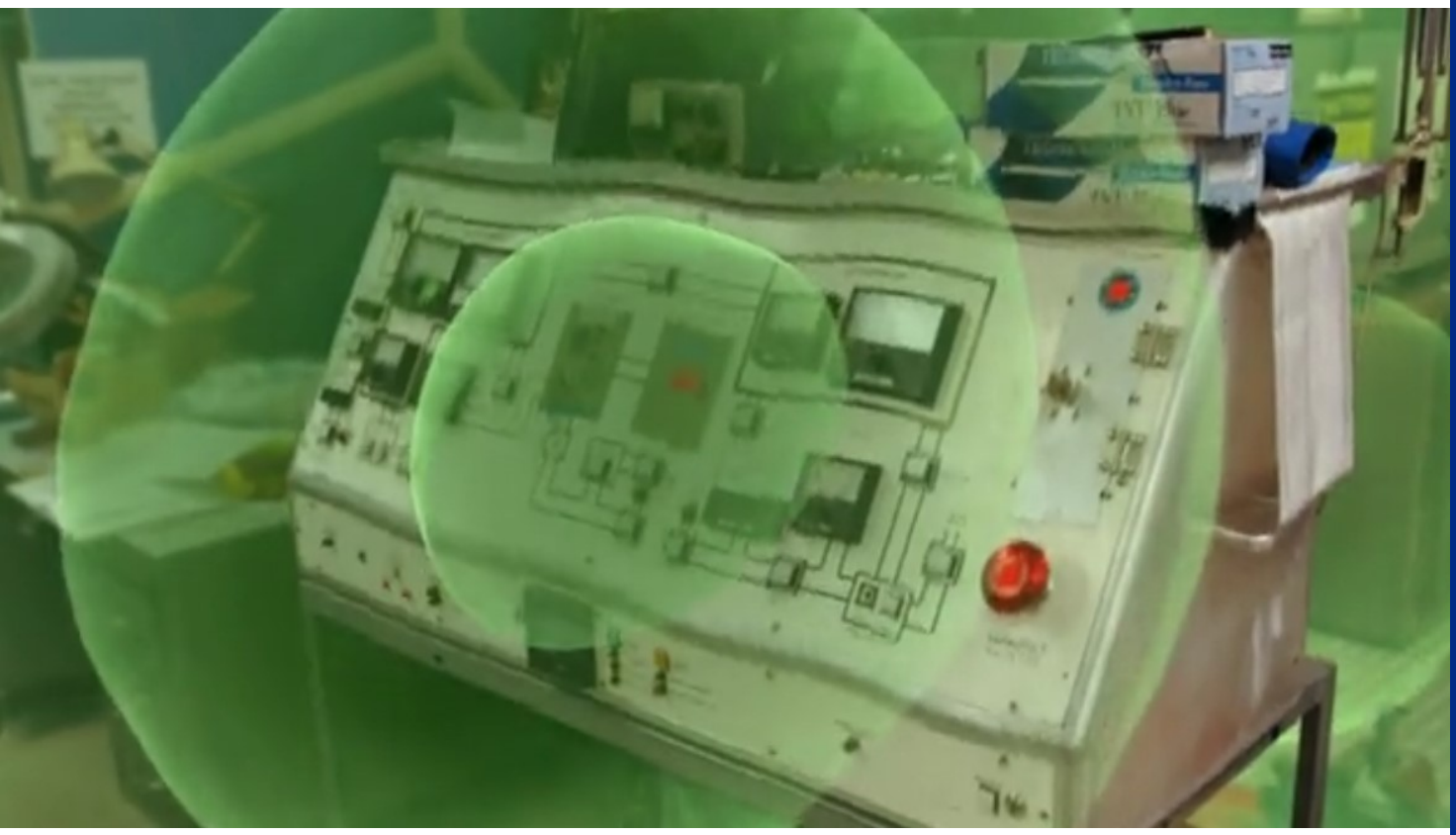
Statements on Conflict of Interest, Open Data and Ethics

There is no conflict of interest in the reported work. The data of our project is in the process of being made permanently accessible through the Data Archiving and Networked Services (DANS) of the joint institute of the Royal Netherlands Academy of Arts and Sciences (KNAW) and the Netherlands Organisation for Scientific Research (NWO), at https://dans.knaw.nl/en. Pupil data collection and handling was complied with local ethical guidelines regarding collection and storage of data involving human subjects. The pupil data was anonymized after data collection, and all data was stored on a secured server behind a password.

Explaining Pupils' Interest in Video for Education

5

A Multiple Case Study



Wijnker, W., Bakker, A., & Drijvers, P. (submitted-b). *Explaining pupils' interest for video in education: A multiple case study*.

Abstract

Interest is key to learning. Video is a promising tool for interest development in education, but professionals in education are in need of more theory-grounded guidance for production, selection, and use of videos. In previous studies, we developed and validated a model on film's interest raising mechanisms in educational contexts, called the FIRM model. In the study reported here, we used the model to explain how pupils' appraisals of video characteristics relate to their interest in the video. We evaluated the use of five videos in seven 12th-grade science and mathematics classrooms (177 pupils). We measured interest at scene level and grouped pupils on general interest. We performed video analyses, case studies, and a cross-case analysis. Our findings resulted in three relationships between appraisals and interest, regarding the video's complexity level and the pupils' knowledge level, pupils' recognition of video categories, and pupils' expectations of videos.

Introduction

Interest is a powerful engine for learning. The urge to find out more, to engage with a topic, is an important factor in the process of making new knowledge and insights grow into meaningful knowledge, rather than superficial and cursory remembrance (Renninger & Hidi, 2016). We know, from classical theories of learning and from empirical studies in education, that interest stimulates learning (Dewey, 1913; Akkerman & Bakker, 2019). But what makes educational material interesting?

Audiovisual media, such as video, are increasingly being adopted as possible interest triggers in educational practices. Online video has become a standard in the blended learning approaches that are taking flight in the globalizing world (Stockwell et al., 2015), and due to the necessity of developing distance education in the worldwide pandemic outbreak in 2020. In this accelerating shift, educators became self-taught technicians who are finding out what works by trial and error. The vast number of webinars and online courses offered to inform teachers with hands-on practicalities proves the demand for research informed guidelines.

Research has shown what characteristics of learning material and contexts are involved in the development of interest in learning, such as novelty, complexity, and comprehensibility (Silvia 2006). A step towards guidelines for teaching professionals to make informed choices in the making, selection, and use of videos, is to apply these theories to specific materials and contexts so that we can better understand the mechanisms that allow videos to raise interest.

In our previous studies we integrated interest theories from educational psychology (EDPSY) and film studies (FLMST) to construct a model on Film's Interest Raising Mechanisms (the FIRM model) that describes the mechanisms involved in pupils' interest development while watching a video (Wijnker et al., in press). The empirical data from our subsequent quantitative study confirmed the validity of this model (Wijnker et al., submitted-a). In the study we present here, we used the model to explain pupils' interest in videos used in education (five videos, seven classrooms, one video in each classroom). We aimed (1) to identify concrete examples of video characteristics in terms of pupils' appraisals that are responsible for pupils' interest development while watching, and (2) to find possible explanations for why these appraisals have a positive or negative effect on pupils' general interest in the video. The research question leading this inquiry was: *How do pupils' appraisals of video characteristics relate to their interest and to the development of their interest in the video?* In this paper, we use the term video when we speak of the actual audiovisual material, and film to refer to the medium genre in general.

Theoretical Framework

Interest is considered an emotion (Frijda, 2009). Emotions are the result of a cursory or a more sustained relationship that evolves between a subject – a person – and an object – a topic, a discipline, an activity, etc. (Krapp, 1999). In our studies, the subject is the pupil and the object is a video used in an educational context. The nature of the relationship that evolves between a pupil and a video is dependent on characteristics of the pupil and of the video, and more specifically on the match between these characteristics. For example, a pupil who is fond of their pet cat (pupil characteristic) is more inclined to develop interest for a video about cats (video characteristic) than one who does not. But that does not mean that every pupil who owns a cat is interested in cat videos. And the contrary does not hold either: Not every pupil without a cat

dislikes cat videos. To better understand the subject–object interest relationship we need to focus on the specific characteristics involved.

Since education more often than not is directed towards groups of pupils rather than individuals, in our approach, we take pupil characteristics as a given set with great diversity. Some will like cats, others will not. Some will like chemistry topics, others will not. Although pupils' preferences may change over time and differ from situation to situation, we take these as given since we cannot control them. In our studies on effective interest raising videos, we therefore focus on the characteristics that are within the teachers' control when selecting a video, and within the film makers' control when making a video, namely the video characteristics.

Theory has given some leads about what characteristics *generally* are likely to raise interest. In emotion theory, how people characterize an object and how they evaluate these characteristics are called *appraisals* (Scherer, 2010). Appraisals are evaluations of an object or event, and are expressed in terms of concerns. Different emotions are associated with different concerns. The emotion of fear, for example, arises from the negative evaluation of the concern for safety. The appraisal that gives rise to this emotion is threat. The emotion of interest arises from the positive evaluation of understanding and knowing. Educational psychology research has shown that interest raising learning materials and contexts exhibit characteristics that are evaluated as novel and/or complex, and comprehensible (Renninger & Hidi, 2016; Silvia, 2006). Thus, the appraisals that typically give rise to interest in education are twofold: novelty–complexity, and comprehensibility.

For an interest relationship to establish, the subject's appraisals of the object need to be well-balanced: An object that is appraised as novel and complex is only found to be interesting if the pupil also feels capable of comprehending that novel complexity (Silvia, 2006). The appraisal of novelty–complexity in an educational context applies to events or materials that are new to the learners, because they have not encountered them before or not in that specific way or at that level of detail. The appraisal of comprehensibility expresses the anticipation of comprehension and knowing with the learner. If the two appraisals are out of balance, for example due to a lack of sufficient prior knowledge, interest drops or does not appear. In the example, pupils might appreciate the novelty of the material, but they will feel incapable of understanding, or they could evaluate the event or material as too complex. Either way, the pupils' appraisal of novelty–complexity is out of balance with the appraisal of anticipated comprehension.

Film theory shows a similar balance between similar appraisals of videos that raise the interest of viewers. Interested viewers positively appraise complex story developments as one side of the balance, and the anticipation of a rewarding comprehensible closure of these developments as the other side. These appraisals are in constant shift while the video continues. Viewers constantly form new expectations about new developments, while earlier introduced developments are being resolved and closed (Tan, 1996). Introduced and resolved developments in videos may take many forms, depending on the videos' structure. A video with a narrative structure presents causal developments and resolutions that take place in the fictional story world, while a rhetorical video presents claims and arguments that ground these claims (Bordwell et al., 2017). Unconditional of the type of structure, viewers will want to be presented new and complex developments that are balanced with the piecemeal delivery of rewarding outcomes of these developments, otherwise interest drops or does not appear (Tan, 1996).

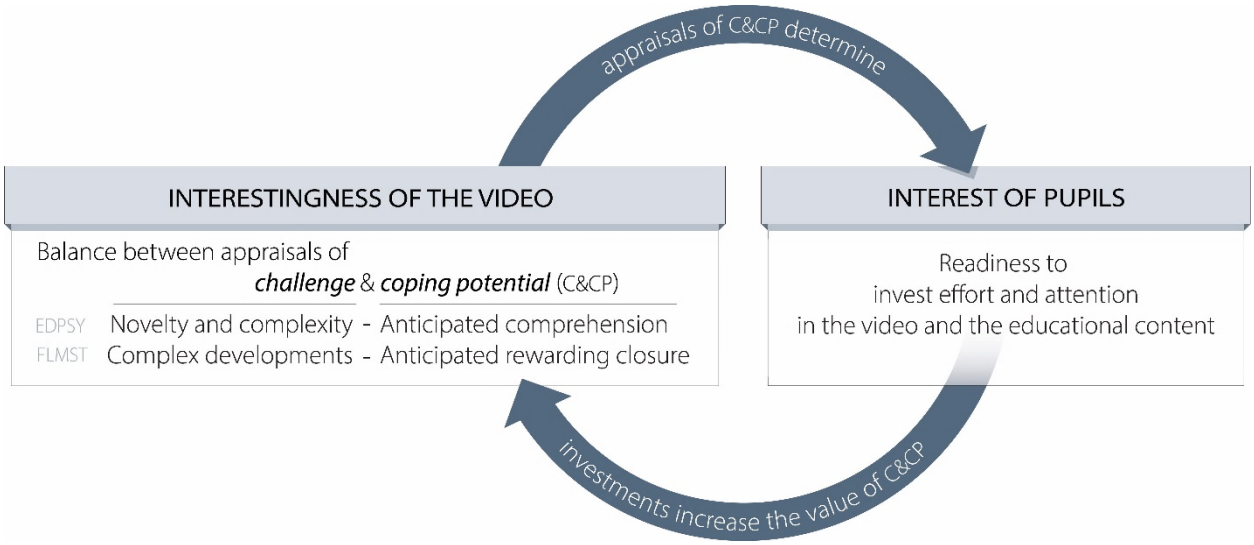


Figure 5.1. Model of Film's Interest Raising Mechanisms (FIRM model) following Wijnker et al. (in press). EDPSY=educational psychology; FLMST=film studies; C&CP=challenge and coping potential.

Wijnker et al. (in press) integrated these two perspectives on interest as an emotion into a single model that describes the mechanisms involved in pupils' interest development while watching a video: the FIRM model (see Figure 5.1). The typical appraisals involved in watching educational videos are grouped as a balance between appraisals of *challenge* (Novelty–complexity and Complex developments) on the one hand, and of *coping potential* (Anticipated comprehension and Anticipated rewarding closure) on the other. This balance between challenge and coping potential (C&CP) appraisals determines what in the model is referred to as the interestingness of the video. Interestingness can either apply to the video's potential interestingness as inferred from film analysis, or to the perceived interestingness as experienced by the pupils. When C&CP appraisals are well balanced and an interest relationship is established, it leads to an action readiness with the subject. Both fields of research describe a similar interest action readiness with pupils and viewers: The inclination to actively engage with the learning object or video by spending effort and attention on it. Subsequently, this effort and attention will increase the (inferred or perceived) value of C&CP. Likewise, repeated interested engagement with an object is thought to promote a more general interest in the object (Renninger & Hidi, 2016).

A first empirical study on pupils' perceived C&CP appraisals validated the core mechanisms of the FIRM model. The results confirmed the theoretical assumptions that the pupils' ratings of the video's appraisals are indeed reliable predictors for their interest in the video, and that their interest in the video predicts their interest development for the educational content (Wijnker et al., submitted-a). These results indicated that, for teachers to get their pupils interested in some educational content, they should select a video that their pupils evaluate as interesting. To select a such a video, it follows that focusing on the C&CP appraisals that pupils are expected to develop while watching the video might be a fruitful approach.

As described above, the FIRM model may also be applied to infer any video's interestingness, and we developed a method for analyzing video characteristics that pupils can be expected to appraise in terms of challenge and coping potential (Wijnker et al., in press). We used the

Table 5.1
Interest Components as Substantiated in the Film Categories, Following Wijnker et al. (in press)

		Film category*			
		Narrative film	Associational film	Categorical film	Rhetorical film
Appraisals	Challenge	Story world complications	Complexity, ambiguity	Induction: uncategorized instances Deduction: unexplained concepts	Ungrounded claim
	Coping potential	Story world resolution	Affective experience	Instances and their categories; Concepts and their instances	Grounded claim
Action tendency	Affectively charged readiness to spend effort and attention	(Causal) Elaboration and anticipation of story world events	Free association	Induction: seeking to find categorizing concepts Deduction: seeking to find exemplifying instances	Check and possible validation of an argument

Note. *As identified by David Bordwell et al. (2017)

four film categories as identified by film theorists (Bordwell et al., 2017) to formulate concrete characteristics that evoke C&CP appraisals, being:

- Narrative films, presenting a fictional story;
- Associational films, presenting related images, sounds or events;
- Categorical films, presenting instances and categories;
- Rhetorical films, presenting an argument.

All film categories can be found in videos used in educational contexts. For example, feature fiction films are narratives, abstract or artistic videos like video-art are often associational videos, knowledge clips may hold a categorical structure, and documentaries are typically rhetorical videos.

For each film category we described the typical challenge and coping potential that is to be expected, and what action tendency it is expected to provoke (see Table 5.1). For example, with narrative videos, the pupil-viewers are confronted with the challenge of dealing with complications evolving in the fictional story world. It challenges them to find cues (indications) to resolve these complications. These cues form the coping potential side of the interest balance. When well-balanced over the course of watching the video, the pupils engage in the action tendency of elaborating and anticipating further story world events. In comparison, in rhetorical videos, challenge and coping potential take a very different form. Then, the challenge that confronts pupils is an ungrounded claim, inviting them to check and search for the possible validation of an argument (action tendency). Pupils will only continue doing this when they feel the video is providing enough cues to ground the claim (coping potential). If these cues do not appear, the balance is distorted and interest in the video drops.

In our second empirical study presented here, we wanted to find concrete examples of video characteristics that match the FIRM model's C&CP components to better understand and explain

what the model can teach us about effective videos for interest development. Based on the literature, we expected pupils' evaluations of the video to be formulated in terms of the C&CP appraisals as presented in Table 5.1. Furthermore, we expected that pupils might either approach the evaluation of the videos from an educational psychology perspective in which they see the video primarily as educational material, or from a film studies perspective in which they see it primarily as film material. This should be expressed in differing ratings within video cases for the two challenge appraisals (EDPSY's Novelty–complexity and FLMST's Complex developments), and the two coping potential appraisals (EDPSY's Anticipated comprehension and FLMST's Anticipated rewarding closure). With regard to the educational psychology and film study appraisals we expected that high balanced C&CP appraisals would be associated with interest increase, and unbalanced appraisals with decrease.

We know from film theory on interest that, for the video to be positively evaluated in the end, interest development while watching it need not be a steadily rising line. Interest increases and decreases over the course of watching due to offered cues for coping potential that partly resolve challenges posed earlier on (Tan, 1996). In our study, we wanted to find out which drops in interest were to be interpreted as developments that could be expected to occur due to partially resolved challenges, and which due to a mismatch between the viewer and the video's characteristics (too high/too low posed challenges, or too complex/not valued offered coping potential). Therefore, we started by exploring the pupil population with respect to their final evaluation of the video, and we divided the pupils into three groups, with a high, mediate or low general interest in the video (see the Methods section for full explanation). In our further inquiry, we looked at the complete set of pupils' reports within each case, and then diverged for the three levels of general interest in the video to see if the pupils' reports showed explanations for their diverging interest in the video.

Another reason why we chose not to simply look at the overall mean and the standard deviation, is that we expected interest in a video not (only) to be a matter of a sliding scale. It can also be a matter of on/off: you like it or not. By diverging between highly and little interested pupils, we wanted to account for the latter (liking it or not) and find out what in the video could be responsible for their differing appraisals. The reports of all pupils together account for the perspective of the sliding scale.

Methods

In this study, five videos were evaluated in seven classrooms (one video per classroom). We performed video analyses, used pupil questionnaires, and held pupil interviews. We measured the pupils' interest in the videos, their interest in the separate scenes within the videos, and we asked them to describe what caused their interest to develop over the course of watching. We performed case studies and cross-case analyses.

