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Improve basic Computer Science competences using Video Infographics
Improve basic Computer Science competences using Video Infographics

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Abstract

In the past decade technology has been pacing at an unprecedented rate. One must keep up with the technological advancement if they were to lead a good life. Due to lack of access to the technology by availability or affordability, or lack of understanding of fundamentals, many are not able to use the technology to their advantage. This is leaving a gap known as digital divide. With the decade of automation ahead of us, those people must be retrained into some skilled jobs. New methods must be devised to effectively train people with fast and effective manner. Visual learning is one of the useful ways to achieve that. Leveraging infographics, visual learning and motion video, many platforms have individuals creating lot of informational videos. This study aims at finding out the effectiveness of a video infographics learning unit at teaching a computer science topics. To achieve the goal in this study the focus is on developing a process to make educational videos and a system to deliver the content and get feedback. An evaluation study is done and the results show that video infographics improve comprehension of a computer science topic and the factors they depend upon.

Chapter 1 Introduction

In this chapter, the motivations and objectives of the thesis are laid out. In section 1.1 the motivation and need to develop alternative teaching methods are discussed, and one such method, Visual learning and its history are discussed in section 1.2. The section 1.3 provides the definition of Infographics and reasons for choosing Video infographics, and the section 1.4 discusses the objectives of the thesis. Finally the section 1.5 discusses the structure of the document.

1.1. Motivation

Technology is changing at a rapid pace and people are always running towards next big thing. For many that are fortunate, every technology is for the better, but for others are not aware or use the technology. The problem is complex with one reason being having access to the technology, or lack thereof and the cost is a lost opportunity. Even deeper problem is when having access to the technology, lacking the background or technical knowledge and experience to understand and use the technology [1]. One such technology that is ground breaking is the internet and digital revolution. Few studies show the cost of *digital divide*, that is lack or higher cost of access to technology and *digital literacy*, that is lack of skills to effectively use the technology for the development of citizens and countries. [2] [3]

To address the problem of availability or affordability of the technology is a policy issue. Over the past decades, many attempts were made to improve the digital divide but the deeper problem of digital literacy is not properly addressed [1].
However this rapid pace of advancement is not stopping and the further advancements like automation of labor jobs means the technology and digital literacy cannot be ignored. The people who are working in basic or unskilled jobs must be retrained or reeducated for skilled jobs. Revamping the traditional classroom education system is one way to solve the problem at a global scale, by making use of internet as a medium of teaching. Techniques must be researched to improve the time required and quality of knowledge transferred. One such possible method of interest is use of visual learning methods, that is visualizing the information.

1.2. Visual Representation of Information

Humans use all 5 senses (vision, auditory, touch, smell and taste) as input sensing the world around us, but research into brain physiology says vision alone accounts for half of brain sensing area [4]. We already use vision for information transfer, like reading a piece of information. Research shows that images or illustrations improve the learning. According to Ware [5], human brain is a parallel processor with images and this is due to our brain wired to see patterns. This phenomenon is called *Pre-attentive processing* and can be tested as Figure 1.1 (source [4]. The left is an image of a text with numbers and find out how many of them are 7. Then the right image used color to show 7's, and the

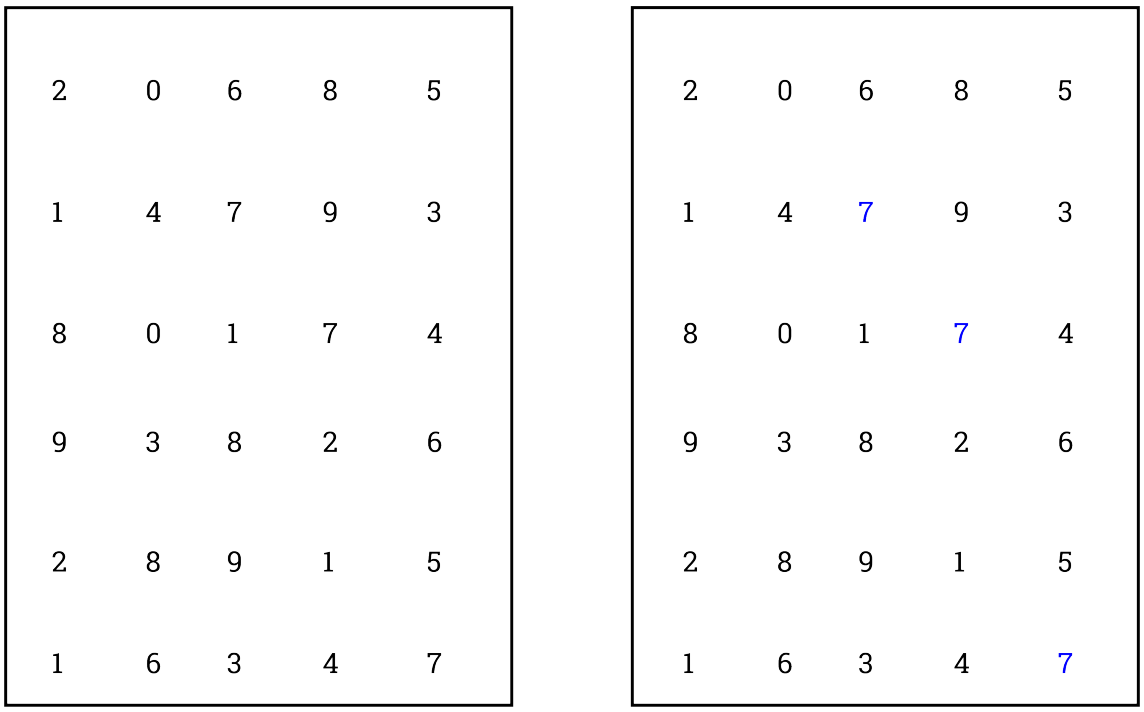

Figure 1.1.: Left: image with text and no attributes. Right: color, a preattentive attribute is used.

recognition is instant. Color is one of the pre-attentive attributes.

Illustrations are some of the earliest works of humans through cave drawings, representing an idea or information in a graphical way. Figure 1.2 (source: [6] depicts one of the cave painting showing various animals in detail. I can imagine this information used by early humans teaching their children how animals looked like and which ones to hunt and which ones to avoid. Thousands of years later, the Egyptian hieroglyph's are also some examples of visual communication. Figure 1.3 (source: [7]) depict some of the hieroglyphs found in tomb of Seti 1.

In recent times, infographics or visual representation of data is widely used from newspaper articles to urban maps [8]. Maps again, are a very good example of visual communication. Consider for example, the figure 1.4 which depicts a modern metro map of train stations and popular visitor sites in a city. The idea is that, using this kind of representation allows the visitors to see their location, and figure out a route from closest station near their location to reach their destination. That is assuming, the person has an access to the map, and knows how to use it, and the map correctly displays information like station names and train lines.

Why Video or Motion Infographics

Infographics when static are plenty powerful. It can be used to differentiate and clearly depict the differences in a set by size, shape, color etc attributes (Pre-attentive attributes) [5]. Video improves on this by having more guided, attention-gaining animations or elaborate explanations through simulations. Video also brings in an emotional connection when made using a story and characters bringing in much higher engagement rates as proven in the case of these studies, *If a picture is worth a thousand words is video worth*

Figure 1.2.: A cave painting from 20000 years ago depicting some animals

Figure 1.3.: Egyptian hieroglyphs found in ancient tomb, depicting some information

