# BRNO UNIVERSITY OF TECHNOLOGY
VYSOKÉ UČENÍ TECHNICKÉ V BRNĚ

## FACULTY OF ELECTRICAL ENGINEERING AND COMMUNICATION
FAKULTA ELEKTROTECHNIKY
A KOMUNIKAČNÍCH TECHNOLOGIÍ

## DEPARTMENT OF FOREIGN LANGUAGES
ÚSTAV JAZYKŮ


# Design of Educational Videos for the Study Programme English in Electrical Engineering and Informatics
NÁVRH EDUKAČNÍCH VIDEÍ PRO STUDIJNÍ PROGRAM ANGLIČTINA
V ELEKTROTECHNICE A INFORMATICE

**BACHELOR'S THESIS**
BAKALÁŘSKÁPRÁCE


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**BRNO 2023**

VYSOKÉ UČENÍ TECHNICKÉ V BRNĚ
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# Bakalářská práce

bakalářský studijní program **Angličtina v elektrotechnice a informatice**
obor Angličtina v elektrotechnice a informatice
Ústav jazyků

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***Ročník:*** 3 ***Akademický rok:*** 2022/23

**NÁZEV TÉMATU:**

**Návrh edukačních videí pro studijní program Angličtina v elektrotechnice a informatice**

**POKYNY PRO VYPRACOVÁNÍ:**

Diskutujte o důležitosti využití edukačního videa v hodinách odborného anglického jazyka zaměřeného na elektrotechniku a informační technologie a pokuste se navrhnout sérii výukových videí pro vybrané předměty.

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***Termín zadání:*** 9. 2. 2023 ***Termín odevzdání:*** 30. 5. 2023

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předseda oborové rady

# Abstract

Nowadays, information technology is actively incorporated into education worldwide, especially after the global pandemic. Advances and innovations in educational technology, such as access to the Internet, multimedia technology, and handheld devices, have led to significant changes in the way people interact and learn. A growing tendency toward the use of technology and its integration into the school curriculum has gained crucial importance. In particular, the use of a video as an audio-visual material in foreign language lessons has grown rapidly because of the increasing emphasis on the communicative approach, and the use of a video is a great stimulus and facilitator for foreign language teachers. The aim of this bachelor's thesis is to discuss the importance of using a video in engineering lessons taught in a foreign language and try to define the distinctive features of a high-quality educational video. A literature review is used to identify and examine relevant theories and methods related to the concept of an educational video. The review reveals that educational videos have emerged as a critical part of higher education, and they provide an important tool for delivering content in many flipped, blended, and online classrooms. Videos increase student engagement, which in turn helps improve their learning outcomes. The use of videos stimulates the cognitive processes of thinking, reasoning, problem-solving, decision-making, and creating. Videos take the student beyond recall-and-relate activities. The practical part reveals the process of creating educational video material and focuses on designing a series of educational videos for selected electrical engineering and information technology subjects taught in English.



# Key words

educational video, media, learning, effectiveness, principles, cognitive load, engagement, active learning, educational video platforms, editing techniques, production

# Abstrakt

V současné době se informační technologie aktivně zapojují do vzdělávání po celém světě, zejména po celosvětové pandemii. Pokroky a inovace v oblasti vzdělávacích technologií, jako je přístup k internetu, multimediální technologie a přenosná zařízení, vedly k významným změnám ve způsobu interakce a učení. Rostoucí tendence k využívání technologií a jejich zařazení do školních osnov získaly zásadní význam. Zejména využití videa jako audiovizuálního materiálu v hodinách cizího jazyka se rychle rozšířilo, protože se stále více klade důraz na komunikativní přístup a využívání videa představuje pro učitele cizích jazyků velký přínos při zprostředkování výuky. Cílem této bakalářské práce je diskutovat o významu využití videa v hodinách technických předmětů vyučovaných v anglickém jazyce a pokusit se definovat charakteristické vlastnosti kvalitního edukačního videa. K identifikaci a zkoumání relevantních teorií a metod souvisejících s konceptem edukačního videa byla použita rešerše literatury, která odhalila, že edukační videa se stala klíčovou součástí vysokoškolského vzdělávání a poskytují důležitý nástroj pro výuku obsahu v převráceném, kombinovaném a online vyučování. Videa také zvyšují angažovanost studentů, což vede ke zlepšení jejich studijních výsledků. Používání videí stimuluje kognitivní procesy myšlení, uvažování, řešení problémů, rozhodování a tvoření. Videa přenesou studenta nad rámec aktivit souvisejících s vybavováním si probrané látky a vytvářením souvislostí. Praktická část představuje proces tvorby vzdělávacích videomateriálů a zaměřuje se na tvorbu sérií edukačních videí pro vybrané elektrotechnické a informatické předměty vyučované v angličtině.



# Klíčová slova

edukační video, média, učení, efektivita, principy, kognitivní zátěž, angažovanost, aktivní učení, vzdělávací video platformy, techniky střihu, produkce

# Rozšířený abstrakt

Oblast vzdělávání a učení se stále více zaměřuje na využívání různých elektronických zdrojů. Učitelé i studenti mají nyní široký přístup k technologickým nástrojům, jako jsou chytré telefony, tablety, notebooky a digitální fotoaparáty, které mohou používat ve výuce. V současné době je pro učitele velmi obtížné upoutat pozornost dnešních studentů obyčejným výkladem nebo přednáškou, proto je využití videa jednou z nových strategií ve výuce, které má podpořit a zapojit studenty do procesu učení a také zvýšit jejich účast ve výuce. Využití videa ve výuce je v současnosti předmětem mnoha diskuzí a považuje se za důležitý a zajímavý způsob výuky. Sledování edukačních videí znamená více než jen nový přístup ke každodennímu učení. Usnadňuje proces učení, zvyšuje motivaci, rozvíjí dovednost poslechu, podporuje pozitivní odezvu a vytváří zajímavou a živou atmosféru. Proto je hlavním cílem této bakalářské práce diskutovat o významu využití videí v hodinách cizího jazyka a technických předmětů a také identifikovat charakteristické znaky kvalitního edukačního videa, které budou následně uplatněny v praxi při tvorbě série edukačních videí na vybrané téma.

Tato bakalářská práce poskytuje ucelený přehled v oblasti edukačních videí, jejich charakteristik a požadavků na jejich kvalitu. První část se zabývá teoretickými koncepty a druhá, praktická část analyzuje vybrané edukační platformy a jejich videa a následně popisuje tvorbu edukačních videí pro vybrané technické předměty studijního programu Angličtina v elektrotechnice a informatice.

Hlavním cílem teoretické části je vymezit koncept videa z nového úhlu pohledu a zbavit se stereotypu, že se jedná o něco, co jednoduše kombinuje zvuk a obraz. Z teoretické části práce, která je zpracována metodou rešerše literatury, vyplývá, že video podporuje imaginativní složku myšlení studentů a jejich osobní angažovanost, usnadňuje jejich porozumění a zvyšuje rychlost plnění úkolů. Analyzované studie rovněž odhalily řadu výhod v souvislosti s využitím videomateriálu ve výuce, jakými jsou možnost opakovaného sledování vytvořených videí, které vede k systematickému osvojování probíraného učiva, možnost přerušovaného sledování, které umožňuje kontrolu procesu učení, a možnost výuky z jakéhokoli místa v libovolném čase.

První kapitola teoretické části, zaměřená na vysvětlení samotného pojmu video pro výukové účely, zdůrazňuje, že významným aspektem je žánr scénáře, který se odehrává před zrakem diváka a jeho bohatost je dosažena kombinací záběrů a jejich digitálního zpracování s využitím nejrůznějších efektů. V kombinaci s technologickým rozvojem je tak možné snímky nejen z kamerového záznamu proměnit ve velice poutavý zdroj informací. Pro pochopení videa jako média masové komunikace na obrazovce je v kapitole popsán i vývoj videoprůmyslu včetně všech jeho zlomových bodů a jejich důsledků. Kapitola okrajově nastiňuje vývoj videa od doby druhé poloviny 20. stolení a shrnuje jeho základní výhody a nevýhody. S příchodem dostupného internetu se audio vizualizace stala nástrojem socializace cílové skupiny – mladých lidí. Následně je kapitola doplněna o shrnutí rozvoje internetových platforem (např. YouTube, Google) a způsoby, jakými ovlivnily oblast mediální výchovy včetně důsledků jejich pokroku.

Následující kapitola pojednává o tom, jaké kvality má splňovat kvalitní edukační video. Studie MacHardyho a Pardose (2015) potvrzují, že obsah některých videí má na studenty jen nepatrný vliv. Studie Brameové (2016) je klíčová pro jednu z kapitol teoretické části této bakalářské práce a představuje podklad pro zkoumání některých aspektů v praktické části. Ukazuje, že video může být při správném použití důležitým nástrojem pro zkvalitnění výuky a účinným nástrojem v jakékoli sadě výukových materiálů. Brameová také upozorňuje na přístupy a metody, které umožňují učitelům udělat výukový materiál zajímavým, a hlavně užitečný s jeho maximálním využitím. V této kapitole je také vysvětleno, jak kontrolovat kognitivní zátěž videa, jak zvýšit angažovanost studentů při jeho sledování a jak jeho prostřednictvím podpořit jejich aktivní učení. Kognitivní zátěž videa má několik složek, které vedou k zapamatování si obsahu a jeho uložení do dlouhodobé paměti. Zapojení studentů u sledování videa se vztahuje k jejich pozornosti, zájmu, celkové soustředěnosti a zvědavosti. Aktivní učení z videí pak zajišťují aspekty jako interaktivní otázky a prvky, které studentům zajišťují jeho řízení, návodné otázky anebo také vytvoření vlastního videa za domácí úkol. Všechny zmíněné teoretické koncepty jsou velmi důležité pro praktickou část, která je zaměřena na metodiku a tvorbu edukačních videí pro technické předměty vyučované v angličtině.

Praktická část se nejprve zaměřuje na výběr a následnou analýzu online vzdělávacích video platforem včetně na nich již existujících videí. Dále také odhaluje proces tvorby výukových videomateriálů a zaměřuje se na tvorbu edukačních videí pro vybrané předměty z oblasti elektrotechniky a informatiky vyučované v angličtině. Tento způsob zpracování praktické části byl zvolen z několika důvodů. Existuje například mnoho různých platforem a zdrojů, kde jsou pro učitele k dispozici edukační videa, ale ne vždy je možné najít potřebné materiály na webu pro streaming videí, proto se v takovém případě může stát, že učitel musí vytvořit vlastní videa. Součástí praktické části je proto také řada tipů, které mohou být pro učitele užitečné při tvorbě vzdělávacího obsahu. Vlastnoručně vytvořené video má oproti videím z veřejně přístupných stránek značné výhody, jako jsou autorská práva a skutečnost, že učitel prezentuje učivo tak, jak potřebuje. Aby bylo pro učitele používání vytvořených videí pohodlnější, je zde k dispozici podrobná charakteristika každého videa v podobě jeho cíle struktury a obsahu. Každé video je také vyhodnoceno z pohledu kognitivní zátěže, angažovanosti a aktivního učení studentů. Transkripty videí jsou uvedeny v příloze k bakalářské práci. Pro tvorbu samotných videí byla využita licencovaná verze programu ClimpChamp, která obsahuje rozsáhlou škálu interaktivních možností a jiných funkcí. Videa jsou doplněna kvízy a animacemi. Druhé video je navíc kombinované s moderní technologií umělé inteligence, což videu dodává profesionálnější kvalitu.

Starykovska, V. (2023). *Návrh edukačních videí pro studijní program Angličtina v elektrotechnice a informatice.* Brno: Vysoké učení technické v Brně, Fakulta elektrotechniky a komunikačních technologií. 80 s.

Vedoucí bakalářské práce: Mgr. Ing. Eva Ellederová, Ph.D.

# Prohlášení

Prohlašuji, že bakalářskou práci na téma *Návrh edukačních videí pro studijní program Angličtina v elektrotechnice a informatice* jsem vypracovala samostatně pod vedením vedoucí bakalářské práce a s použitím odborné literatury a dalších informačních zdrojů, které jsou všechny citovány v práci a uvedeny v seznamu literatury na konci práce.

Jako autorka uvedené bakalářské práce dále prohlašuji, že v souvislosti s vytvořením této práce jsem neporušila autorská práva třetích osob, zejména jsem nezasáhla nedovoleným způsobem do cizích autorských práv osobnostních a/nebo majetkových a jsem si plně vědoma následků porušení ustanovení § 11 a následujících zákona č. 121/2000 Sb., o právu autorském, o právech souvisejících s právem autorským a o změně některých zákonů (autorský zákon), ve znění pozdějších předpisů, včetně možných trestněprávních důsledků vyplývajících z ustanovení části druhé, hlavy VI. díl 4 Trestního zákoníku č. 40/2009 Sb.

V Brně dne 30. 5. 2023 ……………………………………..

Vladyslava Starykovska

## Acknowledgements

I would like to thank the best advisor the universe could give me – Mgr. Ing. Eva Ellederová, Ph.D. Her level of what may seem like endless patience, the amount of work she has done, her sincere support, and her incredible responsiveness deserve a low bow and applause. In all this time she has become a very dear person to me. I truly appreciate it and all she has done for me.

# Table of Contents

# 1 Introduction

The educational sphere is undergoing radical changes: e-learning is actively used, and distance learning technologies are developed. In the past, students passively received educational content, which was changed with the introduction of the communicative approach[1]. The use of information technologies in the educational process encourages students' active participation in lessons and allows conscious mastery of knowledge. The quality of future qualified specialists depends directly on the quality of the educational content, methods, and means of teaching.

The relevance of the stated topic is to identify the possibilities of using video materials in the learning process, which allows significantly increasing the effectiveness of the teacher's learning activities: educational video makes the process of mastering the learning content live, interesting, and problematic. While watching in the classroom, there is an atmosphere of joint cognitive activity. Under these conditions, even inattentive student becomes attentive because they need to make some effort to understand the content of the film. The use of different channels of information (auditory and visual channels) has a positive effect on the strength of capturing the material. Also, the dynamics and imagery of video information promote effective memorization of educational information, increasing the likelihood of reproducing this content in the future.

