Explaining pupils' interest in videos for education: a multiple case study

Wijnker, W.; Bakker, A.; Drijvers, P.

Technology, Knowledge and Learning
https://doi.org/10.1007/s10758-023-09703-4

ORIGINAL RESEARCH

Explaining Pupils' Interest in Videos for Education: A Multiple Case Study

Winnifred Wijnker[1] · **Arthur Bakker**[2] · **Paul Drijvers**[2]

Accepted: 25 October 2023

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 qualitative 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 (N = 5), 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.

Keywords Education · Educational psychology · Film studies · Interest · Video

1 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 (Akkerman & Bakker, 2019; Dewey, 1913). But what makes educational material raise pupils' interest?

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 pandemic outbreak in 2020. In

✉ Winnifred Wijnker
w.wijnker@biology.leidenuniv.nl

[1] Science Communication and Society, Leiden University, Sylviusweg 72, 2333 BE Leiden, The Netherlands

[2] Freudenthal Institute, Utrecht University, Utrecht, The Netherlands

Published online: 29 November 2023

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). However, there are very few studies that link interest development to actual practices of video usage in order to describe how video can effectively contribute to learning processes (Hobbes, 2006; Sachistal, 2021; Savelsbergh et al., 2016; Schukajlow et al., 2017; Schwartz & Hartman, 2007; Thomson et al., 2014). A step towards guidelines for teaching professionals to make informed choices in the making, selection, and use of videos, is to apply theories on interest in learning to specific audio-visual 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., 2021b). The empirical data from our subsequent quantitative study confirmed the validity of this model (Wijnker et al., 2021a). 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?* Our findings offer links between video characteristics and pupils' appraisals that can serve as guidelines for professionals to make goal-oriented decisions when producing, selecting, and using 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.

1.1 Theoretical Framework

Interest is considered a knowledge 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 in 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. Some can take up much information while watching a video while others prefer learning

with texts. Although pupils' individual interests and 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).

Wijnker et al. (2021b) 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 Fig. 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

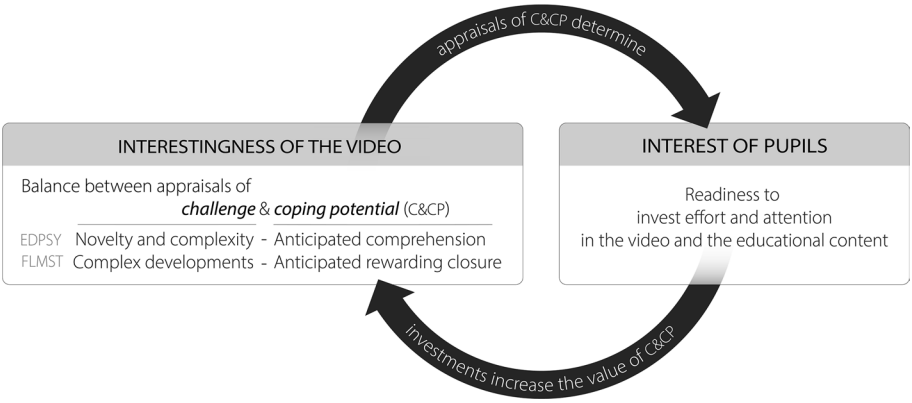


Fig. 1 Model of film's interest raising mechanisms (FIRM model) following Wijnker et al. (2021b). EDPSY = educational psychology; FLMST = film studies; C&CP = challenge and coping potential

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).

1.2 Two Linked Studies

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., 2021a). 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., 2021b). We used the 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 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 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.

2 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.

2.1 Participants

We aimed to include videos that would represent the broad scope of the science curriculum and, therefore, recruited science teachers with different science backgrounds. 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

Table 1 Interest components as substantiated in the film categories, following author (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

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

classes that consisted of 12th-grade pre-university pupils (aged 16–18). In total, 177 pupils participated of whom 55.4% were female. The pupils were all used to watching videos in the classroom occasionally.

2.2 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., 2021b). 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-min interview.

2.2.1 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 min long. This duration limit was applied to make a difference between complete film viewings that would take up the entire lesson and videos that are used as a short intervention to invite discussion afterwards, as these two relate to very different learning activities with different aims. In consultation with the teachers, the cut-off point was set to 12 min to minimize differences in the findings due to the time spent on watching, and to ensure that pupils would still be able to remember sections of longer videos (see Table 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 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	Categorical/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)

*Resulting from our film analysis

2.2.2 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 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 1 for the questionnaire for Video 1).

