How to Make Educational Videos More Effective:

A Comprehensive Analysis of Current Practices and Possible Implications for

AI-Driven Educational Videos

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Abstract

This doctoral thesis examines the creation of educational videos with the objective of enhancing learning outcomes and motivation. To gain a deeper understanding of these dynamics, three studies were conducted. The initial study surveyed over 5,000 users with the objective of identifying the key elements contributing to the success of educational YouTube videos. The focus was on viewer preferences and the perceived importance of video structure and presenter attributes. The study identifies six key elements that significantly influence viewers' perceptions of educational videos: structure, reliability, quality, community integration, presenter, and topic. Based on these key elements, a comprehensive guide to the production of educational videos was formulated, comprising 17 rules. The second study examined the impact of parasocial relationships established by presenters on learners' motivation to learn and educational outcomes. This was accomplished by employing pre- and post-tests to evaluate the extent of learning gains and motivation. A total of 2,500 participants were tested, and it was observed that there was a positive correlation between parasocial relationships and motivation to learn. Nevertheless, no correlation was identified between parasocial relationships and learning gains. The third study employed eye-tracking technology to evaluate the efficacy of animations within videos in a laboratory setting and with a smaller sample size of 32 participants. The objective of the experiment was to ascertain the impact of integrating a presenter into an animation on viewers' attention and learning outcomes. Two videos were created, one with and one without a presenter, and their effects on viewers were compared. It was determined that the learning outcomes and visual attention on the areas of interest were higher for the animation without a presenter.

However, if only the parts including hand gestures were observed, the results were reversed, and the visual attention on the areas of interest was higher in the animation with a presenter.

The findings of this doctoral thesis indicate that the effectiveness of educational videos is contingent upon the informational content and the manner in which the presenters engage with their audience, as well as their ability to integrate animations in a manner that effectively manages cognitive load. Furthermore, parasocial interactions were identified as a crucial factor in fostering viewer engagement and motivation, thereby facilitating deeper learning. These insights demonstrate the potential of leveraging video as an educational tool by strategically utilising video design elements to improve the learning process. This research contributes to the field of educational technology by providing empirical evidence on optimising video elements that enhance learning through educational videos. The findings provide educators and content creators with guidelines for the design of educational media, and in the long term, they can inform the creation process of educational videos using generative AI.

Acknowledgements

I would like to express my sincerest gratitude to my doctoral supervisor, André Bresges, for his invaluable guidance and support throughout the course of my doctoral studies. His encouragement, particularly at the outset of my doctoral journey, was instrumental in motivating me to even pursue this academic endeavour. I would also like to thank Professor Andreas Schadschneider, who reviewed my dissertation and also is part of the examination board together with Professor Dr Benjamin Rott. I would also like to express my gratitude to my colleagues in the physics didactics working group for their unwavering support and motivation throughout the doctoral phase. In particular Jannik Henze and Sascha Therolf, who permitted me to conduct my eye-tracking study in their seminar, as well as Christine Quambusch, who was consistently available to provide guidance on administrative matters. I would be remiss if I did not also express my gratitude to my family and friends. However, I would also like to acknowledge the numerous individuals who have influenced me in various ways throughout my life. I am profoundly grateful for this and recognize that my good fortune is not something I can take for granted.

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1 Introduction

1.1 Why Educational Videos Are Important

Unsurprisingly, many people learn from educational videos (Jebe, 2019; Rosenthal, 2017). According to Jebe (2019), 86% of young people regularly watch videos on YouTube, while 49% claim to use it to learn for school (Jebe, 2019). Recent studies have shown that these high figures remain unchanged, with a trend toward more frequent use of videos on the internet (Medienpädagogischer Forschungsverbund Südwest, 2023). Moreover, the time spent on the internet is also increasing (Statista, 2023). Hence, educational videos are an essential component of digital learning.

However, educational videos are also a broad field. Many definitions are highly technical and cover a wide range. For example, a definition by Corl et al. (2008) stated that educational videos can be “simple slide shows with audio to full-length educational video productions that use a combination of video, slide, illustration, animation, audio lecture, and music” (p. 4). In our first paper we introduced a new definition that focused on the desired outcome of educational videos:

> “The goal of educational videos is to convey knowledge and information. The combination of visual and audio media creates an experience for the participant which is mediated by the creator's purpose. In the case of an educational video the creator’s purpose is to facilitate learning.” (Beautemps & Bresges, 2021, p. 2)

Numerous studies have shown that educational videos can contribute to learning success (Allen Moore & Russel Smith, 2012; Kay, 2012; Lloyd & Robertson, 2012; Stockwell et al., 2015). Individual elements of educational videos have also been studied frequently, including using animations to impart knowledge, particularly in the STEM field (Berney & Bétrancourt, 2016; Dancy & Beichner, 2006; Schneider, 2007; Su & Yeh, 2015).

Most research about educational videos has focused on videos produced for formal learning (Rosenthal, 2017). This learning form is often oriented toward a curriculum, which is the motivation to work with an educational video (Cross, 2007). Conversely, informal learning can be "intentionally or inadvertently. No one takes attendance, for there are no classes. No one assigns grades" (Cross, 2007, p. 16). This informal learning takes place in young people's everyday lives, but it is not just young people who are doing this; an increasing number of older people are also watching informal educational videos online in their spare time (Lee et al., 2022).

From our point of view, this form of informal learning has not yet been studied well enough, so we conducted several studies focused on two aspects. First, we wanted to better understand what successful, informal educational videos look like to give educational video creators practical improvement tips. Second, we believed it was possible to learn from good informal educational videos for institutional learning (e.g., in schools) since viewers enjoy the learning and even do it in their free time, a goal we also follow in institutional learning.

Therefore, the primary objective of this doctoral thesis was to elucidate the learning process facilitated by educational videos and extrapolate principles conducive to creating more effective educational content. Furthermore, it aimed to offer insights into formal education in institutions such as schools or universities. Thus, three pivotal studies were undertaken.

The first was an exploratory study of over 5,000 participants, which utilized a questionnaire to assess the elements deemed essential by viewers of informal educational videos (Beautemps & Bresges, 2021). A notable outcome of this investigation highlighted the significance of the video presenter in the learning experience. This prompted further research into the potential impact of the presenter-learner interaction and relationship on learning efficacy and motivation. For this reason our second study focused on parasocial interaction (PSI) and parasocial relationship (PSR), revealing a positive correlation with learning motivation (Beautemps & Bresges, 2022). Prompted by these findings, the final study analyzed the effectiveness of a human presenter within animations for educational purposes using pre- and post-tests and eye tracking (Beautemps et al., 2024).

1.2 Literature Review

1.2.1 What Makes an Effective Educational Video

The numerous studies on the optimization of educational videos for high levels of learning success, which predominantly focus on formal educational videos, nevertheless also permit learnings regarding the creation of informal educational videos. Brame (2016) identified three essential aspects for effectively creating educational videos: (i) the management of cognitive load, (ii) the maximization of participant engagement, and (iii) the improvement of active learning by using educational videos.

Cognitive load occurs in learners while they are learning and is separated into three categories: intrinsic cognitive load (inherent in the topic of interest), extraneous cognitive load (due to the material, in this case, making a video), and germane load, the learner's ability to connect prior knowledge with new information (Sweller, 1994, 2010). The objective of managing the cognitive load is to ensure that the educational video is not unduly challenging for the learner by avoiding complex vocabulary, distracting music, all of which increase the extraneous load. One way to decrease it was described by Mayer (2001). He elucidated that the human brain processes visual and auditory signals in different channels, thereby both are available for information processing. A combination of these channels can facilitate a reduction in cognitive load and enhance the efficiency of learning (Mayer, 2001). Managing the cognitive load is important, because Brame (2016) noted that the material may be problematic if it fails to engage or overwhelms the learner, as related to the intrinsic load, which can be managed by creating a well-designed learning path. Consequently, those responsible for creating educational videos must clearly understand the intended audience (Brame, 2016; Sweller, 2010).

One challenge in creating educational videos is that human minds tend to wander, especially when learning with videos (Risko et al., 2011). Brame (2016) suggested reducing this problem by chunking the video into parts, each between 6 and 9 minutes long (Risko et al., 2011). This can help to maximize the engagement with the video. In our first study, we also observed that 68% of the participants indicated a preference for informal educational videos with a duration of between 7 and 15 minutes (Beautemps & Bresges, 2021).