Participants

Five teachers (aged 33–59; three male and two female; two chemistry teachers, two biology teachers, and one mathematics teacher) from five different secondary pre-university schools in the Netherlands took part in our study. We evaluated the use of the videos in seven of their classes that

Table 5.2
Video Cases

Video case	Video title	Duration (min:sec)	Discipline	Film category*	# Pupils (# classes)
1	The inner life of the cell	3:12	Biology	Associational	51 (2)
2	Bubble boy trailer	2:07	Biology	Narrative	31 (1)
3	Ehrlich's magic bullet – selective staining	3:03	Chemistry	Narrative / Rhetorical	44 (2)
4	What is nanotechnology?	4:41	Chemistry	Categorical / Rhetorical	24 (1)
5	The Brachistochrone	10:34	Mathematics	Categorical / Rhetorical	27 (1)

Note. *Resulting from our film analysis.

consisted of 12th-grade pre-university pupils (aged 16–18). In total, 177 pupils participated of whom 55.4% were female.

Procedure and Design

The first author attended all lessons to judge treatment fidelity based on a protocol. She confirmed that the videos were treated in accordance with the protocol in each lesson. The pupils watched the video in a plenary setting, and the teacher introduced the video without making any remarks to direct the pupils' attention while watching the video, because this is assumed to interfere with the pupils' course of interest development (Wijnker et al., in press). The teacher was not allowed to interrupt the video or to speak while the pupils were watching, and the pupils filled in the questionnaire directly after watching the video. Afterwards, the teachers continued their lessons as usual. After each lesson, two pupils were invited for a 10-minute interview.

Videos

All teachers were asked to select one video they had already planned to use in September–October 2019. The videos were required to be intended by the teacher to increase pupils' interest in learning, and the video could be a maximum of 12 minutes long to minimize differences due to the time spent on watching (see Table 5.2). We asked the teachers to propose a video themselves, to ensure it would match the content of the lesson, and to safeguard the representative design and ecological validity of this study as much as possible (Araujo et al., 2007). All teachers selected a video they had used before. In this article, for each video used in one or multiple lessons we use the term *video case*.

Table 5.3
Statements in the Questionnaire for Measuring the Model's Appraisals

Statement	Appraisal
I saw, heard or learned something new	Novelty-complexity – EDPSY C
I was well able to follow the video	Anticipated comprehension – EDPSY CP
I wanted to continue watching the video	Complex developments – FLMST C
The video felt like a whole	Anticipated rewarding closure – FLMST CP

Note. EDPSY=educational psychology; FLMST=film studies; C=challenge; CP=coping potential

Pupil Questionnaire

We used a questionnaire directly after watching the video to measure the pupils' interest in the video in general, for their interest in subsequent scenes in the video, and for the FIRM model appraisals. The questionnaire consisted of two open questions, and nine to thirteen statements – dependent on the number of scenes in the video – that were accompanied by a 10 cm Visual Analogue Scale (VAS) ranging from *Totally not true* to *Completely true*. The centre of the VAS was indicated with a small gap in the 10-cm line.

The questionnaire started with one statement to make pupils give a general value for their interest in the video: "The video I just saw was interesting." Next, the pupils were asked to rate each scene in the video with the statement: "I found this part of the video interesting." A scene was defined by unity of time, space and action, and was identified through film analysis. Each scene was illustrated with one or two still images with a maximal total of eight images per video, and was accompanied by a VAS. These items were followed by the open question: "What happened in the video that made your interest increase or drop?"

Finally, the questionnaire measured the pupils' appraisals from the model with a VAS. The items used to measure these are presented in Table 5.3. The pupils' ratings of these appraisals give an idea of the degree to which the pupils evaluated the video they just saw in terms of educational material (EDPSY appraisals), or in terms of film material (FLMST appraisals). For analysis, the pupils' marks on the 10 cm VAS lines were transcoded into one decimal number between 0.0 and 10.0 (see Appendix 5A for the questionnaire for Video 1).

Pupil Interviews

To gain more qualitative in-depth information about the answers in the questionnaire, the first author invited two pupils from each classroom for a one-to-one 10-minute semi-structured interview after the lesson, following the order of the items in the pupil questionnaire. From each lesson, the researcher invited one pupil with high interest in the video, and one with little interest in the video. We balanced gender across the interviews. The interview consisted of open questions, inviting the pupils to clarify each answer from the questionnaire, such as "Here, your interest increased/decreased, what happened?", and "Your mark for *ability to follow the video* is over here (point at the mark on the VAS), can you explain why?". The researcher played the video again on a tablet to stimulate recall, and both the researcher and pupil could pause it when either wanted to elaborate.

Analysis

We analyzed both the questionnaire data and the data from the interviews in parallel in two phases (see Table 5.4). We used the interview data as a verification for our findings.

Phase 1: Case Studies

We started by categorizing the videos following Bordwell et al. (2017) as Narrative film, Associational film, Categorical film and/or Rhetorical film. We searched the videos' structures for C&CP components that match these film categories, following Wijnker et al. (in press) as presented in Table 5.1. Next, in each case we divided the pupils into three groups with different levels of general interest in the video based on their reported general interest in the video. The first quarter (Q1) represented the pupils with little general interest in the video, and the fourth quarter (Q4) the highly interested pupils. Q2 and Q3 represented the pupils with a medium general interest in the video.

Table 5.4
Steps in the Data Analysis

First phase: Case studies	Second phase: Cross-case analysis	
	First round	Second round
Categorizing videos Grouping pupils based on general interest in the video Making boxplots and line graphs of interest development over the scenes Coding pupils' remarks Making scatterplots and bar diagrams of balances between sets of model appraisals	Generating conjectures based on data from single cases Testing conjectures bases on data from all cases Formulating findings	Formulating findings based on data from all cases

To analyze how the pupils' interest in the videos developed while watching, we explored the pupils' data within the video cases by box plotting the scene ratings. This enabled us to describe the average developmental line of interest in each video case. We analyzed how these lines differed between Q1 and Q4 pupils within each video case. From these figures, for each video case we identified the scenes that were rated the highest and the lowest on average, and diverging developmental lines of interest from Q1 and Q4 pupils.

To find possible explanations for the findings from the boxplot analysis, we coded and analyzed the pupils' remarks in the open questions and interviews that could be related to these findings. The pupils' remarks were coded with the challenge (ch) and coping potential (cp) appraisals from the film categories Narrative (Narr), Associational (Ass), Categorical (Cat), and Rhetorical (Rhet) as presented in Table 5.1, or 'Other'. The codes were further specified with 'positive' (pos) for pupils' remarks about why their interest increased, or 'negative' (neg) for reports about decreasing interest. Reports coded as 'Other' were further specified (e.g., 'Other/funny'). We grouped the remarks of Q1 and Q4 pupils to identify differences between these groups. See Results for examples of coded pupil reports.

Furthermore, we explored the balance between the interest appraisals from the FIRM model in relation to the pupils' general interest in the video with scatterplots. This resulted in two scatterplots per video: One for the appraisals stemming from educational psychology and one from film studies. For each set of appraisals, we determined the degree to which the pupils' ratings showed that the appraisals were in balance. We looked at the difference between the ratings of the challenge and the coping potential appraisal within each set. Well-balanced was defined as a difference of two points or less. Differences of more than two points were regarded as unbalanced. For both sets in each case, we calculated the percentage of pupils that showed well-balanced appraisals: the balance percentage. Again, we distinguished between pupils with low (Q1) and high (Q4) general interest in the video.

Phase 2: Cross-case Analysis

After data analysis in the first phase of analysis, we connected our results to formulate generalizable outcomes in phase 2 (see Table 5.4). We further analyzed the results from the case studies in two rounds of cross-case analysis, following the constant comparative method (Boeije, 2010) to find commonalities over all cases. In the first round of cross-case analysis, the data

within one case was searched. Based on the commonalities, conjectures were generated that could be tested against data from other cases. When confirmed by data from other cases, the conjecture was accepted and then reformulated as a finding. In the second round of cross-case analysis, the data *between* cases was searched and found commonalities were directly formulated as findings since they were already based on data from multiple cases.

In the first round of the cross-case analysis, we generated conjectures with regard to the pupils' reports. These conjectures were derived directly from what the pupils reported on why their interest increased or decreased, and thus are formulated positively ("…made interest increase") or negatively ("…made interest decrease"). An example of a positively formulated conjecture is: "Seeing proof of what was claimed made interest increase." An example of a negatively formulated conjecture is: "Repetition of information made interest decrease."

Next, the conjectures were tested against the results from the other cases. Only conjectures that were confirmed by results from at least one other case were accepted. In this process, 21 conjectures were generated, and 19 could be accepted. These 19 conjectures were grouped based on similarities and reformulated into a single conjecture that described all conjectures within that group. For example, the conjectures "The introduction of new insights or knowledge made interest increase", "New facts made interest increase", "Information related to chemistry lessons made interest increase", and "The chemical experiments and outcomes made interest increase", were grouped into the conjecture "When new knowledge or insights were presented, interest increased." This led to 6 accepted conjectures, of which 3 were positively formulated and 3 negatively. Finally, we combined the positive and negative conjectures that described a similar mechanism and formulated them into findings. For example, "Interest increased (or decreased) respectively with the presence (or absence) of new knowledge or insights." This resulted in a total of 3 findings in this round.

In the second round of the cross-case analysis, we formulated findings by looking for commonalities between the cases regarding the pupils' interest development based on their ratings of the video scenes (see Figure 5.2), and the ratings of the appraisals (see Figure 5.3 and Table 5.5). We searched for possible commonalities for all video cases together, or for the video cases within the same video categories (Narrative, Associational, Categorical, Rhetorical).

In this round, we first looked at the pupils' interest development based on their ratings of the video scenes (see Figure 5.2), and formulated six findings, such as for example: "For the categorical videos, Q1 pupils' interest was highest for scenes that provided coping potential." Secondly, we looked at the ratings of the educational psychology and film study appraisals (see Figure 5.3 and Table 5.5), and formulated nine findings by scanning all cases to find possible commonalities for all video cases and within the video categories, such as for example: "General interest was rated highest for the categorical videos, and lowest for the narrative videos." Like the conjectures in the first round, we grouped the findings when possible, for video categories, for general interest in the video, and for type of appraisals (EDPSY, FLMST, or Other). Thirdly, we looked at all results together to see if any additional findings could be formulated that were not yet found based on the separate results. This led to two additional findings, that could be grouped into the single finding: "Videos with unbalanced EDPSY appraisals due to much higher or lower ratings for Anticipated comprehension respectively were perceived as (too) easy or (too) difficult." In this round, 15 findings were formulated.

Finally, as in the first round, the findings were grouped based on similarities and reformulated into single findings that properly described all findings within that group. This resulted in a total of 12 findings in this round, and a total of 15 findings in the two rounds.

Results

Phase 1: Case Studies

To inquire how pupils' appraisals of video characteristics are related to (the development of) their interest in the video, we started by analyzing the pupils' interest development and continued by searching the pupils' reports and ratings for appraisals that could explain that development. We used video analysis to categorize the videos and compare them.

With regard to the development of interest, in all five video cases, the pupils showed different lines of average interest development over the scenes. In all video cases, the average developmental lines of interest diverged to some or a great extent between Q1 and Q4 pupils (see Figure 5.2), with higher values for Q4 pupils than for Q1 pupils in all cases and for all scenes. In video cases 1 and 3, a single video was used in two parallel classrooms which were both taught by the same teacher on the same day. The average interest development of the two separate classes showed similar patterns in both cases.

With regard to the appraisals, in all cases the balance between the FIRM model's appraisals (EDPSY and FLMST appraisals) showed different patterns, and again this differed between Q1 and Q4 pupils (see Figure 5.3). We found pupil reports that closely matched the C&CP appraisals that are related to the four film categories, as formulated in Table 5.1. The video analysis showed that, to a greater or lesser extent, all four film categories (Narrative, Associational, Categorical, and Rhetorical film) were represented by one or more of the videos in our study (see Table 5.2: Video categories). The general interest in the video was highest for the categorical videos, and lowest for the narrative videos, for Q1 pupils as well as Q4 (see Table 5.5). Below we present the results from videos case 1. See Appendix 5B for the detailed results from video cases 2 through 5.

Video Case 1: The Inner Life of the Cell

Video 1 was categorized as a categorical video. The pupils were challenged right from the start with the unexplained concept of 'life inside the cell'. The video showed instances of this concept as coping potential, such as 'Leukocytes', 'Lipid rafts', and 'Vesicles'. Because these instances were not explicitly named in the video, pupils might also have experienced the video more as an associational one. In this case, the pupils felt challenged by complex and ambiguous images that led them into free association, with an affectively rewarding experience as coping potential. Multiple pupils' reports saying that they enjoyed the music and the impressive colorful 3D images strengthen the assumption that this video might also have been perceived as an associational one.

As displayed in Figure 5.1, the average interest of the pupils for the ongoing video increased up until scene 3, peaked in scene 4, dropped back in scene 5, and then remained rather stable until the end. Q4 pupils (see blue line in Figure 5.1) showed a similar pattern to Q1 pupils (orange line), with two main exceptions: The interest development of Q1 pupils showed a much steeper peak in scene 4 than the interest development of Q4 pupils; and interest of Q4 pupils dropped in the final scene, while the interest of Q1 pupils increased a bit in this scene.

The pupils' reports show that their interest was high in scene 4 because they felt they could understand what was shown (coded as Cat-cp-pos), or they appreciated the beautiful imaging or music in the scene (Ass-ch-pos) or saw something unexpected or fascinating (Ass-cp-pos). Pupils reported that their interest was low from scene 5 onward because they could not understand it (Cat-cp-neg), or the animation got less vivid, making them feel bored (Ass-ch-neg). For the final scene, Q1 pupils reported more frequently that they could not understand it than Q4 pupils.

Pupil 21 (Cat-cp-pos): "In scene 4 my interest increased, because I could understand wat was going on."

Pupil 33 (Ass-ch-pos): "There were things that looked very complex."

Pupil 28 (Ass-cp-pos): "The final scene looked very 'satisfying'."

Pupil 2 (Cat-cp-neg): "I didn't know what it was."

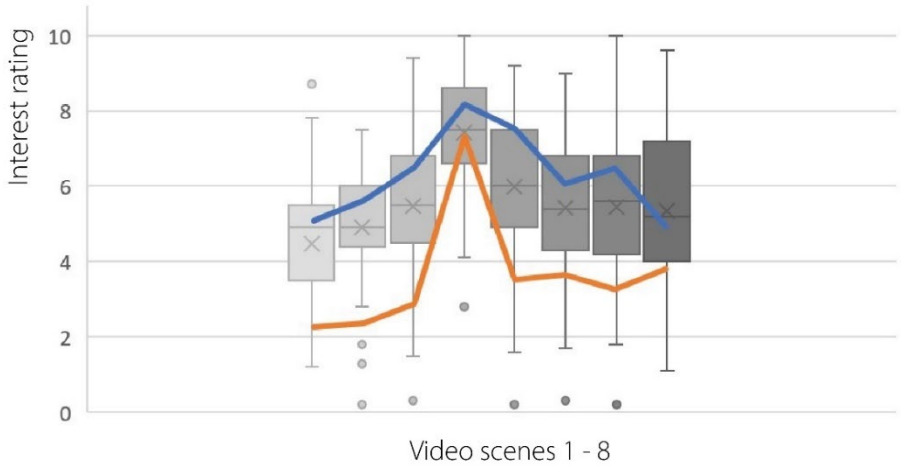
Pupil 14 (Ass-ch-neg): "Nothing much happened and it lasted very long."

The balances of the pupils' ratings for the sets of EDPSY and FLMST appraisals show well-balanced reports from most pupils for both sets, and best for the educational psychology appraisals (see Figure 5.2). The average mean of the balanced appraisals was mediate for both sets (see Table 5.4). Average ratings from Q4 pupils are higher than from Q1 pupils. However, of all pupils the ratings from Q4 pupils are the least balanced. On average, Q4 pupils rated the challenge appraisals (Novelty-complexity, Complex developments) higher than coping potential appraisals (Anticipated comprehension, Anticipated rewarding closure). From this we conclude that, in line with the pupils' reports, Q4 pupils valued the video for the fascinating images and events, although they did not always fully understand what they were seeing, whereas Q1 pupils rejected the video because too often it was incomprehensible to them.

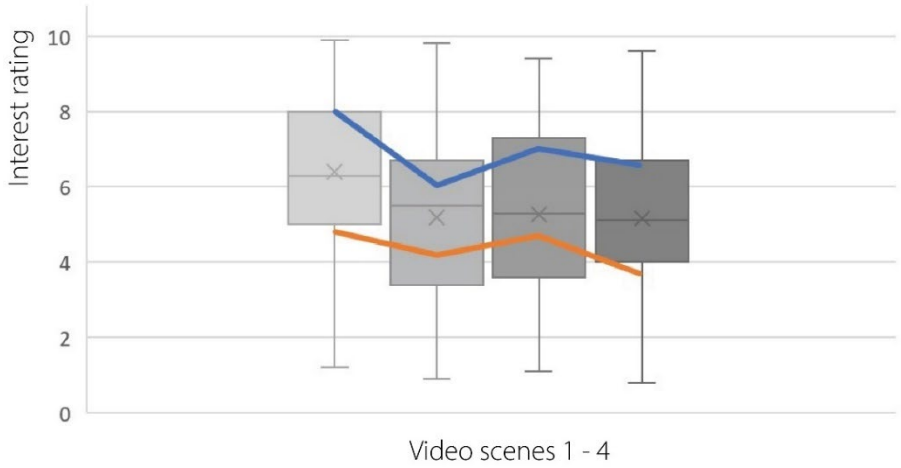
Phase 2: Cross-Case Analysis

In the first round of the cross-case analysis, we started by generating conjectures based on the data from single cases. As described in the methods section, this resulted in 21 conjectures. Next, we tested these conjectures based on the data from all cases. This resulted in 19 confirmed conjectures. Finally, from the confirmed conjectures we formulated 3 findings (see Table 5.6, findings 1-3).

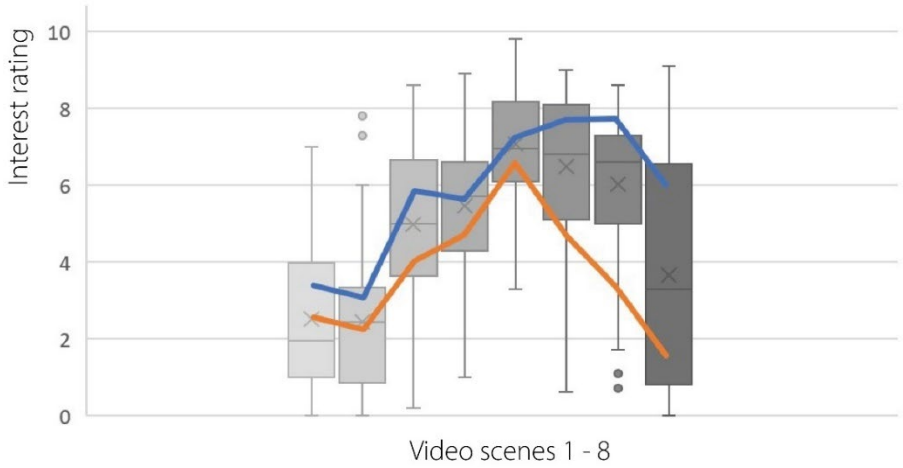
In the second round, we formulated direct findings based on the data from all cases. This resulted in 12 findings (Table 5.6 findings 7-15). We grouped all findings in three central themes, although they are not completely restricted to one theme: *The predictive power of appraisals*; *The role of video categories*; and *Differences between pupils*. Note that the findings formulated in relation to the associational film category need to be treated with some reservation, because only one video was categorized as Associational. Further research is needed to check wider acceptability of these findings.