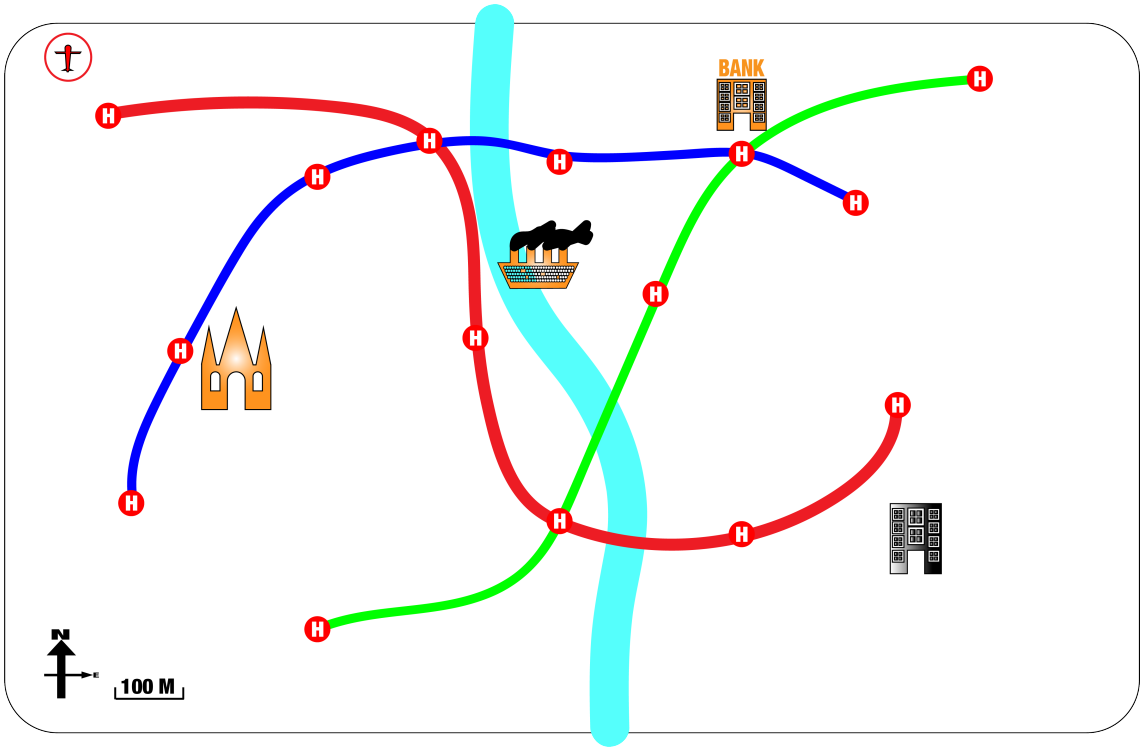

Figure 1.4.: A modern metro map depicting landmarks making it simpler to find directions and trains or interchange stations to destination

a million? [9] and *Science Education in Primary Schools: Is an Animation Worth a Thousand Pictures ?* [10].

1.3. Definition of Infographics

Infographics = Information + Graphics

Infographics is an abbreviation of *Information* and *Graphics*, and is described as information expressed in a graphical format. It is an attempt at gaining attention of someone, and communicate them about some knowledge in a simple and efficient manner as possible.

More formally the definition can be derived from [11] and presented as, *Infographics is a way of presenting complex information in a simple, logically connected and digestible chunks, so as to keep the user engaged and make them gain knowledge.*

It simply means the data or information is presented in a simple and easily navigable manner, so as to not lose attention of the user or intimidate them with scary concepts, while making the user consume the knowledge.

1.4. Objectives

The main objective of this thesis is to find out if video infographics, improves the basic computer science competences over other traditional methods like text with illustrations. To realize this objective, some topics that can be represented by infographics are identified and evaluated against their text counterparts. Factors influencing the user engagement, and what types of content can be represented using infographics must be identified. To reach this goal a method of workflow to produce video infographic content efficiently must be devised and allow for improvements of the content from user

feedback. Finally, an App to deliver the content produced to users, and get the feedback during the user study must be developed. As such the main research question is

- RQ: Does Video Infographics improve user comprehension of a topic, compared to other methods like text ?

1.5. Outline

In following chapter 2 works related to video and infographics in education are discussed and in chapter 3 the factors that may influence infographics are identified, what content types are represented using which of the identified factors, and a work-flow for the development of infographics video content is devised. In chapter 4 a system to distribute the produced content and get feedback is developed. Using this system, chapter 5 an user study on two age groups (elders aged >50 and adults aged 18-49) with 6 participants each (n=6)x2 is performed and the results are reported.

Chapter 2 Related Work

This section covers the related work of Video and Infographics in education and technical education. Recorded Video lectures allow students to learn at their own pace with repetitions and are available to learn anywhere, like home, library or coffee-shop. The only requirement is a device with internet access. Many other individual content creators as well as schools also support creation of technical simulations and animated content to teach complex processes like combustion engine or ramjet engines. There are not many direct works of using computer science with infographics. So, this chapter deals with related work about Video in education 2.1, followed by infographics in education 2.2 and the proliferation of video-infographic content on the internet and it's spillover effect.

2.1. Video in Education

MOOC's are some of the famous examples of using videos to teach advanced courses. Using recorded lectures from universities to be seen over the internet was extremely advantageous. According to [12] [13], this approach allows for many advantages like

- allowing the students to watch the missed classes
- allows the students to re-watch critical parts of the lecture

One area where video is useful is depiction of complex procedures like clinical tests. Video based learning facilitates superior results compared to illustrated pictures of the same. The study [14] tests groups of medical students trained a procedure using illustration with 6 photographs of the process and accompanied text against the procedure taught by video. The results conclude that in some practical clinical skills video based learning is superior to illustrated texts of the procedures.

Outside university education, video based approach to educate parents about the use of antibiotics is highly effective at the task [15]. The test was conducted on three groups, one with illustrated pamphlet, one with animated video and one control group. The survey was done before and after the educational content is shown. The analysis shows animated video group significantly performs better than the pamphlet group.

In some cases interactive video is more useful non-interactive video [16]. Students are given access to interactive video, non-interactive video, and no video, in a e-learning environment as well as a traditional classroom group. The analysis concludes that interactive video is very much powerful than non-interactive videos, suggesting more has to be done than a simple video recording. Another study [17] shows interactive videos powered by collective intelligence gathered from discussions, forums perform better at comprehension and retention of the topics compared to other groups without interactive or interactive without collective intelligence.

2.2. Infographics in Education

Infographics in education are a powerful tool with data visualizations and representations of complex information. The research into use of infographics in higher education is less and spread out over many fields. One such study [18] investigates differences and finds out that readers prefer infographic summaries over text and have lesser cognitive load with infographic summaries. Information retention however is no different between the two groups.

Another study a few years earlier [19] finds that information retention is significantly longer in the group that used infographics over the group that did not. In high stakes nuclear safety [20] discusses the use of infographics in combination with text to effectively train the next generations of nuclear safety experts.

2.3. Summary

The research into using video infographics is very nascent. It is very important to research into the fields or topics best taught using video infographics and infographics, as well as to analyze which content suits what types of age groups.

Chapter 3 Learning Units

Learning Units or *LU's* is the unit of content that makes the user learn some new information or do a new thing that they could not do before [21]. Learning units also contain a performance assessment to analyze the results of training session. In this chapter we discuss the factors influencing the Infographics. Selection of learning units for this thesis and later a working process that is used to make a learning unit.

3.1. Factors influencing Infographics

According to Lankow [4], infographics can be judged using three characteristics. These are:

- ***Appeal***, the infographic must be visually appealing and must follow the information shown.
- ***Comprehension***, the infographic must be clear and concise, and easily understandable to the users.
- ***Retention***, in case of important information, the infographic must stimulate long memories of knowledge.

Other factors identified when asked about educational content online from a small (n=4) focus group are:

- ***Length,*** of the video, the video must be focused to a single problem and prefer the bigger lesson or topic be made into a playlist of videos. This is to help them navigate the topics.
- Narrator's ***accent, speed*** as well as ***clarity of instruction.***

In section 3.2 we discuss what types of information is suited for infographics and also which factors play a role in those cases.

3.2. Types of information represented with infographics

Figure 3.1 (source: [4])represents various types of infographics used in different scenarios and their preferred order of goals. According to Lankow [4],

- Academic or scientific infographics have comprehension as the highest priority, retention as second and appeal as the least. This is because people in academic and scientific backgrounds have audience who are looking for knowledge, and must be presented with minimal bias and allow users to draw their conclusions.
- Editorial infographics are for mass consumption and awareness campaigns. They have highest priority to appeal, as they must keep the audience engaged on the topic. They also have very less information that is necessary to be memorized and hence the least priority of retention. Comprehension is also important as the data must be understandable to masses, and holds middle priority.