The title of this thesis is Design of Educational Videos for the Study Programme English in Electrical Engineering and Informatics. I chose this topic because I find the field of media interesting, and I am keen on creating video content. The process of planning, designing, and bringing an idea to life has always fascinated me and I have devoted some part of my life to this activity. The main aim of this work is to explore the value of integrating a video in engineering and foreign language lessons, e.g., for facilitating foreign language acquisition, students' self-study, and motivation. Also, one of the main contexts of this work is identifying the traits that make a good educational video and providing some innovative methods for shooting and editing videos which will subsequently be used to create a series of my personal educational videos.

[1] The *communicative approach* or *communicative language teaching* emphasizes the ability to communicate the message in terms of its meaning, instead of concentrating exclusively on grammatical perfection or phonetics (Lightbown & Spada, 2006). In the communicative approach, the main objective is to present a topic in context as authentic as possible, so a video has begun one of the most commonly used sources in the classroom.

The thesis is divided into two parts, theoretical and practical, which contain a total of four chapters, subsequently divided into several subchapters. The first chapter acquaints the reader with the concept of a video as a cinematographic medium, with the process of its emergence and subsequent development, as well as a brief introduction to its history and evolution. Based on the literature review, the reader can briefly learn that video materials used in the learning process are understood as a type of technical educational means, providing the function of transmitting information as well as receiving feedback during its perception and assimilation for the purpose of the subsequent development of certain skills and competencies in students. The next chapter deals with approaches and strategies that act as auxiliary tools for maximizing the effectiveness of media education. Regarding this chapter, it could be concluded that the use of modern video resources affects students on an emotional level, creates a high degree of motivation, and, consequently, contributes to the effective absorption of new learning information. This brings satisfaction and forms the desire for further improvement.

The first chapter of the practical part of this bachelor's thesis aims to introduce the reader to the concept of online educational platforms, including all the possibilities that this field can provide. The following subchapters provide the reader with a detailed description, analysis and comparison of the selected educational platforms and their educational videos. The practical part is based on the literature research from the theoretical part of this bachelor's thesis. The main objective of the second chapter is to develop and create educational videos focused on electrical engineering and information technology topics that should comply with all requirements and principles for "effective instructional videos" outlined in the theoretical part of this thesis.

# Theoretical part

# 2 Video and its development as a component of media education

The era of information technology is rapidly changing the educational process of foreign language teaching in educational institutions. As Novoselov (2019) states, the phenomenon of educational video content emerged through the transformation of educational cinematography and developed cyclically.

Köster (2018) claims that these transformations have had an enormous effect on the evolution of digital learning. Notably, educational video content has not only become beloved among society but also has revealed many previously unexplored learning techniques that have heightened teaching skills and professional resources (Köster, 2018). Currently, the interest in different educational videos is still increasing, and, as Ivanova (2012) notes, there is a public demand for educational resources that are available for open mass education. This chapter will deal with the concept of educational video, its historical background, and issues related to its evolution.

## 2.1 The concept of an educational video

First, it is necessary to define what is meant by the term *video* (media is used as a synonym). Official sources consider the term *video* as a screenplay genre where the plot unfolds in front of the audience. The richness of the video visuals is achieved by a combination of all kinds of complex frames through various screen presentations and digital video editing with the use of computer-generated special effects. Today, a video is united by the concept of "computer-mediated communication" and represents a social institution (Ivanova, 2012).

This opinion is endorsed by Bull and Bell (2010). They emphasize that technological advancements have expanded the idea of a digital video. According to them, a "*video* is no longer limited to moving images filmed by a video camera" (2010, p. 2). New technologies have opened a world of many digital opportunities and techniques to students, such as, for example, digital storytelling, Flash movies, and the creation of screencasts, etc. With its help creators can cover any topic with a fresh, engaging, and original approach, and turn something hard, sensitive, or boring into something easy, fun, and understandable!

Bijnens et al. (2006) explain that:

> Video, among other new technologies, offers education a challenge to rethink much of its methods and content, helping it tilt the balance away from teacher-centered instruction towards learner-centered study. It also offers the advantage of utilizing vision, that powerful but neglected sense, in new ways. (p.5).

The concept of an educational video, contrary to simple video clips, consists in revealing the topics which the audience is curious about and delivering useful information that makes value to the viewers. Once the pandemic began to spread, all things about learning online globally changed. People had to deal with self-education and solve their issues remotely. Yum Yum Videos (2020, May 29) points out that now educational videos are needed more than ever, mainly because of a drastic rise in the use of a video in the classroom and the demand for educational videos.

Educational video content, as Yum Yum Videos (2020, May 29) indicates, is not only a reliable source of information but also one that cares about the needs and concerns of users. Video-based learning is memorable and comprehensive, it easily attracts any student, it is accessible and customizable. Rewatching, taking notes, or thinking through the topic in one's brain while pausing – these all, according to Hanzic (2019, January 24), are benefits of using a video for educational goals, which create a personalized learning experience, allowing individuals to learn at their own pace.

## 2.2 History of educational video production

The emergence of a modern video as one of the means of computer-mediated mass communication was preceded by a long, fascinating path of development, including both advantages and disadvantages. Bull and Bell (2010) report that film as an artistic medium first appeared in the late 19th century and completely transformed cinematography in the 20th century. Further, it was complemented by broadcast television in the second half of the 20th century. Nearly 99 percent of all households had a television by the 1970s, watching more than four hours per day on average. As Watson (1997) mentions, broadcast television not only covered history but altered its course in some instances.

The technique of using video content to develop education has been used for a long time and is integrated into many different educational models. According to Ivanova (2012), the progenitor of educational video content – educational cinematography – appeared almost immediately after the invention of classical cinema by the Lumière brothers. The first use of a video for educational purposes dates back to 1898, when the first educational film was released in France.

Initially, the production of educational films was haphazard, and topics were chosen at random; however, the first investigations in this field, proved the effectiveness of techniques and methods being integrated into educational activities (Novolelov, 2019). Many countries began producing their own educational films after realizing their potential. Thus, in 1908, the production of educational films began in the United States (Ivanova, 2012; Novoselov, 2019).

With the development of high-quality broadband streaming video, educational institutions had the opportunity to reach a wider through video education. This development, as Köster (2018) notes, had increased with the spread of one of the most recent approaches: online educational platforms, or MOOCs, which were established in 2010. Among them are companies such as Coursera (2012), Udacity (2011), and Udemy (2010), as well as the university-led edX platform. Their key teaching methods are video lectures, tutorial videos, and other educational video content. Their emergence proved to be the solution to the issues that higher education was facing, including growing expenses and the unstable needs of students. But at the same time, it has also been perceived as the collapse of the conventional system of higher education.

## 2.3 Internet and evolution of educational videos

As time passed, the Internet joined the list of cinematic innovations. It was initially created as a platform to distribute information across a group of computers connected together by a single network. The concept, which in general united sharing information and learning, as Harvey (2019, July 19) adds, was almost the same, i.e., exchanging ideas with the goal of discovering something new.

Audio visualization has become a "tool" for the socialization of the younger generation and, according to Ivanova (2012), the process of assimilation of basic knowledge, norms, and values by present-day students takes place to a great extent digitally. Students could now interactively access a variety of video information, including in foreign languages, and realize their creative ideas in a special virtual way without leaving home.

Human life, as Selwyn (2014) writes, is nowadays thoroughly saturated with digital technologies, and it is simply impossible to imagine our lives without the Internet. The online world becomes a crucial part of the existence of contemporary society almost immediately after birth and, unfortunately, or fortunately, is seen as a necessity for modern existence, much like oxygen and water. As Tapscott (2009) observes, "to them [contemporary youth] technology is like the air." (p.20). Selwyn (2014) further points out that:

> Talking about the Internet and education simply means talking about contemporary education. The Internet is already an integral element of education in (over)developed nations, and we can be certain that its worldwide educational significance will continue to increase throughout this decade. (p.196)

### 2.3.1 Evolution of educational videos on Google and YouTube

Both school education and self-education are primarily responsible for why people use the Internet. Sharma and Sharma (2021) describe that, apparently, the world wide web had a great impact on the education and learning experiences of students. It expanded all kinds of attitudes in the traditional education system, bringing with it new, creative and innovative development dimensions. Thus, the influence of the global system of the Internet was expanding and it was clear that a new wave of changes and new signs of progress would soon influence the users. For these reasons, the hitherto unknown Google had an enormous impact on the whole world. This search engine, as Harvey (2019, July 19) reports, has become the number one most browsed website on the internet since the growing demand of users is to learn a wide range of previously unknown information.

Further, the need to learn began to increase, and thus, in early 2005, YouTube appeared. Later, in 2006, it was purchased by Google, which meant that YouTube, since that moment, has worked "under Google as one of its subsidiaries" (Sharma & Sharma, 2021, p. 2686).

YouTube is a platform where people across the world can upload, like, share, and comment on videos. YouTube has changed the way in which a video is created and consumed (Gannes, 2009). In the first year of use after YouTube was established, individual users created and provided more videos than the three original television networks (ABC[2], NBC[3], and CBS[4]) had produced in the half-century since they were founded. Five years later, hundreds of thousands of videos are uploaded to YouTube every day, at a rate of more than twenty hours of a video per minute (Junee, 2009, May 20).

YouTube has evolved into a reliable source for self-education. Its audio-visual quality has made it an effective educational tool, add Sharma and Sharma (2021), and it has made the topics with hard concepts and complex theories much more fun. Here, everyone had the ability to find anything they were interested in, whether it was video lectures uploaded by teachers, science tutorials, or even videos of simple things, e.g., instructions about how to tie a tie. Studies show that more than 50% of viewers go to YouTube to learn how to do something they have never done before (Hanzic, 2019, January 24).

The mere reading of books, memorization, and rote learning is an outdated scheme of education that requires a practical application. Sharma & Sharma (2021) point out that:

> Blackboards and chalks, which used to rule the education system, have successfully handed over the charge to smart learning techniques. YouTube emerged as a good digitized pedagogical tool to meet the demands of Generation Z. (p. 2686)

Generation Z is "the group of people who were born between the late 1990s and the early 2010s, who were regarded as being very familiar with the internet" (Generation Z, n.d.). However, do not forget that a long time ago such methods were effective, and it can be assumed that even now they may be relevant for some students. YouTube can also help viewer with this: not by limiting students to the knowledge of one teacher or one way of teaching, but on the contrary, by providing them with several options regarding teachers and teaching methods.

All of this is a crucial part of the YouTube system's mechanism. It connects academicians, educators, and researchers from all over the world and provides interesting, knowledgeable, and engaging content that has added a new dimension to education by making it innovative as well as creative, Sharma and Sharma (2021) concluded.

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[2] The American Broadcasting Company
[3] The National Broadcasting Company
[4] Columbia Broadcasting System

## Summary of Chapter 2

*This chapter acquainted the reader with the concept of a video as a medium of cinematography and distinguished it clearly from the concept of an educational video. Then the development of the video industry was thoroughly discussed, including all of its turning points and ramifications. The historical path of video, as one of the means of computer-mediated screen mass communication, with all its turning points and key facts, was fully traversed. The last subchapters dealt with the Internet and the widely known video platforms, their flourishing, and how they have in one way or another influenced the field of media education, focusing on the consequences of its progress.*

# 3 What makes a video effective?

Instructional video content plays a big role in the system of education worldwide, thus standing as an incredibly great tool for delivering educational content in many classes. It makes the schooling process available, affordable, and expandable, creating meaningful learning experiences. Several investigations, according to Means et al. (2010) and Schmid et al. (2014), have shown that technology can improve the process of learning. Besides, Allen and Smith (2012), Kay (2012), Lloyd and Robertson (2012), Rackaway (2012), Hsin and Cigas (2013) and Stockwell et al. (2015) emphasize how a video, in particular, can be a very effective educational tool. On the contrary, Guo, Kim, and Rubin (2014) observe that large fragments of video content simply remain ignored by students. Furthermore, MacHardy and Pardos (2015) demonstrate that some content barely affects students' performance.

What, then, helps mentors select or create video films that effectively lead students toward successful learning outcomes? There are certain factors that, from a professional's perspective, should be considered by lectors, in case they wish to achieve maximum effectiveness from the usage of educational video content. In general, there are three principles emphasized by Brame (2016): how to control the *cognitive load* of the video, how to enhance *student engagement* with the video, and how to encourage *active learning* from the video (see Figure 1). The following chapters will focus on framing these concepts and suggesting practical ways teachers can apply them when using a video as an educational tool.

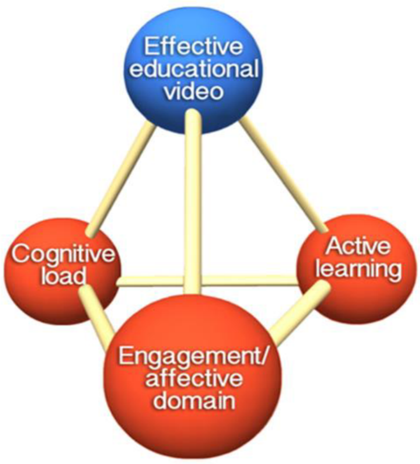


*Figure 1.* The pyramid creating an effective educational video.
Adapted from Brame (2015).