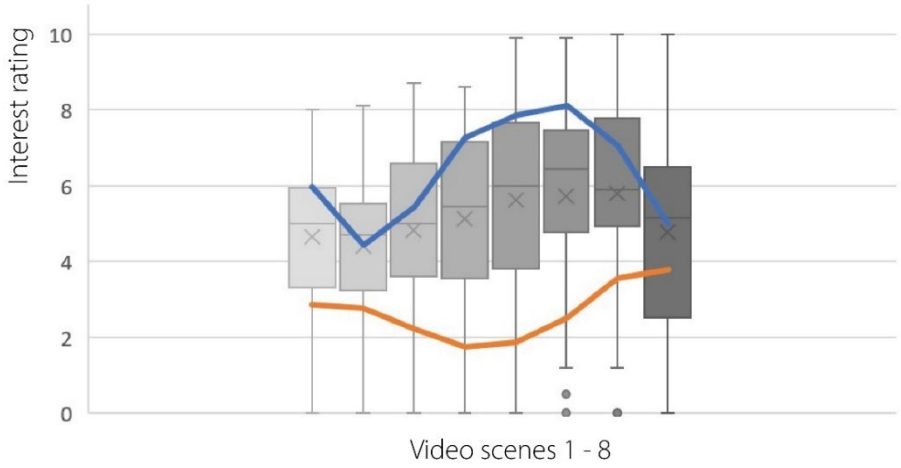
Video case 1: *The inner life of the cell*.



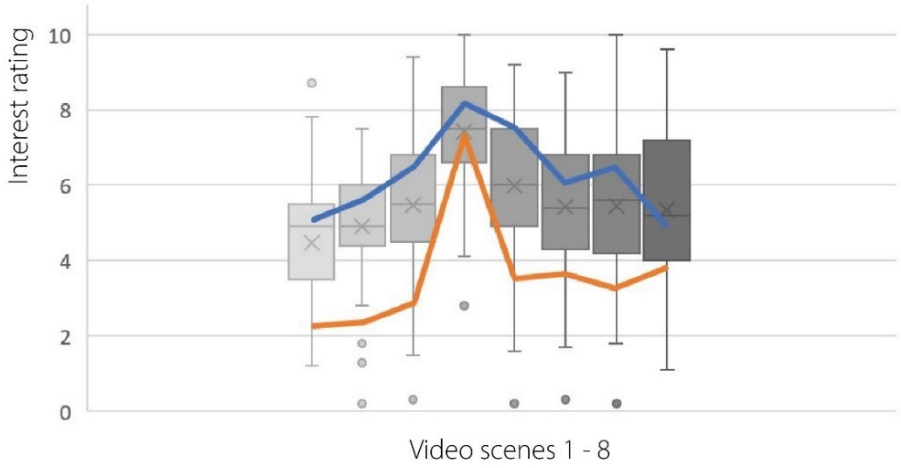
Video case 2: *Bubble boy trailer*.



Video case 3: *Ehrlich's magic bullet – selective staining*.



Video case 4: *What is nanotechnology?*



Video case 5: *The Brachistochrone*.

Figure 5.2. Boxplots of pupils' average interest in the subsequent scenes per video case. Orange line for average interest in the subsequent scenes for the 25% of the pupils (Q1) with the lowest general interest in the video. Blue line for the 25% of the pupils (Q4) with the highest general interest in the video.

From the findings we can derive possible relations between appraisals of video characteristics and pupils' (development of) interest in the video. We clustered the findings in three themes to describe these relationships: *The predictive power of appraisals*; *The role of video categories*; and *Differences between pupils*.

The predictive power of appraisals: Our previous quantitative study (Wijnker et al., submitted-a) already proved that ratings of the appraisals are good predictors of pupils' general interest in the video. Finding 4 in this qualitative study adds to this that the balance between C&CP appraisals may influence the predictive power of appraisals: Balanced appraisals with a high mean were positively related to higher interest in the video. Only in video case 1 were the ratings of the appraisal sets clearly less balanced for Q4 pupils than for Q1 pupils. We discuss this further in the final paragraph of this section. Finding 6 describes that unbalanced educational psychology appraisals were related with lower interest in the video, possibly because the video

Table 5.5
Pupils' General Interest in the Video and Balances of Appraisals of the Videos' Characteristics

Video case	Mean general interest in the video			Edu. psychology appraisals				Film studies appraisals			
				Balance percentage	Mean average of appraisals			Balance percentage	Mean average of appraisals		
	All	Q1	Q4	All	All	Q1	Q4	All	All	Q1	Q4
1	5.8	2.8	8.4	65%	4.5	3.3	5.1	55%	5.0	3.8	6.1
2	5.5	2.3	8.3	19%	5.8	5.3	7.1	45%	5.6	3.6	7.4
3	4.8	2.5	7.6	36%	4.4	3.2	5.4	63%	5.2	3.7	6.6
4	5.9	2.7	8.0	58%	6.7	5.3	8.8	33%	6.4	5.2	7.7
5	7.4	5.1	9.3	52%	8.2	7.6	8.7	59%	6.6	4.7	8.2

Note. Balance percentage = the percentage of pupils who showed a difference of two points or less between the appraisals.

was perceived either as too easy or too difficult. Findings 1 and 2 confirm this latter idea, because both the presentation of new knowledge or insights (finding 1) and the pupils' feeling capable of coping with it (finding 2) appear to have made interest go up, and the other way around, the absence of new knowledge in the video's presentation (finding 1) and pupils' inability to cope with the content (finding 2) made interest decrease.

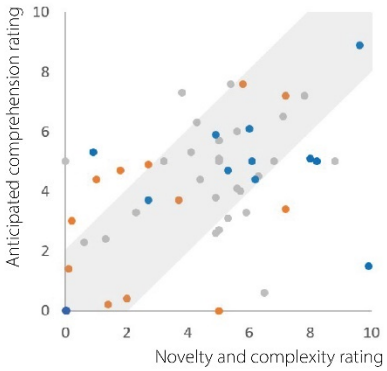
Finding 5 adds to the results of our previous study that pupils' average interest in the scenes may also have predictive power for their interest in the video. This underlines the relevance of research into the videos characteristics that are responsible for pupils' appreciation of the scenes. Findings 1–3 give some indications for influential video characteristics. As just discussed, the introduction of novel and complex content (finding 1) as well as presenting cues for comprehensibility (finding 2) may have caused interest to increase, but also intensifying complex developments within the video's structure (finding 3).

The role of video categories: The number of findings in relation to video categories (findings 8–15) indicates that studying appraisals of video characteristics as represented in the different video categories is a fruitful approach. Finding 7 shows us that interest in the video of the pupils in our study was highest for categorical videos, and lowest for narrative videos. In categorical videos, Q1 pupils most appreciated scenes that provided cues for understanding (finding 8). Possibly, the complexity of the video's content was just above their ability, making them feel reluctant when they finally understood, or they were simply more focused on getting answers ("What should I remember for the test?"). Q1 pupils appreciated the complex development of categorical films much less than Q4 pupils (finding 9), which supports the idea that Q1 pupils did not want to be bothered too much with superfluous information but rather cut directly to the information to be learned. Categorical/rhetorical videos also pointed into this direction, with Q1 pupils seemingly most interested in the introductory scenes that set out the topic, and the final scenes that provided most answers (finding 10). In general, all pupils rated educational psychology appraisals higher than film study appraisals for categorical/rhetorical videos (finding 11).

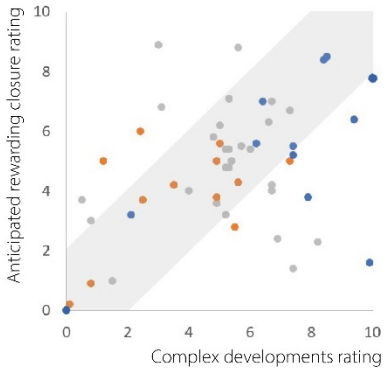
Differences between pupils: An apparent explanation for these findings would be that the nature of videos from different categories pushed pupils into a certain perceptive mode. For example, watching a categorical and/or rhetorical video can be expected to push viewers towards

Table 5.6
Findings for the Three Themes

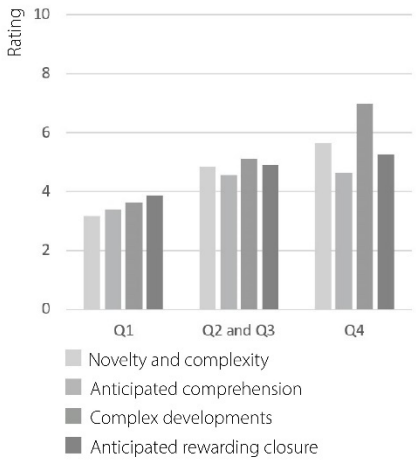
Theme 1. The predictive power of appraisals
Interest increased (or decreased) respectively with the presentation (or absence) of new knowledge or insights into the videos.
Interest increased (or decreased) respectively with the ability (or inability) of pupils to understand what was presented.
Interest increased (or decreased) respectively with the intensifying (or fading out) of complex developments.
High or low general interest in the video respectively coincided with higher or lower mean ratings of balanced appraisals.
High or low general interest in the video respectively coincided with a higher or lower average of interest in the scenes.
Videos with unbalanced educational psychology appraisals due to much higher or lower ratings for Comprehensibility respectively were perceived as (too) easy or (too) difficult.
Theme 2. The role of video categories
General interest in the video was rated highest for the categorical videos and lowest for the narrative videos.
For the Categorical videos, Q1 pupils' interest was highest for scenes that provided coping potential.
For the Categorical videos, the film study appraisal Complex developments was much lower for Q1 pupils than for Q4 pupils.
For the Categorical/Rhetorical videos, Q1 pupils' interest developed negatively from the beginning towards the middle, and positively from the middle towards the end.
For the Categorical/Rhetorical videos, educational psychology appraisals were rated higher than film study appraisals.
Theme 3. Differences between pupils
For the Narrative videos, the interest of Q1 pupils was highest when educational content knowledge was provided.
For the Narrative videos, the film study appraisals were much less balanced for Q1 pupils than for Q4 pupils, due to a much lower rating for the appraisal Complex developments than for Rewarding closure.
For the Associational videos, pupils most appreciated the scene that presented the most complex/fascinating image.
For the Associational videos, Q4 pupils rated the challenge components much higher than the coping potential components.



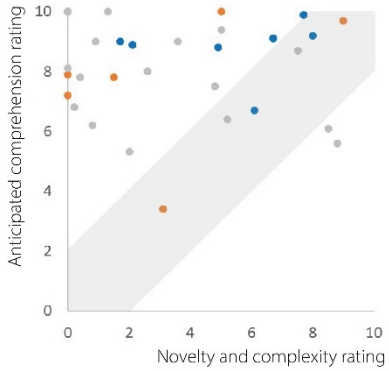
Educational psychology appraisals



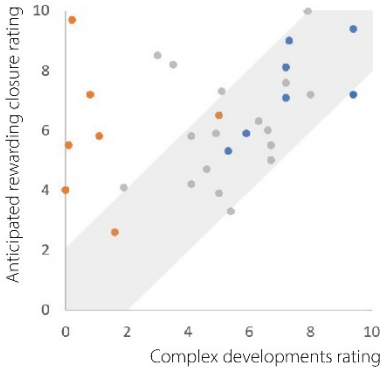
Film studies appraisals



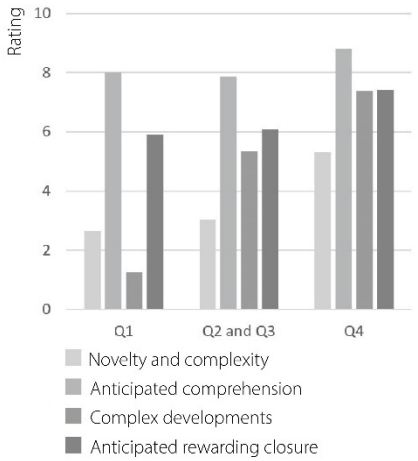
Video case 1: *The Inner Life of the Cell*.



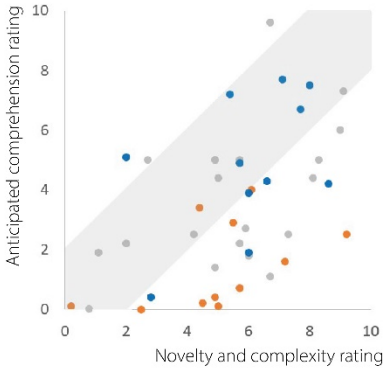
Educational psychology appraisals



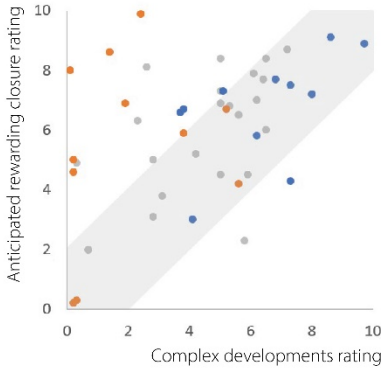
Film studies appraisals



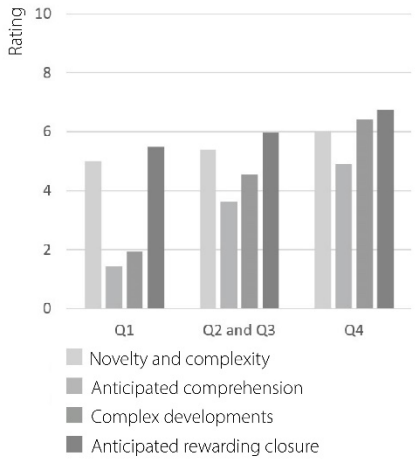
Video case 2: *Bubble Boy Trailer*.



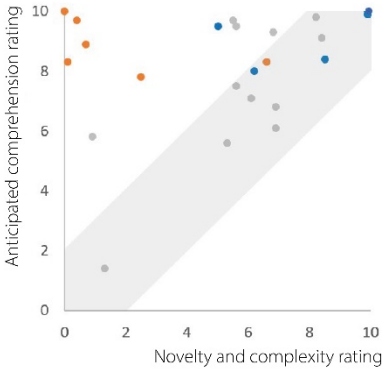
Educational psychology appraisals



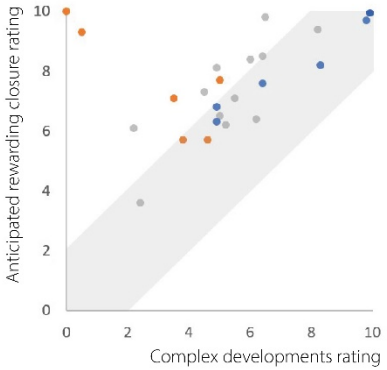
Film studies appraisals



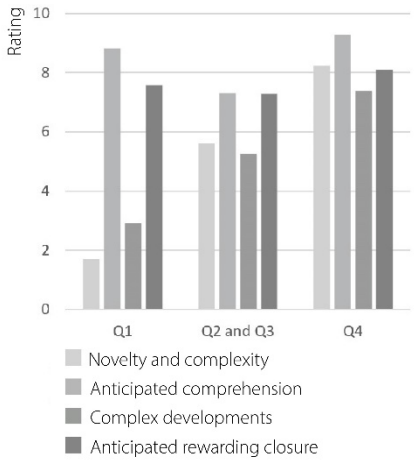
Video case 3: *Ehrlich's Magic Bullet – Selective Staining*.



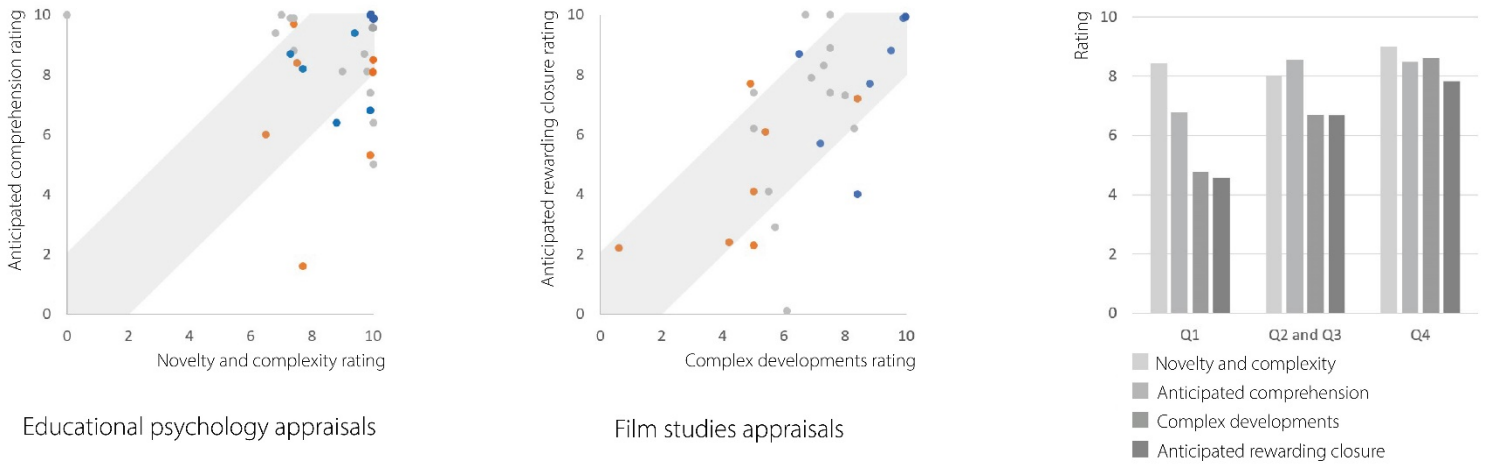
Educational psychology appraisals



Film studies appraisals



Video case 4: *What is Nanotechnology*?



Video case 5: *The Brachistochrone*.

Figure 5.3. Left and centre: Balance of pupils' rating of the two sets of model appraisals from educational psychology and film studies. Orange dots for ratings of the 25% of the pupils (Q1) with the lowest general interest in the video. Grey dots for the 50% of the pupils (Q2 and Q3) with a mediate general interest in the video. Blue dots for the 25% of the pupils (Q4) with the highest general interest in the video. The grey diagonal bar indicates well-balanced ratings of the two related appraisals (difference of 2.0 points or less). Right: Average ratings of the model appraisals of low (Q1), mediately (Q2 and Q3), and highly interested pupils (Q4).

a focus on novel content and answers rather than on exciting structural developments. However, in narrative videos as well, for which it can be expected that they push the viewers into the mode of anticipating story world complications, Q1 pupils still seemed to have been primarily focused on getting new knowledge (finding 12). Q1 pupils did not seem to appreciate the narrative nature of videos as much as Q4 pupils, given Q1 pupils' unbalanced film study appraisals (finding 13). Thus, a more plausible explanation would be that the predominant focus of all pupils – and Q1 pupils in particular – was due to the preference of the pupils for answers and solutions over narrative developments. In other words, they might evaluate videos watched in an educational setting more in terms of educational material than in terms of film material. Pupils who did appreciate the narrative developments, as reflected in their high and balanced ratings for the film study appraisals, also showed greater interest in the video as a whole (finding 13).

This final thought, that appreciation of elements in the video not primarily related to the educational content may lead to a higher appreciation of the video as a whole, is also reflected in the findings about the associational video in our study. All pupils most appreciated the scene in which they saw something they would not believe could exist within a cell (finding 14). For this video, their inability to comprehend what they were presented was overruled by fascination and disbelief. Pupils showing the highest interest in this video also showed a much higher rating for the challenge appraisals (finding 15). From this, we may conclude that *when* pupils allowed the video to lead them away from their focus on comprehension and closure, and into fascination and wonder, they do appreciate the video better as a whole. But again, we only had one video in our study to base these assumptions on.