2.2.3 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-min 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.

Table 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

EDPSY, Educational psychology; FLMST, Film studies; C, Challenge; CP, Coping potential

Table 4 Steps in the data analysis

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

2.3 Analysis

We analyzed both the questionnaire data and the data from the interviews in parallel in two phases (see Table 4). We used the interview data as a verification for our findings.

2.3.1 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. (2021b) as presented in Table 1.

It is known 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. 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.

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.

In our further inquiry, we studied the complete set of pupils' reports within each case, and then diverged for the three levels of general interest in the video to see whether the pupils' reports revealed explanations for their diverging interest in the video. 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.

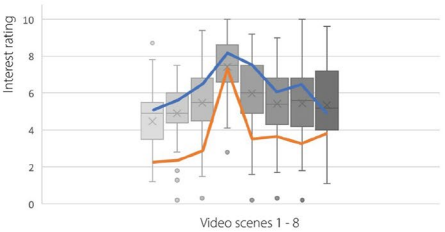
To find possible explanations for the findings from the boxplot analysis, we coded and analyzed the pupils' remarks in the open questions and interviews that could be related to these findings. The pupils' remarks were coded with the challenge (ch) and coping potential (cp) appraisals from the film categories Narrative (Narr), Associational (Ass), Categorical (Cat), and Rhetorical (Rhet) as presented in Table 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.

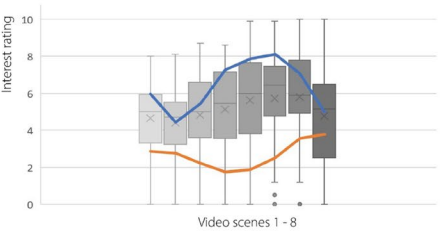
2.3.2 Phase 2: Cross-Case Analysis

After data analysis in the first phase of analysis, we connected our results to formulate generalizable outcomes in phase 2 (see Table 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.

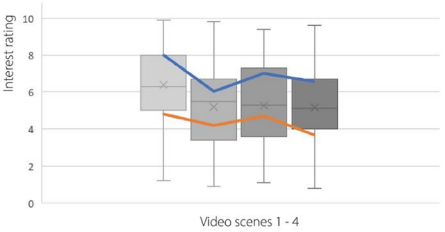
In the first round of the cross-case analysis, we generated conjectures with regard to the pupils' reports. These conjectures were derived directly from what the pupils reported on why their interest increased or decreased, and thus are formulated positively ("…made interest increase") or negatively ("…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."



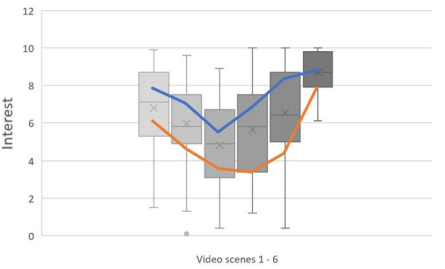
Video case 1: *The inner life of the cell.*



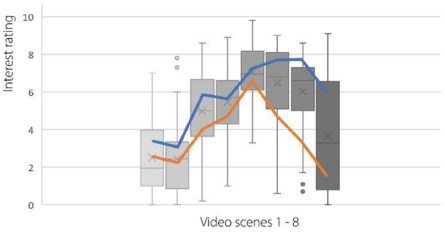
Video case 4: *What is nanotechnology?*



Video case 2: *Bubble boy trailer.*



Video case 5: *The Brachistochrone.*



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

Fig. 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

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

Table 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

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

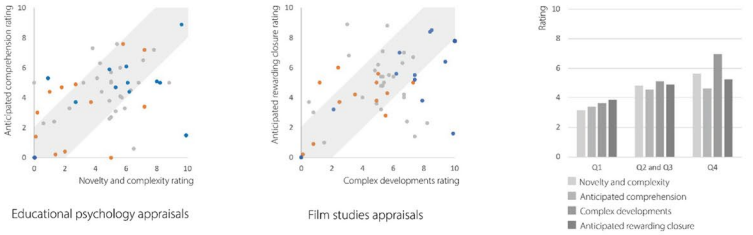
Fig. 3 Left and centre: Balance of pupils' rating of the two sets of model appraisals from educational psychology and film studies. Orange dots for ratings of the 25% of the pupils (Q1) with the lowest general interest in the video. Grey dots for the 50% of the pupils (Q2 and Q3) with a mediate general 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)

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.