## 3.1 The cognitive load

The *cognitive load* is one of the primary factors that is considered while creating educational content. Sweller, van Merriënboer and Paas (1998) claim that:

> The human cognitive system can be characterized as one that places its primary emphasis on the ability to store seemingly unlimited amounts of information in long-term memory. This information does not just consist of small, isolated facts but can include large, complex interactions and procedures. (p.254)

On this basis, the concept of the *cognitive load theory* was developed by Sweller (1988, 1989, 1994) and his colleagues at the University of New South Wales in Sydney. The *cognitive load theory* states that memory has several components: sensory memory, working memory, and long-term memory. The key aspect is to remember and store as much material as possible in a *long-term memory*, which has no known capacity limitations (Paas & van Merriënboer, 1994; Sweller, van Merriënboer & Paas, 1998) and is described as a complex and permanent storehouse for individuals' knowledge about the world and their experiences in it (Baddeley, 1986; Moore, Burton & Myers, 1996; Wyer, Schank & Abelson, 1995). Since *sensory memory* only collects information and briefly holds raw, unprocessed data, transferring it later for processing to the *working memory* slot, which is able to store information for only about thirty seconds (Peterson & Peterson, 1959) and can keep and process about seven information segments at a time (Miller, 1956), it is important for students to carefully choose which information to pay attention to in the learning process. Sweller et al. (1998) equate *working memory* with consciousness and assert that "humans are conscious of and can monitor only the contents of working memory" (p.252). *Working memory* is defined by Pezzulo (2007) as "a limited capacity system that can temporarily maintain, store, and manipulate information for supporting human thought processes" (p. 1). These observations have important implications for the production of instructional materials.

Based on this model of memory by Sweller (1988), the cognitive load theory states that multimedia learning contains three main components, *intrinsic load*, *germane load* and *extraneous load*, as demonstrated in Figure 2.

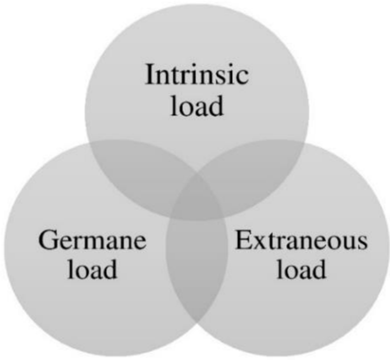


*Figure 2.* Three components of any learning experience based on cognitive load theory Adapted from Sweller (1988, 1989, 1994).

These three aspects are fully described by Sweller (1988, 1989, 1994) in relation to cognitive load theory, learning difficulty, and instructional design. The first of these is *intrinsic load*, which is caused by the complexity of the task being studied and is defined by the degrees of connectivity within the subject. For example, "blue = azul" is a word pair, illustrating a subject with a low intrinsic load, whereas grammar is a subject with a high intrinsic load owing to its many levels of connectivity and conditional relationships. Learning individual vocabulary units or words of a foreign language, according to van Merriënboer, Kirschner, and Kester (2003), is intrinsically less complex than learning grammar because the latter requires consideration of the interaction of different parts of speech and is, therefore, intrinsically more complex. The second component is *germane load*, which is needed for active knowledge construction, for example, making the comparisons, doing the analysis, and having a logical chain for better understanding. This type of cognitive load is assumed by Ibrahim et al. (2012) to be the key factor in the understanding and storing of the learning material, and, thus, it is considered to be germane to learning. The third and last component is *extraneous load*, which, in simple words, does not help the student achieve the expected learning goals. As Sweller et al. (1998) emphasize, the load is extraneous because it is entirely caused by the format of the study and instructional design. This problem usually arises as a consequence of a poorly designed lesson - excessive information and unclear instructions, e.g., too much text on a PowerPoint slide, resulting in extraneous demands on the working memory (Ibrahim et al., 2012).

The intrinsic cognitive load influences whether the extrinsic cognitive load causes problems in students (Sweller and Chandler, 1994). High levels of both intrinsic and extrinsic cognitive load might be detrimental to learning due to an excess of working memory capacity. Given that intrinsic cognitive load cannot be changed, it can be necessary to provide instructional materials that minimize unnecessary cognitive load. In contrast, if the intrinsic cognitive load is minimal due to the low level of element interaction, a high external cognitive load resulting from insufficient teaching methods may not be as damaging. Also, van Merriënboer (1997) adds that redirecting attention is necessary to reduce unnecessary cognitive load while simultaneously boosting germane cognitive load: the focus of l students' attention has to be switched from non-learning processes to learning-related processes. These components are more explicitly described by De Jong (2010).

These studies have significant implications for the design of educational materials and have a great effect on students' outcomes. Teachers, in particular, should try to reduce the extraneous cognitive load requirements and should consider the intrinsic cognitive load of the subject when creating learning experiences, carefully selecting the material. (Ibrahim et al., 2012; Brünken, Steinbacher, Plass, & Leutner, 2002). Table 1 lists some practices, based on the cognitive load theory that help to maximize learning from educational videos.

These cognitive theory-based recommendations and findings have resulted in the development of various design principles to manage the cognitive load demands associated with audiovisuals (Mayer, 2001; Paas et al., 2003). These principles can be categorized into two groups: those that reduce extraneous cognitive load and increase the germane load, namely *signaling* and *weeding*, and those that are aimed at managing intrinsic cognitive load, i.e., *segmenting*. They were tested in a variety of learning scenarios and involved the manipulation of characteristics of the audio-visual materials. The following subchapters will review these principles and include specific prescriptions regarding how they work, for whom, and for what types of learning materials.

Table 1. *Practices to maximize learning from educational videos with regard to cognitive load*

| Element to consider | Recommendation | Rationale | Examples |
|---|---|---|---|
| Cognitive load | • Use signaling to highlight important information. | • Can reduce extraneous load.<br>• Can enhance germane load. | • Key words on screen highlighting important elements<br>• Changes in color or contrast to emphasize organization of information<br>• Changes in color or contrast to emphasize relationships within information<br>• Brief out-of-video text explaining purpose and context for video (e.g., learning objective for video) |
| | • Use segmenting to chunk information.<br>• | • Manages intrinsic load.<br>• Can enhance germane load. | • Short videos (6 minutes or less)<br>• Chapters or click-forward questions within videos |
| | • Use weeding to eliminate extraneous information. | • Reduces extraneous load.<br>• | • Eliminating music<br>• Eliminating complex backgrounds |
| | • Match modality by using auditory and visual channels to convey complementary information. | • Can enhance germane load. | • Khan Academy[5] style tutorial videos that illustrate and explain phenomena<br>• Narrated animations |

Note: Adapted from Brame (2016, p. 3).

### 3.1.1 Signaling

Van Gog (2014) defines *signaling* (or cueing) as a technique of adding cues to signal the main ideas and guide students' attention to the relevant elements of the material. Key concepts are summarized and highlighted in signaled presentations to assist students in selecting relevant information and organizing it into coherent mental chains, which, as Mautone and Mayer (2001) observe, improves both remembering and knowledge transfer. For example, signaling can help students focus on relevant content in audio-visuals through several methods: increasing the brightness of particular text parts (de Koning, Tabbers, Rikers, & Paas, 2007), changing a word's font style to boldface (Mautone & Mayer, 2001),

[5] Khan Academy is an American non-profit educational organization created in 2008 by Salman Khan. It offers practice exercises, instructional videos, and a personalized learning dashboard that empower learners to study at their own pace in and outside of the classroom. (Khan Academy, 2022)

giving related elements the same colour (Kalyuga, Chandler & Sweller, 1999), adding a symbol that draws attention to a region of a screen (e.g., an arrow; de Koning et al., 2009), or by adding an outline and headings indicated by underlining (Mayer, 2005).

Signaling improved recall of data, particularly the information on which it was applied, according to studies aimed at understanding the basic text. Foster (1979), Glynn and Di Vesta (1979), and Cashen and Leicht (1970) state that memory for non-signaled content is unaffected, inhibited, or sometimes even enhanced. De Koning (2009) was convinced that emphasizing particular content may guide students' attention to essential information but does not necessarily reduce attention to uncued information. Research also found that improper use of signaling can even increase the cognitive load of the student.

Signaling was also found to reduce extraneous cognitive processing during studying. Loman and Mayer (1983) compare two groups of students who studied signaled or non-signaled texts and conclude that the students in the signaled condition had a lower cognitive load, which caused a better understanding of the material, as shown by better memory and retelling ability. They conclude that text signaling significantly reduces unnecessary load related to looking for relevant information, thus freeing up working memory resources for real learning activities.

### 3.1.2 Segmenting

*Segmenting* is a design principle of dividing the learning materials into short units of information and distributing them over topics or lessons, called segments (Clark, Nguyen & Sweller, 2006). The goal of this method, according to Sweller (1999), is to help students mentally digest manageable pieces of learning materials before moving on to the next segment of information and give them control over the flow of new information. Segmentation manages the intrinsic load while increasing the germane load, preserving the cognitive capacity required to understand the learning content. Spanjers and van Merriënboer (2010) describe segmentation as a possible solution to the problem of information transiency in educational videos.

Several studies investigate the effects of segmentation on learning and find that this method is good for beginners, especially when the learning material is quite complex, and the presentation is moving at a quick clip. One of these is an investigation by Spanjers et al.

(2011), where they examine the effects of segmentation on the performance of students with different levels of prior knowledge. As a result, students with lower levels of prior knowledge learned more efficiently from segmented animations than from non-segmented animations, while students with higher levels of prior knowledge learned equally efficiently from non-segmented and segmented ones. A possible explanation could be that students with higher levels of prior knowledge might rely more on their already existing knowledge and not use segmentation.

Similar findings reported by Boucheix and Guignard (2005) show that students with higher levels of prior knowledge do not need additional guidance through segmentation because, for students with higher levels of prior knowledge, the number of cognitive resources is reduced.

Moreno (2007) conducted an experiment where participants who studied a segmented version of a video or animation reported lower mental effort and perceived the learning materials as less difficult than participants who studied non-segmented versions of the material. Similarly, a reduction of mental effort was reported by participants in a study by Mayer and Chandler (2001) who used a segmented animation as compared to the group of students that learned from a continuously nonstop animation.

### 3.1.3 Weeding

*Weeding,* according to Ibrahim et al. (2012, p. 3) is a strategy of "eliminating the unnecessary content from learning materials" to reduce the negative effect of extraneous information and allow students to engage in processing only the essential content. Mayer, Heiser, and Lonn's (2001) study reveals that applying weeding to multimedia learning materials reduces extraneous cognitive load, and Sweller (1999) refers to the addition of extraneous material in instruction as an example of extraneous cognitive load. It should also be noted that the information that increases the extraneous load changes as the student moves from beginner to expert level. So, information that may be extraneous for a novice student may actually be useful for a more experienced student, and vice versa, information that is important for a beginner may serve as an already-known distraction for an expert.

It is a fact that removing superfluous information from educational materials leads to more effective learning. Mayer and Moreno (2003) suggest that learning is lower when irrelevant words, pictures, or sounds are added to a presentation, even if they are considered interesting and potentially motivating elements. And, on the contrary, learning is better when unneeded words are eliminated from a presentation. They also discover evidence that background music has a negative effect on knowledge acquisition. Thus, it is important that the teacher takes into account the skills of all their students when creating educational materials, including the information necessary for their processing but excluding the information that they do not need and which can overload their working memory.

Mayer's study (2003) using a free recall test reveals that students given a weeded version of a text had better performance, while students given the original version produced fewer correct answers, which demonstrates a better perception of a more concise text.

### 3.1.4 Matching modality

Finally, the last technique that can maximize multimedia learning is *matching modality* using *the modality effect* (Sweller, 1999) or *modality principle* (Mayer, 2001). It entails substituting spoken text for the visual text accompanying a picture or animation. The verbal information is presented auditorily instead of visually; this way, multimedia becomes more effective and perceived. It can be explained by referring to the *working memory model* of Baddeley (1992). This model divides working memory into *a visual-spatial aspect* for dealing with visually-based information and a *phonological loop*[6] to deal with auditory, primarily speech-based, information. When information is presented in two modalities simultaneously (visual and auditory) rather than one, both systems are involved, which makes use of memory resources more efficiently. Furthermore, using both channels to convey information has been shown to improve students' remembering and transfer ability (Mayer & Moreno, 2003), as well as increase student engagement with videos (Guo et al., 2014; Thomson, Bridgstock, & Willems, 2014). And vice versa, when information consists of a picture and an explanation text, the student has to switch back and forth between the two to mentally digest them. This process, according to Tabbers, Martens, and van Merriënboer (2004), is cognitively demanding in the form of mental resources that could be directed to an alternative type of mental activity. Meanwhile, presenting texts accompanying

[6] The phonological loop is a language learning device and a component of working memory model that deals with spoken and written material. It is subdivided into the phonological store (which holds information in a speech-based form) and the articulatory process (which allows us to repeat verbal information in a loop) (Baddeley, Gathercole & Papagno, 1998).

a picture as the spoken text, as the cognitive load theory states, will decrease the extraneous load and increase the effectiveness of the learning process. The phonological loop is directly addressed, and the visual channel is not overloaded, compared to the situation in which text is presented visually (Baddeley, 1992).

A number of studies have found that replacing visual text in multimedia materials with spoken text improves learning outcomes (Kalyuga et al., 1999; Mayer & Moreno, 1998; Moreno & Mayer, 1999; Mousavi, Low, & Sweller, 1995). Research experiments by Tindall-Ford, Chandler, and Sweller (1997) showed that students in the audio conditions performed much better, which was manifested in a decrease in extraneous load, less mental effort on the materials, and higher test scores.

Another example of the usage of modality channels is a "talking head"[7] in an instructional video to explain a complex process. It makes productive use only of the verbal channel because when students watch the speaker, they do not get any additional information. Whereas, for example, Khan Academy, which was also mentioned in Table 1, creates tutorial content that provides symbolic sketches to illustrate the verbal explanation, using both channels to transmit information.

## 3.2 Student engagement

Another aspect to consider in educational videos is *student engagement*. The term can be traced back to the late 1800s and educational reformer and philosopher John Dewey[8]. According to *The glossary of education reform*, student engagement "refers to the degree of attention, curiosity, interest, optimism, and passion that students show when they are learning or being taught, which extends to the level of motivation they have to learn and progress in their education" ("Student Engagement", 2016). However, it is not just about students. The glossary adds that "student engagement may also refer to the ways in which school leaders, educators, and other adults might "engage" students more fully in the

[7] A talking head video is an interview-style video that features an instructor or subject matter expert who talks directly into the camera as though they are addressing the learner directly (Ch-Video, 2022, July 27).