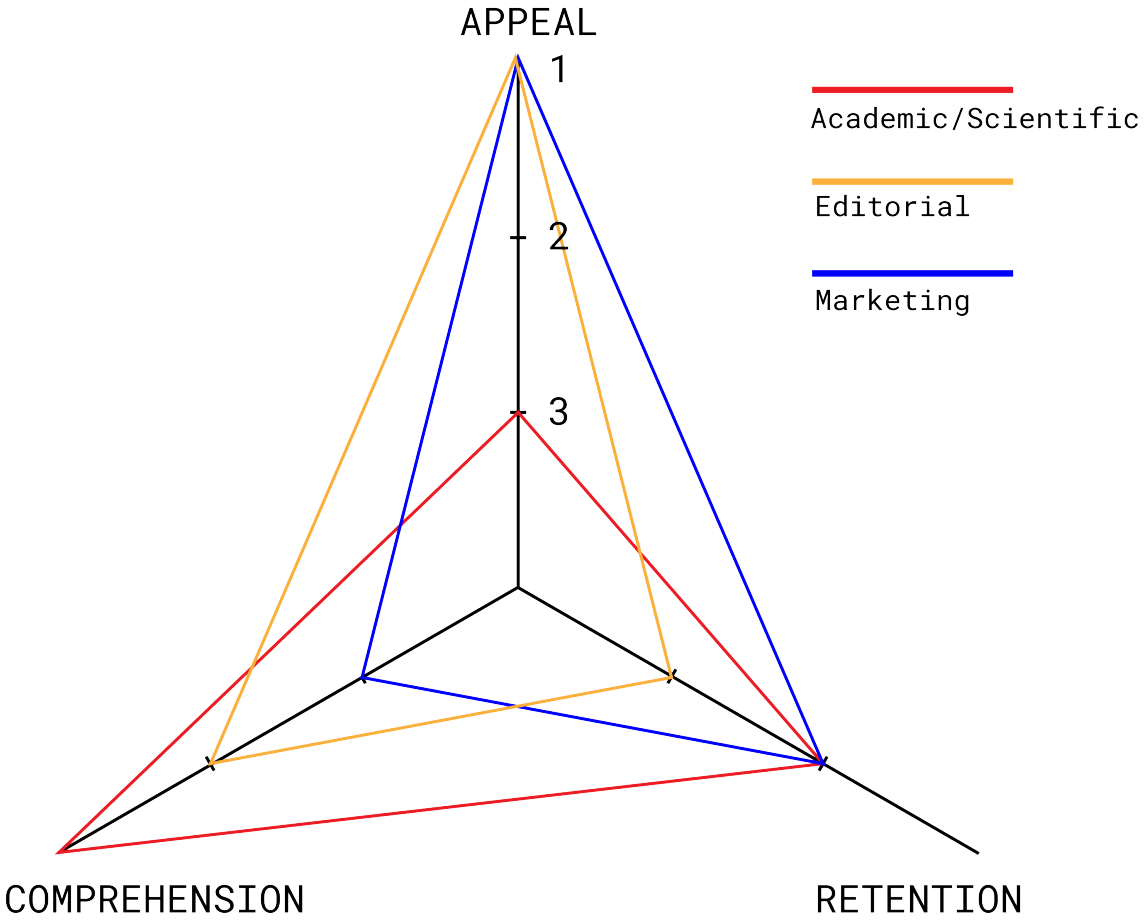

Figure 3.1.: Infographic priorities by application (source: Infographics The power of Visual Storytelling)

- Marketing infographics are a mix and focus is based on type. Most ads focus on attracting the user and associating them to something, and as such Appeal is the highest priority. Followed by retention, as the brands like to be remembered. Comprehension of the Ad is of the least priority.

3.3. Selection of Learning content

Selection of learning content is done in two steps. First using the content identified by Svenja Noichl [22], some topics of interest are identified (subjectively) that are considered basic by computer scientists but useful for non-computer scientists. Additionally some topics are identified from school textbooks and modified to fit an interesting topic [23]. For example the topic on subnets from the textbook is identified, as well as network of networks and there is a gap of missing information of why the private subnets are used. So this gap is presented as a Network Address Translation topic. The topics identified are

- Cryptographic keys and Information security
- Automata theory and internal states
- Email security and Phishing
- Domain Name System (DNS) and how internet connects

- Network Address Translation (NAT) and why private and public IP addresses are used.

Later these topics are shown to few (n=5) non-computer scientists and asked them what topics do they find interesting. Each participant is asked to select 3 topics and to no surprise all the participants selected the well known topics like DNS and phishing. This was under the assumption that non-computer scientists are not interested to know about automatons or cryptography. Phishing was the top selection for 4 participants and cryptography for 1 participant. DNS was the 2nd choice for all and 3 participants selected NAT as third selection. Based on number of votes for each topic, DNS with 5 votes, Phishing with 5, NAT with 3, Cryptography with 2, the top 3 topics were selected as Learning units.

After selecting the learning units, the next process is to gather the content that is to be taught. For the first topic DNS, the basic structure and information follows a lecture material from ComSys department at RWTH Aachen and course, Internet Architectures (Chapter DNS). First it establishes why DNS was needed, followed by the structure and the resolution mechanism and some problems of DNS implementation. Figure 3.2 shows the initial planned structure. Later some of the branches were combined and some are removed to make the unit have consistent difficulty level, particularly the section of latest upgrades, as to explain them some security topics like key signing, Cryptographic verification and TLS security must be explained and logical continuity is lost. This learning unit focuses on Appeal and comprehension, and the length of the video is not constrained to be short. The voice of the narrator is female, British English, computer generated text to speech with consistent pitch, volume and natural pauses, see section 3.4.2

For the topic NAT, as a derived topic the selection of information is in a way to explain public and private addresses, why it was conceived and what are the benefits and shortcomings. This learning unit is made to be very short and high level overview of the topic. Unlike the learning unit DNS, this unit is made with focus on comprehension and retention. The length of the video is constrained to 1 minute, and same voice parameters as the DNS learning unit. The final learning unit phishing is taken from YouTube, requested license and was granted with attribution. The video can be used under fair-use for research as well. The content of the video is a series of warnings or suggestions about how to detect phishing attempts. The video focuses on retention and comprehension, but is also well made. It uses a natural voice and not computer generated like the other two.

All the content from video learning units is transcribed into text information with illustrations as necessary. The information value presented in videos and text is same. As a learning unit must involve some mechanism to measure the performance, and as the common denominator among the topics, *Comprehension* is to be measured. Questions are prepared to evaluate the comprehension with low focus on retention of key information. The questions are in two-choice format and are randomly ordered when displayed to users under evaluation. Additionally some questions in form of likert scale [24] are also prepared to help improve the content as well as presentation of the learning units.

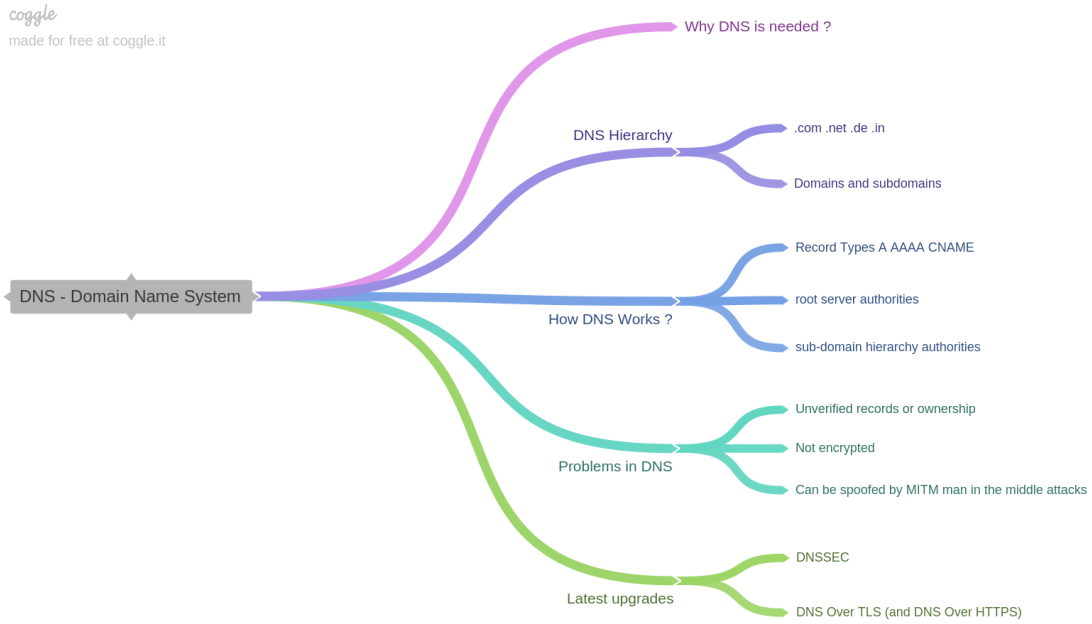

Figure 3.2.: Mind maps help organizing arguments and structure as visual map

3.4. Process of creating a Learning Unit

This section describes a process followed to develop a learning unit. The process was sourced from various tutorials over the internet and adapted to fit with the objectives of the thesis. The process allows to create a learning unit in a format, that can be updated with the feedback and without too much effort. This is realized by breaking up the unit into scenes, and generating chunks of content. With the feedback, these chunks can be modified or more added and render a new version. These steps are crucial to provide the modular flexibility of editing and changing order, or leads to high time/cost when re-doing things after feedback. Some steps can be skipped when doing a simple unit using plain-text or images with minimal animations. Steps written with (*) can be skipped.

Each step discusses what it does, why is it needed, knowledge gained and how it was used to develop the learning units for the thesis.

3.4.1. Mind maps

The first thing to do is to brainstorm the topics that want to be presented in the learning unit. These topics can be from sources like textbooks, or lectures and other sources. Mind maps an active learning tool [25], are the idea of making a visual map of all the information you want present, and arrange them into a hierarchical, readable and understandable manner. Additionally it also allows to arrange thoughts into an order and synthesize a plan. Figure 3.2 (generated from [26]) shows an example of a mind map of learning unit DNS arranged into a format of the learning unit.