The objective of improving active learning is to enhance the interactivity of a video since this is effective for enhancing the learning process in educational settings (Hake, 1998). This principle can also be applied to the learning process facilitated by educational videos (Schacter & Szpunar, 2015). Brame (2016) and Szpunar et al. (2013) proposed that video creators incorporate interactive questions into videos to engage the learners. One of the findings from our research was that a significant proportion of participants expressed a preference for interactive tools, such as voting systems or comments in videos, with the aim of enhancing interactivity (Beautemps & Bresges, 2021). This again can help the learning process. It is noteworthy that the utilisation of comments underneath videos exerts an additional influence. Empirical evidence indicates that a single interaction through comments is sufficient to reinforce the bond between the viewer of a video and the presenter (Bond, 2016). This relation can be describe through a parasocial relationship.

1.2.2 Parasocial Interaction (PSI)

The person presenting the content is another very important element of educational videos. They not just present a topic, they also form a relationship with the viewer, which can be described by parasocial interaction (PSI) and parasocial relationship (PSR). PSI and PSR can facilitate the learning process in educational videos which we measured in our second study (Beautemps & Bresges, 2022). PSI was first introduced by Horton and Wohl (1956), who posited that television audiences have a one-sided interaction with the presenter of the show, which makes it an unreal interaction (Horton & Wohl, 1956). Several studies have indicated that this interaction is more pronounced when there is a stronger one-sided relationship between the viewer and the presenter of the show (Frederick et al., 2012; Horton & Wohl, 1956; Rubin et al., 1985). Horton and Wohl (1956) described this phenomenon as a kind of friendship between the viewer and the presenter.

Additional studies have sought to identify the factors contributing to strengthening PSI and, consequently, the long-term development of PSR. Six factors have been identified that exert a significant influence on PSI, as illustrated in Figure 1:

1) *Social attractiveness* encompasses a person's likability and the extent to which viewers desire a friendship with the media figure (Lee & Watkinson, 2016; Rubin & McHugh, 1987).
2) *Attitude homophily* refers to the similarity in values, beliefs, and opinions between the viewer and the media personality (Frederick et al., 2012; Turner, 1993).

3) *Perceived realism* involves the authenticity of the media personality and the environment (Frederick et al., 2012; Rubin et al., 1985).
4) *Time spent with the media figure* is closely linked to the level of engagement and the PSR (Frederick et al., 2012; Lee & Watkinson, 2016).
5) *Instrumental media use* describes a feature of social media where viewers can now interact with a media figure's content, which improves PSI, even if they are usually one-sided (Frederick et al., 2012).
6) Uncertainty reduction helps strengthen the relationship by knowing more about the media person and comparing one's views to those of the media person (Perse & Rubin, 1989).

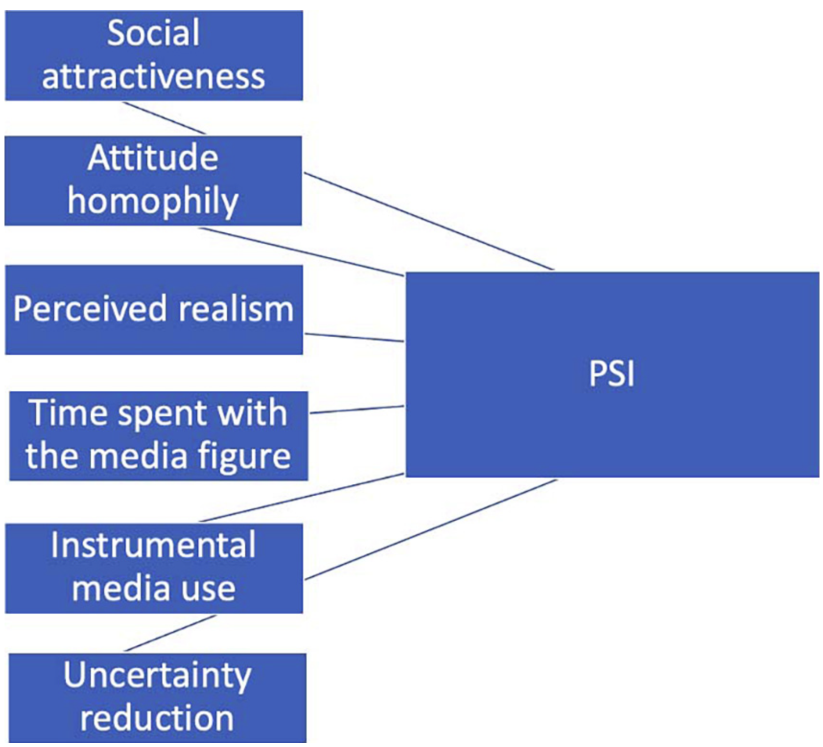

Figure 1 *Aspects Influencing the Strength of Parasocial Interactions (Beautemps & Bresges, 2022)*

PSI and PSR are especially interesting for educational videos since they help viewers accept the content (Boy et al., 2020). Hence, learning outcomes can be improved (Beege et al., 2017; Lauricella et al., 2011), and motivation can be raised (Beautemps & Bresges, 2022; Becker et al., 2022). It thus follows that an understanding of PSI and PSR can facilitate the creation of better educational videos. This, combined with the observation that our initial research demonstrated the pivotal role of the presenter in influencing the perceptions of viewers of educational videos, inspired the second study.

1.2.3 Animation as a Tool in Educational Videos

Another tool often used in educational videos is animation. Mayer and Moreno (2002) characterized animations as simulated videos that illustrate the movement of drawn or simulated objects. They delineate the core attributes of animations as follows: “The main features of this definition are as follows: (1) picture – an animation is a kind of pictorial representation; (2) motion – an animation depicts apparent movement; and (3) simulated – an animation consists of objects that are artificially created through drawing or some other simulation method.” (Mayer & Moreno, 2002, p. 2). Especially in the STEM field, animation can help understand complex interrelationships in processes happening in the real world (Schneider, 2007). One of the reasons for this is that phenomena that cannot be observed with the naked eye become visible. Many studies and meta-analyses have shown that animations can positively affect the learning process (Berney & Bétrancourt, 2016; Höffler & Leutner, 2007; Liu & Elms, 2019) and the learner’s motivation (Barut Tugtekin & Dursun, 2021).

There are several factors that contribute to the effectiveness of educational animations. One such factor is the incorporation of realism, which is believed to enhance the learning process (Höffler & Leutner, 2007). The findings of the second study indicated that forming connections with others can have a beneficial impact on the learning process (Beautemps & Bresges, 2022). Furthermore, the subjects in our first study indicated a preference for the presentation format incorporating animations, which they identified as their second-most preferred mode of presentation right after the use of real footage of a topic. As a consequence, the combination of animation and a real person appeared to be a logical subsequent development. This was also supported by the increasing use of AI-supported techniques and apps such as TikTok or Instagram, which considerably simplify the creation of so-called green screen effects (even if these no longer require a green background). The combination of person and animation is therefore becoming increasingly common in informal educational videos. For this reason, we wanted to better understand whether the integration of a real person as a presenter in animation (named "animation with presenter") positively influenced learning gain compared to an animation without a presenter (named "pure animation") (Beautemps et al., 2024).

1.3 Learning Theories

Learning theories are important to better understand the learning process of individuals from start to finish. It considers a variety of aspects, that are important, when we talk about learning. This can be cognitive processes, but also environmental or emotional factors (Cook & Artino, 2016).

1.3.1 Cognitive Load Theory

Cognitive load theory is a crucial framework for the analysis of educational videos, as the management of cognitive load is a fundamental aspect of an effective learning process (Brame, 2016). The theory separates cognitive load into three categories: intrinsic, extraneous, and germane (Sweller, 2010).

i) Intrinsic cognitive load pertains to the task's inherent difficulty, often determined by the element interactivity, which means how task elements interconnect (Sweller, 1994).

ii) Extraneous cognitive load arises from the instructional design or material complexity (Sweller, 2010).

iii) Germane cognitive load reflects the learner's internal process of integrating new knowledge with pre-existing knowledge (Sweller, 2010).

A heightened extraneous cognitive load, potentially triggered by irrelevant distractions, could unnecessarily complicate learning with educational videos (Sweller, 2010). This concept was expanded on in the cognitive theory of multimedia learning by Mayer (2014), which introduced three core assumptions:

i) The dual-channel assumption suggests that human information processing is divided into auditory and visual channels, advocating for simultaneous learning through both.

ii) The limited-capacity assumption acknowledges that each channel can only process a finite amount of information.

iii) The active processing assumption underscores the necessity of actively engaging with the information for effective learning.

A phenomenon within this theory, the split-attention effect, illustrates how dividing attention between various information sources can increase cognitive load unnecessarily (Mayer, 2014), which is important for video design since not too many elements should be in the frame. Animation should especially be designed to minimize unnecessary learning hindrances by avoiding irrelevant imagery or information overload, precisely because this form of visual and auditory representation offers the opportunity to be abstract and minimize. For example, studies have indicated that closely aligning text with animated objects (Berney & Bétrancourt, 2016) or combining animations with spoken words (Ginns, 2005) enhances learning outcomes. The management of cognitive load, particularly in the context of animations, was also a topic of investigation in our third publication (Beautemps et al., 2024).