[8] John Dewey, an American philosopher and educator, was a co-founder of the philosophical movement known as pragmatism, a pioneer in functional psychology, an innovative theorist of democracy, and a leader of the progressive movement in education in the United States.

governance and decision-making processes." So, the idea is simple: if students do not watch videos, they cannot learn from them.

How can one induce students to engage in class processes rather than simply not use the mental capabilities they have available? Table 2 lists some simple techniques intended to increase the involvement of students in the learning process and help maximize student learning from educational videos. The following subchapters will review these practices and research based on them, subsequently drawing conclusions.

Table 2. *Practices to maximize student learning from educational videos with regard to student engagement*

| Element to consider | Recommendation | Rationale | Examples |
|---|---|---|---|
| Student engagement | • Keep each video brief | • Increases the percentage of each video that students watch; may increase total watch time.<br>• May decrease mind wandering. | • Multiple videos for a lesson, each ≤ 6 minutes. |
| | • Use conversational language | • Creates a sense of social partnership between student and instructor, prompting the student to try harder to make sense of the lesson. | • Placing the student in the lesson by use of "your" rather than "the" during explanations.<br>• Use of "I" to indicate the narrator's perspective. |
| | • Speak relatively quickly and with enthusiasm | • Increases the percentage of each video that students watch.<br>• May increase a sense of social partnership between student and instructor. | • Speaking rates in the 185–254 words per minute range<br>• Expressions of instructor excitement, such as "I love the next part; the way the feed-forward mechanism works is so elegant," or "Consider how the cell solves this tricky problem of needing to regulate three genes in sequence; it's really cool." |
| | • Create and/or package videos to emphasize relevance to the course in which they are used. | • Increases the percentage of each video that students watch.<br>• May increase germane cognitive load by helping students recognize connections. | • Videos created for the class in which they are going to be used, with instructor narration explaining links to preceding material.<br>• Explanatory text to situate video in the course. |

Note: Adapted from Brame (2016, p. 3).

### 3.2.1 Keeping each video brief

The first and most important suggestion for increasing students' concentration on educational material is *keeping it brief* (see Table 2). While YouTube statistics show that the top ten videos on that platform are about three minutes long (Baker, 2018, December 4), Brame (2015) sums up the research of Guo et al. (2014), stating that "making videos longer than 6-9 minutes is likely to be a wasted effort." Upholders of online education, such as Khan (2012) and Koller (2011, December 5), argue that online lectures should be brief—as short as ten minutes. This is due to a number of earlier studies showing that people cannot sustain attention for longer periods of time.

Additionally, Risko et al. (2012) extensively analyze the term *mind-wandering*. According to Murray et al. (2020), mind-wandering refers to the occurrence of thoughts that are not tied to the immediate environment – thoughts that are not related to a given task at hand. Given the frequent occurrence of mind wandering in the traditional classroom, researchers were curious whether mind wandering occurs to a similar, greater, or lesser extent in online settings. That is why two more experiments were provided where Risko et al. (2012) showed participants one of three one-hour lectures on different topics (psychology, economics, or classics). Then they were probed four different times in a lecture, asking if they were mind-wandering at that moment. As a result, participants admitted that they were more mind-wandering during the second half of the lecture than during the first half. Tests given shortly after the lecture also showed poorer performance by students in the second half of the lecture compared with the first half. Thus, it can be concluded that mind wandering would occur much less often during video lectures that are significantly shorter than the one-hour lectures used by Risko et al. (2012).

One more study of this sort was conducted by Cameron and Giuntoli (1972). The main task was to determine how much attention the students paid to the material presented, whether they were listening to the speaker and, if so, how fascinated they were by his speech, or whether it was the opposite, superficial listening with frequent distractions. For this purpose, they randomly diverted the attention of the class with a bell and asked students what was on their minds at the moment. The results revealed that only 40% of students were paying "good attention" to the lecturer or lecture content at any given moment. Unsworth et al. (2012) also asked students to write down in a diary their attention failures during the day, and, as it turns out, the most frequent failures were distraction while studying and mind wandering in class.

Investigations of student attention in education have shown that students often complain about the loss of concentration and mind wandering in class, which most likely appears to increase depending on the amount of time spent in the classroom. Altogether, consideration of the aspect of student engagement in the learning process once again highlights the need for research that considers the way educational material is designed and what else can be applied to it to keep students interested and engaged.

### 3.2.2 Conversational language and speaking rate

Another strategy to maintain student interest is *using a conversational style*. Mayer (2008) thinks that "people learn better from a multimedia lesson when words are in conversational style rather than formal style" (p.766) and calls it the personalization principle. Personalization techniques, such as conversational style or courteous language, in his opinion, create a sense of social partnership with the interlocutor, which causes them to try harder to understand each other, resulting in more effort and involvement in the process. Consistent with Mayer's model (2009), students who learned from instructional materials designed in a conversational style learned more than those who studied more formally expressed materials, which means that the use of a conversational rather than a formal style in the instructional content would generate positive effects across learning outcomes and learning processes.

The next option "is *speaking relatively quickly and with enthusiasm*". Guo et al. (2014), who tested student engagement, note that speaking rate is only a surface feature that interacts with enthusiasm and thus engagement. Through many experiments, they concluded that students' engagement is dependent on the narrator's speaking rate and is generally increased when the instructor starts to speak faster. According to them, fast-speaking instructors gave more energy and enthusiasm, which might have contributed to higher engagement for videos.

## 3.3 Active learning

The active learning concept is a way of teaching that actively involves students in the course material through debates, problem-solving, case studies, interactive activities, and other techniques ("Active learning", n.d.). Active learning has definite advantages over a passive way of learning, such as lectures, and in turn somehow increases the student's level of accountability without erasing the role of the teacher in the active learning classroom (Knight and Wood, 2005; Haak et al., 2011; Freeman et al., 2014).

A conceptual framework has been proposed by two professors of cognitive psychology. Schacter and Szpunar (2015), who explained that learning from different educational videos highlights one of the self-regulated education ideas and serves as a basis for attempts to improve it. Self-regulated learning plays an essential role in education (Zimmerman, 2008). This type of learning requires students to monitor their learning path, identify their own weaknesses and strengths, and judge themselves, taking responsibility to respond to issues faced while learning. Bjork, Dunlosky, and Kornell (2013), on the contrary, reveal that people commonly misjudge themselves and their own learning. According to Salomon (1994), and Choi and Johnson (2005), such a situation can arise when new material is conveyed via a video, which students claim is easier to absorb and remember than textual content. Moreover, students need to be involved in the cognitive process of learning, through which they can enhance their learning abilities from online educational videos and also save the precious time they spend on text reading. As a result, watching an educational video clearly shifts from passive to active learning.

Thus, it can be concluded that the best educational videos for students are those that provide them with the skills to digest the material and assess their own understanding. Education research shows that incorporating active learning strategies into classes significantly improves student performance (Freeman et al., 2014; Theobald et al., 2020). For this purpose, there are several efficient methods and tools, which have successfully proven themselves in some contexts as demonstrated in Table 3.

Table 3. *Practices to maximize student learning from educational videos with regard to active learning*

| Element to consider | Recommendation | Rationale | Examples |
|---|---|---|---|
| Active learning | • Packaging video with interactive questions | • May increase germane cognitive load, improve memory via the testing effect, and improve student self-assessment. | • Integrate questions into videos with HapYak[9] or Zaption.[10] • Follow short videos with interactive questions. |
| | • Use interactive features that give students control | • Increases student ownership and may increase germane cognitive load. | • Create "chapters" within a video using HapYak or YouTube Annotate |
| | • Use guiding questions | • May increase germane cognitive load, reduce extraneous cognitive load, and improve student self-assessment. | • Include guiding questions in educational videos and observe the audience's reaction and behavior. |
| | • Make video part of a larger homework assignment | • May increase student motivation, germane cognitive load, and student self-assessment. | • Package videos with a series of questions or problems that ask students to apply the concepts from the videos. |

Note: Adapted from Brame (2016, p. 3).

### 3.3.1 Packaging a video with interactive questions

The students in the interpolated question group had better results on subsequent tests of the material and reported less mind wandering, according to a study that compared the test performance of students who answered questions asked between five-minute video lectures and students who completed some math tasks in pause. Additionally, those who received the interpolated questions took more notes, felt the learning experience was less "mentally stressful", and had lower test-day anxiety. These findings imply that interpolated questions

9 HapYak is the world-leading interactive video platform. Its mission is to set the standard for social video sharing by empowering people to experience videos on the web more like they do together in person: with remarks, insights, opinions, and personality (HapYak Interactive Video, 2021, October 14)

10 Zaption is the platform that offers teachers the possibility to add interactive elements to videos available on the internet in order to make the learning experience more exciting and engaging for students (Retrieved from http://www.innoveedu.org/en/zaption)

may, via several processes, enhance students' learning from videos. First, they might contribute to cognitive load optimization by reducing the extraneous load, such as stress about a test coming up, and enhancing the germane load, such as notes, and reducing mind wandering (Szpunar, Khan, & Schacter, 2013). Furthermore, according to Roediger and Karpicke (2006); Brame and Biel (2015), the interpolated questions used in this testing method may help students by increasing their memory and capacity to apply the recalled knowledge. Instructors can also incorporate questions directly into videos using tools like HapYak and Zaption, and they can provide targeted feedback depending on student responses. In addition to having the added benefit of making the video interactive, this strategy provides similar advantages to interpolated questions in terms of improving student performance on subsequent exams (Vural, 2013).

### 3.3.2 Using interactive features that give students control

One more research was conducted in a computer science class by Zhang et al. (2006). They investigated the effects of an interactive versus non-interactive video on students' performance. Students who could control all that was happening on the screen, for example, choosing which areas to examine carefully or going back a page if needed, showed superior learning results and higher levels of enjoyment. A given level of interactivity can be achieved, for instance, by adding labeled chapters to the learning video using YouTube Annotate, HapYak, or another application. In addition, it not only gives students more control but can also show the organizational aspect of the class, upping the lesson's relevance and increasing its germane load (Zhang et al., 2006).

### 3.3.3 Using guiding questions

Guiding questions encourage conversation between student and teacher and result in a fundamental sense of understanding ("Guiding Questions", 2022). In the introductory psychology class, Lawson et al. (2006) investigated the effect of guiding questions on students, whose task was to familiarize themselves with the concept of social psychology through a pre-prepared educational video. Kreiner (1997) describes that students in his course were divided into two sections: one in which they asked students to watch the video without much instruction, while students in the second section were given eight guiding questions to lean on while watching the video. A follow-up survey revealed that students who were given guided questions performed better. Guiding questions can be a good way to communicate learning goals and expectations to students, thereby increasing the germane load of the task at hand, while also decreasing the extraneous load by focusing students' attention on key elements. This tactic is often used not only to enhance student learning through reading assignments but can also be used effectively when teaching students through a video (Tanner, 2012; Round & Campbell, 2013).

### 3.3.4 Making a video as part of a homework assignment

Zubair, Brame and Laibinis (2015), as part of a "teaching-as-research" project at Vanderbilt University, participated in the BOLD Fellows program, in which they developed online learning materials for inclusion in a mentor instructor course and then researched their impact on projects. Zubair developed videos that were incorporated into a larger homework assignment in Paul Laibinis' chemical engineering class and found that students appreciated the videos and that they improved students' understanding of complex concepts compared to the semester when the videos were not used in conjunction with the homework assignment.

## Summary of Chapter 3

*This chapter discussed approaches and techniques that help teachers make educational content interesting and, most importantly, useful and get the most out of it. Then, it was revealed that a video can be an important tool to enhance learning and an effective tool in any set of teaching aids. The subchapters introduced new concepts (cognitive load, elements of affecting engagement, and elements that promote active learning) and analyzed research that further illuminated these concepts. An explanation and illustrative examples of these fundamental aspects were provided here. All of this is very important for the following practical part of my bachelor thesis which will be focused on the methodology and creation of educational videos for technical subjects taught in English.*

# Practical part

# 4 Video learning platforms

There are many educational portals on the Internet. The network users have access to a wide range of opportunities, including paid and free online courses, to get any level of education, study at some of the top universities in the world, refresh and strengthen prior knowledge, participate in professional seminars, and share knowledge and experience with peers. Tiunova (2016) highlights that the Internet may meet most of the user's educational demands: it just depends on the user's motivation, goals, individual skills, and qualities, as well as their awareness of the network's educational options.

Educational platforms are one type of online education. They are, in fact, websites where educational materials are published and where online interaction between the teacher and students takes place. Such a space can serve as a channel for communication, a data store, a learning tool, or a way to test newly learned information all at once. Learning platforms come in a wide variety of ways, and according to Bachofner (n.d.), these may be both conventional tools for creating primitive teaching courses and more complex programs that include elements for assessment, social networking, and video conferencing.

Behind educational platforms, there are often different kinds of projects: state-sponsored, those run by large universities, small websites made by students and teachers for educational purposes, and others. Of course, each of these aspects influences the content of the resource, its graphic presentation, literacy of the Internet project construction, technique, and the standard of courses. These projects give institutions the chance to develop a virtual educational space open to all Internet users.

The use of interactive online educational platforms is increasing, especially nowadays when a learning platform is essential for anyone who wishes to design and deliver online courses or use e-learning for instruction and training (Bachofner, n.d.). Users may have access to a platform for learning and development that inevitably contains instructional resources under one or more conditions. With the inclusion of these Internet resources in the curriculum, students can hear or see teachers' viewpoints on current educational issues and acquire more information on a topic or topics that they did not understand in classes. Educational programs provide many levels of training that vary in length and quality.