3.4.2. Script to Voice-over

This is one of the important step of the learning unit, if you are planning a voice-over learning unit. It is very important to note and spend enough time with writing, recording and editing the recording. Only after having full audio, that roughly gives an estimate of time of the learning unit must you leave this stop. If the steps are not followed and changes are needed to be made after the video is made, changing script and re-recording the part, corresponding changing of key-times in animations will prove to be extremely costly. In order to solve this, the script is broken into many small scenes of logically connected information. Thus when changes are needed to be made, they are done to only parts of the unit.

Script

The script is the written, elaborated version of the structure developed in the section3.4.1. Usually it starts by writing a few sentences for each point from the map, following the structure and arranging into sections as needed. Later the script is modified or updated to be more concise [27].

Text to Speech

The next sub-process after the script is to convert the written script into audio. This can be achieved in two ways

- *Voice recording*, where we physically record the audio with our or someone's voice. You just read the script into a microphone and it gives a natural sounding voice. This has many advantages like natural pauses, a flair, diction and style in the voice. Cons include, confusing pronunciations or heavy/thick accents, and access to high quality equipment and noise isolated room.
- *Computer aided text-to-speech*, where you use any local or online text-to-speech converters and generate audio clips. Pros include high availability,no need of audio equipment. This can be automated when using cloud services like Amazon Polly. Amazon Polly [28] can be setup to read scripts from Amayon S3 storage and store the result audio clips into storage. Cons include, lack of natural sounding voice. This can be solved to some extent with *Speech Synthesis Markup Language (SSML)*. You can greatly (not completely) reduce the unnatural sound with a few SSML tags to control the pitch, volume and add pauses [29].

For our learning unit, DNS, Amazon Polly is used with SSML pauses. An example code block is shown below. Everything that is to be spoken is inside <*speak*> tags. Adding natural pauses with <*break*> tags will enhance the quality of computer voice. More granular controls for SSML are included on Amazon Polly docs for better natural sounding voice [29].

```
1
<speak>
Following this convention, <break time='0.1s'> </break>a domain
   ... can have any number of sub domains which are treated like
    ...
</speak>
```

Listing 3.1: A partial code block from DNS Learning unit, encoded using SSML

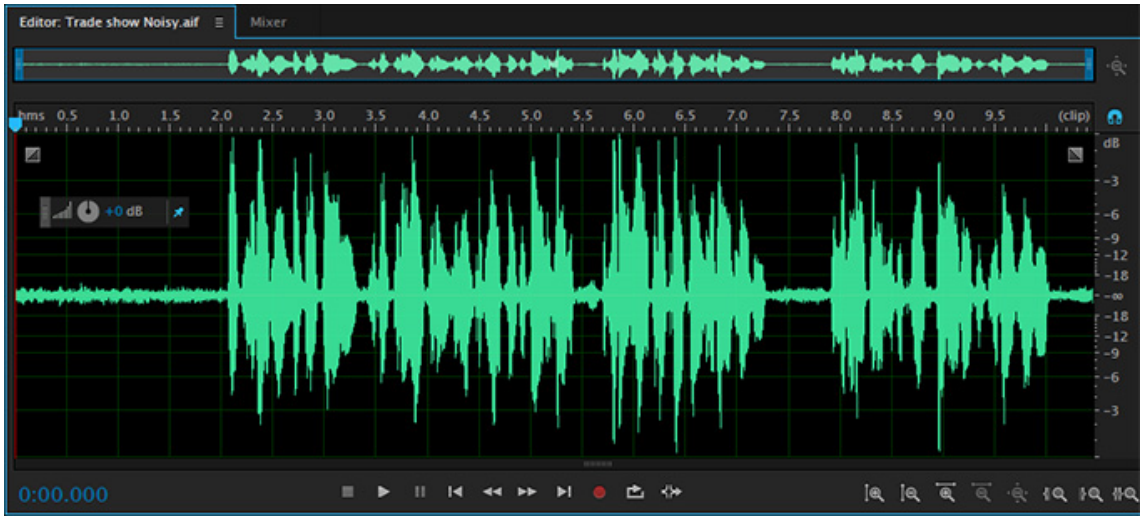

Figure 3.3.: Using the noise print captured from pause time (left) similar noise can be removed from the voice recording time (center, high peaks)

In both the cases of Natural voice or computer generated voice, it is important to separate the script into smaller paragraph size recordings [27]. This will help in processing the voice files to make a final version. In case of voice recording, it is suggested to take breaks or pauses between paragraphs to recuperate and help in noise reduction (next sub-section). If you made a mistake recording in a paragraph, pause for a second or two and restart from that paragraph. The previous recording with mistake can be edited/deleted later.

Voice-over editing

The last phase of this section, is to process the audio files generated in previous step into final version of voice-over. The goal of this process is to generate a single audio file that provides as a guide to further video content design, and animation time-frames. It also gives you basic idea on length of the video. When using professional tools, this single file can be rearranged in the video to make way for advanced transitions or segues.

For a recorded voice with pauses, first we edit away the unwanted or erroneous recording. If recorded in multiple files, place them end-to-end and do the same process. Later using the pauses we run a noise reduction process. Figure 3.3 shows a file with minor peaks to the left, using which a noise print is captured, and applied to speech portions to remove the noise. Most audio programs provide this functionality, for this thesis, Adobe Audition [30] is used. If multiple sources of noise are present at different parts of the audio, try using the pause closest to the source [31].

3.4.3. Prototype structuring video content *

This step is optional when making a simple text motion or minimalist animations. The content for such learning units can be created in the editing application itself. In other cases it is advised to plan and use this step to make a coherent and consistent structuring. This step deals with creating imagery or artifacts that are to be displayed in an order to match the audio. The work is divided into scenes as from the audio recording section. According to AWN *"A scene is an event or conversation between a set of characters, in a single*

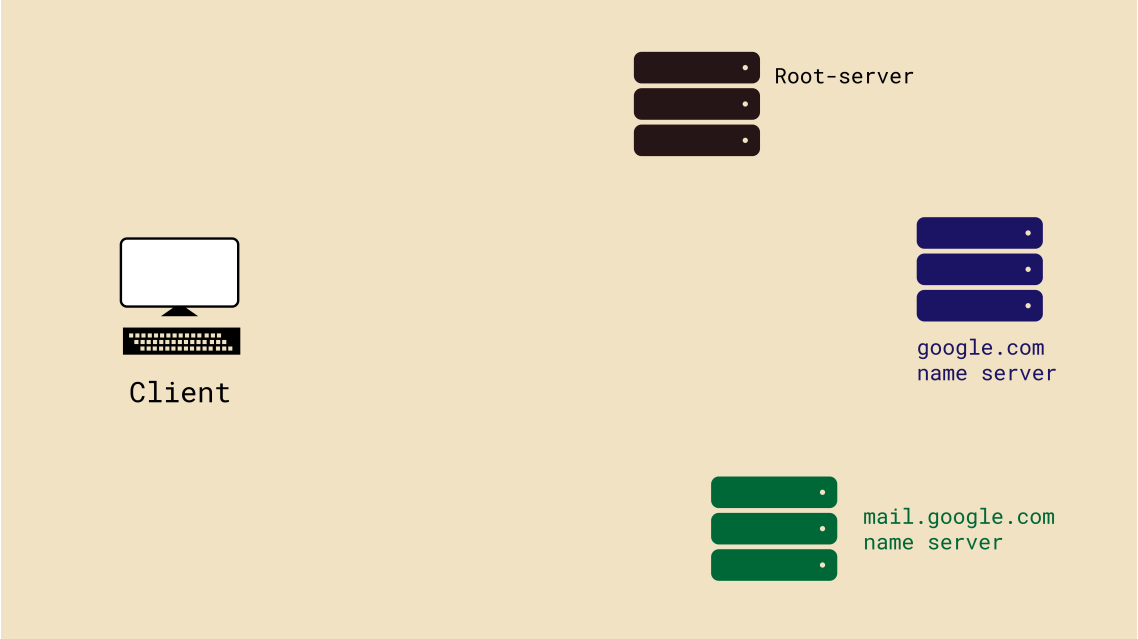

Figure 3.4.: A scene example, each item is in an individual layer which can be shown or disabled to create animations that sync with audio description

place, at a single time that leads to the climax" [32]. In terms of learning units, *"a scene is a block of video where a single unit of content that can be explained with a limited set of items in a coherent manner, where an unit of content is not necessarily a self contained topic"*. That is, a topic can have many scenes. For each scene, brainstorm a best method to explain the concept [33]. Some types of methods can be, if it's a definition, text must be displayed with emphasis on keywords or specific images to help memorize and understand the nuances, or if it's a mechanism then how to visualize the mechanism with animation. Sketching the ideas might help to have an overview and streamlines the process.

A layer is like a sheet of transparent paper, 4 layers with 4 images not in same positions appear as a single item with 4 images.