1.3.2 Self-Regulated Learning

In scenarios such as watching educational videos at home, the absence of a tutor implies that the learning is self-directed. Many German students aged 12 to 19 who engage with YouTube videos at home utilize these resources for learning purposes (Jebe, 2019), making educational videos a common tool for Self-regulated learning (SRL). SRL involves learning autonomously toward a specific objective without the guidance of a tutor (Rheinberg et al., 2000; van Alten et al., 2020).

The SRL framework is divided into characteristics of the "person and the situation" (Rheinberg et al., 2000, p. 82). The learning environment's setting, the subject matter, and the complexity of the learning material define the situation. The person is defined by the motives, interests, and motivational orientation. The dynamic interplay between the persons characteristics and the situational factors contributes to the current motivation for learning (Rheinberg et al., 2000, p. 83). However, this model is not the sole conceptualization of learning motivation since many models have highlighted the interaction between a learner's internal traits and the learning environment's external influences, delineating intrinsic and extrinsic motivations (Deci & Ryan, 2010; Harlen & Deakin Crick, 2003).

Rheinberg et al. (2000) describe, that the current learning motivation is influenced by factors that precede the learning outcome, such as the time allocated to the learning task, the effectiveness of the learning process, and the learner's condition. The acquisition of knowledge gauges learning outcomes, the ability to apply new knowledge to different contexts, and any performance improvement (Figure 2). When learning from videos, the interaction with the presenter and the resultant relationship are integral parts of the learning environment that directly influence learning motivation. This connection can be explored through PSI and PSR, what we did in our second publication (Beautemps & Bresges, 2022).

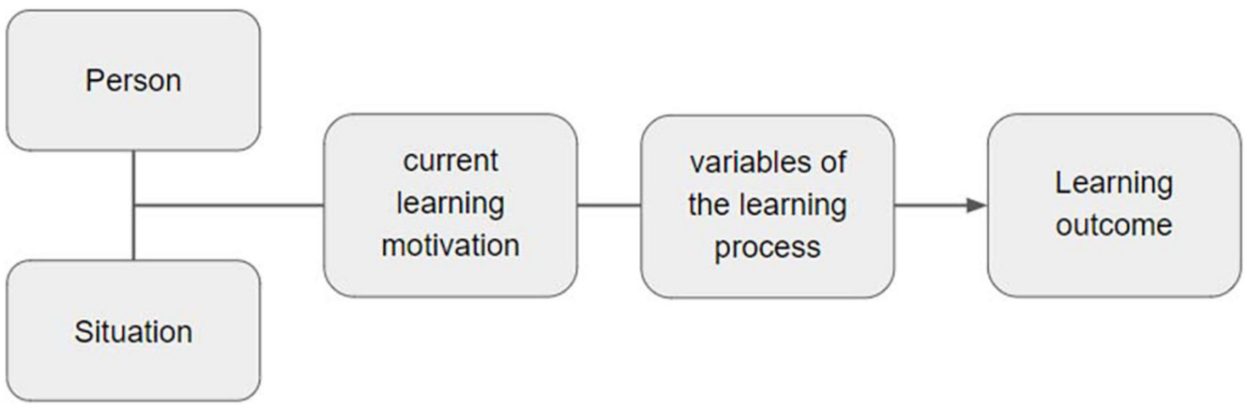

Figure 2 *Motivation in SRL (compare Rheinberg et al., 2000, p. 83)*

1.3.3 Theory of Visual Attention

Another vital part of learning with videos is to direct the viewer's visual attention to different areas of the video through the theory of visual attention (TVA). The TVA delineates a cognitive mechanism responsible for filtering visual inputs to identify which information is pertinent and which is not (Bundesen, 1990). This filtering is crucial because humans face a bottleneck due to the vast array of visual information available. The human brain would be overwhelmed if it attempted to process all incoming information at maximum resolution. Therefore, a selective process is necessary (McMains & Kastner, 2009).

This selection is primarily based on the relevance and the salience of stimuli. Thus, more relevant and conspicuous stimuli tend to receive heightened attention (Bundesen, 1990; McMains & Kastner, 2009). Furthermore, visual attention can be influenced by cueing (Posner, 1980) and expectations (McMains & Kastner, 2009). Eye tracking is widely used to measure visual attention (Vehlen et al., 2021; Zelinsky & Sheinberg, 1997). Research has indicated a correlation between learning outcomes and visual attention (Becker et al., 2023; Becker et al., 2022; Yang & Wang, 2023).

Specifically, animation can enhance visual attention and learning outcomes by reducing the visual stimuli to the most important aspects (Praveen & Srinivasan, 2022). Similarly, cueing can direct visual attention and positively affect learning outcomes or the time required to learn (de Koning et al., 2009; Lin & Atkinson, 2011). Our third study used hand gestures for cueing because research has shown that hand gestures activate a specific area in the brain linked to mirror neurons (Hurley & Chater, 2005). Actions mirrored based on visual cues and processed by mirror neurons are a fundamental mechanism of response and learning (Wapner & Cirillo, 1968).

1.4 Physical Concepts

Educational videos are particularly effective in addressing challenges in science, technology, engineering, and mathematics (STEM) education. They facilitate the reduction of the intrinsic cognitive load and encourage connections between different subjects, thereby supporting generative processing (Lijo et al., 2024). Our interventions consistently focused on physical concepts. Two topics were discussed in greater detail: Newton’s Laws (Beautemps & Bresges, 2022) and the physics of the seasons (Beautemps et al., 2024). This section overviews these concepts.

1.4.1 Newton's Laws

In 1686, Isaac Newton published *Philosophiæ Naturalis Principia Mathematica*, formulating three laws of motion (NASA Glenn Research Center, 2024):

1. An object persists in its state without external forces. Thus, an object at rest stays at rest, while an object in constant motion stays in constant motion with the same speed and direction if no external force affects it. This law is known as inertia (Demtröder, 2021).
2. The equation of force per mass defines the acceleration of an object (Demtröder, 2021).
3. When an object exerts a force, an equal and opposite force is created in the opposite direction, a phenomenon known as actio equals reactio (Demtröder, 2021).

Our video interventions employed Newton's first law, focusing on inertia by presenting two balls of differing weights falling to the ground. Individuals were interviewed on camera and asked to predict which ball would hit the ground first. This study aimed to identify and address misconceptions. As elucidated by Muller et al. (2007), the rationale behind the interviews is that they constitute an efficacious method of addressing preconcepts and misconceptions through the use of videos. Most respondents predicted the heavier ball would hit the ground first. Although this response was erroneous (both balls would have hit the ground simultaneously had they not been thrown from a considerable height), the participants correctly stated that the ball with the higher mass exerted a greater gravitational pull because the gravitational force was proportional to the mass (Halliday et al., 2014). However, their explanation did not consider Newton's first law of motion, which states that an object that is in motion remains in motion unless there is an external force (Demtröder, 2021). Instead, the inertia of an object, which depends on its weight, has an effect, resulting in the two balls falling to the ground simultaneously. This effect was explained throughout the video, using experiments and animations (Figure 3).

Two additional experiments with integrated illustrations were conducted to clarify the concept. One experiment demonstrated that vertical and horizontal forces could be considered separately. In this instance, a single ball was released from a height while a second ball was also released, but with an initial horizontal velocity imparted, illustrating that the horizontal motion was unimpeded, as no opposing force was present (Figure 3). Therefore, both balls reached the ground simultaneously due to the identical acceleration acting upon them in the vertical direction. The second experiment was a straightforward illustration of the inertia of objects with varying weights, demonstrating that a car could only be pushed with significant effort, whereas a lightweight toy car could be easily moved (Beautemps & Bresges, 2022).