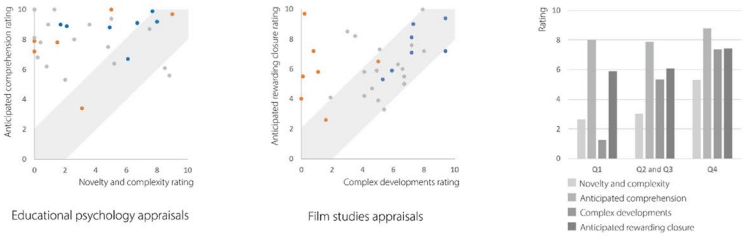
In the second round of the cross-case analysis, we formulated findings by looking for commonalities between the cases regarding the pupils' interest development based on their ratings of the video scenes (see Fig. 2), and the ratings of the appraisals (see Fig. 3 and Table 5). We searched for possible 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 Fig. 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 Fig. 3 and Table 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.

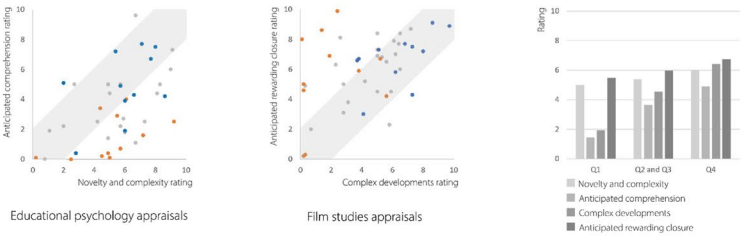
Finally, as in the first round, the findings were grouped based on similarities and reformulated into single findings that properly described all findings within that group. This resulted in a total of 12 findings in this round, and a total of 15 findings in the two rounds.



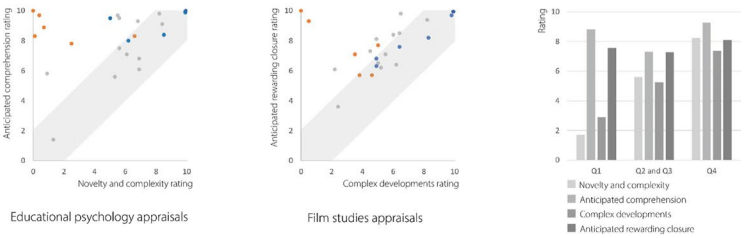
Video case 1: *The inner life of the cell*.



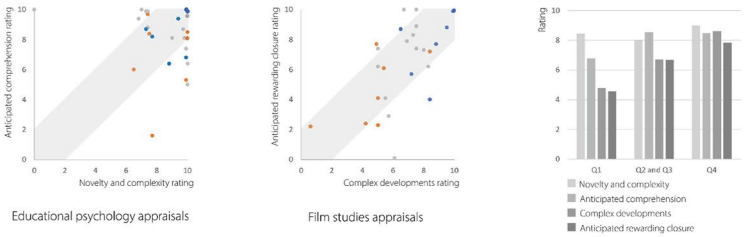
Video case 2: *Bubble boy trailer*.



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



Video case 4: *What is nanotechnology?*



Video case 5: *The Brachistochrone*.

3 Results

3.1 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 Fig. 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 Fig. 3). We found pupil reports that closely matched the C&CP appraisals that are related to the four film categories, as formulated in Table 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 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). Below we present the results from videos case 1. See Appendix for the detailed results from video cases 2 through 5.

3.1.1 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 Fig. 2, the average interest of the pupils for the ongoing video increased 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 Fig. 2) 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 what 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 Fig. 2). The average mean of the balanced appraisals was mediate for both sets (see Table 5). 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.

3.2 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 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 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.

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*.