After prototyping a scene, by sketching or brainstorming the method to show content, the next step is to turn the prototypes into workable content. This include finding relevant images or creating own images. For this thesis Adobe suite is used, particularly Adobe Illustrator [34], a vector image creation and editor. Using adobe illustrator the content to be shown in a scene is created, like clients and server diagrams and text description. Figure 3.4 shows one of the scene from a learning unit DNS, and shows the process of DNS resolving. In this each image of server or client is in a layer of itself. Reasons for this are explained in detail in section 3.4.5. Simply put, this allows to animate each object by hiding and showing them as each are on individual layers. This step is followed for both the learning units developed.

3.4.4. Story and Character design *

This is another step that is not strictly necessary. This is particularly useful when creating a series or episodes of learning units. Similar to movies, main characters are those who appear frequently and are carefully crafted to fit into the story. This character based learning is particularly useful for children and helps in promoting scientific thinking and induces curiosity [10]. A story is just a way how the characters interact and give

additional comprehension visually that helps in better grasp of the original concepts.

For this study, the target groups are Adults (18+), Elders (49+) and not children, so characters are not used throughout. In DNS Learning unit, one scene has good use of this step when attempting to teach 'Man-In-The-Middle-Attack'. For this 2 primary characters for DNS Client and resolver, and a nefarious character listening on the wire, are prepared. The story part goes as the client and resolver are communicating and the nefarious actor moves in between them and listens the un-encrypted communication. Additionally the communication between them is shown as bubbles and communicates extra information.

3.4.5. Animating and assembling

This step is the most important and time consuming in the entire process. Animations for content (not to be confused with commercial animations) are simple and a lot of repetitive steps. The most common animations available in Adobe After Effects [35] are built up on basics like *position, rotation and scale*. A keyframe is defined as a start or end of a smooth transition [36]. For example consider one of the learning units NAT created for this study, it has many times text IP packet representing communication from one client to NAT broker(s) and destination server(s). To make a text motion animation, we need two keyframes. First at the starting position of the text add a keyframe, and drag the item to destination position and at a different time add another keyframe. The program then adds all frames in between source and destination and generates a smooth animation. The time of animation must be considered as if it's too short or too long animation looks jerky.

Another key program used for animation of complex characters is Adobe Character Animator [37]. Character Animator makes use of pre-built or custom-built characters called puppets. The significant feature is using web-camera to animate characters by using facial expressions, including lipsync. Additionally all of these can be controlled by keystrokes too. Usually many 'takes' are needed for live recording, and with keystrokes, these takes are controlled granular. A pass with blinks is recorded, later lipsync with audio, then hand movements and eyelids etc. After finishing the scene animation it can be exported to After effects and used as a footage [38] .

It is beneficial to animate according to the audio description by adding an audio layer to the timeline. In the section 3.4.3 it is discussed that each object is created on an individual layer. This is done so that when imported into After effects, each layer can be controlled individually as a composition. Finally adding various compositions to make a scene, and scenes are added to form a video. Transitions must be added to separate sections signifying the different topics and also to improve appeal.

A composition is basically a layer specific to animation, with additional characteristics to scale, rotate etc.

Pre-render at low quality to save time and check if any discrepancies like black/blank screens or missed audio sync and overwritten text etc. If found make a note of time and continue watching the full video. Later change the scenes to fix those errors and render again with low quality. Once satisfied with video, render at full quality for deployment [33].

3.4.6. Feedback and Improvement

This step deals with changing or updating the content in scenes after feedback from a user. When done according to the steps above with scene based structuring, it will be relatively straightforward and easier to change, add or remove content by only editing part of the video. If a concept needs to be updated, then start with modifying the script and re-record a newer version. Since the scene is replaced with newer version, the voice file output is changed to newer version. Then update the scene composition in After effects if necessary edit the source from illustrator and character animator. With three steps, edit script and record new script parts, update the scene data and animations, and render again.

As a learning unit, feedback must also be designed in a way that helps in making the content better. Apart from basic comprehension questions of the topics explained, some quality control questions like user satisfaction on speed of the explanation, distractions faced, and audio quality of narration etc must be gathered. Additionally in the future it is possible to automate and gather non-verbal feedback data in the form of learner drop-off points, if user stops watching the unit signifying losing interest, or repetition of a concept signifying confusing explanation can be retrieved by making the app to perform these measurements.

3.5. Summary

The factors involved in infographics are appeal, comprehension and retention of content. For video infographics, additionally length of the video and accent of narration also affect the quality. Different types of infographics focus on different factors depending on users. Selection of content to be implemented is made and a process is devised that allows modularity of the video content. The process involves creating a mind map and writing a script from that. The script is recorded into audio and content for displaying is brainstormed and animated per individual scenes. Finally all the scenes are stitched to make a video. Following a feedback session the scenes that need corrections are listed and updated, and an improved content is rendered.

Chapter 4 Software Implementation

One of the goals of this thesis is to develop an iterative approach that allows users to access learning units and provide feedback. The approach is split into different modules to achieve architectural flexibility and not to be locked into tight coupling of systems. Figure 4.1 provides an overview of the developed system. The system is divided into three distinct planes,

Object Storage is a service where static files can individually stored and accessed

- **User plane** where *Android app* to show video content and get feedback, and an *Admin Interface* to manage the learning units/content and feedback questionnaires. It also had responses charted to questionnaires for quick mapping of feedback.
- **Data plane** which is a *Firebase Cloud Firestore*. This can be any database of any kind as long as the middle plane is modified accordingly.
- **Middle plane** is an interface between the other two planes, and decouples the user plane from data plane. This allows us to change data-store structure without changing user plane implementation by exposing endpoint REST API's. It even allows changing the data-store to some other self-hosted or managed data-store.

An external *Video Content Delivery Network* (Video CDN) is used to serve static video content. For this any Object Storage service can be used and *Digital Ocean Spaces* [39] is used for this thesis. The modularity allows in future to deploy the datastore and object storage containers along with API's for a possibility of a single command deployment.

4.1. Data Plane

Data plane is the persistence part of the application, where all the application data must be stored. This includes user's, learning unit's, learning unit questions, responses by users and must be highly available. One of the key features of designing modular microservices is the invisibility of structure of data and data is exchanged using standard API's. This allows for swapping of entire data-store stacks or completely rewriting data structures without effecting the user plane. For our application we are using one of the cloud data-store's available free with limitations.