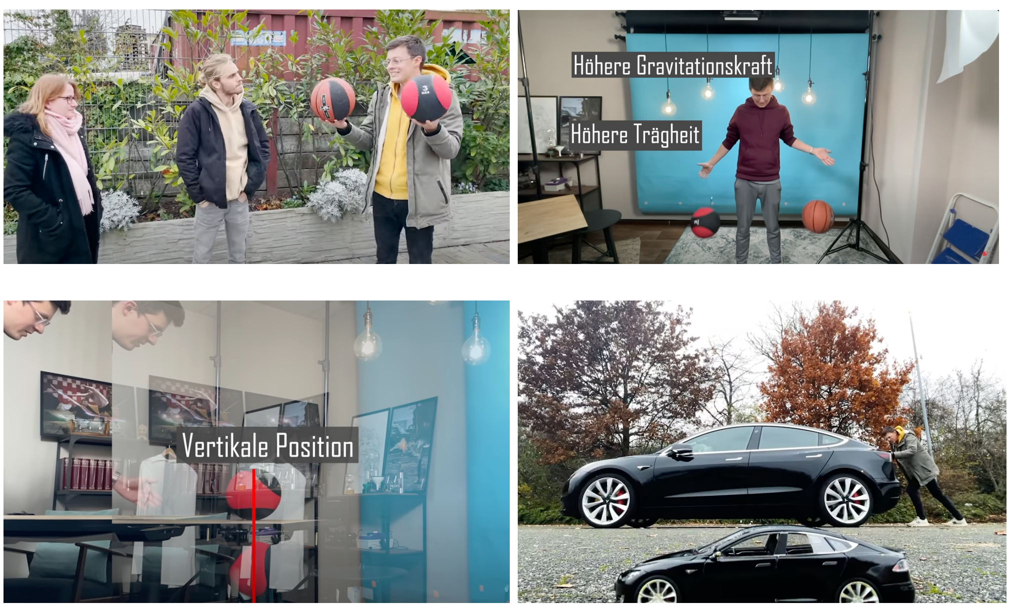

Figure 3 *Interview situation with heavy and leight weight ball (top left); Drop experiment in slow motion (top right); Comparison Ball drop with vertical velocity vs. without (bottom left); heavy car push vs. toy car push (bottom right)*

1.4.2 Physics of the Seasons

The second physical concept addressed in the third publication was the formation of seasons (Beautemps et al., 2024). The seasonal variations observed on Earth are primarily attributed to its axial tilt, approximately 23.5 degrees. This tilt affects the angle at which sunlight strikes the Earth throughout its orbit around the Sun. When sunlight enters the atmosphere at a shallow angle, it spreads over a larger area, leading to less intense heating than when it arrives at a steeper angle, concentrating the energy over a smaller area, as seen in Figure 4. This is the main effect coursing the temperature differences during the seasons.

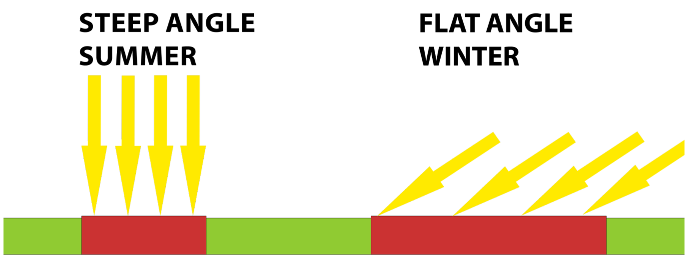

Figure 4 *Sunbeams Hitting the Earth at Different Angles (Left: Summer With Steep Angle, Right: Winter With Flat Angle) (*Beautemps et al., 2024)

Furthermore, the longer daylight hours experienced during the summer months result in the Earth absorbing solar energy for a more extended period, thereby further enhancing the warming effect. Research has explored common misconceptions regarding the causes of the seasons. For instance, it was demonstrated that many students incorrectly attributed seasonal changes to variations in the Earth's distance from the Sun (Kikas, 2000). Additionally, some beliefs inaccurately suggested that the moon played a role in forming the seasons (Fromme, 2018). The animation was created in three stages. Initially, the presenter was recorded in a studio setting. Subsequently, the studio was recorded from different angles without the presenter. The next step involved the creation of the animation. Two versions were then rendered: one with the presenter in the picture and one without (Figure 5).

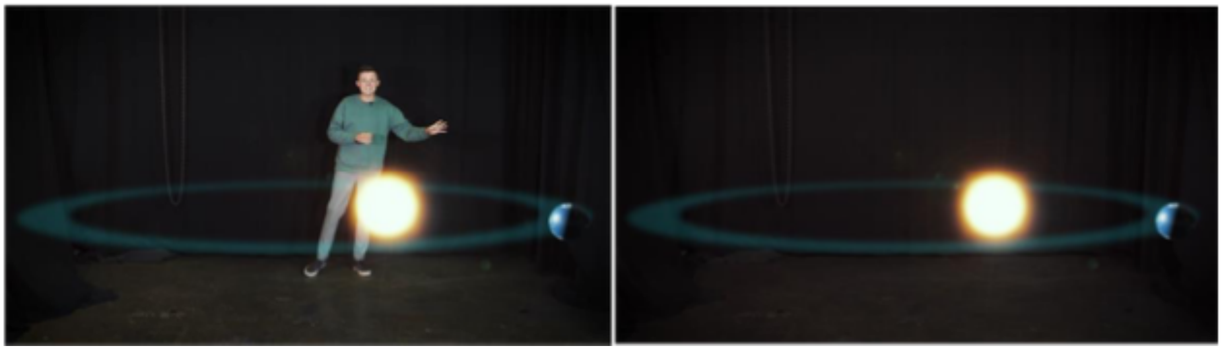

Figure 5 *Animation with presenter and pure animation*

The audio was identical in both videos. Once more, misconceptions were addressed, this time not with an interview but by the presenter himself, who appeared as a clone on the right side of the screen (Figure 6).

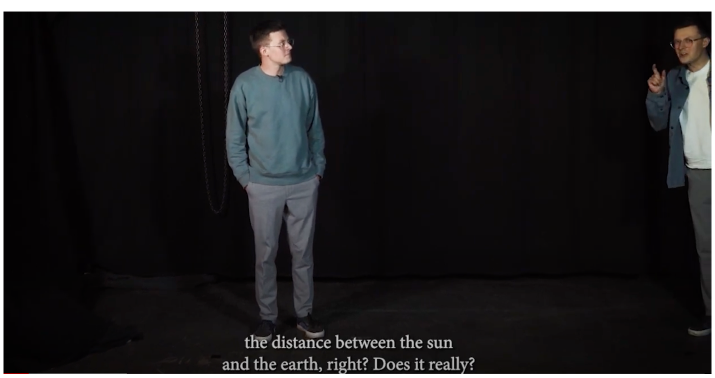

Figure 6 *Addressing the misconceptions through a clone of the presenter*

1.5 Tools

A variety of tools were used to better understand and explore educational videos.

1.5.1 Questionnaire

One of the most crucial instruments employed in our investigation were questionnaires. We employed existing questionnaires, such as the PSI questionnaire by Rubin et al. (1985) or the FAM questionnaire on learning motivation (Rheinberg et al., 2019). However, we also created questionnaires by scratch to more effectively comprehend the utilization of educational videos in an exploratory manner. A variety of techniques were employed in the construction of the questionnaires, including the utilisation of expert interviews and the administration of preliminary surveys via online platforms such as YouTube. The user comments that were generated through this process were then categorised in order to develop the questions (Beautemps & Bresges, 2021).

1.5.2 Pre- and Post-Tests

Pre- and post-tests were employed on numerous occasions to assess the impact of an intervention. This was done, for example, to measure learning success. Therefore, the participants' knowledge before and after an educational intervention was surveyed. In our research, the interventions were educational videos, which the participants watched. A statistical method such as Cohen's d was often used to analyze changes because it allows for comparison across individuals with varying initial knowledge or motivation levels. Cohen’s *d* can be calculated by taking the difference between the mean scores of the post-test and pre-test, then dividing by the standard deviation of the pre-test scores (Cohen, 1977):

$$d = \frac{\bar{x}_{post} - \bar{x}_{pre}}{SD}$$

Equation 1 *Formula for Cohen's d*

This formula provides a standardized measure of effect size, enabling a meaningful comparison of learning outcomes across diverse groups, regardless of their starting point. This method ensured that even participants who began with higher knowledge or motivation were equitably compared to those with less initial knowledge, facilitating an accurate assessment of the educational intervention's impact.

1.5.3 Eye Tracking

The eye-tracking method has become established in the video sector to gain a deeper insight into the recording of information from videos (Hahn & Klein, 2022). A static eye tracker (we used a Tobii Pro Fusion for our third study) positioned below a monitor utilizes near-infrared light to illuminate the eye, allowing internal cameras to detect the pupil's location. Initial calibration involves displaying several markers on the screen. The cameras then record the pupil's position, enabling the software to deduce the viewer's gaze direction. The high camera frequency (120Hz) captures rapid eye movements. Hence, by analyzing gaze points over time, it is possible to ascertain fixation durations (Mestre, 2012; Tobii, 2023). Eye tracking data reveal which parts of a video or animation draw the participants' focus, indicating areas where information absorption is heightened (Fiorella et al., 2019).