There are positives and negatives, as usual. DD Planet (2021, March 11) stresses some of the benefits, e.g. obtaining information at a time that is convenient for users regardless of their location, having access to visual and easily comprehensible educational content, having a personal approach and pace, receiving feedback at all stages of course completion, providing a unique chance to modify the platform and enhance the learning process, and indeed, the growth of student self-organization, discipline, and initiative. However, some psychologists argue that these educational methods have certain disadvantages, such as the absence of communication and the social and informational aspects of learning.

## 4.1 Description of selected learning platforms

### 4.1.1 Crash Course

Crash Course is an educational YouTube channel launched by John Green and Hank Green (the Green brothers), who initially gained notoriety on YouTube (Pot, 2012, April 7). They represent themselves as one of the best resources for educating oneself, one's peers, and one's family on YouTube, and they believe that everyone should have free access to high-quality educational videos. According to Crash Course (2023), they have over 45 courses, hundreds of millions of views on YouTube and a worldwide audience inside and outside the classroom. The video content from their channel is used to supplement classes at a variety of educational institutions, schools, and colleges, making it an immensely beneficial tool for both students and teachers. Nonetheless, their content is popular with casual students as well as those who conduct their online searches for educational content. Thus, the video platform has not only altered society's perception of education but has also fostered the development of a virtual student community that seeks out resources beyond test and exam preparation.

The Crash Course platform transforms the traditional textbook model by presenting information at a fast pace, which enhances learning. *Merriam-Webster dictionary* (n.d.) defines the term "crash course" as "a rapid and intense course of study", which can be considered as an indirect confirmation of this statement.

Since 2011, brothers John and Hank Green have pioneered digital education through their YouTube series. Initially, they taught themselves subjects like biology and world history, but today they have a sizable crew who teach a wide variety of subjects from the humanities to the sciences, including organic chemistry, anatomy, literature, world history, biology, philosophy, astronomy, theatre, and ecology. From balancing chemical reactions to analysing classic literature, their video library is one of the most diverse in the video education market.

### 4.1.2 Khan Academy

Khan Academy is an American non-profit organization founded by Salman Khan (Khan Academy Help Center, 2022, June 2). Its main objective is to provide everyone across the whole world with free access to top-quality online education content. By releasing short lessons in the form of videos, the organization creates a supportive set of online tools that help educate students and users with individual needs. Khan Academy (2023) believes that "Everyone has a right to an education".

The Khan Academy platform offers students tutorial videos, articles, interactive practice tasks and its own dashboard, which enables users to learn new material both in the classroom and at home, at whatever pace suits them. They provide courses in a wide range of areas on their platform, including mathematics, chemistry, biology, physics, programming, world history, art history, and economics. WeProject (2021) claims that the academy website gives users access to a library of more than 8,000 free courses translated into different languages. The website also offers versions in Portuguese, Spanish, French, and Russian. According to Noer (2012, November 2), Khan Academy's videos have been viewed more than 200 million times, 6 million students use the website each month, collectively solving an average of 750 million problems, and the free learning materials are used in 20,000 classrooms worldwide.

The platform makes use of tried-and-true individualized adaptation technology that, according to WeProject (2021), evaluates each student's strengths and limitations and indicate the most effective individualized approach on their part. As OpenAI (2023, March 14) points out that each student is unique, and their understanding of concepts and skills varies greatly. For these reasons, teachers have access to detailed information about each student and their progress, providing them with a complete overview and the chance to focus on gaps in learning and, as a consequence, provide tailored instruction. This is why not only learners and teachers are privy to the learning process, but also the learners' parents. They can monitor the progress of their child to better understand what they need, whether the subject material is too difficult or too simple for them, and how they can best help them.

Lectures and practical classes are designed on the principle of "from simple to complex", so videos are organized into theme blocks, and lectures and practical lessons cover a wide range of topics. Each video lasts between 2 and 25 minutes. The library of lectures is constantly being expanded, supplemented, and revised. Furthermore, as the academy itself notes, NASA, the Museum of Modern Art, the California Academy of Sciences, and the Massachusetts Institute of Technology have also provided specialized teaching materials for the project.

### 4.1.3 Fuse School

Fuse School is a global education charity initiative. The goal of this organization is to enhance the lives of millions of students by offering them free education whenever and wherever they need it. Fuse School (2023) believes that "Free education for everyone, everywhere, no matter who you are".

Their web platform offers learning resources for the math and science curricula for secondary schools. They cover concepts that pupils aged 13 to 16 are taught in classrooms throughout the world. According to their web pages, their team consists of enthusiastic, top-tier educators and a group of talented animators from all over the world who collaborate to produce a comprehensive collection of educational materials for students and teachers that include subjects like biology, chemistry, physics, and math. Their video library has more than 800 high-quality animated videos covering all the concepts of the school curriculum. Every year, more than 10 million children use Fuse Online School, which is endorsed by thousands of teachers and educational organizations worldwide.

### 4.1.4 The Engineering Mindset

The Engineering Mindset is an English-language educational YouTube channel founded by Paul Evans whose videos concentrate on teaching engineering (The Engineering Mindset, n.d.). Its aim is to provide quick, straightforward tutorials that would help students, engineers, and other like-minded people learn technical engineering topics. It is meant to be the premier online learning resource for all engineering-related topics in the online education field. The distinguishing feature of this channel is that it uses thorough animations and visuals to help convey each topic in engineering on demand while minimizing the use of technical jargon. As WikiTubia (n.d.) stresses, it is one of the most popular YouTube channels dedicated to engineering. The motto of their organization is simple: "Simplify. Educate. Inspire."

As Nilakantan (2021, November 23) reports, the term "engineering mindset" is characterized by unique ways of processing information that differentiate it from all other types of mindsets, which coincides with the statements of the creators of this learning platform. They add that engineers are always looking to expand their knowledge; they are constantly curious about how things work, where else they have seen something used, or where it can be applied, which is what the creators of these videos are guided by.

## 4.2 Comparison of selected educational platforms

According to Tasneem (2022, December 20), a competent video education platform must meet the following requirements: to be easy to use, provide the necessary functionality for the smooth functioning of platforms, provide unquestionable data protection and security and prompt, reliable support in case of crisis or emergency. Table 4 was created to compare educational platforms, their functionality and content. It lists some fundamental criteria, such as the type of educational video, accessibility, functionality, privacy and security, technological assistance, and the possibility of an online subscription. These criteria were established because they are the most essential; in my view, no educational portal can function without them. There are certainly other features to evaluate, but these are less important. The following subchapters will describe these criteria and evaluate the extent to which each platforms meets them. Personal experience as well as some types of practical suggestions will be considered as well.

Table 4. *Criteria for subjective evaluation and comparison of educational platforms*

| Educational platform | Type of videos | Simplicity of use | Functionality | Security and privacy | Technical support | Online subscription |
|---|---|---|---|---|---|---|
| **Crash Course** | Explainer | ✓ | Partially | × | Partially | ✓ |
| **Khan Academy** | Lecture | ✓ | ✓ | ✓ | ✓ | ✓ |
| **Fuse School** | Explainer | ✓ | ✓ | ✓ | Partially | ✓ |
| **The Engineering Mindset** | Explainer + How-to | Partially | Partially | Partially | × | ✓ |

### 4.2.1 Type of an educational video

The Crash Course platform uses a type of educational video called the Explainer as the basis for all videos. According to Karel (n.d.), the Explainer type of video explains something, as suggested by its name. Such videos primarily serve to teach a subject, present a concept, outline a solution, and tell a narrative. All of this is performed by animation or visual support. Having analysed this platform, it can be said that most of their videos are created using this technique. There is a clear use of animation or a mix of real people (live-action) and animated graphics. In my opinion, and from the perspective of a learning video, this type of video is the perfect way to visualize a complex process.

The Khan Academy platform is based on the lecture video type. Karel (n.d.) says that such videos include an instructor speaking or appearing on screen while narrating a visual slide show, for example via PowerPoint. The main goal is to communicate the content of the lesson to the students. The narrator and full-screen slideshow images are frequently edited together in this format, and in this way, the video usually comes out quite long (30–90 minutes). Most videos on this platform are created so that the student can have the impression that the teacher is sitting next to them and going through the content with a pencil and paper. Lecturers discuss and illustrate the content by writing and drawing on the computer screen, which serves as their whiteboard. To make the subject as clear to the student as possible, they can also add resources like books, magazine clippings, articles, and images on the "fictitious" whiteboard. Because of its simplicity, I consider it to be the most popular kind of educational video. Even I have used this platform numerous times and found the help that

I had received to be satisfactory.

Another Explainer-style platform is the Fuse School platform. As already mentioned, the purpose of these videos is to thoroughly explain the subject matter. Storytelling is the core of the Explainer video. The approach used by Fuse School, which I find highly effective, combines the use of animation with the teacher's voiceover. The animation keeps the viewer's attention and prevents him from losing concentration, while the teacher's voice mimics their actual presence in the classroom and unwittingly helps the student as they soak in, process, and ultimately absorb the content.

The Engineering Mindset platform mixes two types of educational videos: the Explainer One and How-to. According to Karel (n.d.), the How-to video includes detailed instructions that demonstrate how to do a task step-by-step, and this type of video is very popular. This platform uses both types since it is aimed more at the technical sphere than any other. It is important for the authors to show everything not only in animation but also in practice, live, with the aim of uncompromisingly understanding the viewer's information. Visual demonstration of any technical thing improves behaviour modelling. As a result, the audience will understand everything in theory and practice, and will even be able to do it themselves. In my opinion, people who are not simply theorists would find this kind of video to be highly beneficial. It is feasible to surpass expectations by combining all these factors into one.

### 4.2.2 Simplicity of use

All the aforementioned platforms are really simple to use. They are easily navigable and designed in a bright, somewhat contemporary manner. With a very simple user interface and a fixed navigation menu, their websites are easy to use. The main pages contain all the information ones are looking for: information about the project, contacts, login and sign-up buttons. Each video is categorized according to its theme, genre, and even educational class. In the event that this is ineffective, all platforms provide a search bar that will enable users to locate this video among thousands, even if they forget its name. The Engineering Mindset is the only exception since it lacks the same level of contemporary design as the others, which is not unexpected given that their project was initially intended for a strictly technical audience who do not require attractive design and eye-catching interface components because getting meaningful material is what matters most to them. But despite this, the website has simple navigational tools that will guide you to the appropriate topic or issue.

### 4.2.3 Functionality

Under the functionality of the online platform, it appears to be loaded with varied functionality and features that make it simpler for students to use. Only two of the four platforms in this instance resemble contemporary, multipurpose online learning platforms. Khan Academy and Fuse School allow their users not only to watch their content but also to register and log in to their profiles where ~~a sea of~~ a wide range of learning opportunities are offered, such as keeping track of their own progress, modifying the program to suit their requirements, and communicating with teachers frequently. Although these features do not somehow differ from the other two platforms, they do help make this kind of online education more usable. Furthermore, all the videos on the platforms include high-quality animation design and editing, subtitles in many languages, and video segmentation.

### 4.2.4 Security and privacy

As Tasneem (2022, December 20) notes, the content that someone puts on the Internet is extremely valuable, thus it is improper for someone to take it, use it, and claim it to be their own work. Some of the security features that every online learning platform should have belong private hosting, secure video upload, end-to-end encryption, password protection, and domain limits. Madelyn (2021, December 26) adds, that for total privacy, only authorized people should be able to access the platform and its videos.

Only Khan Academy and Fuse School, out of the platforms reviewed, provide users with access to their privacy policies. All information is made available to the public and is accessible to anybody using their websites. These platforms give students the assurance that their data and personal information are protected. Besides, these online platforms completely secure themselves and the resources present on their pages. Regarding The Engineering Mindset portal, their website does not provide any information concerning their privacy policies. Nevertheless, authors appeal that their content is protected by copyright and that they should issue copyright strikes against any channels that use it without their consent. Unfortunately, there is no information concerning the privacy of the channel on the Crash

Course website. This is not in the public domain, even if the creators secured their own and the users' data. Nowadays, I think security is more of an issue than ever because of how virtualized life has become and the growing tendency toward remote work and distance education.

### 4.2.5 Technical support

According to the Merriam-Webster dictionary (n.d.), "technical support" is a department or person that helps people with computer problems. I would, however, add that technical support refers to a service that customers of a product or service can turn to for assistance with any technical problems as well as for additional information on a particular topic. My own research revealed that all four platforms provide help in some way, some more than others. Today, it is crucial for any company to have a trustworthy customer support team that can assist in finding a solution swiftly. Support can be obtained in a number of ways, from direct calls and emails to videos and FAQs.

For example, Khan Academy provides a direct Help Center button or a Support Community where users can find any information they are interested in regarding the platform. For example, there are frequently asked questions by users, guides and resources for parents, teachers, and students, as well as a place to report any appeared technical or other problems to the site's developers.

The Fuse School portal provides its users with a contact form where the personal information needed, such as first and last name, e-mail, and the specific message user want the content creators or developers of this website to get. Additionally, they include their mail and phone number, which gives the student a better chance of getting in touch with the organization.

Similar setups can be found on The Engineering Mindset and Crash Course. A button called "Contact Us" on the Crash Course website will direct users to a form that requests the standard information mentioned above. The Engineering Mindset, on the other hand, emphasizes that their contact form is for commercial inquiries only, which obviously excludes any questions or solutions pertaining to technical matters. If a user tries hard, as I did, they can find their work email; the portal lists it on its YouTube channel, which sounds like a rather ill-conceived concept to me.

I think that support for projects like educational platforms should be at a high level and be useful to their users. Support must be available around-the-clock because failures or hiccups can occur unexpectedly. A reliable website will not abandon users when they are most in need. I know from my own experience that the contact form format has never really worked smoothly, so occasionally the user must accept that they will not ~~get~~ find an answer. The creators of the platform should make sure that all information, including emails, phone numbers, and even contact forms, is in one convenient location so the user does not need spend time searching through the whole platform, especially when the platform does not offer online technological support.