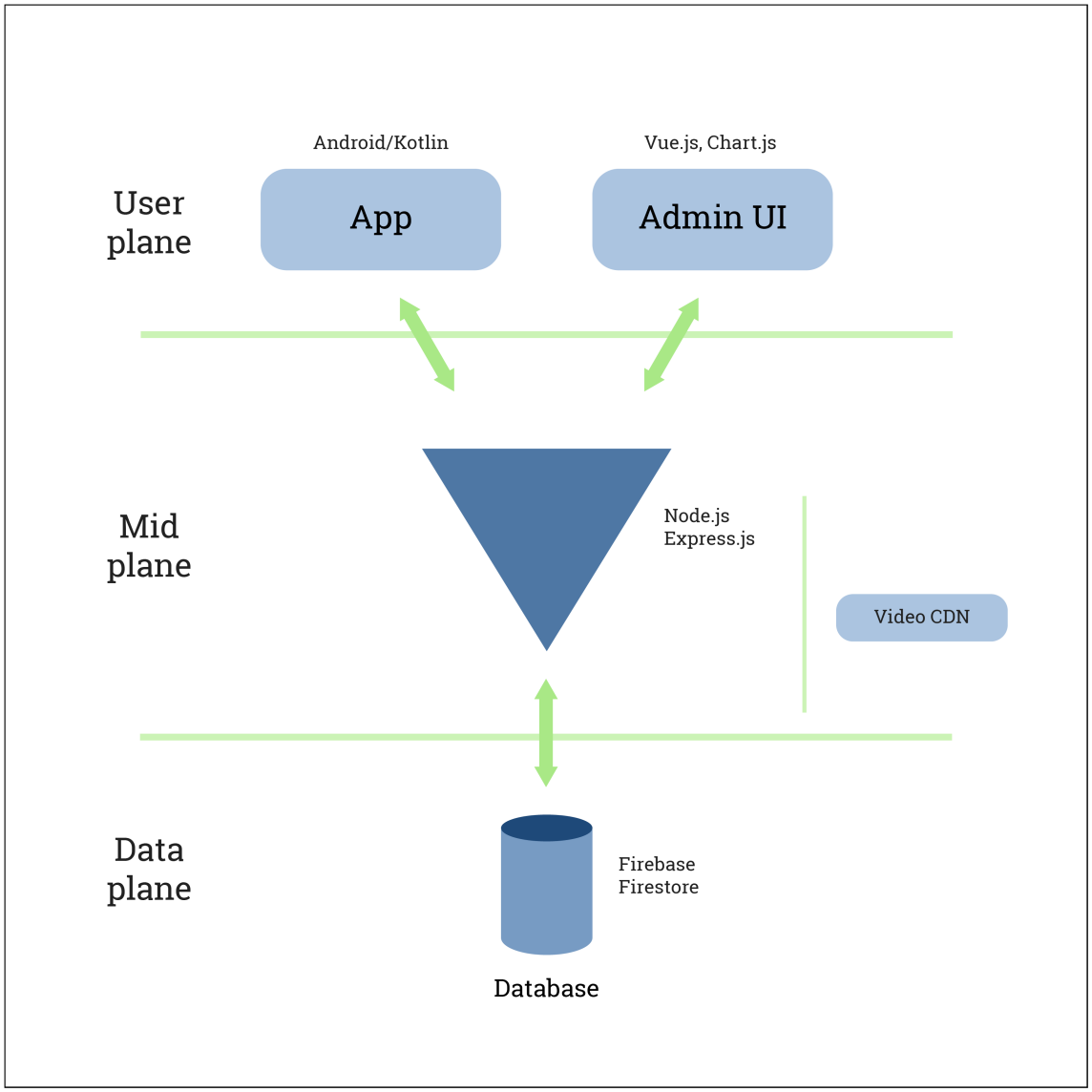

Figure 4.1.: Architecture Overview

4.1.1. Firestore (Introduction and background)

Firebase Cloud Firestore [40] or simply referred as ***Firebase*** for service provider and ***Firestore*** for data-store from here on, is a NoSQL, document oriented database that is available platform as a service (PaaS) and maintained by *Google Inc*. A NoSQL database means data is stored without any rigid structure, and is more flexible. The lack of rigid structure allows us to add additional attributes as needed without any changes to previously stored data. *Firestore* additionally builds upon NoSQL with document oriented structure where information is stored as documents having key-value pairs. Documents can further be arranged into collections. This key-value pairs in addition to NoSQL make a highly indexed data-store with high performance [41].

- A *Document* is a key-value pair object and information is stored as a value and can be accessed with a key. A value can be another key-value pair called a map, other available value types are number, string etc. The only real limitation is Document size is limited to 1 Mega-Byte.

JSON *or JavaScript Object Notation is a data-interchange format*

- A *Collection* is a group of Documents. Documents can be arranged into Collections when they are similar to structure the storage. It allows for fast querying based on one or more attributes, sort and filter documents. A Collection can contain any number of Documents but cannot have other sub-collections. In-order to have a sub-collection we need a Document in Collection, and the Document contains sub-collection. This chaining of alternating Documents and Collections is strictly imposed and the root element of a chain is always a Collection.

Firebase provides libraries to access *Firestore* on multiple platforms including Android and web(Node.js), it is not used because it creates a dependency of using *Firestore* as the only database. When you want to change the data-store to another you need to change the implementation of the App significantly because the libraries provided by *Firebase* handle asynchronous requests and the callback promise on a separate thread. Further Android limits User Interface changes to only on main thread. This means when we handle the async requests ourselves and wait for promise callback, we need to execute on main thread, and async on background threads. Considering modularity, even when the library is extremely powerful, it was not used.

4.1.2. Application Data Model

For this application there are 4 objects to be stored, to have high flexibility and re-usability. They are

- **users** collection to store documents of user, with attributes like language preference, ageGroup, and random unique identifier.
- **videos** collection to store learning units which is generalized for all languages. Each video has attributes like *title*, *length* of the video, Number of accompanying *questions* and Video access *url*. Additionally an unique identifier and the ***language*** attribute is used to identify and filter learning units by user language preference.
- **questions** collection with attributes like *title*, *type* of question, currently two question types are supported and allows to set custom answers with *option1, option2* attributes. The key attribute in this collection is the ***videoid*** which is used to filter questions to a particular learning unit/video.
- **answers** collection is the most complex in the model, as it is layered with sub-collections. Every *question* present in *questions* collection with any responses is stored as a document and ***responses*** are it's sub-collection. The responses sub-collection stores the answer documents with attributes *userid*, and the *answer* value. The answer values are defined by question type. For type 1 questions, answer values are 0 and 1, for type 2 question they are 2 - 7 for 5 possible options. Further question models can be added or removed and answers values can be modified accordingly providing modularity

A partial, simplified model of the datastore can be found in Fig 4.2. The *users* collection has an *user* document, with payload as key value pairs. Similarly the *videos* collection has a *video* document with attributes in payload.
Fig 4.3 helps in visualizing slightly complex *answer* collection, where the collection have documents with same identifiers as the *questions*, the payload field is empty, and each document has a sub-collection ***responses*** which has an *answer* document with payload attributes.