Discussion and Conclusion

The need of teaching professionals for guidelines to make informed choices in the making, selection and use of videos for interest development in education, inspired us to set up our research project on interest mechanisms that underly video watching in educational contexts. In the study presented here, we applied the model of Film's Interest Raising Mechanisms (FIRM model), drawn from interest theories from educational psychology and film studies, to videos used in actual classrooms, so that we can better understand how videos can raise interest in educational contexts. The research question leading our inquiry was: *How do pupils' appraisals of video characteristics relate to their interest and to the development of their interest in the video?* Inquiring into this research question, we aimed to identify pupils' appraisals that are responsible for their interest development, and to explain why these appraisals affect pupils' interest the way they do. We performed case studies and cross-case analysis on pupils' evaluations of five science and mathematics videos.

We grouped our results in three themes. We named the first theme *The predictive power of appraisals*. Pupils' appraisals of video characteristics were indicated as good predictors of pupils' interest in the video's scenes and in the video as a whole. Moreover, we found that when C&CP appraisals are high and well balanced, interest in the video is high as well. Low or unbalanced C&CP appraisals were related to low interest in the video. Unbalanced appraisals indicated a mismatch between the pupils' level of education and the videos' level of complexity, leading to incomprehension (video was too difficult for these pupils) or boredom (video was too easy).

The second theme is *The role of video categories*. The results confirmed our expectation that it is fruitful to approach the analysis of video appraisals with the four video categories as a basis (Narrative, Associational, Categorical, and Rhetorical). With a few exceptions, all pupils' reports were formulated in terms of the challenges and coping potential of these four video categories (Table 5.1), and within cases matched the categories that resulted from our video analysis. These findings suggest that any theory on the interest raising mechanisms in video watching needs to consider the structural differences inherent in different types of videos. Categorical and rhetorical videos – the common formats of educational videos – were generally rated higher than narrative and associational videos, especially by pupils with a low general interest in the video (Q1 pupils).

The third theme is *Differences between pupils*. The higher ratings for educational psychology appraisals compared to film study appraisals with categorical and rhetorical videos confirmed our expectation that pupils approached these videos more as educational material than as a film. However, pupils who appreciated the diverging structures from narrative and associational videos, also showed a higher general interest in these videos than pupils who did not. In other words, when watching video in class, the pupils might have been more focused on what is to be learned from it than on the filmic experience they might be drawn into. But when pupils allowed the video to lead them away from knowledge and comprehension, and towards experience and fascination, their interest increased.

As mentioned before, interest is key to learning. A video watched in an educational context that pupils find interesting, makes pupils' interest for the educational content rise, and promotes further engagement with that content. The balance between appraisals of challenge and coping potential form the basis of the interest relationship between a pupil and the content. Our study shed light on what pupils' C&CP appraisals look like when they become interested in the videos they are presented in an educational context. We can use these insights as a first step towards guidelines for teaching professionals when selecting, making, and using videos for learning.

With respect to our study, there were some limitations we like to address. First of all, the scale of the study was limited to five videos. The videos included all four different video categories (Narrative, Associational, Categorical, Rhetorical). Had we used five videos from one category, our assumptions would have been stronger with respect to that category. We chose not to restrict the teachers in our study to a single video category, firstly because we were not yet sure that approaching videos in terms of categories would make a valuable contribution to the analysis. Secondly, we did not want to interrupt the natural course of the class meetings to safeguard the representative design of this study. This links to the second limitation of our study, being the limited number of pupils involved (177 pupils from 7 classrooms). To safeguard the representative design of our study, we chose not to evaluate the videos with other pupils from outside those classrooms. The videos would then be used out of their natural educational context, which can be expected of influence how the pupils perceive the videos (Araujo et al., 2007). Further research is needed to scale up. Rather than quantitative empirical proof, our approach returned a qualitatively coherent and inclusive overview with leads for future research opportunities. As a third limitation, we might mention the impossibility of addressing all the leads we found in our data for inquiries that were outside the scope of this article. Below, we discuss some as possible starting points for further research.

As options for further research that result from our study, we want to draw attention to the pupil reports categorized as 'other'. These reports give leads to inquire if and if so, how the FIRM model might be meaningfully expanded. A frequently used Other-category was Other/funny. Inquiry into the relationship between humour and interest development in videos seems fruitful. Another possible direction for further research links the second and third theme of our findings, and could form a possible fourth theme: *The role of the teacher*. We instructed our teachers not to make any remarks about the video (other than the topic) that could direct the pupils' attention, because doing so is assumed to interfere with the pupils' course of interest development (Wijnker et al., in press). Indeed, our findings give leads to believe that preparing the pupils for the type of video (video category) that they are about to watch might make them more receptive for filmic video characteristics such as experience, narration, and free association. This might lead pupils who tend to focus on typical educational characteristics such as knowledge that is to be remembered, to better appreciate the filmic characteristics with a possible positive effect on their interest development.

For all educational material, teachers need to judge the quality, complexity and usefulness of the material for their pupils to know what it is worth. With video, this is equally the case. From our results, two questions for assessing videos for education can be distilled that might be worth further investigation to formulate guidelines: 1. Does the complexity level of the video match the pupils' knowledge level? Videos that present challenges (such as new information or concepts) that are well above, or well below, the pupils' level will not lead to interest but to either frustration or boredom. 2. Does the video allow the pupils to form balanced C&CP appraisals throughout the video? The challenge the video poses should be proportionately balanced with cues for coping potential, so that pupils will gradually comprehend and feel rewarded with gained knowledge or insights. A third question following our results is directed towards the use of videos in educational contexts: 3. Are the pupils' expectancies properly managed? A clear introduction about the nature of the video's content (be it informative, contextualizing, fascinating, etc.) can manage pupils' expectancies and make them more inclusively receptive. We believe these three questions are key to developing effective and valuable guidelines for professionals in education for the making, selection, and use of videos when aiming for interest development.

Acknowledgement

We want to thank Gitte van Helden for her contribution to the data management.

Statements on Conflict of Interest, Open Data and Ethics

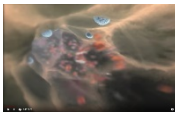
There is no conflict of interest in the reported work. The data of our project is in the process of being made permanently accessible through the Data Archiving and Networked Services (DANS) of the joint institute of the Royal Netherlands Academy of Arts and Sciences (KNAW) and the Netherlands Organisation for Scientific Research (NWO), at https://dans.knaw.nl/en. All co-authors had complete access to data supporting the manuscript. Pupil data collection and handling was complied with local ethical guidelines regarding collection and storage of data involving human subjects. The pupil data was anonymized after data collection, and all data was stored on a secured server behind a password.

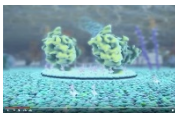
Appendix 5A
Pupil Questionnaire for Video Case 1

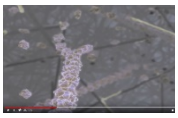
The video I just saw was interesting

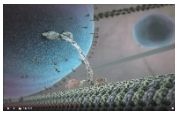
Totally not true ⟷ Completely true

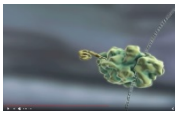
I found this part of the video interesting

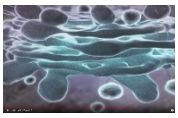
.  Totally not true ⟷ Completely true

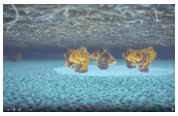
.  Totally not true ⟷ Completely true

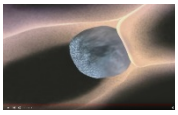
.  Totally not true ⟷ Completely true

.  Totally not true ⟷ Completely true

.  Totally not true ⟷ Completely true

.  Totally not true ⟷ Completely true

.  Totally not true ⟷ Completely true

.  Totally not true ⟷ Completely true

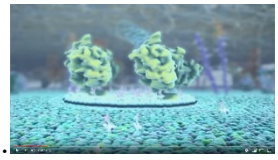
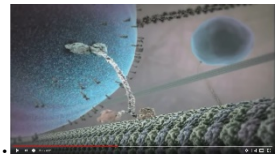
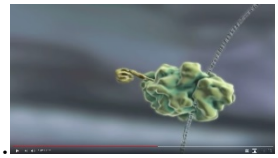
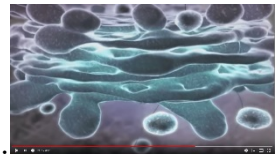
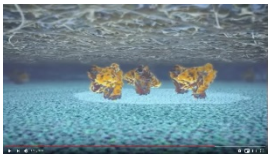
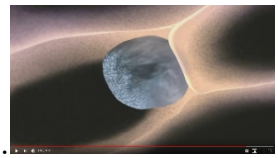
Keep the previous page vertical while drawing a fluent line from left to right through your marks for the video parts 1-8.

This results in a line graph showing how your interest changed while watching the video.

What happened in the video that made your interest increase or drop?

Look at the graph and refer to the numbers of the video parts in your explanation.

Video parts

1. 
2. 
3. 
4. 
5. 
6. 
7. 
8. 

I saw, heard or learned something new

Totally not true ⟷ Completely true

I was well able to follow the video

Totally not true ⟷ Completely true

I wanted to continue watching the video

Totally not true ⟷ Completely true

The video felt like a whole

Totally not true ⟷ Completely true

Appendix 5B
Case Study Results

Video case 1: The inner life of the cell

See main text.

Video case 2: Bubble boy trailer

Video 2 was categorized as a narrative video. The pupils were challenged by story world complications, which led them to elaboration and anticipation of further events. Resolutions of these complications formed the coping potential in the video.

The average interest of the pupils for the ongoing video steadily decreased (see Figure 5.1). There were no high peaks or dips in the developments, and the Q4 pupils showed a higher but similar pattern to Q1 pupils. The average interest of all pupils was highest for scene 1.

The pupils' reports showed that scene 1 was valued mostly for the introduced challenges of the main character, having to live with an allergy to almost anything (coded as Narr-ch-pos). For scene 2 and 3, the pupils reported often about the narrative developments in the video, and their experiences were mixed. Some liked the introduction of the girl in scene 2 (Narr-ch-pos), but others thought it was a cliché to turn it into a love story (Narr-ch-neg). Some liked how the boy started his mission to stop the wedding (Narr-ch-pos), but others thought it was rather predictable (Narr-ch-neg). Positive reports on scene 4 were that pupils thought it was funny (Other/funny-pos), but again the pupils' reports were mixed.

Pupil 60 (Narr-ch-pos): "He explained all about his allergies and how difficult that was, and I thought it was interesting to see his positive attitude."

Pupil 80 (Narr-ch-pos): "I liked it when the girl was introduced, because I was curious about what she had to do with the story."

Pupil 71 (Narr-ch-neg): "This part was less interesting because nothing much exciting happened."

Pupil 69 (Other/funny-pos): "Many funny things happened that made my interest rise."

Pupil 74 (Other/funny-neg): "It didn't interest me, it's not my kind of humor."

The balances of the pupils' ratings for the sets of EDPSY and FLMST appraisals show unbalanced reports from most pupils for the EDPSY appraisals with a mediate to high mean average rating (see Figure 5.2 and Table 5.4). This disbalance is mostly due to the (much) lower rating of the appraisal Novelty-complexity in relation to Anticipated comprehension. While about half of the pupils reported positively on the interesting rare disease in scene one, almost no reports on interesting new content were found for the following scenes. The reports for the FLMST appraisals had a mediate mean average rating, and were quite well balanced, especially for Q4 pupils. On average, the challenge appraisals (Novelty-complexity, Complex developments) were rated much lower by Q1 pupils than Q4 pupils. From this we may conclude that, many pupils – and specifically Q1 pupils – thought the video did not bring them much new knowledge or

insights. Q4 pupils may have appreciated the video mostly for the funny uncomplicated story about a rare disease.

Video Case 3: Ehrlich's Magic Bullet – Selective Staining

Like the video in case 2, video 3 was categorized as a narrative video. The pupils were challenged by story world complications, which led them to elaboration and anticipation of further events. Resolutions of these complications formed the coping potential in the video. The video also included rhetorical elements. Challenging ungrounded claims, such as "Methylene blue has an affinity for the nerves of worms" led the pupils to check and find validation for an argument. Ground for these claims, such as Dr. Behring saying "The whole nerves system is blue" while looking at the staining results, formed the coping potential in the video.

The average interest of the pupils for the ongoing video started very low in scenes 1 and 2, then rapidly increased in scene 3 and continued to increase until scene 5, remained high for three scenes and then dropped (see Figure 5.1). Q4 pupils showed a remaining interest after scene 5, with a slight drop in scene 8, whereas the interest of Q1 pupils immediately started to drop quickly after scene 5 until the end.

The pupils' reports showed that many pupils had trouble comprehending the video due to bad sound quality or not understanding the English (coded as Other/comprehension-neg). In scene 3, this improved. Pupils also reported that they found the development of the story uninteresting in the first two scenes (Narr-ch-neg). From scenes 3 through 7, when the men started discussing methods of the actual chemical experiment and the outcomes (Narr-ch-pos), pupils reported increasingly positive on the story developments, with a peak for scene 5 and 6. For scenes 5 and 6, pupils reported their interest increased because they could relate it to their chemistry lessons (Cat-ch-pos). About scenes 7 and 8, pupils reported they disliked how nothing much happened anymore (Narr-cp-neg). The main differences between Q1 and Q4 pupils for scenes 6 through 8 is that Q4 pupils more often reported positively about the storyline developments (see report of pupil 101), while Q1 pupils more often reported negatively about it (see report of pupil 90).

Pupil 110 (Other/comprehension-neg):	"In the beginning I didn't understand because I could not properly hear the characters."
Pupil 93 (Narr-ch-neg): for scene 1-3	"It was just people talking."
Pupil 115 (Narr-ch-pos):	"When they started talking about the dyeing and the science behind it, it became interesting."
Pupil 101 (Narr-ch-pos):	"The interesting thing is that the video is not just informative, but there is also a story involved."
Pupil 110 (Cat-ch-pos):	"I was interested because this was about what we are going to discuss in the lesson."
Pupil 90 (Narr-cp-neg): for scene 8	"It was the final resolution and nothing much happened there."

The balances of the pupils' ratings for the sets of EDPSY and FLMST appraisals show rather unbalanced reports from most pupils for the EDPSY appraisals with a mediate mean average rating (see Figure 5.2 and Table 5.4). This disbalance is mostly due to the (much) lower rating of the appraisal Anticipated comprehension in relation to Novelty-complexity. The reports for the FLMST appraisals were quite well balanced (and best for Q4 pupils) with an equal mediate mean average rating. Q1 pupils showed a great disbalance with much lower ratings for the appraisal of Complex developments in relation to Anticipated rewarding closure. From this we may conclude that, in line with the pupils' reports, due to many pupils having difficulty hearing or understanding what was being said in the beginning of the video, following the story line developments was too great a challenge for many pupils. The pupils that did manage valued the video for the information about a chemical experiment and its outcomes. Q4 pupils valued the video better, probably because of the video's narrative character.

Video Case 4: What is Nanotechnology?

Video 4 was categorized as a rhetorical video as well as categorical. It was categorized as a rhetorical video as it held an argumentative structure. In this structure, an ungrounded claim such as "How the different atoms in something are arranged can affect things like how strong or how weak it is" formed a challenge that led pupils to check the argument and see if there was ground for this claim as coping potential. As a categorical video, the pupils were challenged right from the start with the unexplained concept 'nanotechnology'. The video showed instances of this concept as coping potential, in the form of everyday life products that are made with the use of nanotechnology.

The average interest of the pupils for the ongoing video decreased slightly in scene 2, then started to increase gradually up until scene 6, and then decreased again until the end (see Figure 5.1). Q4 pupils showed a very different line of development from Q1 pupils. The interest of Q4 pupils increased rapidly from scene 2 to 4 and continued to rise, up until scene 6, and then decreased quickly towards the end, whereas the interest of Q1 pupils gradually decreased from scene 2 until scene 4, and then started to increase from scene 4 until the end.

The pupils' reports showed that in general many pupils thought the video did not give them much new (coded as Rhet-ch-neg), especially Q1 pupils. On scene 2, some pupils reported positively about the examples given of nanotechnology applied in everyday life (Cat-cp-pos). Scene 5 was valued most for the clear and structural explanation (Rhet-ch-pos), especially by Q4 pupils. For scenes 7 and 8, the reports were predominantly positive about the value of nanotechnology's applicability (Rhet-cp-pos).

Pupil 135 (Rhet-ch-neg): "The content being explained was below level and almost no new information was given."

Pupil 146 (Cat-cp-pos): "The video showed instances out of daily life, which made it more interesting."

Pupil 149 (Rhet-ch-pos): "They said matter can get very different just by changing the structure of the atoms."

Pupil 142 (Rhet-cp-pos): "The video was more about the applicability and the purpose of nanotechnology, and I thought that was interesting."

The balances of the pupils' ratings for the sets of EDPSY and FLMST appraisals show balanced reports from most pupils for the EDPSY appraisals with a mediate to high mean average rating, but not for Q1 pupils (see Figure 5.2 and Table 5.4). In line with the pupil reports, Q1 pupils rated the appraisal Novelty-complexity much lower than the related appraisal Anticipated comprehension. From this we may conclude that, in line with the pupils' reports, the pupils thought the video did not teach them anything new or was below their knowledge level. The balance of pupils' ratings for the FLMST appraisals showed balanced reports for only a third of the pupils, with a high mean average rating. This disbalance is mainly due to an slightly higher average rating of Anticipated rewarding closure compared to the related appraisal of Complex developments – most dots are only just off the grey bar. The disbalance is mostly due to the extremely low ratings of Complex developments from two Q1 pupils. From this, we may conclude that the balance between challenge and coping potential with regard to the filmic structure of the video was quite well balanced for most pupils to keep them interested, but that the content was too easy for some, which made them reject the video all together.

Video Case 5: The Brachistochrone

Like the video in case 4, video 5 was categorized as both categorical and rhetorical. As a categorical video, it challenged the pupils right from the start with the unexplained concept 'Brachistochrone'. The video showed instances of this concept as coping potential, in the form of examples in which the phenomenon can be found. It was also categorized as a rhetorical video as it held an argumentative structure. In this structure, an ungrounded claim such as "We can actually build a cycloid curve" formed a challenge that led pupils to check the argument and see if there was ground for this claim as coping potential. This ground was provided by the presenter actually building it.

The average interest of the pupils for the ongoing video started quite high, decreased up until scene 3, and then increased again until the end with a quick rise in the final scene (see Figure 5.1). Q4 pupils showed a similar pattern to Q1 pupils, with two exceptions: In scene 4, the interest of Q4 pupils already started to increase, whereas the interest of Q1 pupils did not start to increase until scene 5, and in the final scene the interest of Q1 pupils increased much more than that of Q4 pupils.

The pupils' reports showed that they valued scene 1 mostly for the large number of novel facts that was given (coded as Rhet-cp-pos), while for scenes 3 and 4, the pupils' reports showed decreased interest, with negative reports about repeated explanations or content that was not new to them (Rhet-ch-neg). Some pupils also reported that they disliked how scenes 2 through 4 contained a lot of "boring theory," which was much less interesting than the vivid experiments and examples in scenes 5 and 6 (Rhet-ch-neg/pos). An explanation for the high interest of all pupils in scene 6 seems to be that the scene showed how the theory works in practice. Many pupils reported that this led to better comprehension (Rhet-cp-pos). The more negative reports from Q1 pupils on the theoretical elaborations in scene 4 might be an explanation for the diverging interest developments of Q1 and Q4 pupils for this scene. Several pupils reported they disliked the presenter in the video (Other/character-neg).