Studies by Becker et al. (2022, 2023) demonstrated that eye tracking, when applied to micro areas of interest (AOIs), can predict task outcomes, such as extracting information from a graph. Unlike larger AOIs encompassing entire questions or diagrams, which showed no significant correlation with participant performance, focusing on smaller, relevant AOIs proved pivotal (Bi & Reid, 2017). It was therefore essential to identify the appropriate areas of interest (AOIs) in the animation, ensuring that they were of an appropriate size and concentrated on the essential information required to understand the presented physics concepts. The creation of an animation for the study ensured that the focus was on a single concept at a time, with specific animation areas highlighted as particularly pertinent. This strategy enabled the precise determination and establishment of focused AOIs. In our study we emphasized the total visit duration (TVD). It measured the cumulative time spent on a specific AOI or a set of AOIs calculated from the first fixation within an AOI to the moment of the first fixation outside it. This metric was selected for its effectiveness in quantifying the extent of attention a viewer dedicates to a particular area (Albert & Tullis, 2023).

2 Paper Overview

This doctoral thesis was written cumulatively and derived from three papers:

#1 **[published]** Beautemps, J., & Bresges, A. (2021). What Comprises a Successful Educational Science YouTube Video? A Five-Thousand User Survey on Viewing Behaviors and Self-Perceived Importance of Various Variables Controlled by Content Creators. Front. Commun. 5:600595. doi: 10.3389/fcomm.2020.600595

#2 **[published]** Beautemps, J., & Bresges, A. (2022). The influence of the parasocial relationship on the learning motivation and learning growth with educational YouTube videos in self regulated learning. Front. Educ. 7:1021798. doi: 10.3389/feduc.2022.1021798

#3 **[published]** Beautemps, J., Bresges, A., & Becker-Genschow, S. (2024). Enhancing Learning Through Animated Video: An Eye-Tracking Methodology Approach. In Journal of Science Education and Technology. Springer Science and Business Media LLC. https://doi.org/10.1007/s10956-024-10162-4

The author of the doctoral thesis is also the principal author of these papers. In this context, he developed the study design, set up the study, analyzed the data, and wrote the manuscript. In Studies 1 and 2, he also conducted data collection independently, while in Study 3, the data were collected in the test room by student assistants, who were guided and supervised by the author of the doctoral thesis.

Publication #1: What Comprises a Successful Educational Science YouTube Video? A Five-Thousand User Survey on Viewing Behaviors and Self-Perceived Importance of Various Variables Controlled by Content Creators.

In this article, we examine the factors that contribute to the success of educational science videos on YouTube, drawing from a survey of over 5,000 participants who regularly watch such content. The study identifies six key elements—structure, reliability, quality, community integration, presenter, and topic—that significantly influence viewers' perceptions of video effectiveness.

From the perspective of content structure, our findings emphasize the importance of clear organization, including the introduction of the topic, repetition of key information, and a concluding summary. In terms of reliability, viewers place a high value on the presence of credible sources and expert input. However, the actual verification of these sources is less common among viewers. The audio quality is deemed to be of greater importance than the visual quality, particularly given the prevalence of smartphone usage for viewing.

The role of the presenter is of paramount importance, with personal appeal and humour being key attributes that can drive viewer engagement. It is also crucial to facilitate community integration, as interactive features such as voting and responding to viewer suggestions can foster a stronger connection between creators and their audience. Ultimately, the relevance of the topic is the primary determinant of viewership, with the majority of participants driven by a desire to expand their knowledge about subjects they are already interested in.

The study presents a practical checklist for content creators, offering 17 recommendations for optimizing the production of educational science videos. While the model captures important dynamics in viewer engagement, further research is needed to explore its applicability to different audiences and contexts, particularly in formal educational settings. In addition, some follow-up questions emerged during the research. For example, further investigation is required to gain a deeper understanding of the role of the presenter in the video, given the study's findings on the significance and clear preferences for the visual appearance of a presenter. Furthermore, it is essential to examine how the presenter influences the learning process.

Publication #2: The Influence of the Parasocial Relationship on the Learning Motivation and Learning Growth with Educational YouTube Videos in Self Regulated Learning.

In this article, we investigate the impact of parasocial relationships (PSRs) on learning motivation and learning growth in the context of educational YouTube videos, specifically in the context of self-regulated learning (SRL). The study included 2,643 participants with an average age of 24 years. PSRs, typically studied in the fields of marketing and media, describe the one-way relationships that viewers form with media personalities. This study explores whether these relationships also influence educational outcomes.

The study involved participants recruited through science and technology-focused YouTube channels. They completed a pre-test on Newton's Laws, watched an educational video on the same topic, which was created for this study, and then completed a post-test. Learning motivation and PSR with the presenter were measured using established questionnaires. The results showed a slight correlation between PSR and learning motivation, especially among female participants, but no significant correlation between PSR and learning growth.

From a theoretical perspective, the study highlights the potential of PSR to increase learning motivation, which is consistent with existing research highlighting the importance of motivation in learning. However, the lack of a significant correlation between PSR and learning growth suggests that while PSR may increase engagement, it does not necessarily translate into immediate learning gains.

The lack of correlation between PSR and learning success was unexpected, given the findings of previous studies in this area. One potential explanation for this discrepancy is the age of the test subjects in the current study, which was older than those in previous studies. Additionally, different measurement methods for determining PSR may have contributed to the observed differences. Another challenge was that the test subjects had a relatively high level of prior knowledge, which may have made it more difficult for them to demonstrate improvement. Statistical methods were employed to address this issue, but further investigations are necessary to gain a more comprehensive understanding of this effect.

Publication #3: Enhancing Learning Through Animated Video: An Eye-Tracking Methodology Approach.

This study examines the impact of two different animation styles on learning outcomes, using the example of the physics of the seasons. The research employs a combination of pre- and post-tests and eye-tracking technology to compare animations featuring a presenter in the animation with those utilising a pure animation without a presenter. The sample comprised 32 prospective physics teachers, with an average age of 23.9 years.

The findings indicated that both animation styles resulted in notable learning gains. However, the pure animation format demonstrated a more pronounced effect size and greater directed visual attention to pivotal areas of interest (AOIs), which are essential for comprehending the content. It is noteworthy that the hand gestures employed in the animation featuring a presenter were observed to enhance gaze attention on relevant AOIs, thereby partially mitigating the observed split-attention effect.

From a theoretical standpoint, the findings of this study align with the cognitive load theory, indicating that the supplementary information provided by the presence of a presenter may elevate the extraneous cognitive load, which could potentially impede learning. This effect was observed in the reduced fixation duration on critical content areas in the animations featuring a presenter.

The findings of this research have practical implications for the design of educational media in physics and other STEM fields. Additionally, they prompt the question of the optimal use of presenters in educational videos, particularly in regard to striking a balance between the benefits of human presence and the necessity of minimizing cognitive overload. Further studies should investigate these dynamics further, especially in broader and more diverse populations, in order to validate the generalizability of these findings.

3 Publications

3.1 Publication #1

Beautemps, J., & Bresges, A. (2021). What Comprises a Successful Educational Science YouTube Video? A Five-Thousand User Survey on Viewing Behaviors and Self-Perceived Importance of Various Variables Controlled by Content Creators. Front. Commun. 5:600595. doi: 10.3389/fcomm.2020.600595

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Author Contributions:

- Jacob Beautemps: Research design, Questionnaire creation, Data collection, Data analysis, Writing - original draft, Writing - review & editing (incorporating feedback from second author and reviewers), Communication with reviewers and journal.
- André Bresges: Guidance, Feedback on final manuscript, Consultation on incorporating reviewer feedback.

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3.2 Publication #2

Beautemps, J., & Bresges, A. (2022). The influence of the parasocial relationship on the learning motivation and learning growth with educational YouTube videos in self regulated learning. Front. Educ. 7:1021798. doi: 10.3389/feduc.2022.1021798

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Author Contributions:

- Jacob Beautemps: Research design, Questionnaire creation and setup (supported by literature review), Data collection, Data analysis, Writing - original draft, Writing - review & editing (integrating feedback from the second author and reviewers), Communication with reviewers and journal.
- André Bresges: Research guidance, Feedback on the final manuscript draft, Consultation on incorporating reviewer feedback.

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3.3 Publication #3

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Author Contributions:

- Jacob Beautemps: Collaboration on research design, Script creation for animation and creation of the two videos, Questionnaire creation and setup (supported by literature review), Data analysis (with advice from other authors), Writing - original draft, Writing - review & editing (incorporating feedback from other authors and reviewers).
- André Bresges: Collaboration on research design, Data analysis advice, Manuscript review, Consultation on incorporating reviewer feedback.
- Sebastian Becker-Genschow: Collaboration on research design, Data analysis advice, Manuscript review, Consultation on incorporating reviewer feedback.