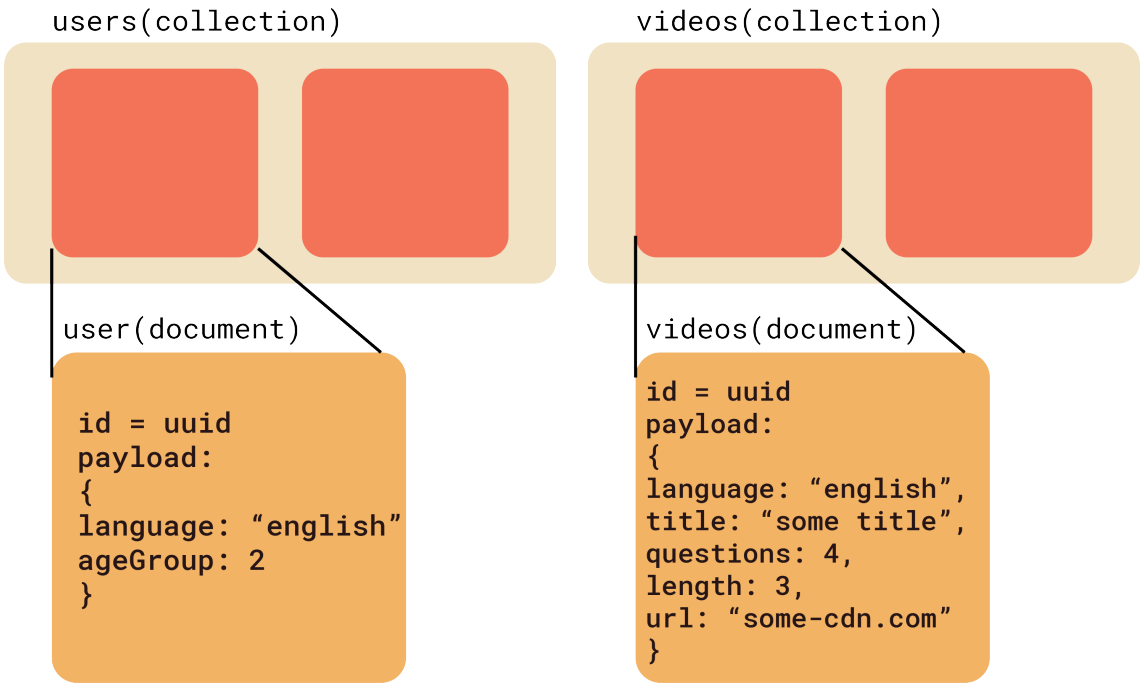

Figure 4.2.: Firestore Data Model of one level collections

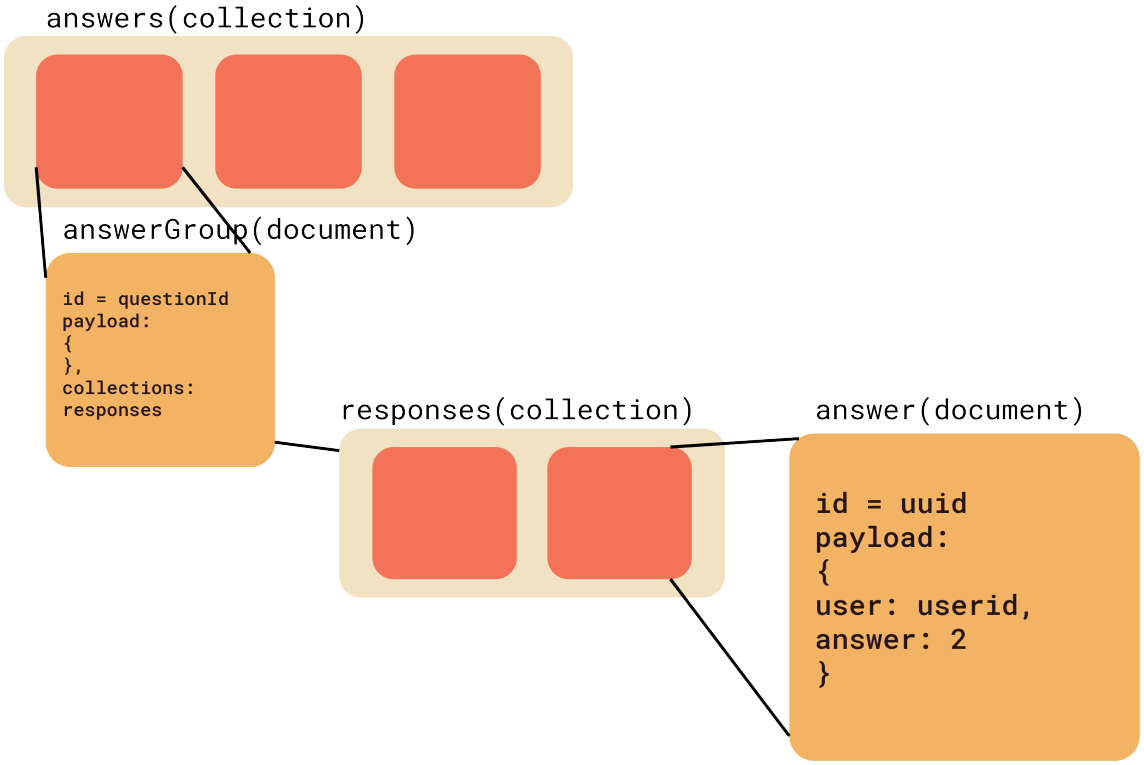

Figure 4.3.: Firestore Data Model with nested collections

4.2. Middle Plane

Middle plane serves as an interface between the data plane and user plane and allows for high level of flexibility. Both user plane and data plane can be changed without modifying the other by changing the middle plane accordingly. This is realized by exposing a series of **API's** which can be reached for either retrieving or posting the data. If the model is changed, the plane is updated accordingly to provide the same JSON data structure to the user, who can reach and retrieve the data from same API endpoint without knowledge of the underlying change.

Objectives and tools used

In early prototype development the *Firebase* libraries for android were used, which is as simple as adding a line in project file, and a *JSON* file containing authentication keys to the project root folder [40]. Traversing the document-collection structure is possible and collections are created easily. The libraries handle *Asynchronous requests* using *threads* and handles the promises. Android enforces TLS security and limits UI changes to main thread [42]. The problems faced in User plane will be discussed in subsection of Android App. The middle plane needs to account for all these issues, which are to remove firebase dependency and async calls on user side, provide TLS connectivity, and allow for changing of datastore without change in android client implementation.

The architecture of the middle plane consists of ***Node.js*** and a derivative ***Express.js***. Node.js is described as *asynchronous event driven JavaScript runtime* [43], and Express.js is a framework built to run on top of Node.js to handle advanced routing and is widely used as a middleware [44]. Since the middle layer only returns *JSON Data* and HTTP status codes [45], the middleware is not heavily used including and not limited to headers. Transport Layer Security and CORS policy [46] is handled externally, and no admin authentication is used.

Security in transport layer (TLS) is strictly enforced in Android and while there are workarounds, it is not skipped [42]. This system is setup to use TLS/HTTPS end-to-end. The connections from between Data plane and Middle plane uses certificates provided by *Firebase* and have no issues. Between user layer and middle layer connection(s) a *trusted, valid TLS certificate* matching the domain name in use is obtained from *Let's Encrypt* a non-profit *Certificate Authority* [47] whose mission is to achieve 100 % TLS/HTTPS. While the certificate itself is free, there is a condition of validity for 90 days and must be renewed. Although *Node.js* has https implementation, keeping in mind the shortcoming of 90 day certificates that needs it to be updated to new certificate and recompiled, a load balancer apache proxy [48] is used to handle https.

Figure 4.4 shows a block overview of server(s), including the flexibility to run containers of databases and object storage servers locally behind Apache https proxy [48].

Implemented API routing model

Express.js router is used to route the requests to different url's. Routes are stored under the folder ***routes/api/*** in individual files for *answers, videos, questions* for separation of data objects and structure. Express router holds all the available methods and transfers request to appropriate method, along with request data. The files in any folder other than

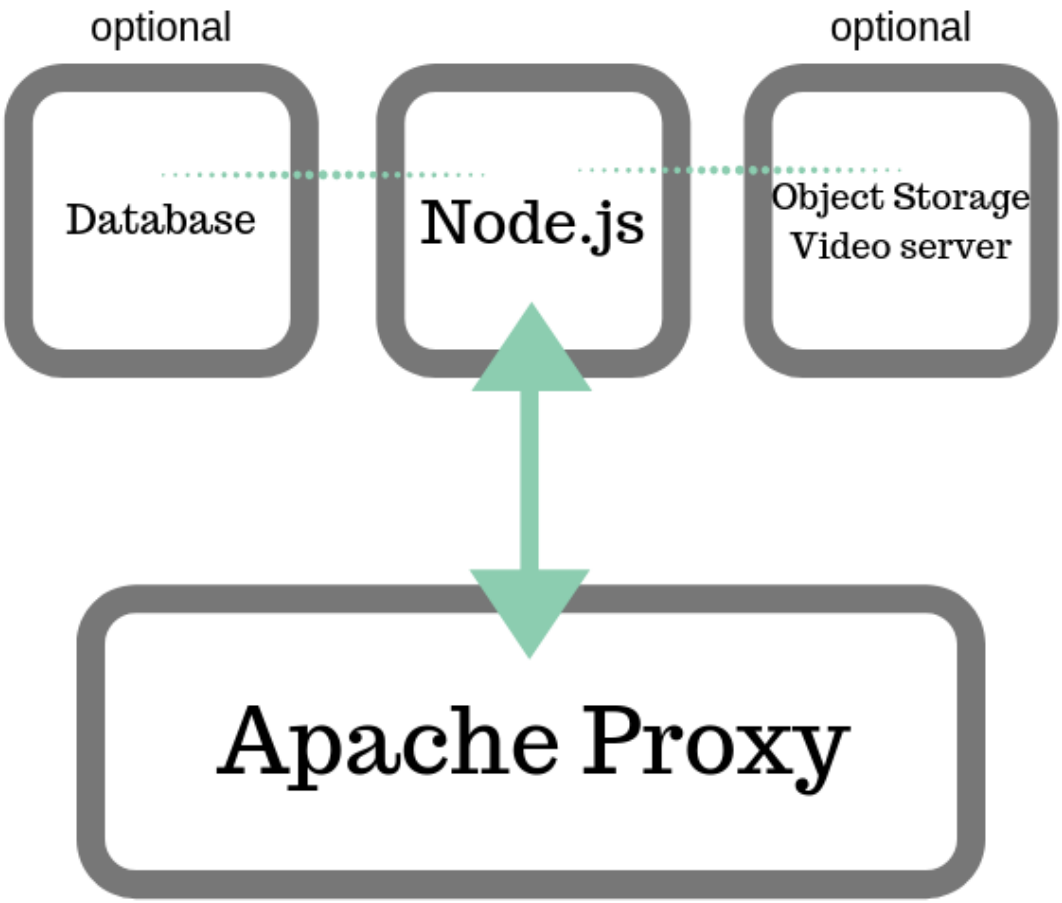

Figure 4.4.: Server architecture with adding further optional containers

public/ are not accessible over the internet. All the API's must be appended to server url, which is the IP address or domain which can be reached over a network, including localhost. Following the server url the api follows hierarchical naming structure starting as ***server_url/api/**** to help with organizational as well future extensions when using local object stores to directly address as ***server_url/video/****. Following is the type of data accessed, either *videos*, *questions*, *answers* or *users*. This is followed by request parameters usually either id for GET or DELETE requests or body for POST requests. The responses usually are *HTTP status codes* for POST requests and *JSON data* for GET requests.

Figure 4.5 shows some of the main methods exposed for requests. When a video is to be deleted, one needs to make a delete type request to *server_url/api/videos/videoid*. If the status code is *200 OK* the operation is successful, or *404 Not found* when the requested video is not available [45].