### 4.2.6 Possibility of online subscription

The platform's online subscription feature makes it easier for users to follow updates, discover new material, stay "on trend", and much more. In my view, there does not seem to be any compelling reasons why not to subscribe to the content if this subscription is free. There are YouTube channels for each of the aforementioned four platforms, and it is possible to subscribe to them for free. On their webpages, Fuse School and Khan Academy both offer signup and seamless user login options. The educational content of the other two platforms, Crash Course and The Engineering Mindset, can be accessed on YouTube and on their websites, even though they lack this feature. All services offered by these portals are entirely free, which is a major benefit for students. However, Fuse School, Khan Academy, and Crash Course are non-profit organizations. On their webpages, users can find a Support Us or Donate option where they can select the amount to donate or even the amount of monthly support. Additionally, they have the option to donate anonymously or through an organization. Nowadays, charity is a decent and admirable cause. It is important to note that this is optional; the creators realized that not everyone could afford a paid subscription, that most of their audience were jobless students, and that no one forces or coerces anything from anyone.

## 4.3 Comparison of educational videos on specific topics in electrical engineering and informatics

In order to better understand how educational platforms design and present their content, specifically videos, the comparative analysis was made. The key elements, tricks, and principles to which the developers of these videos adhere will be discussed here. The main comparative characteristic will be the criteria that were described in Chapter 3 of the theoretical part of this bachelor's thesis. Specifically, the components of the cognitive load, student engagement, and the active learning.

Four videos were selected, in particular two videos from the discipline of informatics and two from the field of electrical engineering. These videos were selected from the educational platforms that were reviewed in Chapter 4.2. The comparison was made to discuss how methods of effective video making are adopted in practice and to suggest some improvements and implement them in my own design of educational videos.

### 4.3.1 Comparison of educational videos in informatics

The selected videos deal with the topic of algorithms (Crash Course, 2017, May 24; Khan Academy Computing, 2015, July 28). Tables 5, 6 and 7 present the main criteria for evaluation and comparison (see Chapter 3). In the following text, secondary considerations based on my personal opinion and the theoretical concepts related to educational videos design will be included.

Table 5. *Criteria for subjective evaluation and comparison of educational videos in informatics (see Chapter 3.1)*

| The cognitive load | | | | |
|---|---|---|---|---|
| **Educational platform** | **Signaling** | **Segmenting** | **Weeding** | **Matching modality** |
| Crash Course video: *Intro to Algorithms* | ✓ | Partially | × | ✓ |
| Khan Academy video: *What is an algorithm and why should you care?* | ✓ | Partially | × | Partially |

Table 5 shows that both videos have almost identical results on the evaluation criteria. As far as highlighting certain information, and text, playing with colours in relation to the overall picture, and in general the factor of focusing the student's attention on something specific, or in other words, *signaling*, both videos completely meet this criterion. Including many images, gif animations, brightly appearing text, and graphics at a good level allow us to view a vibrant picture.

None of the videos were divided their videos into segments. Over the course of the entire video, they tried different ways to internally separate the learning material into short chunks of information, such as the following question, voice acting, pauses, and animated transitions. The best option of all possible ones, which is also the most frequent and convenient on YouTube, is when the video is divided into segments according to the time at which this topic is discussed; the most frequent are the introduction, conclusion, and even advertising.

The amount of "unnecessary" information in a video can fluctuate considerably, and sometimes the student cannot do the so-called *weeding* without the process of reducing it. The fact that one video is twice as long as the other, does not mean that it contains less relevant information. In this case, the Crash Course video is twice as long as the Khan Academy video. In my opinion, the video from Crash Course does not include much extra information, but there is a lot of it, as for someone, for example, who has just decided to get acquainted with algorithms and this is their first introductory video. Around the middle of the video, information begins to wander around the head and collide with extraneous thoughts, thereby losing the main content of the lesson and creating the effect of *mind-wandering* (see Chapter 3.2.1). In the case of the Khan Academy video, the extraneous information seems to have begun to leak out towards the end, when the student's attention begins to dissipate for physical reasons, so it is not necessarily a great hindrance. Also, I think irrelevant pictures and sounds were added to the material several times, which reduces the learning curve.

Regarding the latter criterion, Khan Academy uses a method in which it combines visual components with a voice-over to accompany them. The voice-over does not dub the entire text appearing on the screen, which is a benefit because the auditory channel is not overloaded. The material becomes more perceptible, thereby increasing the effectiveness of the learning process. Thus, both human memory channels, visual and auditory, are engaged, which improves learning outcomes and maintains the balance of the modality effect in the educational video.

As for the Crash Course video, I think the developers put more emphasis on the verbal aspect than the visual. The lecturer's voice and voice-over narration present most of the information that needs to be conveyed to the viewer. The visual aspect, in turn, is mostly in the form of elements such as tables, graphs, and numbers. However, despite the lack of the so-called proportion of educational video elements, the modality effect in this video is sufficient due to the excellent graphic functionality and good explanatory skills of the lecturer.

There are many ways to keep a student's attention, and some of them have a greater effect on concentration than others. Table 6 provides the three main criteria for student engagement highlighted in the previous chapters. To what extent and how exactly the following criteria influenced the videos reviewed will be considered. A key aspect of a successful educational video is its brevity. According to all the aforementioned studies (see Chapter 3.2.1), it is very difficult to hold one's attention for longer periods of time, and one has to try very hard not to miss the point and not to lose the information one has already received.

Table 6. *Criteria for subjective evaluation and comparison of educational videos in informatics (see Chapter 3.2)*

| **The student engagement** | | | |
|---|---|---|---|
| **Educational platform** | **Video brevity** | **Conversational language** | **Speaking rate** |
| Crash Course video: *Intro to Algorithms* | Partially | ✓ | ✓ |
| Khan Academy video: *What is an algorithm and why should you care?* | ✓ | × | × |

Table 6 shows that the Crash Course video partially meets this criterion, as it is longer than ten minutes in total, which is the golden mean according to many in the field of online education. I found that long videos contribute to distracted attention in about two-thirds to half of the videos. As I watched this video, my attention span drifted in the second half. As I tried to focus on the material and increase my concentration, I gradually lost the information I had already heard and my mind began to wander. Of course, everything about concentration and absent-mindedness is individual, and not everyone has the same difficulty concentrating on longer content. The Khan Academy video was half the length of the opponent's, but the developers made sure that it had all the necessary information for an introductory video on the topic. I would call it "short and to the point" because, after the first video, the viewer can understand whether this format of educational content suits them, whether they should look for more, or whether they are generally interested in the topic and want to study it further. Again, it is all very individual; conclusions are based on knowledge gained and personal experience.

The last thing to consider is everything about the conversation, its style, and its speed. It is not for nothing that it is said that a person is recognized by their speech, the manner of presentation, as is the case with video. A conversational style is much more engaging to the viewer than, for example, a formal style; the lecturer builds a trusting relationship with the viewer through their voice, and as a result, the person becomes more and more involved in the process. The Crash Course platform uses this method in its videos. The lecturer in their video speaks openly, in clear words, and in this way attracts the audience. The speed of her speech is fast enough, which brings more energy and enthusiasm, increasing the student's involvement in the learning process. The lecturer's voice in the Han Academy video sounded more like a robot or with some kind of sound-affecting effect added. This speech was in a conversational style, the information was delivered in simple words and was clearly presented. As for the speed of the narration, there were unnecessary pauses at some moments, and was not characterized by excessive enthusiasm and additional energy.

Table 7 in this chapter contains the criteria for the *active learning*, which implies something that engages students in the learning process. As discussed in the previous chapters, different interactive features included in the educational material can help with this. The main ones will be listed in Table 7.

Table 7. *Criteria for subjective evaluation and comparison of educational videos in informatics (see Chapter 3.3)*

| The active learning | | | |
|---|---|---|---|
| **Educational platform** | **Interactive questions** | **Interactive features** | **Guiding questions** |
| Crash Course video: *Intro to Algorithms* | Partially | Partially | ✗ |
| Khan Academy video: *What is an algorithm and why should you care?* | ✓ | ✗ | ✓ |

Interactive and guiding questions throughout the educational video help students learn, improve their memory skills, and help them sequence the material. Both types of questions are present in Khan Academy videos, engaging the viewer in the process. The lecturer maintains a triggered interest in the question with his or her intonation and a sustained pause. In Crash Course's video, the guiding questions are presented only in auditory form, which partially engages the student in the process and to some extent forces interest in the content. As far as the interactive features of the videos are concerned, neither platform is particularly distinctive. The fact that their educational content is on YouTube gives the students the ability to control what is happening on the screen and to replay certain elements over and over again. Crash Course has a lot of cool graphical tricks like moving charts and tables; the viewer is supposed to be able to move the data around or answer a question correctly. This is the point of interactivity.

### 4.3.2 Comparison of educational videos in electrical engineering

The selected video focus on the topic of electric current (The Engineering Mindset, 2018, November 19; Fuse School – Global Education, 2020, August 2). Tables 8, 9 and 10 present the main criteria for evaluation and comparison (see Chapter 3). Secondary considerations on the basis of personal subjective opinion and studied materials will also be applied.

Table 8. *Criteria for subjective evaluation and comparison of educational videos in electrical engineering (see Chapter 3.1)*

| **The cognitive load** | | | | |
|---|---|---|---|---|
| **Educational platform** | **Signaling** | **Segmenting** | **Weeding** | **Matching modality** |
| The Engineering Mindset video: *What is current– electric current explained, electricity basics* | ✓ | ✗ | ✓ | ✓ |
| Fuse School video: *Current \| Electricity \| Physics \|* | ✓ | ✗ | ✓ | ✓ |

The Fuse School video is rich in signaling components that direct the student's attention in the right way to particular elements of the learning material. In this educational video, it is possible to see different colored texts appearing on the screen, graphically highlighted elements, and different shaded arrows signaling the information that needs to be emphasized. It is also impossible not to notice the high quality of the graphics and the rather bold use of color palettes in the whole video as well as in the separately inserted signaling elements. The signaling in the Engineering Mindset video was designed to concentrate on the essential content of the lesson's audio-visual material. They achieved this effect by using different coloured element texts, graphically moving fragments (flow of electrons or current, flowing water, a light bulb burning out, etc.), adding a title, accentuating symbols that draw attention to a particular area of the screen, and highlighting specific parts of the diagrams.

In this video, segmentation was not fully applied rather because of its length. Since the video was an introduction to the topic, it did not contain the amount of material that was directly subject to segmentation. The research discussed in the previous chapters (see Chapter 3.1.2) proves that more complex learning material, which is presented at a fast pace, is subject to segmentation. However, it is my opinion that some part of the segmentation was applied toward the end of the video when the viewer was given time to think and consider the solution to the problem. This was done in order to help students mentally digest this piece of learning material before moving on to the next and to give them control over the flow of new information. The Engineering Mindset video does not directly employ segmentation either. Although segmentation has been described as a potential fix for the fleeting nature of information in video lessons, the creators of this study material believed that it was not necessary to use segmentation. Despite the lack of segmentation, the material was presented consistently, without jumping from topic to topic or deviating from the main theme of the lesson.

Speaking of the weeding out of the Fuse School educational video, it should be noted that there was no unnecessary information that could overload the working memory. In fact, in my opinion, the information in the educational video was even somewhat lacking. This video contained no irrelevant words, pictures, or sounds, and the background music did not strain the auditory channels. All of this helped to keep the viewer focused on processing only the core content. Even though the Engineering Mindset video is quite long, there is no superfluous information in it. Absolutely everything was said factually and appropriately; there was no floating information. Despite the fact that there were some additional elements that may not be familiar and understandable for a beginner, the material was presented in the easiest way possible, and there were no questions left after the video.

The creators of the Fuse School video did their best to increase the effectiveness of learning with the help of the modality effect. All the main information was spoken in the voice of the lecturer, and only some visual textual elements appeared on the screen; this was done to visually emphasize certain verbal information. Thus, neither the visual-spatial aspect nor the phonological outline was overwhelmed. The modality in the Engineering Mindset video was at a good level. The lecturer's voice accompanies the viewer throughout the video, aurally complementing and emphasizing some of the visual elements of the educational material. The visual channel focuses on the colorfulness and interactivity of the picture rather than on redundant fragments that increase the extraneous load.

Table 9. *Criteria for subjective evaluation and comparison of educational videos in electrical engineering (see Chapter 3.2)*

| **The student engagement** | | | |
|---|---|---|---|
| **Educational platform** | **Video brevity** | **Conversational language** | **Speaking rate** |
| The Engineering Mindset video: *What is current– electric current explained, electricity basics* | Partially | ✓ | ✓ |
| Fuse School video: *Current* \| *Electricity* \| *Physics* \| | ✓ | ✓ | ✓ |

The first and most important rule for keeping people's attention on the learning material is the length of the video. The Engineering Mindset made their video almost twelve minutes long but managed to avoid filling it with unnecessary information, facts, or advertisements. The mind did not start wandering around looking for new thoughts but was interested in what was coming next. The Fuse School video, in almost five minutes of airtime, was able to convey basic information to the viewer without cluttering the mind. The concentration was not lost, the mind did not even have time to wander, and the material was absorbed to its fullest.

Both videos were distinguished by a good level of narration by the lecturer. The speech was pleasant, understandable, without unnecessary pauses, and at a good pace. Lecturers use simple conversational language rather than complicated formal language, which attracts the viewer and makes the presentation of material much clearer, increasing the involvement in the process. The speech speed of both lecturers was satisfactory, sufficient to give time to grasp and mentally process the material.

Table 10. *Criteria for subjective evaluation and comparison of educational videos in electrical engineering (see Chapter 3.3)*

| **The active learning** | | | |
|---|---|---|---|
| **Educational platform** | **Interactive questions** | **Interactive features** | **Guiding questions** |
| The Engineering Mindset video: *What is current– electric current explained, electricity basics* | Partially | × | × |
| Fuse School video: *Current* \| *Electricity* \| *Physics* \| | ✓ | Partially | × |

One of the great advantages of the Fuse School video is that it is moderately full of various interactive things, such as questions, tests, and mini-tasks with circuits. At the end, the lecturer displayed the correct answers on the screen with explanations. This gives the material a sense of an imaginary student-teacher connection, as if the student were in the classroom answering questions and solving tasks. Despite the fact that there were no interactive questions in The Engineering Mindset video, at the end of the video there were tasks of different variations and levels of difficulty. The student has the opportunity to pause the video and think about the answer, thus creating a kind of interactivity. In my opinion, these types of activities help students learn the material more effectively and improve their working memory.