Pupil 172 (Rhet-cp-pos): "I liked the facts in the beginning."

Pupil 166 (Rhet-ch-neg): "It felt like a lot of repetition to me."

Pupil 165 (Rhet-ch-neg/pos):	"My interest got less when there were less practicals involved, and it got greater with experiments."
Pupil 159 (Rhet-cp-pos):	"I liked how it proved the theory discussed earlier."
Pupil 168 (Other/character-neg):	"The man irritated me because he talked very childish."

The balances of the pupils' ratings for the sets of EDPSY and FLMST appraisals show well-balanced reports from most pupils for both sets, with high mean average ratings (see Figure 5.2 and Table 5.4). With regard to the FLMST appraisals, the appraisals are similarly balanced and the average ratings from Q4 pupils are higher than of Q1 pupils. From this, we may conclude that all pupils experienced a well-balanced structure in the video, and that Q4 pupils valued this structure more than Q1 pupils. The EDPSY appraisal Novelty-complexity is rated similarly by all pupils, whereas the related appraisal Anticipated comprehension was rated lower by Q1 pupils than by Q4 pupils. In line with the pupils' reports, we may conclude that most pupils thought the video presented them something new and complex, and that for Q1 pupils there was too much theory, which made the video boring.

Towards an Interdisciplinary Perspective

6

General Discussion, Reflections and Recommendations

Research Overview and Main Findings

Two motives formed the starting point for this research project. The first was to offer guidance for educational professionals to optimize video as a tool for raising interest in learning. The second was to make the unheard voice of film studies relevant in the scientific discourse on video in education. These motives led to four more specific research aims that were addressed in the four studies presented in Chapters 2 through 5. The first aim was to present a structured overview of the current state of video usage in education and the share of interest in it. The second aim was to integrate film theory with theories from educational research in a framework on educational use of video for raising pupils' interest. The third aim was to apply this integrated theoretical framework to videos used in educational practice, to test its empirical validity. The fourth aim was to offer worked examples of what works well and what does not when using film and video for raising interest, to guide teachers.

In the study described in **Chapter 2**, we performed explorative research to describe the use of videos in secondary science and mathematics education. The research question leading this study was *Which video characteristics can be expected to help achieve which teacher aims?* We interviewed seven teachers about their aims, we analyzed 13 videos on structure and style, and we used pupil questionnaires to inquire to what extent the video perception of 233 pupils matched the teachers' aims. We combined the data to perform case studies and a cross-case analysis.

With regard to the teacher aims, we found aims that matched the categories as defined by Schwartz and Hartman (2007), of which each contains two sub-aims: Doing aims (attitude and skills), Engaging aims (contextualize and interest), Saying aims (explanations and facts), and Seeing aims (discernment and familiarity). The aims found mostly with the teachers in our study were Saying and Engaging aims. Moreover, we found that many teachers used videos without an explicitly formulated aim, or with mixed multiple aims.

With regard to the video characteristics, we found that they matched the film types as defined by McCluskey (1947): Discursive, Evidential or Factual as mutually exclusive film types, and Emulative, Incentive, Narrative, and Problematic as inclusive film types that simultaneously can apply to a single video. Each video was categorized as either of the exclusive film types depending on the amount of information presented, and one or more inclusive film types depending on how that information was presented. The film types found most in our study's videos were Discursive and Problematic.

With regard to the pupils' perceptions of the videos we found that videos used for Saying aims were perceived by the pupils as most effective. After seeing these videos, pupils reported to feel more knowledgeable about the topic of the video. Videos used for Engaging aims were perceived as least effective. After seeing these videos, pupils often reported to have gained interest in the topic, but only a little.

In our case studies and cross-case analysis we found that pupils perceived Problematic videos as most effective for Engaging aims if the videos posed genuine questions that served to lead the direction of the video. Discursive videos were perceived to be most effective for Saying aims if the information was presented by an authoritative speaker. Our study resulted in presumed connections between teacher aims and film types (see Figure 6.1), and an assisting framework for educational professionals to select or make videos that match their aims (see Figure 6.2). The outcomes of this exploratory study showed that teachers found raising interest (Engaging aim) an

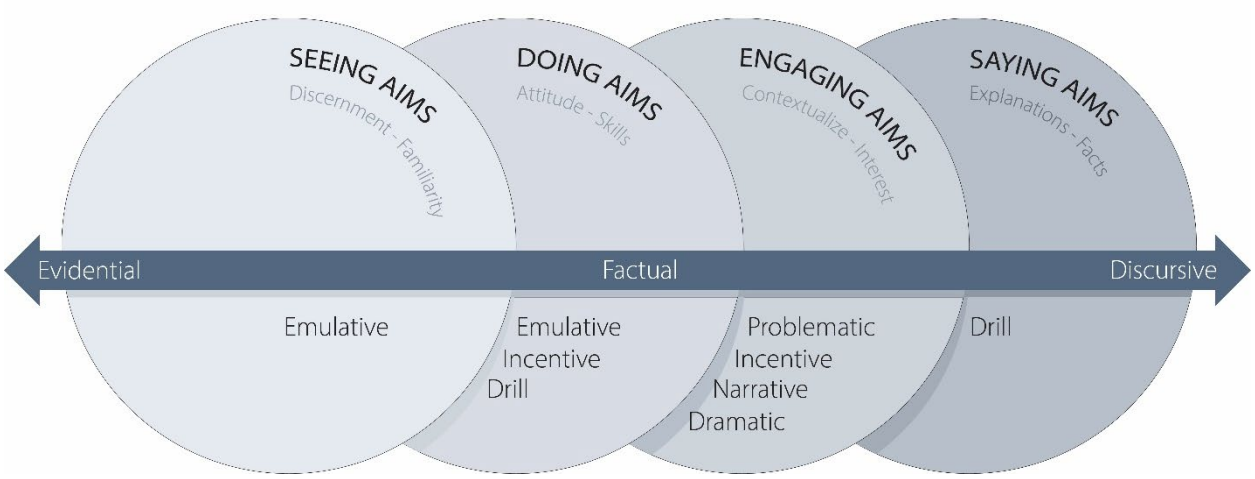


Figure 6.1. Model of presumed connections between teacher aims and film types, based on Schwartz and Hartman (2007, p. 338) and McClusky (1947). The teacher aims (grey circles) with presumably related inclusive film types attached (below in black) are positioned indicatively on the sliding scale of exclusive film types (black horizontal arrow).

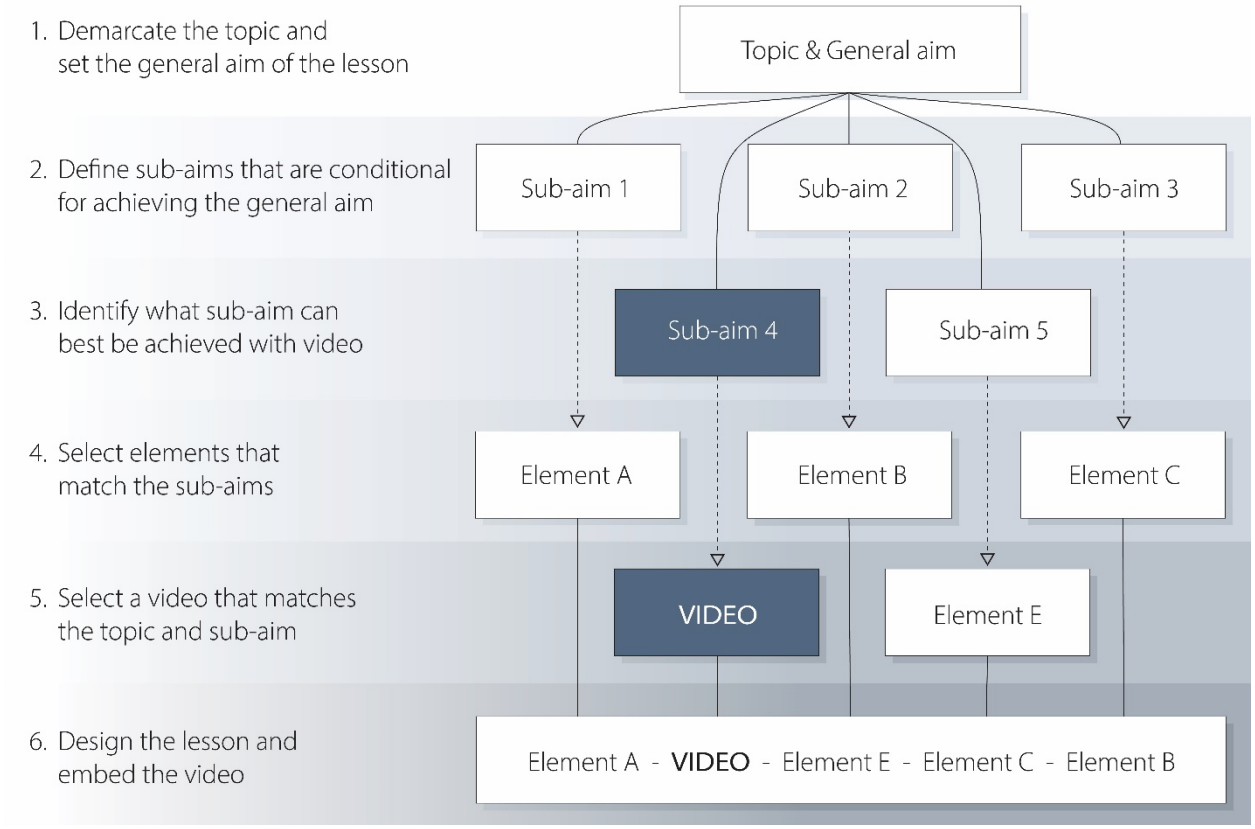


Figure 6.2. Assisting framework for educators to select or make videos that match their aims.

important aim, which they believed could be reached with video, but failed to be successful. The outcomes underlined the relevance of researching how video can help achieve the aim of raising pupils' interest, and strengthened our inclination to do so.

Chapter 3 describes a theoretical study that was set up to develop a model of film's interest raising mechanisms in learning contexts. We drew parallels between interest theories from educational psychology and film studies that consider interest as an emotion. Emotions are states that refer to a relationship between a subject (in our study the pupil-viewer) and an object (a video used in an educational context). The relationship evolves as a result of the subject's evaluations of the object, referred to as appraisals. In turn, a specific readiness emerges with the subject to take action, a motivation to act. This conceptualization of interest involves two core mechanisms: First, the subject's appraisals of the object lead to interest, and second, interest is expressed as the subject's urge to act.

In educational psychology, pupils' appraisals of learning materials that have found to raise interest (the first core mechanism) are appraisals of novelty–complexity and anticipated comprehension. It is assumed that interest relationships evolve when pupils experience a certain balance between the novelty or complexity of the material, and their anticipated potential to cope with that novelty or complexity. When an interest relationship is established, pupils are motivated to engage with the educational material by spending effort on and attention to it (the second core mechanism).

In film studies, viewers' evaluations of films and videos that have found to raise interest (first core mechanism) are appraisals of complex developments and anticipated rewarding closure. Similar to how interest relationships are described in educational psychology, for an interest relationship to evolve viewers need to feel confident to be able to cope with the complex developments they are presented with. When an interest relationship is established, viewers are motivated to spend effort and attention to anticipation and hypothesis generation and testing (second core mechanism).

We integrated these two perspectives into the model of Film's Interest Raising Mechanisms (FIRM model; see Figure 6.3). The model describes the balance between challenge appraisals (novelty–complexity and complex developments) and coping potential appraisals (anticipated

comprehension and anticipated rewarding closure) as a precondition for interest relationships. We described the action readiness that results from interest in film and video as the readiness to invest effort and attention in the videos and the educational content. Table 6.1 presents how challenge, coping potential and action readiness are substantiated in the four film categories Narrative, Associational, Categorical, and Rhetorical film.

With our model, we proposed two claims on what makes videos suitable for raising pupils' interest. The first claim is that the video should deliver on promise, meaning that all challenges posed in the video should come to a satisfactory closure at some point. The second claim is that interestingness should increase across the video, meaning that the (first) challenge should be introduced early in the video and that its resolution should be presented piecemeal over the course of the video. The general assumption lying at the basis of these claims is that the challenge and coping potential represented in the video should be nontrivial, while challenges that are not perceived as worth the effort are not interesting even if optimally balanced over the course of the video. Additionally, we presented a method for assessing a video's interestingness in educational contexts, to make the FIRM model operational for video analysis. It follows from

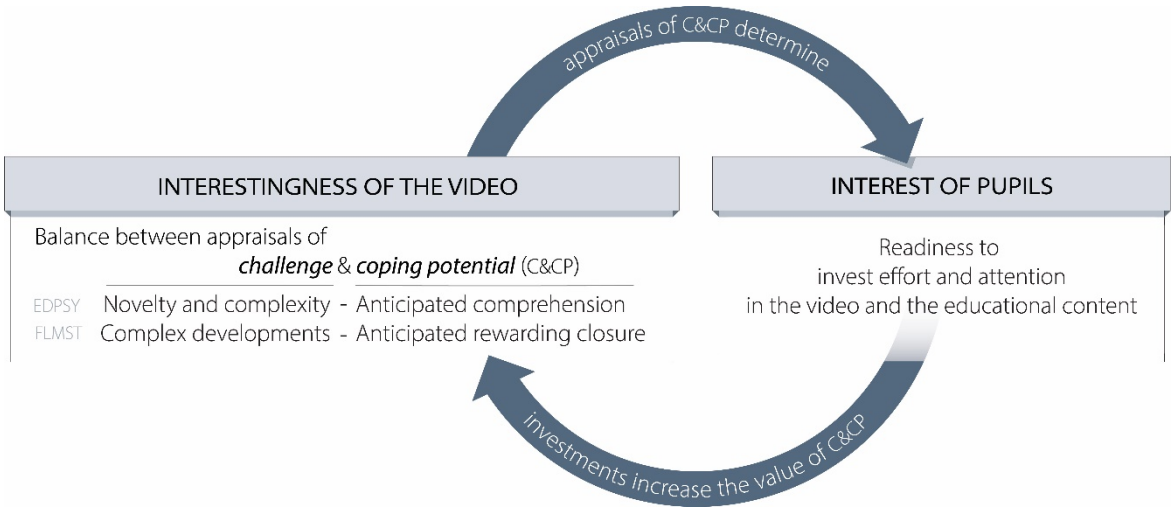


Figure 6.3. Model of Film's Interest Raising Mechanisms (FIRM model). This model describes how film raises interest in learning contexts. The interestingness of a video reflected in the video's balance between challenge and coping potential predicts the potential interest of the pupil-viewers reflected in their motivation to engage with the educational content. Pupils' actual investments reflect their interest development. Investments made increase the value pupils attribute to the appraisals and may result in further interest development. EDPSY=educational psychology; FLMST=film studies; C&CP=challenge and coping potential.

Table 6.1
Interest Components as Substantiated in the Film Categories

		Film category*			
		Narrative film	Associational film	Categorical film	Rhetorical film
Appraisals	Challenge	Story world complications	Complexity, ambiguity	Induction: uncategorized instances Deduction: unexplained concepts	Ungrounded claim
	Coping potential	Story world resolution	Affective experience	Instances and their categories; Concepts and their instances	Grounded claim
Action tendency	Affectively charged readiness to spend effort and attention	(Causal) Elaboration and anticipation of story world events	Free association	Induction: seeking to find categorizing concepts Deduction: seeking to find exemplifying instances	Check and possible validation of an argument

Note. *As identified by David Bordwell et al. (2017)

our model that pupils' appraisals of a video are predictive for their interest in the video, and that their interest in the video is predictive for their interest in – and readiness to further engage with – the educational content.

In **Chapter 4**, we report a quantitative empirical study to assess the validity of the core mechanisms of the FIRM model. To achieve this goal, we set up and tested three hypotheses:

1. *Pupils' appraisals of a video's characteristics predict the pupils' interest in the video;*
2. *Pupils' interest in the video predicts the development of pupils' interest in the educational content of the video;*
3. *Pupils' appraisals of a video's characteristics predict the pupils' development of interest in the educational content of the video indirectly via their interest in the video.*

In our hypotheses we included *development of interest in the educational content* as a measure for pupils' readiness to further engage with the educational content. To investigate if the concept referred to as immersion, transportation, or absorption, which is central to game theory, could further enrich the FIRM model, we included the appraisal of Absorption, adding up to a total of five appraisals.

We evaluated the use of four videos in six 12th-grade science and mathematics classrooms (one video per classroom), with a total of 151 pupils. We used pre- and post-viewing questionnaires prior to and directly after watching the videos to measure the pupils' ratings for the five appraisals, their interest in the video, and the development of their interest in the educational content. In the analysis we set up a Structural Equation Model (SEM) for path-modelling.

Our findings confirmed all three hypotheses, indicating that pupils' appraisals predict their interest in the video, and that their interest in the video predicts their interest in the educational content. These findings validate the mechanisms described in the FIRM model. The added appraisal Absorption was also found to be a significant indicator for interest.

In the final study described in **Chapter 5**, we performed a qualitative empirical study to explain, and so to better understand, the mechanisms that underlie the FIRM model. We aimed to identify concrete examples of video characteristics in terms of pupils' appraisals that are responsible for pupils' interest development while watching. Furthermore, we aimed to find possible explanations for why these appraisals have a positive or negative effect on pupils' general interest in the video. The research question leading this study was: *How do pupils' appraisals of video characteristics relate to their interest and to the development of their interest in the video?*

We evaluated the use of five videos in seven 12th-grade science and mathematics classrooms (one video per classroom), with a total of 177 pupils. We used pre- and post-viewing questionnaires prior to and directly after watching the videos to measure the pupils' general interest in the video, and their ratings for the five appraisals. We also measured the development of their interest in the video over the course of watching it with their ratings of the subsequent scenes in the video, and we asked them to elaborate on that development. This dataset was collected simultaneously with the dataset for the study reported in Chapter 4. In each study we used different subsets of data, except from the data on general interest for the video. This subset was used in both studies. The study reported in Chapter 4 included data that were collected with pre-viewing pupil questionnaires. In one video case, the protocol was not followed strictly with regard to the pre-viewing pupil questionnaire. We could not guarantee an equal status of the pre-

viewing data from this video case as compared to the other cases, and therefore excluded the data from further analysis. This is why Chapter 4 only includes reports on four video cases, while Chapter 5 includes five. We performed video analysis, case studies and cross-case analysis.

Our findings resulted in relationships between appraisals and interest that we clustered in three themes. The first theme is *the predictive power of appraisals*. This theme describes the essential match between pupils' cognitive levels, and the video's level of complexity (either with respect to the content or the video's structure). If there is no match due to too big a difference between these levels, pupils will appraise the video negatively and describe it as either too complex or as boring. The challenge is evaluated as too high, the coping ability too low or vice versa.

The second theme is *the role of video categories*. It discusses the expressions pupils used to explain their interest development. With few exceptions, pupils' reports matched the challenge and coping potential appraisals we proposed for the four video categories (see Table 6.1). This indicates that analyzing videos on the basis of the video category is a fruitful approach.

The third theme is *differences between pupils*. It discusses the expectations pupils might form based on the video categories. The pupils in our study showed more interest in videos that are typically associated with learning (categorical and rhetorical videos), because these present a lot of information. However, we also saw that pupils who allowed alternative videos (narrative and associational videos) to lead them away from knowledge and comprehension and towards experience and fascination, became more interested in the video.