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4 Overall Conclusion

Three studies and almost 4 years of research for this doctoral thesis yielded several insights into creating and using educational videos. While it has become evident that videos are an effective tool for conveying information, it is equally apparent that creating educational videos is highly complex. The analysis has demonstrated that many factors influence the effectiveness of educational videos. This process begins with the PSR between the viewer and the presenter and extends to the design of animations and the involvement of experts. The length of videos and how hand gestures are employed for cueing in animations also play a role. Or even the use of hand gestures in animations.

Despite considerable knowledge about these factors, significant gaps remain in understanding optimal educational videos. It can be postulated that the optimal design of educational videos has not yet been achieved, as some of the results found did not align with the expectations derived from previous research. Hence, further research is needed concerning the characteristics of effective educational videos in greater depth because the creation of such videos will become increasingly straightforward in the future thanks to generative AI, allowing the findings from research to be implemented directly. This leads to the expectation that the creation of educational videos for various learning purposes, whether at school, university, further education, or leisure time, will become increasingly important and also to have a better understanding of the target audience, since through generative AI we have the opportunity to create videos custom-made for individual groups becomes a possibility.

4.1 A Look Into the Future of Learning With Media

The following section examines the potential future of learning with media. One of the most crucial elements to consider is the potential impact of generative AI.

4.1.1 Generative Artificial Intelligence (AI)

IBM defines generative AI as "deep-learning models that can generate high-quality text, images, and other content based on the data they were trained on" (Martineau, 2023, p. 1). Over the past year, this technology's prevalence has been notable, largely due to the remarkable success of generative AIs such as Chat GPT, Dall:E, Gemini, Midjourney, and Sora, which can generate text, images, and videos. However, the history of this technology extends much further back in time.

In 2014, a group led by computer scientist Ian Goodfellow presented generative AI in a paper in which they referred to it as "generative adversarial networks" (Goodfellow et al., 2014; Wang et al., 2023). Furthermore, the authors clarified that most AI applications currently used are supervised machine learning applications, which involve training a neural network using manually labeled data sets (Liu & Wu, 2012). Thus, these applications are also called "learning with a teacher" (Haykin, 1998). Creating high-quality data is a laborious process, for this reason the initial idea was that generative AI can synthesize data for training purposes (Goodfellow et al., 2014).

This field has developed to such an extent that photorealistic images can be created and also 3D videos are possible that remain consistent even if they are several minutes long. Hence, the individual frames of the video physically follow each other logically, whereby distortions or jumps caused by movements of objects or the camera create no or at least fewer errors (Li et al., 2024; OpenAI, 2024). The advancement of generative AI in creating videos has attracted considerable attention, which naturally prompts the question of how this technique can be employed in producing educational videos.

4.1.2 Generative AI for Educational Videos

As generative AI for educational videos is a relatively new field, a paucity of research exists in this area. The existing research focuses on explainer videos, in which the efficacy of an artificially created presenter, who explains frontally into the camera, is investigated compared to a real person. Leiker et al. (2023) found no difference in learning success between the AI-generated presenter and the real person in their study. This result is not entirely unexpected because AI-generated characters appear more and more realistic.

However, one of the most intriguing questions remains: to what extent does it matter to the learners if they learn from an actual human that they now is real, and can this knowledge have a long-term effect, for example, on PSIs? A further study by Chen and Wu (2024) did not focus on AI-created presenters in educational videos but rather on AI-generated videos that present poems in video form. The findings indicated that the system could reduce the cognitive load associated with learning poems, compared to learning the poems through traditional text and photographic materials in books. These studies have shown the potential of creating educational videos with generative AI. Nevertheless, in the long term, this form of utilization of generative AI represents only a minor aspect of the potential applications.

One of the most significant constraints on the efficacy of video-based learning is the dearth of interactivity. Research by Hake (1998) demonstrated the significance of interactivity for the success and comprehension of learning, which is only possible to a limited extent when learning with videos, for example, through a quiz or open questions built into the video. Hence, the possibility of real individual interaction that specifically responds to the viewer's answers is severely limited, not least because it necessitates a significant investment of resources, such as creating a separate video for each option.

The long-term solution to this limitation is using text comprehension with large language models (LLMs) and generative AI. Learners can already interact with LLMs, such as Chat GPT in text form, by posing questions or being tested by it (Dijkstra et al., 2022; Li, 2023). However, this approach does not utilize the media modality effect that facilitates learning by systematically combining auditory and visual information so that individuals can absorb information via both channels, thereby enhancing their learning efficiency (Mayer, 2014). Indeed, video content could be generated using generative AI to achieve this objective. Combining this approach with immersive VR learning environments in the long term could significantly improve digital learning on a scalable basis.

Moreover, creating educational videos with AI can facilitate the utilization of the research findings in this field by revising scripts with an AI fed with research data on the structure and wording of educational videos. Generative AI can also incorporate knowledge from published research, which is one aim of this research project. The three papers resulted in practical rules for creating educational videos more effectively to enhance the learning experience and facilitate knowledge transfer, which can be applied in the long term with the assistance of AI.

In conclusion, the present era is witnessing a remarkable surge in digital learning. Despite the imminent challenges of AI, there is a glimmer of hope in its potential to enhance digital education and make it more accessible to the masses. I anticipate this future.

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6 Appendix

6.1 Data Backup and Accessibility

All raw data were anonymized and are available for consultation on a hard drive at the University of Cologne, Faculty of Mathematics and Natural Sciences, Institute of Physics Education, Cologne, Germany.

6.2 List of Tools Used

SPSS

LimeSurvey

Deepl Pro

Excel

Word

Tobii Pro

Chat GPT

Gemini

7 List of Figures

7.1 Publication #1 - Appendix

Questionnaire – What comprises a successful educational science video

Complete questionnaire (German - original language) (Beautemps & Bresges, 2021)

1. Thematik
   a. Wie oft schaust du Wissensvideos auf YouTube? (T1)
      1. mehrmals täglich
      2. täglich
      3. mehrmals die Woche
      4. seltener
      5. nie

   b. Ich schaue Wissenvideos, um… (T2)

1. Ein Problem zu lösen (Mathe Tutorial, Flecken aus dem Teppich entfernen, …)
2. Mehr über ein Thema zu erfahren, was mich interessiert
3. Abzuschalten und mich unterhalten zu lassen
4. Mich für eigene Projekte inspirieren zu lassen
5. Neue Themen zu entdecken
6. Anderen Grund angeben

c. Welcher Themenbereich interessiert dich besonders? Mehrere Antworten möglich (T3)
    1. Physik
    2. Chemie
    3. Biologie
    4. Mathe
    5. Weltraum
    6. Wie sieht unsere Zukunft aus?
    7. Politik
    8. Geschichte
    9. Künstliche Intelligenz
    10. Andere

d. Hast du einen Themenvorschlag für ein Video, das du gerne schauen würdest? (T4)

2. Seriosität
    1. Wie wichtig ist es dir, dass bei einem Wissensvideo Quellen angegeben werden? (1-4) (S1)
    2. Schaust du bei einem Video in die Beschreibung um die Quellen aus dem Video zu prüfen? (ja, nein) (S2)
    3. Wie wichtig ist es dir, das der Autor/Moderator einen wissenschaftlichen Abschluss hat? (S3) (1-5)

1. Darstellung und Tonqualität
    1. Auf welchem Gerät schaust du meistens Wissensvideos auf YouTube? (D1)
        1. Handy
        2. Ipad
        3. Fernseher
        4. Computer
    2. (Video Ausschnitt mit schlechter Videoqualität) (D2)

        1. Würdest du dir das Video zu Ende anschauen?
        2. Wie wichtig ist dir die Bildqualität von Wissensvideos? (1-5) (D3)
        3. Wie wichtig ist die Tonqualität bei Wissensvideos? (1-5) (D4)
        4. Ordne die visuellen Elemente so an, dass das wichtigste für dich ganz oben steht und das unwichtigste unten (D5)
            1. Hohe Auflösung
            2. Ruhiger Hintergrund
            3. Reales Bildmaterial zum Thema
            4. Animationen
            5. Videoaufnahmen des Sprechers
        5. Wie findest du Hintergrundmusik in Wissensvideos? (1-5) (D7)
3. Expertise
    1. Wie wichtig sind dir Experteninterviews in Wissensvideos? (1-5) (E2)
    2. Wie viel Zeit sollten diese Interviews im Video einnehmen? (E4) (0/4-4/4)
    3. Wie sollte deiner Meinung nach ein Experte ins Video eingebaut werden? (E3)
        1. Interview
        2. Aussagen zusammengefasst
        3. Zitate
4. Titel und Thumbnail
    1. Wie sehr stört dich Clickbait auf YouTube? (1-5) (TT1)
    2. An welchen Tagen der Woche schaust du in der Regel Wissensvideos? (TT2)
        1. Montag
        2. Dienstag
        3. Mittwoch
        4. Donnerstag
        5. Freitag
        6. Samstag
        7. Sonntag
5. Struktur
    1. Wie wichtig ist es dir, dass am Anfang vom Video das Thema genannt wird? (1-5) (ST1)
    2. Hilft es dir, eine Fragestellung zu Beginn des Videos zu hören? (1-5) (ST2)
    3. Wie wichtig ist dir ein Fazit am Ende vom Video? (1-5) (ST3)

    4. Sollten wichtige Informationen im Video wiederholt werden? (ST4)
        1. Ja
        2. Nein
        3. Egal
    5. Was würdest du gerne mehr in Videos sehen?