3.2.1 The Predictive Power of Appraisals

Our previous quantitative study (Wijnker et al., 2021a) already proved that ratings of the appraisals are good predictors of pupils' general interest in the video. Finding 4 in this

Table 6 Findings

Theme 1. The predictive power of appraisals	
1.	Interest increased (or decreased) respectively with the presentation (or absence) of new knowledge or insights into the videos
2.	Interest increased (or decreased) respectively with the ability (or inability) of pupils to understand what was presented
3.	Interest increased (or decreased) respectively with the intensifying (or fading out) of complex developments
4.	High or low general interest in the video respectively coincided with higher or lower mean ratings of balanced appraisals
5.	High or low general interest in the video respectively coincided with a higher or lower average of interest in the scenes
6.	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	
7.	General interest in the video was rated highest for the categorical videos and lowest for the narrative videos
8.	For the Categorical videos, Q1 pupils' interest was highest for scenes that provided coping potential
9.	For the Categorical videos, the film study appraisal Complex developments was much lower for Q1 pupils than for Q4 pupils
100	For the Categorical/Rhetorical videos, Q1 pupils' interest developed negatively from the beginning towards the middle, and positively from the middle towards the end
11.	For the Categorical/Rhetorical videos, educational psychology appraisals were rated higher than film study appraisals
Theme 3. Differences between pupils	
12.	For the Narrative videos, the interest of Q1 pupils was highest when educational content knowledge was provided
13.	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
14.	For the Associational videos, pupils most appreciated the scene that presented the most complex/fascinating image
15.	For the Associational videos, Q4 pupils rated the challenge components much higher than the coping potential components

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 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).

3.2.2 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).

3.2.3 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 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.

4 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) a confirmation of what is theorized by Tan (1996) for fiction film viewing and in line with non-interest categories Disappointment (not novel or challenging enough) and Frustration (too difficult), as described by Draijer et al. (2022).

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 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. These results relate to the findings by Sachistal (2021), saying that for teenagers, the informational value of educational videos is an important factor in their evaluation of these videos. A focus on the informational value matches the Progress valuation mechanism as described by Slot et al. (2020): interest grounded in knowledge or skill progression. When pupils in our study allowed the video to lead them away from knowledge and comprehension towards experience and fascination, matching the Engagement appreciation mechanism (Slot et al., 2020), however, 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 in 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., 2021b). 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.

5 Video links

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

Appendix 1: Pupil Questionnaire for Video Case 1

The video I just saw was interesting

Totally not true ⟷ Completely true

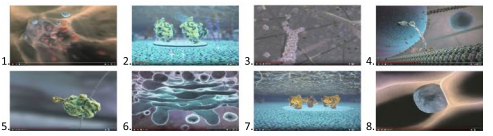
I found this part of the video interesting

1.  Totally not true ⟷ Completely true
2.  Totally not true ⟷ Completely true
3.  Totally not true ⟷ Completely true
4.  Totally not true ⟷ Completely true
5.  Totally not true ⟷ Completely true
6.  Totally not true ⟷ Completely true
7.  Totally not true ⟷ Completely true
8.  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



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 2: 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 Fig. 2). 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 Fig. 2 and Table 5). 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 Fig. 2). 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 Fig. 2 and Table 5). 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 Fig. 2). 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 Fig. 2 and Table 5). 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 a 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 Fig. 2). 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 Fig. 2 and Table 5). 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.

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

Author contributions WW: Conceptualization, Methodology, Analysis, Visualization, Writing—original draft. AB: Conceptualization, Methodology, Writing—Review and editing, Supervision. PD: Conceptualization, Writing—Review and editing, Supervision. All co-authors had complete access to data supporting the manuscript.

Funding Not applicable.

Data Availability 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.

Declarations

Conflicts of interest There is no conflict of interest in the reported work.

Ethics Approval Pupil data collection and handling was complied with local ethical guidelines regarding collection and storage of data involving human subjects. The Science-Geosciences Ethics Review Board of Utrecht University approved the research proposal (Bèta L-19292). The pupil data was anonymized after data collection, and all data was stored on a secured server behind a password.

Consent to Participate Participants have all signed an informed consent form.

References

Akkerman, S. F., & Bakker, A. (2019). Persons pursuing multiple objects of interest in multiple contexts. *European Journal of Psychology of Education, 34*(1), 1–24. https://doi.org/10.1007/s10212-018-0400-2

Araujo, D., Davids, K., & Passos, P. (2007). Ecological validity, representative design, and correspondence between experimental task constraints and behavioral setting: Comment on Rogers, Kadar, and Costall (2005). *Ecological Psychology, 19*(1), 69–78. https://doi.org/10.1080/10407410709336951

Boeije, H. (2010). *Analysis in qualitative research*. Sage Publications Ltd.