These findings inspired us to formulate a fourth theme as a recommendation for future research and educational practice: *The role of the teacher*. Preparing the pupils for the type of video (video category) that they are about to watch might make them more receptive for filmic video characteristics that support experience, narration, and free association. This might lead pupils who tend to focus on typical educational characteristics such as knowledge that is to be remembered to better appreciate the filmic characteristics with a possible positive effect on their interest development.

Together with the themes, the validated FIRM model can inform the formulation of guidelines for effective and intentional use of film and video for learning. Suggestions for further steps are presented below, under *Recommendations for Educational Professionals*.

Limitations and Recommendations for Future Research

In this research project, four studies have been carried out. Each resulted in contributions both to educational practice and research, as will be discussed below. But there are four limitations to our studies that need to be addressed as well, concerning the scale of the set-up, the lack of validated measures, the scope of our studies, and the as yet undefined relatedness of Absorption to the FIRM model.

A first limitation to our empirical studies has been the scale of the set-up. We chose to evaluate the use of videos in actual classrooms, in which the teachers intended to use these videos. We could also have evaluated the videos in experimental set-ups, as a way to isolate the impact of the videos on the pupils' interest from the 'messy' environment of education in which so many factors are involved (teacher behaviour, group dynamics, class structure). It would have been easier to scale up in an experimental set up with many more participants watching a video outside a classroom context. But we chose not to. When videos are used in education, all kinds

of factors interplay. Stripping videos from their educational contexts will not inherently make research more precise, clean or goal oriented. In this research project, I considered interest an emotion that involves subjects' appraisals of objects and events. Possibly, some events are appraised equally in any kind of environment, for example because of moral considerations. But in most cases, subjects appraise events in the context of the environment they occur in. Watching a film in a home environment, in the evening, with friends and drinks, is a completely different experience from watching that same film in class on Monday morning. As we can never know all elements within a natural environment that may be of influence on the process of appraisal, let alone select which ones are crucial, we chose not to dismiss any element and stick with natural classrooms. And even then, we must acknowledge the effects of conducting the research on the classroom.

We also purposefully chose to work with videos selected by the teachers themselves. This was a logical choice in our first study since we wanted to explore what kinds of videos were used in classrooms, but in our two other empirical studies we could have chosen differently. Making our own selection of videos would have enabled us to only include one type of video, making it possible to cluster results and compare on a bigger scale. However, this would have meant a great impact on the natural course of the events in the classrooms we evaluated these videos in. And for reasons just discussed, we did not want to minimize our interference with the events and contexts.

I believe that doing research in an actual classroom with videos that real teachers selected was the most valid way to safeguard the representative design of our study. This has made our findings optimally reliable for generalization. However, the disadvantage associated with these choices is the limited amount of – and thus variety in – data underlying our findings, weakening the grounds for generalization. The empirical findings that resulted from my research project are not to be mistaken as proof for how things *are*, but rather should be taken as examples of how they *can be*. From these examples, combined with our theoretical model, one can try not to define how things are, but to come to understand why things appear the way they do.

A second limitation was formed by the recurring challenge to measure concepts that appeared rather elusive or inconclusive, and the lack of validated measures for these. Situational interest itself is such a concept. It can be easily confused with curiosity, attention, enjoyment, and flow (e.g., Ainley & Hidi, 2014; Peterson & Hidi, 2019). In our studies we have accounted for similar concepts, and described how we dealt with their distinction. We have worked with validated measures as much as possible to secure that our findings are indeed measures of the intended concepts. However, for measuring the FIRM model appraisals no such validated measures are yet available. Hopefully, future research may find a way to validate (a derived form of) our proposed measures and scales for challenge and coping potential appraisals.

A third limitation concerns the limited scope of our studies. The FIRM model we developed (Chapter 3) is comprehensive, and we were able to validate only two core mechanisms of the model in our empirical study (Chapter 4). We invite other researchers to work on and with the model to establish the value of the model. Using the model in empirical studies with more videos and more pupils, and with different set-ups and methods will lead to more examples that enrich our understanding of the mechanisms it describes. For example, as discussed earlier, it seems fruitful to explore video designs aimed at knowledge transfer with the use of the FIRM model.

The connection with game theory has been attempted in Chapter 4, by including Absorption as a fifth appraisal to possibly enrich the FIRM model. Future research in this direction seems particularly relevant, since it connects directly to the audiovisual characteristic of film that turns viewing into an experience. Challenge and coping potential appraisals are evoked by cues in the film's or video's discursive structure, and can either be presented in images or sound. Likewise, a written or told story can exhibit a discursive structure and present cues that evoke challenge and coping potential appraisals. This is quite different with the appraisal of absorption. Absorption, transmission and immersion are concepts used to describe an experiential state of the viewer (with film), player (with games), reader (with novels), or listeners (with told stories) as if being taken to another world. Again, books can accomplish this, like films and games, but it can be assumed that the interplay of visual perception in games and films, makes this experience quite different from the experience caused by reading or hearing – stronger, presumably. The FIRM model does not (yet) address this function of visual perception, and I regard it as the most fundamental limitation to my research project: The FIRM model describes film's interest raising mechanisms in educational contexts, but is not exclusively applicable to film. It may be attributed to any medium with a discursive structure. As discussed above, it is the audiovisual characteristic that distinguishes film from other discursive media, and that is responsible for film's ability to offer an experience to its viewers. Future research is needed to find out and describe how absorption is related to film's interest raising mechanisms, and how it can be optimized for education. I look forward to taking up this challenge in my future scientific career.

Reflections on the Interdisciplinary Approach

One of the motives for this research project was to bring to light the unseen potential of film and video for interest in learning contexts, by introducing a film studies perspective in research on the educational use of film and video. If realized this would help to fulfill my second motive, to guide educational professionals in the use of film and video for interest development. These motives asked for an interdisciplinary approach that would bring together and connect film theory and educational theory. Interdisciplinarity as an approach to complex topics is gaining popularity in policy, practice and research (Huutoniemi, 2010). An approach that includes multiple domains does justice to the complexity and multi-perspectivity of real-world phenomena. The exchange of knowledge and ideas across domain borders extends the scope of research output and accelerates scientific progress. I believe that the use of film and video in education is such a topic that would benefit from an interdisciplinary approach.

Communication for mutual understanding between disciplines can be challenging. However, it is crucial to get from multidisciplinarity, as a collection of many perspectives, to interdisciplinarity as connected perspectives. As a researcher trained in the tradition of humanities (film- and television studies, and philosophy), appointed at a research institute within a Faculty of Science (Freudenthal Institute of Utrecht University), and conducting educational research studies, I experienced firsthand what it takes to come to mutual understanding in a multidisciplinary discourse. Ranging from language differences (jargon, concepts, schools) and different research methods (set-up, scale, scope) to ways of reporting research (standards, unwritten rules), each domain has its habits that need to be stretched for the purpose of a mutual approach. An interdisciplinary approach in research is no easy task, but the outcomes of this research project show what the effort may bring about.

In what follows, I discuss the multiple disciplinary perspectives that are dominant in the discourse on film and video in education, and how this thesis aims to contribute to the discourse. Next, I discuss the main contributions of the research project as a result of our interdisciplinary approach and how they support interdisciplinary within the discourse. I conclude with offering recommendations for educational practice and end this thesis with a final thought.

Multiple Disciplinary Perspectives

With respect to the issue of film and video in education I distinguish at least five relevant perspectives. These can be labeled as the perspective of technology, the educational sciences, cognitive psychology, educational psychology, and media studies.

The perspective of *technology* is most common with educational professionals such as teachers and film makers. In this domain, the focus is on how the use of audiovisual recordings can be beneficial to the practice of teaching: the possibility to record in advance, to share online for use at any place and any time, to facilitate self-paced learning, to reuse, to pause, to replay. Video examples that primarily exploit this focus are video lectures, screen captures, how-to videos, and registrations. Educational professionals with this focus on the use of video are interested in what software to use and how to effectively use videos for blended learning and flipped classrooms (Van Alten et al., 2020).

The perspective of the *educational sciences* is present in most research conducted on educational videos. In this domain, the main focus is on how audiovisual material can be effectively designed and embedded in a didactical structure to maximize learning effects. Research studies with this focus may inquire the effects of video length, presenter visibility, and segmentation for in-class use as well as online learning environments (Van Merriënboer & Kester, 2013). Close to the perspective of the educational sciences is the perspective of *cognitive psychology*. In this perspective, the main focus is on how the brain can effectively processes audiovisual information by maximizing structural guidance, and by minimizing the risk of working memory overload. Research studies empirically inquire the effects of combinations of audio and visual cues (Clark & Paivio, 1991; Mayer, 2009).

Related, but more focused on psychological mechanisms rather that neuroscientific processes, is the perspective of *educational psychology*. From this perspective, research aims to find mechanisms that can explain when and why we learn from audiovisual educational material, and theorizes – based on empirical findings – on what learning really entails (Krapp, 1999; Renninger & Hidi, 2016; Silvia, 2006).

Last but not least, the perspective of *media studies* is the domain of the communication experts. In this domain, the main focus is on how a medium technically or structurally communicates audiovisual information, and on the psychological processes involved in how a user ‘reads’ or experiences that information. Film studies is part of this domain (Bordwell, 1985). However, when relating it to the issue at stake here, it appears that research on the use of film for educational purposes is limited (Masson, 2012). The near absence of the media studies perspective in the scientific discourse was one of the motivating factors to set up the research project leading to this thesis.

A second motivator lies within in the practical discourse. While working in the field of science education, my multidisciplinary background enabled me to recognize how a problem in one domain might be solved with insights from another: A major issue in science education

practice is pupils' decreasing interest in science subjects (Savelsbergh et al., 2016), while the medium of film has proven to be a true interest magnet (Tan, 1996). The combination intuitively tells us that science films might help to raise pupils' interest in science subjects. Sadly, in science education, the most commonly used videos display talking heads and aim primarily for knowledge transfer, and are not designed to function as the powerful interest triggers they could be. Our first exploratory study on the use of film and video in secondary science and mathematics education confirmed this picture. Being inspired by the many beautiful science films that are also available (such as *Magnetic Movie* by Semiconductor – see cover photo), and confident to find a great match between film and science education both in research and in practice because of these film examples, I decided to fully focus on the educational potential of film for interest development in an interdisciplinary research project.

An Interdisciplinary Perspective

The perspectives present in the current scientific discourse on film and video for education are dominated by the domains of the educational sciences and cognitive psychology. The dominant perspective in the educational practice discourse is that of technology. This thesis aims to broaden the perspectivity of these discourses by approaching the issue from the under-represented perspective of media studies – and more specifically film studies – and connecting it to the perspective of educational psychology as an interdisciplinary approach. As a result of taking up these two perspectives, the focus on film and video's function for learning also shifted in our inquiries. Our research moved away from the common foci on efficient knowledge transfer, production and opportunities for blended learning to a focus on interest development.

Our novel approach and focus resulted in concrete contributions to science and theory: the FIRM model describing the mechanisms involved in raising pupils' interest in learning with film and video (Chapter 3), and the derivatives of that model. We are not aware of similar attempts to apply film theory on viewer activity to viewers in educational contexts. Our contribution to make film theories on interest applicable to not only narrative, but to discursive films in general (including narrative, associational, categorical and rhetorical films following Bordwell et al., 2017), opens up new directions for film research.

These contributions could not have come about without making a fundamental connection between the two fields of research that lie at the basis of the model: educational psychology and film studies. We did not just want to add yet another perspective in multi-disciplinarity. We aimed for the integration of perspectives in interdisciplinarity. The following is an attempt to further integrate our contribution into the discourses that exist in educational research and practice, and may hopefully become the starting point for new discussions. Suggestions for future research are made along the way. We invite researchers and practitioners to join in.

A possible premise for educational research and practice that can connect the various perspectives, is that video is an *audiovisual* and *discursive medium* that can be used as a *teacher tool*. Let us consider each of the three characteristics used in this qualification, and start with the latter, the teacher tool.

Teacher Tool

Good teachers are skilled in setting up a coherent didactical plan, which is purposefully structured, and includes all components that are necessary to optimize the learning of their pupils. What these necessary components are depends partially on the specific topic or skill, but

in general a lesson plan will include aims such as the activation of relevant prior knowledge, scaffolded introduction to novel concepts, and familiarization through repeated deliberate practice. Raising interest is also one such aim. There are numerous ways to substantiate these aims in educational materials and activities, and the use of video can be one of them. The materials and activities in a good didactical plan are selected in the service of the aims set by the teacher. This means that the inclusion of any kind of material or activity can never be a goal in itself. Nor should it be a means to replace the teacher: it should add something to the toolbox of teachers that enables them to better accomplish what they aim for.

There are three conditions to enabling purposeful use of tools: knowing what you want to do, what the tool can be used for, and how to handle it. In the context of teaching, this translates into the teacher knowing what the selected aims entail, what the available materials and activities can accomplish, and how to effectively integrate these materials and activities in the lesson. With regard to raising pupils' interest with video, teachers need to know (1) what it is to raise their pupils' interest, (2) what are video's potentials for learning, and (3) how to use video in education to make it effective for raising interest.

This thesis offers insight into the first two conditions, and suggestions for the third. I will discuss the first two now, and save the third for later: (1) Interest is considered an emotion that can arise when pupils' appraisals of challenge and coping potential that the material or activity evoke are well-balanced and valued by the pupils; (2) Video is proposed as a medium that uses a filmic language to balance challenge and coping potential appraisals with the viewers. It does so by providing cues that invite the viewer to anticipate new developments over the course of the video. This property makes it an excellent tool for raising pupils' interest. We refer to this property as the *discursive* characteristic of video – the second characteristic in our qualifying premise.

Discursiveness

All discursive media activate their 'watcher, reader or listener, be it a film, a book, a newspaper or a storyteller. Any medium that can hold a discursive structure invites those who watch, read or listen to it to anticipate how the story will develop, be it a narrative, a categorical, an associational or a rhetorical story. A narrative story will make the viewer start to wonder about when, where, and why what happened, and who were involved, just by starting with the words "Once upon a time…" As the events take form, they invite the viewers to anticipate further developments and make them long for a rewarding closure of the events and anticipations. A rhetorical lecture typically starts with a claim that makes the viewers hypothesize on possible grounds for that claim, or reasons to reject it, and anticipate a resolution at the end of the film. It is the posed challenge that evokes anticipation of future developments, and the rewarding closure of anticipations as coping potential, that make discursive media activate viewers, readers, and listeners into forming challenge and coping potential appraisals. When balanced well, their readers' interest is likely to be raised. A beautiful example of an activating narrative mathematics video is *Wind and Mr. Ug*, made by Vi Hart.[13]

This powerful discursive characteristic of film and video is rarely addressed in educational research on video. With a focus on knowledge transfer, researchers tend to opt for a smooth line of reasoning in the video, but with the often overseen risk of nullifying video's activating power

[13] https://vimeo.com/147906386

due to instructional fluency (Muller, 2008). However, it can be expected that video designs aimed at knowledge transfer would also benefit from maximizing video's activating potential by optimizing the discursive structure – an interesting lead for future research. Some video examples that were designed accordingly can be found on the YouTube channel of *Veritasium*, in which misconceptions were intentionally included to activate viewers for more effective knowledge transfer.

Although powerfully present in film and video, the discursive nature of film is not unique to the medium. Teachers might as well use a book or a newspaper item if they need the property of discursiveness to reach their goal. So, let us have a look at the second characteristic of the medium in our premise: the *audiovisual* nature.

Audiovisuality

From the perspective of technology, the audiovisual nature of video enables the recording and sharing of information. This property makes video a valuable tool for teachers, but for different goals than raising interest; for example, to promote self-paced learning, or to open up courses to larger audiences. These too are valuable goals for education, and it supports the claim that taking various perspectives may open up new possibilities, but when connected to the discursive characteristic of film and video we return to raising interest, because of the common effect of audiovisual media, referred to as Absorption, Immersion and Transportation.

Seeing is believing. In our digital era, this claim starts to falter, but still our senses trick us into convincing experiences. The result: we feel absorbed, immersed or transported into another world. The more audiovisual media resemble natural perception, due to for example movement, 3D effects, continuity editing, matching sound, and the power to control, the more powerful the experience. It is game study's primary focus of research – yet another perspective in the common discourse. Absorption is responsible for the flow one might get into, that makes viewing – or playing – seem effortless. Experiences are often heavily emotionally loaded, and because of this may be used as strong leads for remembrance. It would be an interesting inquiry in future research to also explore the beneficial effects of absorption in educational videos on working memory load and long-term memory.

One of our studies indicated the absorbing power of film and video as a possible strengthening mediator on the FIRM model's interest appraisals (Chapter 4): The audiovisual experience film and video offer to present their discursive structure, intensifies the viewers' activity of anticipation. This is why discursive and audiovisual characteristics united in one medium can make it such a powerful tool for raising interest. These are the perfect ingredients for intense and memorable emotional experiences that instigate strenuous viewer activity. In what follows, I return to the function of video as a *teacher tool* and discuss how to make the combination of these characteristics beneficial for raising interest in the educational practice – the third condition to enabling intentional use of tools.

Recommendations for Educational Professionals

Speaking in general, a teacher tool may possess many characteristics, that can serve various aims. In this thesis, a match is made between film and video's characteristics of discursiveness and audiovisuality, and the aim of raising interest. But as discussed above, considered from other perspectives matches to other aims are also possible, and there are other characteristics of the medium that have as yet been left undiscussed. And of course, other media, with other

(combinations of) characteristics may also serve the aim of raising interest. Hopefully, this thesis promotes the promising possibilities to use film and video as a tool to raise interest. In Chapter 5's discussion section, we propose three key questions that may guide educational professionals to use film and video intentionally, as a tool, when aiming for raising pupils' interest.

The first question is: *Does the complexity level of the video match the pupils' knowledge level?* Central to this question is the idea that challenge and coping potential appraisals need to be well balanced for interest to rise. Educational material and activities may pose great challenges, but pupils will only be motivated to engage with these challenges if they feel capable and supported well enough to cope with them. An early introduction of cues for coping potential that match the knowledge level of the pupils, is crucial to this feeling. This matching goes two ways: It should not be too complex (too challenging), nor should it be too obvious (not challenging enough). Our final study (Chapter 5) showed the relationship between unbalanced challenge and coping potential appraisals and little interest in the video. Little interest in the video due to low coping potential appraisals is expressed by the pupil as frustration, and little interest due to low challenge appraisals as boredom.

As film theory on interest showed us (Chapter 3), offering a good balance of challenge and coping potential is not just a matter of starting off with the right challenging question and then dropping off the answer as coping potential. To obtain a good balance throughout the video, in such a way that interest builds up towards a maximum, this second question is leading: *Does the video allow the pupils to form balanced challenge and coping potential appraisals throughout the video?* Films that raise the interest of viewers offer piecemeal resolutions to posed challenges along the way. The longer anticipations are stretched, the stronger they become, and the more rewarding the final resolution becomes. Of course, there is a limit to expectancies' stretchability; at some point the viewer will lose confidence in a challenge being resolved, or even forget about it. But as a guiding principle, challenges that stretch over the entire course of the video, with piecemeal resolution (and complication of the challenge with the introduction of sub-challenges) have a better chance of raising viewers' interest, than videos that resolve each question before moving on to the next one.