Both videos on these educational platforms lack any interactive features that give students control. The only control the student is to pause or rewind the video. This encourages repetition of the material in case the student misunderstands or misses something and, as a result, better comprehension. It is also worth adding that the Fuse School video allows the viewer to pause the video to give them time to think and come up with a solution to a task. This is a partial benefit.

Guiding questions are often part of many educational videos. They help to focus the students' attention on key elements, give an interactive effect, and create a mental connection between the lecturer and the student sitting in front of the screen. Asking students to answer guiding questions is another effective technique to communicate students' expectations and learning goals. It is just worth noting that the Engineering Mindset lecturer gave very good examples from life to establish an association in the viewer's mind, for example, comparing electricity to water in a hose or equating alternating and direct current to the flow of water in a river and a boat moving through it. This is a very good plus because it facilitates the process of understanding a concept or processes more easily.

## Summary of Chapter 4

*This chapter introduced the reader to the concept of educational online platforms, describing all the opportunities that this field offers the Internet user. Then, based on the selected educational platforms, the reader could get acquainted with their basic descriptions, which subsequently resulted in a comparative analysis. This might help the reader to identify the features in which the educational platforms can differ and which are worth paying more attention to when choosing a suitable base for further online education. In the last subchapter, a comparative analysis of educational videos on certain topics was conducted. The theoretical knowledge gained in Chapter 3 of this bachelor's thesis served as the basis for the comparison. It can be concluded that the analyzed videos to a greater extent meet the requirements for the "effective educational video" outlined in Chapter 3. The shortcomings that were found are insignificant and may not greatly affect the students' learning outcomes. Overall, the videos did a good job of communicating the topic being* *taught and reinforcing the results. In Chapter 5, I will attempt to develop videos that would best meet the requirements for the "effective educational video" outlined in the theoretical part of the thesis, along with the positive aspects of the videos analyzed.*

# 5 Designing educational videos for selected electrical engineering and IT subjects

## 5.1 Educational videos design process

The process of creating the educational videos was quite time-consuming and, in both cases, involved almost the same stages. First, the topic of the video had to be selected. The selected topics should be interesting, and they should stimulate imagination during the process of editing. At the same time, the topics should not be very complicated because such videos might be difficult to understand, and they might lack interactivity.

The next stage was to write a transcript for the video. The main thing here was to follow some basic rules: not to exceed the standard length of the video, make sure that the video will be structured, that is, will contain the introduction, the main part, and the ending, and use language that is not heavy, to preserve the conversational style and the mental connection with the viewer.

The other important aspects were the selection of the right place for the shooting and the speaker's[11] appearance. In both cases, a neutral background that would not distract the viewer was chosen. The speaker's clothes were chosen in such a colour scheme that they did not blend in with the background, and that nothing extraneous was distracting to the viewer. And the last thing was the makeup, which the camera usually eats up, but here it should not be too excessive.

During the shooting itself, the main thing was to convey the mood, not to speak monotonously and under breath, to keep the same pace and style of speech. Lighting, picture quality, and the absence of extraneous noise were also important.

The last stage of the video production included editing. The main thing here was not to underestimate this process and prepare for it well. For editing the educational videos, the program ClipChamp, which has all the necessary tricks to achieve the desired result, was used. The main task was to make the video as interactive and colourful as possible. Therefore, editing involved a lot of transitions, animations, stickers, coloured backgrounds, and frames, as well as background music, sound effects, voice-over narration of speaker's and the voice created by artificial intelligence. Choosing all these elements depends on the

[11] The speaker in the videos is the author of this bachelor's thesis.

personal taste and the fact that in the end, it all looks good on the screen because it is important from the aesthetic point of view. ClipChamp enabled to create attractive introductions, transitions and endings.

The problems that can arise during the creation of the educational videos can be, for example, knocking down the tone and mood of speech at the time of the shooting. It is important to maintain the same style of speech throughout the frames following one another, or vice versa, to dramatically change the tone in combination with the facial expression. Besides, it is necessary to be alert and ready for different situations, such weather conditions and technical difficulties. The main thing is to understand that there are no hopeless situations and that sometimes it is better to change the conceived plan than to abandon it altogether. Finally, the editing process should not be underestimated, and the recorded materials should be thoroughly reviewed.

## 5.2 Characteristics of the educational videos

**Video 1: What is Electrical Engineering and Its History?**

1) *Video Title*: What is Electrical Engineering and Its History?

2) *Length*: 10 minutes 35 seconds.

3) *Objectives*: The video should familiarize the student with the history of electrical engineering as a science, detailing all the discoveries, processes and dramatic changes.

4) *Content*: The video reveals the history of the beginnings of electrical engineering from all angles, tells what inherited many breakthroughs, and mentions many historically involved personalities and their discoveries.

5) *Type of a video*: A combination of a lecture and a little of the explainer type of a video.

6) *Structure*: The video is divided into an introduction, a division into three main sections, an overview of electricity, magnetism, and electrical conductivity, a sequential presentation of all the discoveries including their inventors, a detailed narrative of each branch including examples and animations, and a conclusion.

7) *Elements of an effective educational video (cognitive load, student engagement, active learning)*: This video is more than sufficiently consistent with Brame's (2016) principles

outlined in Chapter 3. Because of the elements based on cognitive theory, germane load should be stable, extrinsic cognitive load should not rise above normal, and intrinsic cognitive load should be manageable. This was achieved through the use of the principles of signaling and weeding, as well as segmentation with all its implications.

The engagement aspect of the video was accomplished by selecting an interesting topic for the video as well as trying to put all the key information into the entire length of the video in order to be useful to the viewer and leave a mark in the viewer's memory. It was not unimportant to speak in language understandable to students, without the use of abstruse expressions and terms, while maintaining an average pace of speech using the right tone.

This video was based primarily on the active learning factor since the video is the most appropriate tool for applying all the strategies involved. The effect was achieved through the use of guiding and interactive questions, the presence of mini-assignments or quizzes, and many interactive units included in the video.

8) *Tips for working with the video*: For successful learning with this video, students need to be ready to accept information, be motivated to learn, watch and listen carefully, and possibly take notes. It is worth paying attention to the highlighted key fragments because they are such for a reason and can carry the information necessary for successful learning. Teachers should carefully review this educational material and adjust it for themselves and their classes. It is possible to add or exclude something, depending on their teaching style and the relevance of the lesson. This topic is very broad, and it should not be a problem to find any additional material or assignments.

**Video 2: The History of Early Computing**

1) *Video Title*: The History of Early Computing.

2) *Length*: 13 minutes 21 seconds.

3) *Objectives*: This video should be an introduction to the world of computers for students, and it should help them better understand the role of computing while revealing its journey through the history.

4) *Content*: The video deals with the history of computing and all the interesting facts related to it, as well as the many innovators and inventions of the time that may have changed the course of history and the further development of the computer world.

5) *Type of a video:* A combination of a lecture and an explainer type.

6) *Structure*: Introduction and statement of objectives of this video, the basis of the video are historical facts, personalities, and their inventions, as well as logical examples based on the facts of life, provided in the form of animations and elementary questions and calculations. At the end of each segment, there are one or two quiz questions with time to answer them.

7) *Elements of an effective educational video (cognitive load, student engagement, active learning)*: This video, as well as the previous one, was purposefully created in compliance with all the principles specified by the Brame (see Chapter 3). The ideal was to achieve a typical, not elevated level of external load, a stable level of germane load, and a generally controlled internal load. And thanks to the application of all the recommended principles this result, in my opinion, has been achieved at a sufficient level.

Though the main principle of student engagement, namely, the shorter the video, the better, was not one hundred percent followed, as this video is longer than the norm specified by Brame and other researchers. The rest of the factors, such as style and speed of speech, were met, and in my opinion, collectively, all of these should not have had any noticeable impact on the students' learning outcomes.

This video is more stuffed than the previous one with all sorts of interactive features. Segmented quiz questions, gif-stickers, animations, transitions, voice-over with artificial intelligence – this and much more performs the role of active learning applied in this video.

8) *Tips for working with the video*: This video will not require mega-complex actions. It will be enough for students to be concentrated and avoid mind wandering as much as possible. Then the result will not be long in coming and they will be able to cope successfully with all the tasks. Teachers will need to prepare for the lesson in advance by selecting the necessary material from this video or adding new material to the existing one that suits them personally.

# 6 Conclusion

The main aim of the theoretical part was to consider the value of integrating video in engineering and informatics classes as well as discovering effective techniques that will be useful in creating educational online content. I dealt with this issue by conducting literature research, including an analysis of certain aspects and practical experiments. On the basis of all the materials researched, I can conclude that a video is one of the best teaching tools that allow students to practice what they have learned through numerous techniques and that the use of video materials in teaching is attracting more and more attention from teachers. Its use has many advantages for them because it is a tool that can be utilized in different approaches, for example as a teaching self-regulation tool or as a conference tool. This was confirmed by different ways of using a video described in the thesis.

On the other hand, it was revealed that a video is a medium that can be added to the curriculum, but it must be handled carefully in order to provide significant benefits to students. Many of the studies approved the advantages of the video; however, the downsides must no longer be overlooked. In order to avoid such unexpected complications, the theoretical part provides special tables where the reader can familiarize himself not only with the recommendations for creating educational materials but also with tips on what mistakes teachers should avoid in this process.

Numerous studies and tests have proven that a video has many benefits for students, such as developing listening skills or increasing motivation. Videos engage students of all ages and abilities, motivate them with authentic content, provide context to aid understanding, expose students to different languages and cultures, and also represent new ideas. Based on a number of surveys, language teachers are interested in the use of video as it provides auditory and visual input that can facilitate language learning. It is also a great method of increasing student engagement especially because of the eye-catching quality of the video. Students themselves report greater interest and enjoyment, so teachers report improved classroom performance and a richer understanding of core content.

The last chapter of the theoretical part dealt with the issue of achieving maximum effectiveness of video materials, the peculiarities of their impact on the audience, and many other theoretical and psychological issues that somehow play a role in the creation of educational video content. According to all the data gathered, educational videos have repeatedly proven to be surprisingly effective in promoting student engagement and retention. The chapter focuses on, for example, strategies teachers can apply to optimize the effectiveness of using video as a teaching medium, such as managing cognitive load, maximizing student involvement, and opportunities to make the most of media-included learning. All these theoretical aspects were probably the most key and important because they became the base for the creation and development of the practical part of this bachelor's thesis and were applied in practice as well.

The practical part's main focus was on creating educational videos for selected subjects focused on electrical engineering and information technology taught in the English language and also on providing them with a manual for teachers including the objective of each video, its structure and content, video tasks and transcripts. Besides, in order to expand the reader's understanding of online education, a number of comparative studies were conducted in the field of educational platforms, which included providing their detailed characteristics and subsequent analysis. This was supposed to help the reader learn the distinctive features that should be paid more attention to if choosing a suitable online platform.

One of the limitations of my thesis is that I did not manage to assess the quality of my videos through "English for Electrical Engineering and Informatics" (H-AEI) teachers' and students' feedback because of time constraints. As an alternative, considering future research or analysis, I recommend that H-AEI teachers and students evaluate the design of my educational videos and suggest how to improve them.

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## List of figures



## List of tables



## List of appendices

# Appendix 1: Video transcripts

## What is Electrical Engineering and Its History

Electricity powers our world and we harness it through electrical engineering, the field that focuses on the application of electricity and electromagnetism in our everyday lives.

Just as blood pumps through your veins, machines and systems often need electrical power flowing through their wires to work. It is the lifeblood of our society.

And it is hard to imagine society today without three of the main branches of electrical engineering: telecommunications, power and lighting, and computer engineering. They each came about in their own way, with their own challenges and victories, their own heroes and sometimes villains. And you would be surprised how much death is involved in the history of electrical engineering. It can be really dangerous.

Electrical engineering deals with the properties of electricity and magnetism. So, it stands the reason that the field did not really exist until we knew what those things were. No one had a very good understanding of electromagnetism until English physicist William Gilbert released his principal work "De Magnete", or "On the Magnet", back in 1600. After years of experimentation, he found that the needle of a compass points north-south and dips downwards because the Earth is basically a giant magnet. He was the first to describe the phenomena we now associate with electrical attraction and magnetic poles, which is why many view him as the father of electrical studies.

Now, electrical conduction – which is the movement of electrically charged particles through a transmission medium – was not discovered until around 1729, by a British scientist – Stephen Gray. He discovered it while doing experiments in which he connected a glass tube to various objects, like an ivory ball or a piece of cork, by a wire or string. When he rubbed the glass tube, creating fiction, he found the object at the other end of the line would be electrified.

With the age of discovery and colonization upon the world, could Gray's work be used to produce faster means of communication?

This brings us to the beginning of the first field of electrical engineering: telecommunication. Efforts to communicate over long distances, using things like the semaphore, were undertaken as early as the 1700s. But it was not until 1837 that Sirs William Fothergill Cooke and Charles Wheatstone patented the first electric telegraph. Their design used five or six magnetic needles to sway right or left to indicate specific letters. This early model was a little impractical because of its cost, but the men later patented a new version that only used one magnetic needle. Their invention was clearly a neat idea. But it did not really take off until it was used to solve a murder that sounds like it was taken from the pages of a Sherlock Holmes novel.

On New Year's Day 1845, a man named John Tawell gave a woman he was seeing a fatal dose of poison. As the poison set in, she started to scream, which alerted the neighbours. And Tawell ran off in a panic, thinking he escaped the law as he boarded a train from Slough to London. But his escape was foiled by technology. His description was sent by telegraph to London, where Tawell was arrested and later tried and hanged.