Bordwell, D., Thompson, K., & Smith, J. (2017). *Film art: An introduction.* McGraw-Hill.

Dewey, J. (1913). Interest and effort in education. *Houghton Mifflin*. https://doi.org/10.1037/14633-000

Draijer, J., Bronkhorst, L., & Akkerman, S. (2022). Manifestations of non-interest: Exploring the situated nature of students' interest. *International Journal of Educational Research, 113*, 101971. https://doi.org/10.1016/j.ijer.2022.101971

Frijda, N. H. (2009). Emotion experience and its varieties. *Emotion Review, 1*(3), 264–271. https://doi.org/10.1177/1754073909103595

Hobbs, R. (2006). Non-optimal uses of video in the classroom. *Learning, Media and Technology, 31*(1), 35–50. https://doi.org/10.1080/17439880500515457

Krapp, A. (1999). Interest, motivation and learning: An educational-psychological perspective. *European Journal of Psychology of Education, 14*(1), 23–40. https://doi.org/10.1007/BF03173109

Renninger, K. A., & Hidi, S. (2016). The power of interest for motivation and engagement. *Routledge*. https://doi.org/10.4324/9781315771045

Sachisthal, M. S. M. (2021). *Science interest: Conceptualizing the construct and testing its predictive effects on current and future behavior*. Thesis, Universiteit van *predictive effects on current and future behavior*. Thesis, Universiteit van Amsterdam. Amsterdam.

Savelsbergh, E. R., Prins, G. T., Rietbergen, C., Fechner, S., Vaessen, B. E., Draijer, J. M., & Bakker, A. (2016). Effects of innovative science and mathematics teaching on student attitudes and achievement: A meta-analytic study. *Educational Research Review, 19*, 158–172. https://doi.org/10.1016/j.edurev.2016.07.003

Scherer, K. R. (2010). The component process model: A blueprint for a comprehensive computational model of emotion. In K. R. Scherer, T. Bänziger, & E. B. Roesch (Eds.), *Blueprint for affective computing: A sourcebook* (pp. 47–70). Oxford University Press.

Schukajlow, S., Rakoczy, K., & Pekrun, R. (2017). Emotions and motivation in mathematics education: Theoretical considerations and empirical contributions. *ZDM, 49*(3), 307–322. https://doi.org/10.1007/s11858-017-0864-6

Schwartz, D. L., & Hartman, K. (2007). It is not television anymore: Designing digital video for learning and assessment. In R. Goldman, R. Pea, B. Barron, & S. J. Danny (Eds.), *Video research in the learning sciences* (pp. 335–348). Lawrence Erlbaum Associates.

Silvia, P. J. (2006). *Exploring the psychology of interest*. Oxford University Press. https://doi.org/10.1093/acprof:oso/9780195158557.001.0001

Slot, E. M., Vulperhorst, J. P., Bronkhorst, L. H., van Der Rijst, R. M., Wubbels, T., & Akkerman, S. F. (2020). Mechanisms of interest sustainment. *Learning, Culture and Social Interaction, 24*, 100356. https://doi.org/10.1016/j.lcsi.2019.100356

Stockwell, B. R., Stockwell, M. S., Cennamo, M., & Jiang, E. (2015). Blended learning improves science education. *Cell, 162*(5), 933–936. https://doi.org/10.1016/j.cell.2015.08.009

Tan, E. S. (1996). Emotion and the structure of narrative film: Film as an emotion machine. *Erlbaum*. https://doi.org/10.4324/9780203812761

Thomson, A., Bridgstock, R., & Willems, C. (2014). Teachers flipping out. Beyond the online lecture: Maximising the educational potential of video. *Journal of Learning Design, 7*(3), 67–78. https://doi.org/10.5204/jld.v7i3.209

Wijnker, W., Bakker, A., Schukajlow, S., & Drijvers, P. (2021a). Modelling the mechanisms of interest raising videos in education: An empirical validation study. *Human Behavior and Emerging Technologies, 3*(5), 823–831. https://doi.org/10.1002/hbe2.314

Wijnker, W., Tan, E. S., Bakker, A., Van Gog, T. J. M., & Drijvers, P. (2021b). Film as the engine for learning: A model to assess film's interest raising potential. *Projections, 15*(2), 50–90. https://doi.org/10.3167/proj.2021.150203