Expectancies are powerful assets to play with. From the early childhood on, children are familiarized with narrative structures in stories of all kind, and what to expect from them. In cognitive film theory, this process of familiarization is explained as the formation of schemata that guide our expectations whenever confronted with anything that may fit that scheme (see Chapter 3). As we grow older, these schemata become more extensive and refined due to experience. This is how we come to recognize film genres. For example, while watching we are still frightened when the killer suddenly jumps out of the bushes, but no longer surprised. Now, suspense builds up as we know the killer is close by when the filmic image gets darker, we see point of view shots from behind a parked car, and the music comes to a climax.

From this, it can be expected that over the course of their school career, pupils form specified expectations with respect to films and videos for learning that differ from expectations of films watched for entertainment. Educational films may activate schemata that make them search for important information that is to be remembered (as we saw in Chapter 5). However, teachers may select non-educational films in the hope to activate different kinds of schemata to reach aims that differ from knowledge transfer, such as raising interest. In other words, teachers' aims

with the use of a specific film or video may differ from what their pupils expect and thus get out of watching it (as we saw in Chapter 2), due to diverging expectations.

This brings us to the third and final question: *Are the pupils' expectancies properly managed?* In our final study, teachers were instructed not to introduce the video, other than naming its topic, because this can be expected to interfere with the way pupils view the video – for reasons just discussed. By measuring how pupils rated challenge and coping potential appraisals formulated in terms of educational psychology and film studies, we saw that pupils with higher general interest in the video also rated the filmic appraisals higher than the educational appraisals, and higher than pupils with a lower general interest (Chapter 5). In other words: The aim of raising interest in the video was fulfilled better with pupils who took on more, say, filmic schemata instead of educational ones. It seems obvious that the teacher can play an important role in directing pupils' views and expectations. Future research could inform teachers on how pupils' expectations can be managed to optimize their use of film and video for raising interest.

Final Thought

Returning to how I started the introduction of this thesis, what makes good education and good educational research are discussions with no end, and studying these questions are learning paths in themselves. A leading motive in this research project was to bring to light the unseen potential of film for learning, and to introduce a film studies perspective in the discourse on educational use of video. New perspectives open up new possibilities to improve current practices of education and research with joint forces. I hope my interdisciplinary approach will lead to further integration of the multiple perspectives involved in this discourse.

The second motive was to guide educational professionals in using film and video for raising pupils' interest. Learning is not limited to knowing facts. If we continue to use film and video only as means to disseminate knowledge, and we dismiss it of the potential to raise interest, we lose a powerful tool, an emotion machine – an engine for learning.

At the end of this thesis, I would like to leave you with a thought, a dedication if you will: Education does not stop after graduation, we are all eager to engage ourselves with things that catch our interest. I invite you, every now and then, to sit yourself down with a film. Allow it to shake your mind, to carry you away, and to explore the world from a different perspective.

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Video Links

Lieke and the drum	https://www.youtube.com/watch?v=SQr_mWkac1Q
Dr Quantum - Double slit experiment	https://www.youtube.com/watch?v=fwXQjRBLwsQ
Het Klokhuis: Figure it out! Earth	http://www.hetklokhuis.nl/tv-uitzending/2484/Zoek%20Het%20Uit%21%20Aarde%20
Heart rhythm dance	https://youtu.be/EqUfgffJx_8
NOAA ocean acidification - The other carbon dioxide problem	https://www.youtube.com/watch?v=MgdlAt4CR-4
Chemistry at work	Not available online
Ted Edu: Why do honeybees love hexagons?	https://www.youtube.com/watch?v=QEzlsjAqADA
Antifungal drugs: Mayor types and functions	https://www.youtube.com/watch?v=Iez8H9y5yAk
ß-Lactams: Mechanisms of action and resistance	https://www.youtube.com/watch?v=qBdYnRhdWcQ
Het Klokhuis: Molecular cooking	https://www.youtube.com/watch?v=S8S_F4clWVQ
Ted talk: Religions and babies, by Hans Rosling	https://youtu.be/ezVk1ahRF78
Welcome at the world heritage site of the Wadden Sea	https://www.youtube.com/watch?v=S5sQK61Rr0Q
How mussel banks shape the landscape of the Wadden Sea	https://www.youtube.com/watch?v=9EWkxiycA0A
The inner life of the cell	https://youtu.be/wJyUtbn0O5Y
Bubble boy trailer	https://youtu.be/jSRU48wCphI
Ehrlich's magic bullet – selective staining	https://youtu.be/iRxNxrfxnjc
What is nanotechnology?	https://youtu.be/DAOFpgocfrg

The Brachistochrone	https://youtu.be/skvnj67YGmw

Summary

Video is increasingly being used in education. The outbreak of the 2020 COVID pandemic strengthened this trend. In a digitizing world in which open online education and forms of blended learning are common practice, video offers interesting opportunities. Perspectives from technology, pedagogy, and educational sciences dominate how we look at video in educational contexts: a digital document of a recorded instruction, which can be preserved in time, shared online, and replayed at any moment, anywhere. Deploying these characteristics of video, the medium optimizes methods for self-paced, online, and differentiated learning that are of great value to learning in the 21st century. But video is more than an audiovisual technology for knowledge dissemination.

From the perspective of film studies, video is a filmic medium that communicates in film language, with its own ways to guide, activate and surprise viewers, and to make them anticipate. Film activates and motivates, and this makes it a powerful tool to evoke emotions, such as interest. Interest considered as an emotion triggers action tendencies and motivates further engagement. It is an important engine for learning. Pupils who engage in educational topics with interest learn more, knowledge is processed more deeply, and they experience more enjoyment while learning. In the Netherlands and abroad, interesting pupils in science and mathematics contents is a difficult task, and it seems that film and video could make a difference.

However unfortunately, the perspective of film studies is close to absent in educational practice and research. This thesis is an attempt to introduce the film studies perspective in both domains, to approach the topic of video in educational contexts from an interdisciplinary perspective. This approach is preferable, because such a perspective does more justice to the broad potential of film and video for learning. The focus is on pupils' interest development for science and mathematics education with video.

Motives and Aims

Two motives formed the starting point for this research project. The first was to offer guidance for educational professionals to optimize video as a tool for raising pupils' interest. The second was to make the unheard voice of film studies relevant in the scientific discourse on video in education. These motives led to four research aims that were addressed in the four consecutive studies presented in this thesis:

1. *Generating insight into the video usage in education and for what aims teachers use video;*
2. *Integrating film theory with theories from educational research in a framework on educational use of video for raising pupils' interest;*

3. *Applying this integrated theoretical framework to videos used in educational practice, to test its empirical validity;*
4. *Offering worked examples of what works well and what does not when using film and video for raising interest, to guide teachers.*

In this thesis, *film* is used as a theoretical concept as referred to in film studies, and *video* is used as the carrier of the audiovisual content. Film is only used as a concrete carrier of audiovisual material when it refers to a feature length film, such as a fiction film or documentary – the kinds we watch in film theatres and cinemas.

Overview of the Chapters and Studies

The study in **Chapter 2** is an explorative study to describe how teachers use videos in secondary science and mathematics education. Starting the research project with an open mind offered the opportunity to explore rather than imply and infer the strategy of teachers when using video. Getting to know the topic within the intended context could then reveal unforeseen factors involved, and offer grounds for the exact focus of the studies that were yet to follow. The research question leading this study was: *Which video characteristics can be expected to help achieve which teacher aims?*

In this study, we interviewed seven teachers about their aims, we analyzed 13 videos on structure and style, and we used pupil questionnaires to inquire to what extent the video perception of 233 pupils (aged 13–18 years) matched the teachers' aims. We combined the data to perform case studies and a cross-case analysis.

With regard to the teacher aims, we found aims that matched the categories as defined by Schwartz and Hartman (2007), of which each contains two sub-aims: Doing aims (attitude and skills), Engaging aims (contextualize and interest), Saying aims (explanations and facts), and Seeing aims (discernment and familiarity). The aims found mostly with the teachers in our study were Saying and Engaging aims. Moreover, we found that many teachers used videos without an explicitly formulated aim, or with mixed multiple aims.

With regard to the video characteristics, we found that they matched the film types as defined by McCluskey (1947): Discursive, Evidential or Factual as mutually exclusive film types, and Emulative, Incentive, Narrative, and Problematic as inclusive film types that can simultaneously apply to a single video (see Chapter 2, Table 2.2). Each video was categorized as either of the exclusive film types depending on the amount of information presented, and one or more inclusive film types depending on how that information was presented. The film types found most with the videos in our study were Discursive and Problematic.

With regard to the pupils' perceptions of the videos, we found that videos used for Saying aims were perceived by the pupils as most effective for that aim. After seeing these videos, pupils reported to feel more knowledgeable about the topic of the video. In this study, it was not examined whether the knowledge levels of the pupils did in fact increase. Videos used for Engaging aims were perceived as least effective. After seeing these videos, pupils often reported to have gained interest in the topic, but only a little.

In our case studies and cross-case analysis, we found that pupils perceived Problematic videos as most effective for Engaging aims if the videos posed genuine questions that served to lead the direction of the video. Discursive videos were perceived to be most effective for Saying aims if the information was presented by an authoritative speaker.

The study resulted in presumed connections between teacher aims and film types (see Chapter 2, Figure 2.4), and an assisting framework for educational professionals to select or make videos that match their aims (see Chapter 2, Figure 2.3). The outcomes of this exploratory study showed that teachers found raising interest (Engaging aim) an important aim, which they believed can be reached with video, but it failed to achieve. The outcomes underlined the relevance of researching how video can help reach the aim of raising pupils' interest, and strengthened our inclination to do so.

Chapter 3 describes a theoretical study that was set up to develop an integrative model of interest theories from educational psychology and film studies that consider interest as an emotion. Emotions are states that refer to a relationship between a subject (in our study the pupil-viewer) and an object (a video used in an educational context). The relationship evolves as a result of the subject's evaluations of the object, referred to as appraisals. In turn, a specific readiness emerges with the subject to take action, a motivation to act. This conceptualization of interest involves two core mechanisms: First, the subject's appraisals of the object lead to interest, and second, interest is expressed with the subject as an urge to act.

In educational psychology, pupils' appraisals of learning materials that have been found to raise interest (the first core mechanism) are appraisals of novelty–complexity and anticipated comprehension. It is assumed that interest relationships evolve when pupils experience a certain balance between the novelty or complexity of the material, and their anticipated potential to cope with that novelty or complexity. When an interest relationship is established, pupils are motivated to engage with the educational material by spending effort on and attention to it (the second core mechanism).

In film studies, viewers' evaluations of films and videos that have found to raise interest (first core mechanism) are appraisals of complex developments and anticipated rewarding closure. Similar to how interest relationships are described in educational psychology, for an interest relationship to evolve, viewers need to feel confident to be able to cope with the complex developments they are presented with. When an interest relationship is established, viewers are motivated to spend effort and attention on anticipation and hypothesis generation and testing (second core mechanism).

We integrated these two perspectives into the model of Film's Interest Raising Mechanisms (FIRM model; see Chapter 3, Figure 3.3). The model describes the balance between challenge appraisals (novelty–complexity and complex developments) and coping potential appraisals (anticipated comprehension and anticipated rewarding closure) as a precondition for interest relationships. We described the action readiness that results from interest in film and video as the readiness to invest effort and attention in the videos and the educational content. Table 3.1 in Chapter 3 presents how challenge, coping potential and action readiness are substantiated in the four film categories Narrative, Associational, Categorical, and Rhetorical film.

With our model, we proposed two claims on what makes videos suitable for raising pupils' interest. The first claim is that the video should deliver on promise, meaning that all challenges posed in the video should come to a satisfactory closure at some point. The second claim is that interestingness should increase across the video, meaning that the (first) challenge should be introduced early in the video and that its resolution should be presented piecemeal over the course of the video. The general assumption lying at the basis of these claims is that the challenge and coping potential represented in the video should be nontrivial, while challenges

that are not perceived as worth the effort are not interesting even if optimally balanced over the course of the video. Additionally, we presented a method for assessing a video's interestingness in educational contexts, to make the FIRM model operational for video analysis. It follows from our model that pupils' appraisals of a video are predictive for their interest in the video, and that their interest in the video is predictive for their interest in – and readiness to further engage with – the educational content.

In **Chapter 4**, we report a quantitative empirical study to assess the validity of the core mechanisms of the FIRM model. To achieve this goal, we set up and tested three hypotheses:

1. *Pupils' appraisals of a video's characteristics predict the pupils' interest in the video;*
2. *Pupils' interest in the video predicts the development of pupils' interest in the educational content of the video;*
3. *Pupils' appraisals of a video's characteristics predict the pupils' development of interest in the educational content of the video indirectly via their interest in the video.*

In our hypotheses, we included *development of interest in the educational content* as a measure for pupils' readiness to further engage with the educational content. To investigate if the concept referred to as immersion, transportation, or absorption, which is central to game theory, could further enrich the FIRM model, we included the appraisal of Absorption, adding up to a total of five appraisals.

We evaluated the use of four videos in six 12th-grade science and mathematics classrooms (one video per classroom), with a total of 151 pupils. We used pre- and post-viewing questionnaires prior to and directly after watching the videos to measure the pupils' ratings for the five appraisals, their interest in the video, and the development of their interest in the educational content. In the analysis we set up a Structural Equation Model (SEM) for path-modelling.

Our findings confirmed all three hypotheses, indicating that pupils' appraisals predict their interest in the video, and that their interest in the video predicts their interest in the educational content. These findings validate the mechanisms described in the FIRM model. The added appraisal of Absorption was also found to be a significant indicator for interest.

In the final study described in **Chapter 5**, we performed a qualitative empirical study to explain, and so to better understand, the mechanisms that underlie the FIRM model. We aimed to identify concrete examples of video characteristics in terms of pupils' appraisals that are responsible for pupils' interest development while watching. Furthermore, we aimed to find possible explanations for why these appraisals have a positive or negative effect on pupils' general interest in the video. The research question leading this study was: *How do pupils' appraisals of video characteristics relate to their interest and to the development of their interest in the video?*

We evaluated the use of five videos in seven 12th-grade science and mathematics classrooms (one video per classroom), with a total of 177 pupils. We used pre- and post-viewing questionnaires prior to and directly after watching the videos to measure the pupils' general interest in the video, and their ratings for the five appraisals. We also measured the development of their interest in the video over the course of watching it with their ratings of the subsequent scenes in the video, and we asked them to elaborate on that development. We performed video analysis, case studies and cross-case analysis.

Our findings resulted in relationships between appraisals and interest that we clustered in three themes. The first theme is *the predictive power of appraisals*. This theme covers the essential match between pupils' cognitive levels and the video's level of complexity (either with respect to the content or the video's structure). If there is no match due to too big a difference between these levels, pupils will appraise the video negatively and describe it as either too complex or as boring. The challenge is evaluated as too high, the coping ability too low or vice versa.

The second theme is *the role of video categories*. It covers the expressions pupils used to explain their interest development. With few exceptions, pupils' reports matched the challenge and coping potential appraisals we proposed for the four video categories (see Chapter 5, Table 5.1). This indicates that analyzing videos on the basis of the video category is a fruitful approach.

The third theme is *differences between pupils*. It covers the expectations pupils might form based on the video categories. The pupils in our study showed more interest in videos that are typically associated with learning (categorical and rhetorical videos), because these present a lot of information. However, we also saw that pupils who allowed alternative videos (narrative and associational videos) to lead them away from knowledge and comprehension and towards experience and fascination, became more interested in the video.

These findings inspired us to formulate a fourth theme as a recommendation for future research and educational practice: *The role of the teacher*. Preparing the pupils for the type of video (video category) that they are about to watch might make them more receptive for filmic video characteristics that support experience, narration, and free association. This might lead pupils who tend to focus on typical educational characteristics such as knowledge that is to be remembered to better appreciate the filmic characteristics with a possible positive effect on their interest development.

Together with the themes, the validated FIRM model can inform the formulation of guidelines for effective and intentional use of film and video for learning. Future research and application in educational practice is needed to concretize. **Chapter 6** offers three guiding questions: Does the complexity level of the video match the pupils' knowledge level? Does the video allow the pupils to form balanced challenge and coping potential appraisals throughout the video? And are the pupils' expectancies properly managed?

In Closing

The first motive for this research project was to bring to light the unseen potential of film and video for interest in learning contexts, by introducing a film studies perspective in research on the educational use of film and video. If realized, this would help to fulfil the second motive, to guide educational professionals in the use of film and video for interest development. These motives asked for an interdisciplinary approach that would bring together and connect film theory and educational theory. Interdisciplinarity as an approach to complex topics is gaining popularity in policy, practice and research. An approach that includes multiple domains does justice to the complexity and multi-disciplinarity of real-world phenomena. The exchange of knowledge and ideas across domain borders extends the scope of research output and accelerates scientific progress. This thesis shows why the use of film and video in education is such a topic that benefits from an interdisciplinary approach.

Samenvatting

Video wordt in toenemende mate gebruikt in het onderwijs. De COVID-pandemie van 2020 heeft deze trend versterkt. In de digitaliserende wereld waarin open online onderwijs en vormen van *blended learning* niet meer zijn weg te denken, biedt video interessante mogelijkheden. Perspectieven vanuit technologie, didactiek en onderwijswetenschappen domineren het beeld van de onderwijsvideo: video als digitaal document om kennis te registreren, te bewaren en te delen, dat overal en op elk moment kan worden (her)bekeken. Door deze eigenschappen van het medium te benutten kan zelf-gereguleerd en gedifferentieerd leren worden gefaciliteerd, evenals afstandsonderwijs – wat van grote waarde is voor leren in de 21ste eeuw. Maar video is meer dan een audiovisuele technologie voor kennis disseminatie.

Vanuit het perspectief van filmstudies is video een filmisch medium dat communiceert in filmtaal, met eigen manieren om kijkers te sturen, te doen anticiperen en te verrassen. Film activeert en motiveert en is daarmee een uiterst krachtige taal die de emoties aanspreekt, zoals interesse. Interesse beschouwd als emotie lokt actietendensen uit en motiveert tot verdere betrokkenheid. Het is een belangrijke motor voor leren. Leerlingen en studenten die zich met interesse verdiepen in een onderwerp leren meer, nieuwe kennis wordt dieper verwerkt en zij ervaren meer plezier in het leren. In Nederland en daarbuiten blijkt het een grote uitdaging te zijn om leerlingen te interesseren voor wiskunde en natuurwetenschappen, en het is te verwachten dat film en video daarin een verschil kunnen maken.

Helaas is dit perspectief van filmstudies in de onderwijspraktijk en -onderzoek vrijwel onbekend. Dit proefschrift is een poging om dit te doorbreken door filmtheorie in deze domeinen te introduceren, en zo video in het onderwijs vanuit een interdisciplinair perspectief te benutten. Dit is wenselijk omdat zo'n perspectief meer recht doet aan de brede potentie van film en video voor leren. De focus in dit proefschrift ligt op de ontwikkeling van de interesse van leerlingen voor wiskunde en natuurwetenschappelijk onderwijs met video.

Motieven en Doelen

Aan dit onderzoeksproject lagen twee motieven ten grondslag. Het eerste motief is om onderwijsprofessionals handvatten te bieden om film en video te gebruiken voor interesseontwikkeling bij leerlingen. Het tweede is om het perspectief van filmstudies te integreren in het wetenschappelijke debat over film en video in het onderwijs. Hieruit vloeiden vier doelen voort, die zijn geadresseerd in de vier opeenvolgende studies die in dit proefschrift worden gepresenteerd:

1. *Inzicht krijgen in videogebruik in het onderwijs en voor welke doelen docenten video inzetten;*

2. *Interessetheorieën uit filmstudies en onderwijspsychologie met elkaar verbinden in een integratief model dat beschrijft hoe film de interesse van leerlingen kan wekken;*
3. *Dit model toepassen op video's die in het onderwijs gebruikt worden, om zo de empirische validiteit van het model te toetsen;*
4. *Uitgewerkte voorbeelden genereren van hoe de kernmechanismen in het model functioneren, als basis voor het formuleren van handvatten voor onderwijsprofessionals om film en video in te zetten voor interesseontwikkeling.*

In dit proefschrift wordt de term *film* gebruikt voor het theoretische concept zoals daaraan gerefereerd wordt in film studies, en *video* voor de concrete drager van het audiovisuele materiaal. Film wordt alleen als concrete drager gebruikt wanneer het verwijst naar een film zoals we die kennen uit het filmhuis en de bioscoop.