It's a rather gruesome way to make an invention popular, but it nonetheless spread the story of the electric telegraph.

Around the same time as all this was happening, Samuel Morse was making his own developments in the United States. He figured out how to use an electromagnet with a pen so that when the electromagnet was energized, the pen made a mark on a paper. In 1838, he developed a system of dots and dashes, now known as Morse code, so that messages could be easily transmitted. By 1844 he had obtained financial support from Congress and built the first telegraph line in the United States. It travelled between Baltimore and Washington, and on May 24$^{th}$, he sent the line's first message, "What hath God wrought".

About 20 years later, in 1866, the British ship Great Eastern succeed in laying the first permanent telegraph line across the Atlantic Ocean. Before it, large bodies of water were a big obstacle for means of telecommunication.

After the transatlantic telegraph line, some engineers began to realize that by fluctuating an electrical current, they could induce different sound vibrations. It made them wonder if they could manipulate sound vibrations. Could they input the sound on the end of a telegraph line and replicate the same sound on the other end? Could they capture the human voice?

They succeeded in doing so by 1876 when they created the telephone. A few different minds came up with similar ideas at the same time, but Alexander Graham Bell was the first to get a patent. He was able to use a fluctuating current to vary the magnetism in the coil of an electromagnet, which caused a small piece of iron to vibrate on a diaphragm. This replicated the vibration that had initially sent the fluctuation, which reproduced the initial sound. Now you could talk to people who were far away, but you still needed telephone lines and a phone with a physical connection to them.

But that changed when Heinrich Hertz discovered electromagnetic waves around 1887. It was soon realized that these waves could carry a signal by modifying their wavelength, amplitude, and frequency. This led to the radio and the never-ending confusion over who gets credit for inventing it.

Now, after World War I, electrical engineers manipulated these signals and found that along with the conversion of light of electrical impulses, they could create a visual broadcast: television. Since then, we have taken these signals even further. With the Internet and Wi-Fi, we have developed nearly instant, wireless communication around the world.

But electrical engineering is far more than telecommunication. We have electrical engineering to thank for supplying power and light. In 1801, Sir Humphry Davy discovered that he could produce a brilliant spark, or arc, between two carbon rods in a battery circuit. This is called arc lighting. Davy's battery was not powerful enough to produce a stable arc. So, arc lighting was not commercially feasible until the 1870s after Belgian-born engineer Zénobe-Théophile Gramme developed a generator that could support a higher power capacity. It was called the Grammes dynamo, a continuous-current electrical generator that drove the push for electrical power.

While arc lighting began showing up on streets around the world, Thomas Edison realized that arc lighting was too bright to be used in the home. This led to his development of the incandescent lamp. By capitalizing on the work of many others, his incandescent lighting systems were soon featured at popular exhibits such as the Paris lighting exhibition in 1881 and the Crystal Palace in London. But Edison quickly gained competition, most notably from George Westinghouse and Nikola Tesla. This led to what is now remembered as the War of Currents with Westinghouse and Tesla as proponents of an alternating, or AC, current against Edison's direct, or DC, current. Edison did his best to discredit AC currents by trying to convince the public they were dangerous. He had animals electrocuted by AC currents on public display and even recommended electrocution as a death-penalty alternative to hanging prisoners. At which he succeeded. The first person to be executed by electricity was a convicted murderer named William Kemmler, who was put to death in the electric chair in 1890.

Despite his other efforts, though, Edison failed to discredit the push for AC. Westinghouse won the contract to supply electricity to the 1893 World's Fair in Chicago, and AC currents have since become dominant in the electric power industry.

We also have electrical engineering to thank for many of the electronic devices we use every day. That brings us to the third field of electrical engineering: computers. In their beginning, before World War II, most computers were part of what was called "radio engineering". Most of the computer's focus was on radar, radio, and early television. Their primary work was in processing the signals of those devices. Computers only began to gain a broader audience after the transistor was developed in 1947. The point-contact transistor was a semiconductor device that could amplify or switch electrical signals. It allowed electrical engineers to replace vacuum tubes, which were bulky, unstable, and consumed too much power.

But while the computers could be smaller, they were still pretty large. They also needed a separate integrated chip for each one of their functions. Then, in 1968, an American engineer Marcian Hoff helped solve these problems. He conceived of a universal processor that could be used by all computers. His work led to the Intel 4004, the world's first commercial microprocessor. Since microprocessors were so tiny, the computers themselves could be even smaller.

And that is how electrical engineers shaped the world we live in today: with telecommunications, electric power and lighting, and computers. The fact is it takes all three of these fields – none of which existed until a couple of hundred years ago – to work together for you to watch this educational video right now.

So today we explored the history of each of these fields (telecommunications, electric power and lighting, and computers), touching on such topics as magnetism, electrical conduction, telegraphy, lighting, and computers.

Thank you for watching.

## The History of Early Computing

Computers are the lifeblood of today's world. If they were to suddenly turn off all at once, the power grid would shut down, cars would crash, planes would fall, water treatment plants would stop, stock markets would freeze, trucks with food would not know where to deliver, and employees would not get paid. Even many non-computer objects – like for example the shirt I am wearing or the chair I am sitting on – are made in factories run by computers. Computing really has transformed nearly every aspect of our lives.

This video will be your introduction to the world of computers, and it will help you better contextualize computing's role, and how humanity's greatest invention is just in its infancy, with its biggest impact yet to come. We should start with computing's origin because although electronic computers are relatively new, the need for computation is not. At the end of each segment of this video, you will be given a little quiz to test what you have just learned. This will help you consolidate your knowledge and assess your own level of concentration. Let's go.

Advances in manufacturing during the Industrial Revolution brought a new scale to human civilization – in the agriculture industry and domestic life. Mechanization meant superior harvest and more food, mass-produced goods, cheaper and faster travel and communication, and usually a better quality of life.

And computing technology is doing the same right now – from automated farming and medical equipment to global telecommunications and educational opportunities, and new frontiers like Virtual Reality and Self Driving Cars.

We are living in a time likely to be remembered as the Electronic Age. With billions of transistors in just your smartphones, computers can seem pretty complicated, but really, they are just simple machines that perform complex actions through many layers of abstraction.

**Question 1**

During which revolution did advances in production bring a new scale to the agricultural industry and everyday life? (the name)

a) Agricultural
b) Industrial
c) Scientific

**Question 2**

What is the name of the time that will likely be remembered as the time our society currently lives in?

a) electrical age

b) modern age
c) electronic age

The earliest recognized device for computing was the *abacus*, invented in Mesopotamia around 2500 BCE. It is essentially a hand-operated calculator that helps add and subtract many numbers. It also stores the current state of the computation, much like a hard drive does today. The abacus was created because the scale of society had become greater than what a single person could keep and manipulate in their mind. There might be thousands of people in a village or tens of thousands of cattle.

There are many variants of the abacus (representation of the abacus), but let's look at a really basic version with each row representing a different power of ten. So, each bead on the bottom row represents a single unit, in the next row, they represent 10, the row above 100, and so on. Let's say we have 3 heads of cattle represented by 3 beads on the bottom row on the right side. If we were to buy 4 more cattle, we would just slide 4 more beads to the right for a total of 7. But, if we were to add 5 more after the first 3 we would run out of beads, so we would slide everything back to the left, slide one bead on the second row to the right, representing ten, and then add the final 2 beads on the bottom row for a total of 12. This is particularly useful with large numbers. So, if we were to add 1,251, we would just add 1 to the bottom row, 5 to the second row, 2 to the third row, and 1 to the fourth row. We do not have to add in our head and the abacus stores the total for us.

**Question 3**

What is the name of the earliest recognized device for computing?

a) abacus
b) calculator
c) hard drive

Over the next 4000 years, humans developed all sorts of clever computing devices, like the astrolabe, which enabled ships to calculate their latitude at sea. Or the slide rule, for assisting with multiplication and division. And there are literally hundreds of types of clocks created that could be used to calculate sunrise, tides, positions of celestial bodies, and even just the time. Each one of these devices made something that was previously laborious to calculate much faster, easier, and often more accurate — it lowered the barrier to entry, and at the same time, amplified our mental abilities.

As an early computer pioneer Charles Babbage said: “At each increase of knowledge, as well as on the contrivance of every new tool, human labour becomes abridged.” However, none of these devices were called “computers”. The earliest documented use of the word “computer” is from 1613, in a book by Richard Braithwaite. And it was not a machine at all - it was a job title. Braithwaite said, “I have read the truest computer of times, and the best arithmetician that ever breathed, and he reduceth thy dayes into a short number”. In those days, a computer was a person who did calculations, sometimes with the help of machines, but often not. This job title persisted until the late 1800s when the meaning of computer started shifting to refer to devices.

**Question 4**

What was the word “computer” used for in the earliest documented use?

a) name of a hand-operated calculator
b) name of a job
c) name of a typewriter

Notable among these devices was the *step reckoner*, built by German polymath Gottfried Leibniz in 1694. Leibniz said, “... it is beneath the dignity of excellent men to waste their time in calculation when any peasant could do the work just as accurately with the aid of a machine.”

It worked kind of like the odometer in your car, which is really just a machine for adding up the number of miles your car has driven. The device had a series of gears that turned; each gear had ten teeth, to represent the digits from 0 to 9. Whenever a gear bypassed nine, it rotated back to 0 and advanced the adjacent gear by one tooth. Kind of like when hitting 10 on that basic abacus. This worked in reverse when doing subtraction, too. With some clever mechanical tricks, the Step Reckoner was also able to multiply and divide numbers. Multiplications and divisions are really just many additions and subtractions. For example, if we want to divide 17 by 5, we just subtract 5, then 5, then 5 again, and then we cannot subtract any more 5’s. So, we know 5 goes into 17 three times, with 2 left over.

The step reckoner was able to do this in an automated way and was the first machine that could do all four of these operations. And this design was so successful, that it was used for the next three centuries of calculator design. Unfortunately, even with mechanical calculators, most real-world problems required many steps of computation before an answer was determined. It could take hours or days to generate a single result. Also, these hand-crafted machines were expensive, and not accessible to most of the population.

**Question 5**

The first automated machine for calculating numbers, built by German polymath Gottfried Leibniz in 1694 was:

S _ _ _ R _ _ _ _ _ _ _ (step reckoner)

**Question 6**

What mathematical operations the step reckoner was capable of?

a) multiplication, exponentiation, and division
b) addition, subtraction, multiplications, and division
c) addition and subtraction

Before the 20$^{th}$ century, most people experienced computing through *pre-computed tables* assembled by those amazing "human computers" we talked about. So, if you needed to know the square root of 8 million 6 hundred and 75 thousand 3 hundred and 9, instead of spending all day hand-cranking your step reckoner, you could look it up in a huge book full of square root tables in a minute or so.

Speed and accuracy are particularly important on the battlefield, and so militaries were among the first to apply computing to complex problems. A particularly difficult problem is accurately firing artillery shells, which by the 1800s could travel well over a kilometre (or a bit more than half a mile). Add to this varying wind conditions, temperature, and atmospheric pressure, and even hitting something as large as a ship was difficult.

*Range tables* were created that allowed gunners to look up environmental conditions and the distance they wanted to fire, and the table would tell them the angle to set the canon. These Range Tables worked so well; they were used well into World War Two. The problem was if you changed the design of the cannon or of the shell, a whole new table had to be computed, which was massively time-consuming and inevitably led to errors.

**Question 7**

What type of computing instead of a step reckoner could a human use in the 19$^{th}$ century, for example, to calculate the square root of a huge number?

a) a calculator
b) their fingers
c) tables

**Question 8**

Who was one of the first to use tables to calculate and solve complex problems?

a) militaries
b) domestics
c) academics

So, by the end of the $19^{th}$ century, computing devices were used for special purpose tasks in the sciences and engineering, but rarely seen in business, government, or domestic life. However, the US government faced a serious problem with its 1890 census that demanded the kind of efficiency that only computers could provide. The US Constitution requires that a census be conducted every ten years, for the purposes of distributing federal funds, representation in Congress, and good stuff like that. And by 1880, the US population was booming, mostly due to immigration. That census took seven years to manually compile and by the time it was completed, it was already out of date – and it was predicted that the 1890 census would take 13 years to compute. That is a little problematic when it is required every decade!

The Census Bureau turned to Herman Hollerith, who had built a *tabulating machine*. His machine was "electro-mechanical" – it used traditional mechanical systems for keeping count, like Leibniz's Step Reckoner — but coupled them with electrically-powered components.

Hollerith's machine used *punch cards* which were paper cards with a grid of locations that can be punched out to represent data. For example, there was a series of holes for marital status. If you were married, you would punch out the married spot, then when the card was inserted into Hollerith's machine, little metal pins would come down over the card – if a spot was punched out, the pin would pass through the hole in the paper and into a little vial of mercury, which completed the circuit. This now completed circuit powered an electric motor, which turned a gear to add one, in this case, to the "married" total. Hollerith's machine was roughly 10x faster than manual tabulations, and the Census was completed in just two and a half years - saving the census office millions of dollars.

Businesses began recognizing the value of computing and saw its potential to boost profits by improving labour- and data-intensive tasks, like accounting, insurance appraisals, and inventory management. To meet this demand, Hollerith founded The Tabulating Machine Company, which later merged with other machine makers in 1924 to become The International Business Machines Corporation or IBM which you have probably heard of.

**Question 9**

What problem did the bureau approach Herman Hollerith with?

C _ _ _ _ _ problem (Census problem)

**Question 10**

What was the main component used in Hollerith's tabulating machine?

P _ _ _ _ C _ _ _ _ (Punch Cards)

These electro-mechanical "business machines" were a huge success, transforming commerce and government, and by the mid-1900s, the explosion in world population and the rise of globalized trade demanded even faster and more flexible tools for processing data, setting the stage for digital computers.

Thank you for watching.