6. Persönlichkeit
    1. Geschlecht des Moderators/der Moderatorin (Bilder (Beide unbekannt, gleiches Alter, Aussehen, …)) - Welches Video würdest du dir anschauen? (P1)
    2. Spielt das Geschlecht, der Person die moderiert, eine Rolle für dich? (P2)
    3. Schaust du manchmal Wissensvideos zu einem Thema, nur weil du die YouTuberin oder den YouTuber gut findest? (P3)
    4. Wie wichtig ist dir Humor/Unterhaltung bei Wissensvideos? (P4) (1-5)
    5. Würdest du aufhören Videos von einen Kanal zu schauen, wenn der Moderator wechselt? (P5)

7. Storytelling
    1. Wie wichtig ist dir, dass die Frage aus dem Titel des Videos beantwortet wird? (1-5) (STO1)
    2. Schaltest du ein Video aus, wenn die Frage aus dem Titel beantwortet wurde? (1-5) (STO2)

8. Länge
  1. Was ist für dich die optimale Länge für ein YouTube Video? (L1)
      1. 1-6 Minuten
      2. 7-10 Minuten
      3. 11-15 Minuten
      4. 16-30 Minuten

9. Community basiert
  1. Wie wichtig ist es dir, dass Themenvorschläge aus der Community umgesetzt werden? (1-5) (C1)
  2. Wie empfindest du Abstimmungen in Videos? (1-5) (C2)
  3. Kommentierst du regelmäßig unter Videos? (oft, selten, nie) (C3)
  4. Kommst du zu Videos zurück, um weiter mit zu kommentieren, wenn es neue Antworten gibt? (oft, selten, nie) (C4)
  5. Welche Netzwerke nutzt du noch? (C5)
      1. Instagram
      2. Twitter

    3. TikTok
    4. Reddit
    5. Facebook

10. Erklärung
    1. Kannst du dich noch an die Informationen aus dem Wissensvideo erinnern, dass du vor einer Woche geschaut hast? (Ja, eher weniger, gar nicht) (ER2)
    2. Beschäftigst du dich weitergehend mit einem Thema, nachdem du ein Video geschaut hast? (ER6)
    3. Wenn ja, wie? (ER7)
        1. Weitere Videos gucken
        2. Recherche im Internet
        3. Bücher
        4. Gespräch mit Lehrer*In
        5. Anderes

11. Machart
    1. Sprechgeschwindigkeit (Videos) - Welches Video sagt dir mehr zu? (ER1)

       https://youtu.be/JAKRbPJnUOA

    2. Sprechgeschwindigkeit (Videos) - Welches Video sagt dir mehr zu? (ER4)

       https://youtu.be/iU8au-PxJHk

    3. Sprechgeschwindigkeit (Videos) - Welches Video sagt dir mehr zu? (ER5)

       https://youtu.be/UD3S5Skm1mc

12. Demographische Daten
    1. Alter (DE1)
    2. Geschlecht (DE2)
        1. Männlich
        2. Weiblich
        3. Divers
    3. Ausbildung/Studium im Bereich Naturwissenschaften? (DE3)
    4. Wie sehr interessierst du dich für Naturwissenschaften? (DE4)
    5. Wie viel weißt du schon, bevor du ein Video anschaust über die Thematik? (DE5)
    6. (LETZTE FRAGE) Welchen deutschen YouTube Wissens Kanälen folgst du? (DE6)
        1. Breaking Lab

2. Clixoom
3. Mai Lab
4. Doktor Whatson
5. Marius Angeschrien
6. MrWissen2Go
7. Techtastisch
8. Neugierzone
9. Astro Comics
10. Simplicissimus
11. Kurz Gesagt
12. Raumzeit
13. ANDERE

7.2 Publication #2 - Appendix

Questionnaire PSI

Slightly changed to fit the topic of the research (Rubin et al., 1985; Beautemps & Bresges, 2022):

1. The video shows me what the youtuber is like
2. When the youtuber jokes around it makes the video easier to watch
3. When the youtuber shows me how he feels about the topic, it help me to make up my own mind about it
4. I feel sorry for the youtuber when he makes a mistake
5. When I'm watching the youtuber I feel like I am part of his community
6. I like to compare my ideas with what the youtuber says
7. The youtuber makes me feel comfortable, as if I am with friends
8. I see the youtuber as a natural, down to earth person
9. I like hearing the voice of the youtuber at home
10. The youtuber keeps me company when I am watching the video
11. I look forward to watching the youtuber in the next video
12. If the youtuber appeared on another channel, I would watch that videos
13. When the youtuber reports about a topic, he seems to understand the kinds of things I want to know
14. I sometimes make remarks to my favorite youtuber during the video
15. If there were a story about the youtuber in a newspaper or magazine, i would read it
16. I miss seeing the youtuber when he is on vacation
17. I would like to meet the youtuber in person
18. I think the youtuber is like and old friend
19. I find the youtuber to be attractive
20. I am not satisfied when I get my information from another youtuber

Questionnaire for PSI (German)

Translated and slightly changed to fit the topic of the research (Rubin et al., 1985):

1. Das Video zeigt mir, wie der YouTuber ist
2. Wenn der YouTuber Witze macht, macht es das Video leichter zu sehen
3. Wenn der YouTuber mir zeigt, wie er über das Thema denkt, hilft es mir, mir eine eigene Meinung darüber zu bilden
4. Der YouTuber tut mir leid, wenn er einen Fehler macht
5. Wenn ich dem YouTuber zuschaue, habe ich das Gefühl, Teil seiner Gemeinschaft zu sein
6. Ich vergleiche gerne meine Ideen mit dem, was der YouTuber sagt
7. Der YouTuber gibt mir das Gefühl, dass ich mich wohl fühle, als wäre ich unter Freunden
8. Ich sehe den YouTuber als eine natürliche, bodenständige Person
9. Ich höre die Stimme des YouTuber gerne zu Hause
10. Der YouTuber leistet mir Gesellschaft, wenn ich das Video anschaue
11. Ich freue mich darauf, den YouTuber im nächsten Video zu sehen
12. Wenn der YouTuber auf einem anderen Kanal auftreten würde, würde ich mir das Video ansehen
13. Wenn der YouTuber über ein Thema berichtet, scheint er die Dinge zu verstehen, die ich wissen möchte
14. Ich mache manchmal Bemerkungen zu dem YouTuber während des Videos
15. Wenn es einen Bericht über den YouTuber in einer Zeitung oder Zeitschrift gäbe, würde ich ihn lesen
16. Ich vermisse es, den YouTuber zu sehen, wenn er im Urlaub ist
17. Ich würde den YouTuber gerne persönlich treffen
18. Ich denke, der YouTuber ist wie ein alter Freund
19. Ich finde den YouTuber attraktiv
20. Ich bin nicht zufrieden, wenn ich meine Informationen von einem anderen YouTuber bekomme

Questionnaire for motivation

Translated from German to English and slightly modified (Rheinberg et al., 2001):

1. I like the theme of the video. (I)
2. I think I will understand the video. (E)
3. I probably won't be able to do the task in the follow-up test. (E)
4. In the task, I like the role of the scientist who discovers connections. (I)
5. I feel pressured to do well on the task. (M)
6. The task is a real challenge for me. (H)
7. After reading the instruction, the topic seems very interesting to me. (I)
8. I am very curious to see how well I will do here. (H)
9. I am a little afraid of making a fool of myself here. (M)
10. I am determined to make a full effort in this task. (H)
11. I don't need a reward for tasks like this, I enjoy them as much as I do. (I)
12. I feel a little embarrassed about failing here. (M)
13. I think anyone can do this. (E)
14. I don't think I can do this task. (E)