Overzicht van de Hoofdstukken en Studies

De studie in **Hoofdstuk 2** was een exploratieve studie om te beschrijven hoe docenten video's gebruiken in het voortgezet wiskunde en natuurwetenschappelijk onderwijs in Nederland. Deze open benadering bood ons de mogelijkheid om de werkwijze van leraren bij het gebruik van video te verkennen en te duiden. Deze verkenning vormde het uitgangspunt voor de focus en het ontwerp van de vervolgstudies. De onderzoeksvraag die in deze studie centraal stond, was: *Van welke video-eigenschappen kan worden verwacht dat zij bijdragen aan het verwezenlijken van welke docentdoelen?*

In deze studie zijn zeven docenten wiskunde en natuurwetenschappen geïnterviewd over hun doelen bij het gebruik van video in hun onderwijs. Er zijn 13 video's geanalyseerd op structuur en stijl en er participeerden 233 vwo-leerlingen in het onderzoek, in de leeftijd van 13 tot 18 jaar. We gebruikten leerling-vragenlijsten om te evalueren in welke mate de door de docenten beoogde doelen ook bereikt werden volgens de leerlingen. De verzamelde data hebben we gecombineerd in case studies per gebruikte video en in een cross-case analyse.

Met betrekking tot de docentdoelen vonden we doelen die aansloten bij de categorisering van Schwartz en Hartman (2007). Zij benoemen vier kerndoelen met elk twee subdoelen, zijnde: Leren doen (kan bepaald gedrag vertonen, kan bepaalde handelingen uitvoeren), Geëngageerd raken (kan theorie contextualiseren, heeft interesse ontwikkeld voor het onderwerp), Leren zeggen (kan iets uitleggen, kan feiten reproduceren) en Leren zien (kan iets ontwaren, kan iets herkennen) (zie Hoofdstuk 2, Tabel 2.1). De doelen die we het meest aantroffen bij de docenten in onze studie waren Leren zeggen en Geëngageerd raken. Daarnaast zagen we dat veel docenten video gebruikten zonder een specifiek doel, of voor meerdere doelen tegelijk.

Met betrekking tot de video-eigenschappen vonden we eigenschappen die aansloten bij de categorisering van McCluskey (1947). Hij beschrijft drie exclusieve (elkaar uitsluitende) filmtypen die weergeven hoeveel informatie er gepresenteerd wordt, zijnde Discursief (veel informatie aanvullend op het beeld), Evident (beperkte aanvullende informatie) of Feitelijk (geen aanvullende informatie). Daarnaast beschrijft hij enkele filmtypen die inclusief worden genoemd omdat een enkele film of video er meerdere kan bevatten. Vier daarvan troffen wij aan bij de video's in onze studie, zijnde Emulatief (imitatief), Overtuigend (argumentatief), Narratief (verhalend) en Problematiserend (probleem stellend) (zie Hoofdstuk 2, Tabel 2.2). De filmtypen die we het vaakst aantroffen waren Discursief en Problematiserend.

Met betrekking tot de leerlingevaluaties zagen we dat volgens de leerlingen de video's die gebruikt werden voor Leren zeggen-doelen het effectiefst waren. Na het zien van deze video's voelden de leerlingen zich goed geïnformeerd. In de studie is niet onderzocht of hun kennisniveau ook daadwerkelijk was toegenomen. Video's die gebruikt werden voor Geëngageerd raken-doelen waren volgens de leerlingen het minst effectief. Na het zien van deze video's rapporteerden de leerlingen dat zij wel iets meer interesse voor het onderwerp hadden, maar slechts een klein beetje.

In de case studies en de cross-case analyse vonden we dat de Problematische video's door de leerlingen het meest effectief werden gevonden voor Geëngageerd raken-doelen, maar alleen wanneer in de video's oprechte vragen werden opgeworpen die richtinggevend waren voor het verloop van de video. Discursieve video's werden het meest effectief gevonden voor Leren zeggen-doelen, maar alleen wanneer informatie in de video's werd gepresenteerd door een gezaghebbende spreker.

Deze studie resulteerde in veronderstelde verbanden tussen docentdoelen en filmtypen (zie Hoofdstuk 2, Figuur 2.4), en een ondersteunend kader voor onderwijsprofessionals om video's te selecteren of te maken die passen bij hun doelen (zie Hoofdstuk 2, Figuur 2.3). Verder bleek dat de docenten het wekken van interesse een belangrijk doel vonden dat volgens hen met video kan worden bereikt, maar waarvan de inzet volgens de leerlingen niet erg succesvol was. De resultaten onderstrepen het belang en de relevantie van onderzoek naar hoe video de interesse van leerlingen kan wekken.

Hoofdstuk 3 beschrijft een theoretische studie die was opgezet om een integratief model te ontwikkelen van interessetheorieën uit filmstudies en de onderwijspsychologie waarin interesse wordt beschouwd als een emotie. Emoties refereren aan een relatie tussen en subject (in onze studie leerling-kijkers) en een object (in onze studie een video die in een leercontext wordt gebruikt). De relatie ontstaat als gevolg van de beoordeling van het object door het subject, een zogenaamde *appraisal*. Hieruit ontstaat een actietendens bij het subject, een motivatie om te handelen. Deze conceptualisatie van interesse behelst twee kernmechanismen: Ten eerste, de beoordeling leidt mogelijk tot interesse en ten tweede, de gewekte interesse wordt geuit als een actietendens.

Uit onderwijsonderzoek blijkt dat leerlingen, die leermaterialen en -activiteiten interessant vinden, deze positief beoordelen omdat het nieuw of complex is, en waarvan zij verwachten dat zij die complexiteit kunnen bevatten (eerste kernmechanisme). Aangenomen wordt dat interesse ontstaat wanneer leerlingen een zeker evenwicht ervaren tussen de nieuwigheid en complexiteit van het materiaal of de activiteit enerzijds, en hun mogelijkheid om daar mee om te gaan anderzijds. Als een interesserelatie tot stand komt, raken leerlingen gemotiveerd om met het materiaal of de activiteit aan de slag te gaan en er moeite en aandacht aan te besteden (tweede kernmechanisme).

Uit filmonderzoek blijkt dat kijkers die films interessant vinden deze positief beoordelen om de complexe ontwikkelingen en de verwachte afwikkeling en uitkomst daarvan (eerste kernmechanisme). Vergelijkbaar met hoe het ontstaan van een interesserelatie wordt beschreven in onderwijspsychologie, moeten kijkers het gevoel hebben dat zij in staat zijn om met de complexiteit van de ontwikkelingen in de film om te gaan om geïnteresseerd te raken. Als een interesserelatie ontstaat zijn kijkers gemotiveerd om moeite en aandacht te besteden aan

anticipatie van verdere ontwikkelingen en het genereren en testen van hypothesen (tweede kernmechanisme).

We hebben de interessetheorieën van onderwijspsychologie en filmstudies geïntegreerd in een model, genaamd Film's Interest Raising Mechanisms (film's interesse wekkende mechanismen; FIRM model; zie Hoofdstuk 3, Figuur 3.2). Het model beschrijft de balans tussen beoordelingen van *uitdaging* (nieuw en complex, en complexe ontwikkelingen) en van *verwacht begrip* (verwachting het te kunnen bevatten, en verwachte afwikkeling en uitkomst) als voorwaarde voor het ontstaan van een interesserelatie. We beschreven de actietendens die voortkomt uit interesse die gewekt wordt door een film of video, als de bereidheid om moeite en aandacht te besteden aan de video en de educatieve inhoud ervan. We presenteerden daarbij welke vormen uitdaging en verwacht begrip aannemen in de vier filmcategorieën die worden beschreven door Bordwell, Thompson en Smith (2017), zijnde Narratieve, Associatieve, Categorische en Retorische film (zie Hoofdstuk 3, Tabel 3.1).

Met het FIRM model presenteerden we twee claims over video's die geschikt zijn om de interesse van leerlingen te wekken. De eerste claim is dat de video gemaakte beloften moet inlossen. Dit betekent dat alle uitdagingen die in de video worden opgeworpen, op een zeker moment in de video tot een bevredigende afwikkeling of uitkomst moeten leiden. De tweede claim is dat de mate waarin een video interessant is, over het verloop van de video moet toenemen. Dit betekent dat de (eerste) uitdaging al vroeg in de video wordt geïntroduceerd en dat de afwikkeling of uitkomst ervan stukje bij beetje wordt gepresenteerd. De algemene aanname die aan deze twee claims ten grondslag ligt is dat de uitdaging en het verwachte begrip niet triviaal zijn, omdat uitdagingen die niet de moeite waard worden geacht niet interessant worden gevonden, ook niet als ze optimaal in balans zijn met het verwachte begrip. Daarnaast presenteerden we een methode om video's in leercontexten te beoordelen, door het FIRM-model operationeel te maken voor videoanalyse. Uit ons model volgen twee kernmechanismen: Ten eerste, dat de video-beoordelingen van leerlingen voorspellend zijn voor hun interesse in de video en ten tweede, dat de interesse van leerlingen in de video voorspellend is voor hun interesse in de educatieve inhoud – en hun bereidheid om zich daar verder in te verdiepen.

Hoofdstuk 4 beschrijft een kwantitatieve empirische studie die we hebben uitgevoerd om de validiteit van de kernmechanismen van het FIRM-model te toetsen. Hiertoe hebben we drie hypothesen opgesteld en getest (zie Hoofdstuk 4, Figuur 4.2):

1. *Leerling-beoordelingen van video-eigenschappen voorspellen hun interesse in de video;*
2. *De interesse van leerlingen in een video voorspelt de ontwikkeling van de interesse van leerlingen in de educatieve inhoud van de video;*
3. *Leerling-beoordelingen van video-eigenschappen voorspellen de ontwikkeling van de interesse van leerlingen in de educatieve inhoud van de video, via hun interesse in de video.*

In onze hypothesen hebben we de ontwikkeling van de interesse van leerlingen in de educatieve inhoud als maat genomen voor de bereidheid van leerlingen om met die inhoud aan de slag te gaan (actietendens). Om te onderzoeken of het concept immersie, transportatie, of absorptie, wat centraal staat in game theorie, het FIRM-model verder zou kunnen verrijken, hebben we Absorptie als *appraisal* eraan toegevoegd. Het totaal aantal *appraisals* in onze studie kwam daarmee op vijf.

In deze studie hebben we het gebruik van vier video's geëvalueerd in zes vwo-6 klassen voor wiskunde en natuurwetenschappelijk onderwijs (één video per klas), met een totaal van 151

leerlingen. We gebruikten pre- en post-video vragenlijsten voorafgaand aan en direct na het kijken van de video's. We gebruikten items voor het meten van de leerling-beoordelingen van de vijf *appraisals*, de algemene interesse van leerlingen in de video en de ontwikkeling van hun interesse in de educatieve inhoud. In de analyse hebben we een *Structural Equation Model* (SEM) gebruikt voor een pad-analyse.

De uitkomsten van de studie hebben alle drie de hypothesen bevestigd. De leerling-beoordelingen bleken hun interesse in de video te voorspellen, en hun interesse in de video bleek voorspellend voor de ontwikkeling van hun interesse in de educatieve inhoud. Deze bevindingen hebben de kernmechanismen in het FIRM-model gevalideerd. De toegevoegde *appraisal* absorptie bleek eveneens een significante indicator voor interesse.

In de laatste studie, beschreven in **Hoofdstuk 5**, hebben we een kwalitatieve empirische studie uitgevoerd om een beter begrip te krijgen van de kernmechanismen in het FIRM-model en om deze te kunnen verklaren. We zochten naar concrete voorbeelden van video-eigenschappen in termen van leerling-beoordelingen, die verantwoordelijk waren voor hun interesseontwikkeling tijdens het kijken. We zochten ook naar verklaringen voor het positieve of negatieve effect van deze eigenschappen op hun interesseontwikkeling. De onderzoeksvraag die in deze studie centraal stond was: *Hoe zijn leerling-beoordelingen van video-eigenschapen gerelateerd aan (de ontwikkeling van) hun interesse in de video?*

We hebben het videogebruik van vijf video's geëvalueerd in zeven vwo-6 klassen voor wiskunde en natuurwetenschappelijk onderwijs (één video per klas), met een totaal van 177 leerlingen. We gebruikten pre- en post-video vragenlijsten voorafgaand aan en direct na het kijken van de video's. We gebruikten items voor het meten van de leerling-beoordelingen van de vier *appraisals* in het FIRM-model en voor de algemene interesse van leerlingen in de video. We hebben ook de ontwikkeling van de interesse van leerlingen tijdens het kijken gemeten, door de leerlingen de opeenvolgende scènes in de video te laten beoordelen en ze hierop te laten reflecteren. We voerden video-analyses uit, case studies en een cross-case analyse.

Deze studie resulteerde in relaties tussen *appraisals* en interesse die we hebben geclusterd in drie overkoepelende thema's. Het eerste thema is *de voorspellende waarde van appraisals*. Dit thema gaat over de essentiële match tussen het kennisniveau van de leerlingen, en de complexiteit van de video (zowel ten aanzien van de educatieve inhoud, als de complexiteit van de structuur van de video). Als er geen match is door een te groot verschil tussen deze beide levels, zullen leerlingen de video-eigenschappen negatief beoordelen en de video te moeilijk of juist saai vinden. De uitdaging wordt als te groot beschouwd en het verwachte begrip te laag, of andersom.

Het tweede thema is *de rol van videocategorieën*. Het gaat over de manier waarop leerlingen hun interesseontwikkeling uitlegden. Vrijwel zonder uitzondering kwamen de termen die leerlingen gebruikten overeen met de typen uitdaging en verwacht begrip die we voorstelden bij de verschillende videocategorieën (zie Hoofdstuk 3, Tabel 3.1). Deze bevindingen geven aan dat videoanalyse op basis van de videocategorieën een vruchtbare benadering lijkt te zijn.

Het derde thema is *verschillen tussen leerlingen*. Het gaat over de verwachtingen die leerlingen kunnen hebben, gebaseerd op de videocategorieën. De leerlingen in onze studie hadden meer interesse in video's die doorgaans met onderwijs worden geassocieerd (categorische en retorische video's), omdat daarin veel informatie wordt gepresenteerd. Tegelijkertijd zagen we ook dat leerlingen die zich openstelden voor alternatieve video's

(narratieve en associatieve video's) waarin de nadruk niet ligt op kennis en begrip maar op ervaring en fascinatie, meer interesse rapporteerden in deze andersoortige video's.

Deze bevindingen inspireerde ons om een vierde thema te formuleren, als aanbeveling voor het onderwijs en toekomstig onderzoek: *De rol van de docent*. Door leerlingen goed voor te bereiden op de video (videocategorie) die zij gaan bekijken, zullen zij mogelijk meer open staan voor alternatieve videovormen en hen ontvankelijker maken voor meer filmische video-eigenschappen die ervaring, narratieve ontwikkeling en vrije associatie ondersteunen. Dit kan ervoor zorgen dat leerlingen die vooral gefocust zijn op typische educatieve video-eigenschappen die nieuwe kennis opleveren, ook de meer filmische eigenschappen beter gaan waarderen wat mogelijk een gunstig effect heeft op hun interesseontwikkeling.

Samen met deze thema's kan het FIRM-model een basis zijn voor het formuleren van richtlijnen en handvatten voor doelgericht en effectief gebruik van film en video in het onderwijs. Vervolgonderzoek en toepassing in de onderwijspraktijk is nodig om dat concreet te maken. In **Hoofdstuk 6** wordt daartoe een drietal richtinggevende vragen geopperd: Is de complexiteit van de video passend voor het kennisniveau van de leerlingen? Stelt de video de leerlingen in staat om een balans te vinden tussen uitdaging en verwacht begrip over het geheel van de video? En zijn de verwachtingen van de leerlingen goed gemanaged?

Tot Slot

Het eerste motief om dit onderzoeksproject te starten was om het onderbelichte potentieel van film en video voor interesseontwikkeling in leercontexten zichtbaar te maken in het wetenschappelijke debat. Dat is in dit proefschrift gedaan door het perspectief van filmstudies op film en video in het onderwijs te introduceren en toe te passen. Als het slaagt draagt dat bij aan het verwezenlijken van het tweede motief, om onderwijsprofessionals handvatten te bieden voor het gebruik van film en video voor interesseontwikkeling. Deze twee motieven vroegen om een interdisciplinaire benadering die film- en onderwijstheorie bij elkaar zou brengen en verbinden. Interdisciplinariteit als benadering voor complexe onderwerpen wint aan populariteit in beleidvorming, praktijktoepassingen en onderzoek. Een benadering die diverse domeinen betrekt doet recht aan de complexiteit en multidisciplinariteit van onderwerpen die in de echte wereld leven. De uitwisseling van ideeën en kennis over de grenzen van kennisdomeinen heen, vergroot het bereik van onderzoeksresultaten en brengt de wetenschap verder. Dit proefschrift laat zien waarom het gebruik van film en video in het onderwijs zo'n onderwerp is dat gebaat is bij een interdisciplinaire benadering.

Curriculum Vitae

Winnifred Wijnker was born on May 9, 1981 in Wijk bij Duurstede, the Netherlands. She completed her secondary education (including natural science disciplines and mathematics) at the Montessori Lyceum Herman Jordan in Zeist. She finished in 1999 and then followed a language course in Salamanca, Spain.

When she returned, Winnifred studied Theatre, Film and Television Studies at Utrecht University, specializing in Film. She graduated with a study on the film style of the Spanish filmmaker Julio Medem. After obtaining her drs. degree, she continued with a master Philosophy of Film at the University of Amsterdam, graduating with a study on Deleuze and Dutch documentary films.

In 2009, Winnifred started working with the national public broadcasting company RVU (now NTR) as editor/producer of short educational videos on science and philosophy. In 2010, she started working as an employee of the Freudenthal Institute at Utrecht University, for various science education projects. This introduced her to perspectives on innovative science and mathematics education. She enrolled in teaching as a guest lecturer, teacher, and teacher trainer in various courses. Her main teaching experience resulted from the course she designed and taught in the Science Education and Communication master, titled Communicating Science with the Public (CSP). In this course students were challenged to design and make a short video for science education or communication purposes. In 2020 she received her teacher's degree (BKO).

In 2016, Winnifred received a grant from the Netherlands Initiative for Education Research (NRO, project number 405-16-511). This enabled the start of her PhD project at Utrecht University on the potential of film and video for secondary science and mathematics education for interest development. Over the course of the project she worked with scientists from various disciplines, such as the educational sciences, media studies, and mathematics, from Utrecht University, the University of Copenhagen, and the University of Münster. In addition to conducting her research project, Winnifred continued to teach.

In March 2021, Winnifred started as a postdoc researcher at the Science Communication group of Leiden University. Participating in an interdisciplinary research team studying misleading graphs, she continues doing research on the power of visuals and imaging for communicating and teaching science.