15. If I manage the task, I will already be a little proud of my efficiency. (H)
16. When I think of the task, I feel a little worried. (M)
17. I would work on such a task even in my spare time. (I)
18. The specific performance requirements here paralyze me. (M)

M) fear of failure
E) probability of success
I) interest
H) challenge

Questionnaire for motivation (German)

Original German language (Rheinberg et al., 2001):

1. Ich mag das Thema des Videos. (I)
2. Ich glaube, dass ich das Video verstehen werde. (E)
3. Wahrscheinlich werde ich die Aufgabe im Anschluss-Test nicht schaffen. (E)
4. Bei der Aufgabe mag ich die Rolle des Wissenschaftlers, der Zusammenhänge entdeckt. (I)
5. Ich fühle mich unter Druck, beim Test gut abschneiden zu müssen. (M)
6. Der Test ist eine richtige Herausforderung für mich. (H)
7. Nach dem Lesen der Instruktion erscheint mir das Thema sehr interessant. (I)
8. Ich bin sehr gespannt darauf, wie gut ich hier abschneiden werde. (H)
9. Ich fürchte mich ein wenig davor, dass ich mich hier blamieren könnte. (M)
10. Ich bin fest entschlossen, mich bei dieser Aufgabe voll anzustrengen. (H)
11. Bei Aufgaben wie dieser brauche ich keine Belohnung, sie machen mir auch so viel Spaß. (I)
12. Es ist mir etwas peinlich, hier zu versagen. (M)
13. Ich glaube, dass kann jeder schaffen. (E)
14. Ich glaube, ich schaffe diese Aufgabe nicht. (E)
15. Wenn ich die Aufgabe schaffe, werde ich schon ein wenig stolz auf meine Tüchtigkeit sein. (H)
16. Wenn ich an die Aufgabe denke, bin ich etwas beunruhigt. (M)
17. Eine solche Aufgabe würde ich auch in meiner Freizeit bearbeiten. (I)
18. Die konkreten Leistungsanforderungen hier lähmen mich. (M)

Video

https://youtu.be/_aMwrmzLtbo

7.3 Publication #3 - Appendix

Pre-Post Test (Beautemps et al, 2024)

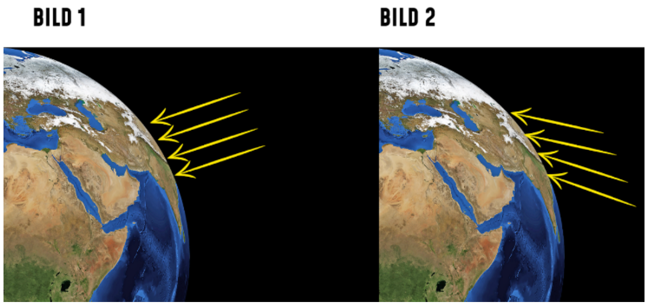
Pre-Post Test Physics of the Seasons (German)

1. Welchen Einfluss hat der Abstand von Sonne und Erde auf die Jahreszeiten?
    a. Einen sehr großen
    b. Einen sehr kleinen
    c. Keinen
    d. Kann man nicht beantworten
2. Stellen Sie sich vor, die Umlaufbahn der Erde wäre eine perfekte Kreisbahn um die Sonne, so dass sich der Abstand zur Sonne nicht ändert. Wie würde sich dies auf die Jahreszeiten auswirken? (Toast Frage 12)

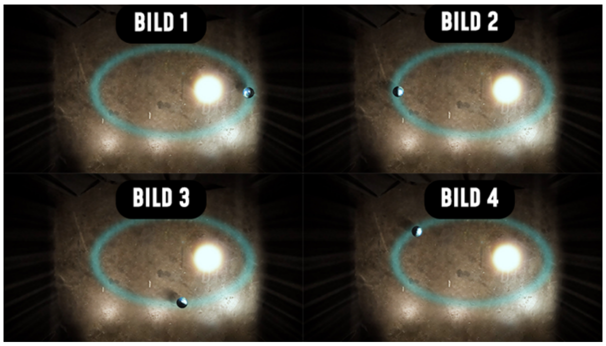
. Wir wären nicht in der Lage, einen Unterschied zwischen den Jahreszeiten zu bemerken.
a. Der Unterschied zwischen den Jahreszeiten wäre weniger auffällig als jetzt.
b. Der Unterschied zwischen den Jahreszeiten wäre deutlicher als heute.
c. Wir würden die Jahreszeiten auf die gleiche Weise erleben wie jetzt.

3. Welche Grafik zeigt die Position der Erdachse korrekt?

4. Was für einen Effekt hat die Position der Erdachse? (mehrere Antworten richtig)
a. Durch die schräge Stellung zur Sonne ist der Sonneneinfall immer gleich.
b. Durch die parallele Stellung zur Sonne ist der Sonneneinfall immer gleich.
c. Durch die schräge Stellung zur Sonne unterscheidet sich der Sonneneinfall je nach Position auf der Umlaufbahn um die Sonne.
d. Durch die parallele Stellung zur Sonne unterscheidet sich der Sonneneinfall je nach Position auf der Umlaufbahn um die Sonne.
5. Stellen Sie sich vor, die Erde stünde aufrecht und wäre nicht geneigt. Wie würde sich das auf die Jahreszeiten auswirken? (Toast Frage 7)
. Wir würden keinen Unterschied mehr zwischen den Jahreszeiten erleben.
a. Wir würden immer noch Jahreszeiten erleben, aber der Unterschied wäre weniger auffällig.
b. Wir würden immer noch Jahreszeiten erleben, aber der Unterschied wäre deutlicher spürbar.
c. Wir würden die Jahreszeiten im Wesentlichen so erleben, wie wir es jetzt tun.
6. Welchen Einfluss hat der Mond auf die Entstehung von Jahreszeiten?
. Einen sehr großen.
a. Einen sehr kleinen.
b. Keinen.
c. Kann man nicht sagen.
7. Wenn das Licht flacher auf die Erde auftritt:
. Ist es bei uns wärmer.
a. Ist es bei uns kälter.
b. Das hat keinen Einfluss auf die Temperatur.
c. Der Einfluss ist minimal und nicht messbar.
8. Welches der Bilder zeigt den Lichteinfall der Sonne im Sommer?



.
9. Welches Bild zeigt die Position der Erde, wenn bei uns auf der Nordhalbkugel Winter ist?



10. Wenn bei uns auf der Nordhalbkugel Herbst ist, was herrscht zu diesem Zeitpunkt auf der Südhalbkugel?
a. Sommer
b. Winter
c. Frühling
d. auch Herbst
11. Warum ist es im Sommer heißer als im Winter? (AMS Frage 6)
. Die Erde ist im Sommer näher an der Sonne.
a. Die Tageslichtdauer ist im Sommer länger.
b. Die Sonne steht im Sommer höher am Himmel.
c. [Sowohl Antwort b als auch c oben]
d. [Alle oben genannten Gründe]

Videos

Animation with Presenter: https://youtu.be/UKIFUhoi7Lc

Pure Animation: https://youtu.be/047NEasveXg

8 *Eidesstattliche Erklärung* (Declaration of Honor)

Hiermit versichere ich an Eides statt, dass ich die vorliegende Dissertation selbstständig und ohne die Benutzung anderer als der angegebenen Hilfsmittel und Literatur angefertigt habe. Alle Stellen, die wörtlich oder sinngemäß aus veröffentlichten und nicht veröffentlichten Werken dem Wortlaut oder dem Sinn nach entnommen wurden, sind als solche kenntlich gemacht. Ich versichere an Eides statt, dass diese Dissertation noch keiner anderen Fakultät oder Universität zur Prüfung vorgelegen hat; dass sie - abgesehen von unten angegebenen Teilpublikationen und eingebundenen Artikeln und Manuskripten - noch nicht veröffentlicht worden ist sowie, dass ich eine Veröffentlichung der Dissertation vor Abschluss der Promotion nicht ohne Genehmigung des Promotionsausschusses vornehmen werde. Die Bestimmungen dieser Ordnung sind mir bekannt. Darüber hinaus erkläre ich hiermit, dass ich die Ordnung zur Sicherung guter wissenschaftlicher Praxis und zum Umgang mit wissenschaftlichem Fehlverhalten der Universität zu Köln gelesen und sie bei der Durchführung der Dissertation zugrundeliegenden Arbeiten und der schriftlich verfassten Dissertation beachtet habe und verpflichte mich hiermit, die dort genannten Vorgaben bei allen wissenschaftlichen Tätigkeiten zu beachten und umzusetzen. Ich versichere, dass die eingereichte elektronische Fassung der eingereichten Druckfassung vollständig entspricht.

Köln, 07.12.2024 J. Beautemps