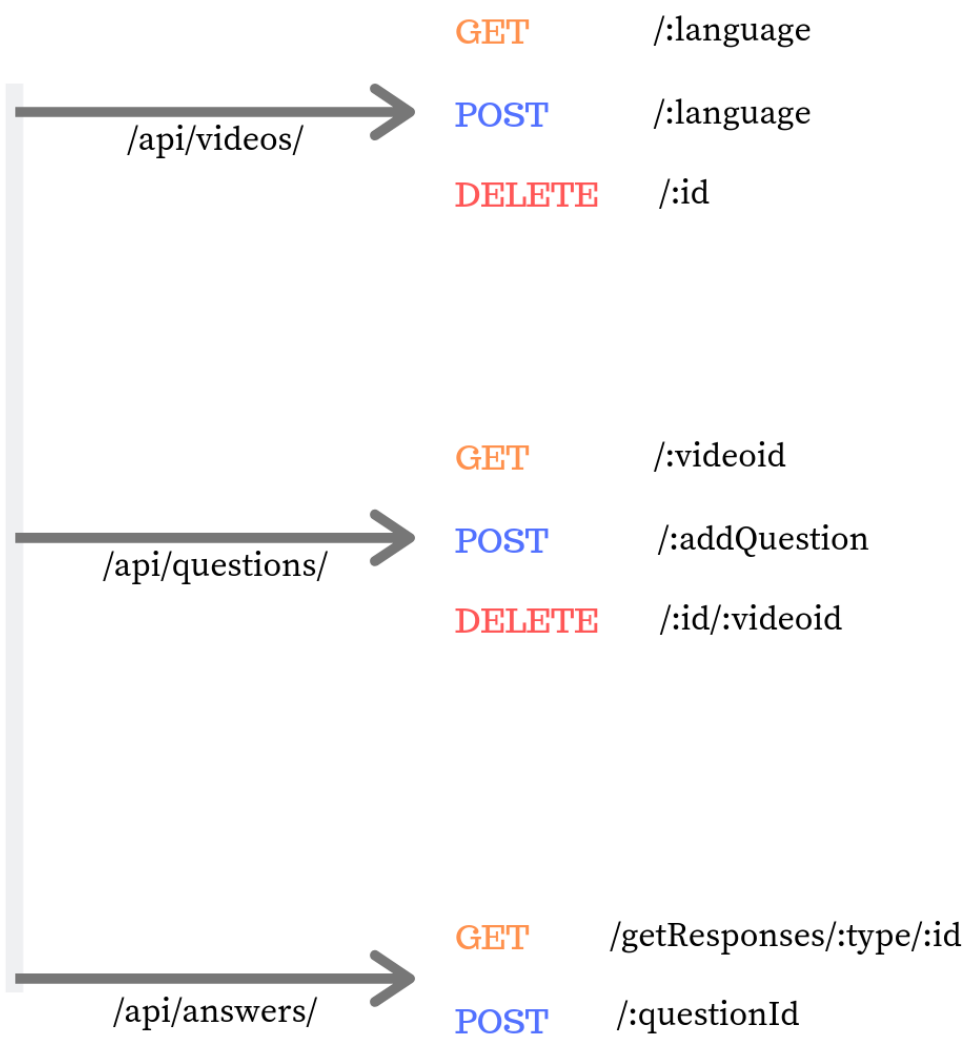

Figure 4.5.: Server API methods (partial)

Connecting to DataStore

Firebase provides libraries for Node.js, which must be added to package.json [40]. It also needs an access key which must be created from Firebase console on web. Then a json file containing login keys must be placed in ***secrets/*** folder with the name *vinfographics_-node.json*, ofcourse this can be named anything as long as you update the file importing credentials which is *firebase-admin.js*.

Apache Proxy

In order to safeguard communication data, android enforces all connections to be encrypted, and blocks insecure communications by default [42]. This can be overridden by adding a property but that defeats the purpose and so this server must support TLS/HTTPS. Node.js offers TLS as a module and can be written into application, but this introduces additional complexity to code and needs to be recompiled when changes are made to certificates. Instead, the idea is to run apache proxy server as TLS broker on the

same machine as another container or in memory. This has two advantages, (i) it can be extended to further server side deployments, like a video object store and (ii) it can be set up to automate deployments of new certificates, and nothing else need to be recompiled.

4.3. User Plane

User plane is where the users interact with the system and the most visible part of the stack. In this there are two roles,

- *admins* who manage the system, add learning units, questions, and check responses, manage users and languages, usergroups etc.
- *users* who perform tasks from the learning units, give feedback for the units. They have preferences set like language choice and get the learning units based on those preferences.

Section 4.3.1 explains the model and implementation of *Admin Interface*, and section 4.3.2 describes the model and implementation of *Android App* for users.

4.3.1. Admin Interface

The Admin Interface is the controller, where learning units are added, deleted and questions on them. It also provides the visualization of responses to the questions. It is written using JavaScript and uses **Vue.js** and **Chart.js**. Vue.js one of the most popular JavaScript frameworks.

Vue background (components and events)

Vue.js [49] offers a CLI as well as a graphical manager of the development installation and management of the projects. CLI generates a template and builds + converts the code into minified CSS, JavaScript and HTML files for simpler web hosting [50]. This means the server doesn't need to run any specialized software like php compiler or Node.js or any dependencies. Everything in Vue is a component that can have independent style and functionality, which makes the components reusable.
Figure 4.6 shows a typical structure of a Vue component. At the main.js is executed and it sets the root component for the App. Vue router (explained later) is used and so the App is set to router. Now we attach any component to router and to navigate through a menu structure. At each menu item the respective Component is attached to router-view. This effectively makes the application a single page app without reloading and so no loss of data.
A component is made of 3 parts:

- **HTML** part where the structure is built using html5 tags, and other Vue components. Further attributes of event emitters and data-props are also configured here. The v-dom (Virtual DOM) also allows to dynamically update the data displayed when underlying objects change.
- **Scripts** part where the behaviour of the component is controlled. Methods, data objects etc are created, mounted and handled. Vue allows for either JavaScript or TypeScript with Babel compiler. This is where props from parent component are defined and exports to parent are handled. In case of events(explained in later sections), too can be handled locally or emitted to parent.

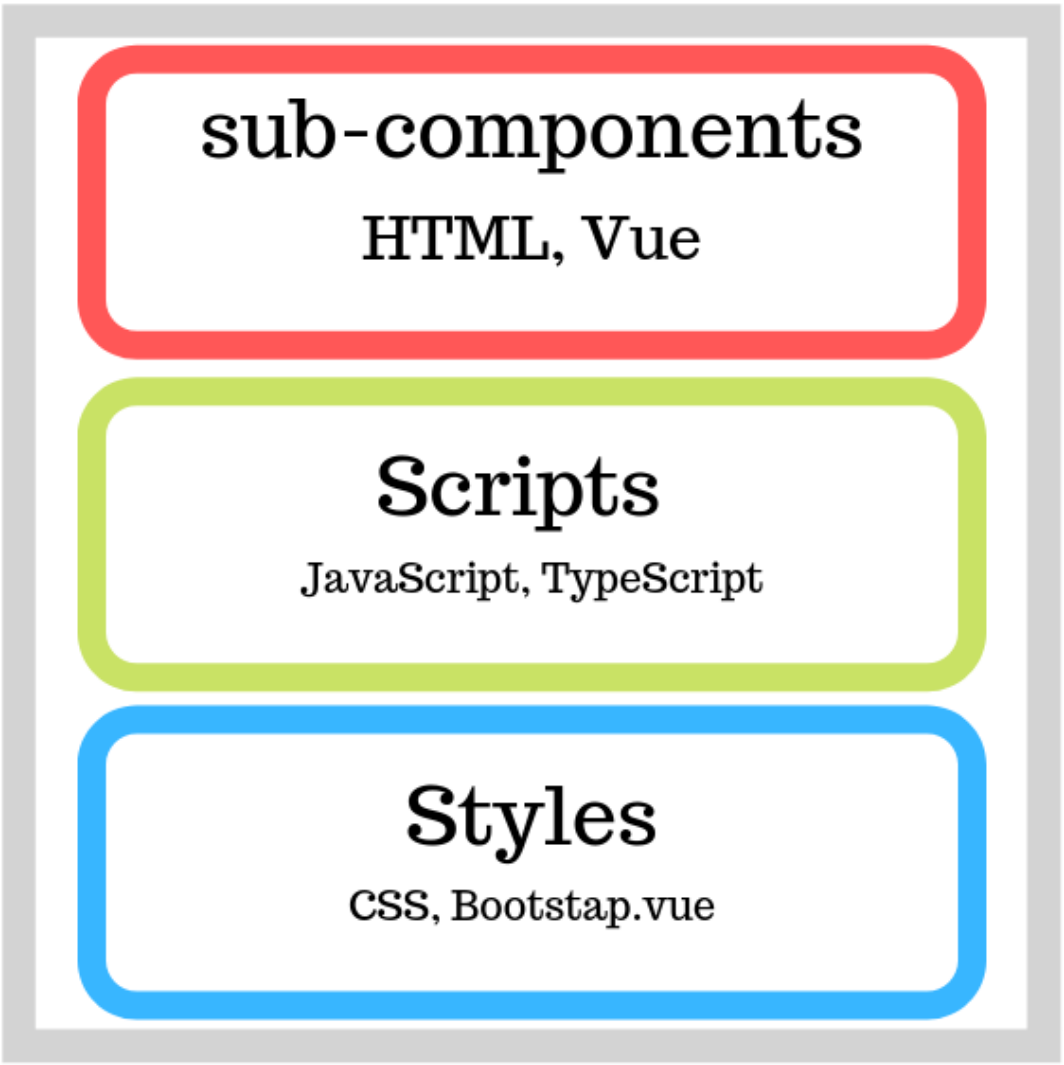

Figure 4.6.: A Typical Vue Component Structure

- **Style** part where the styling of the components is handled. It can be either by defining classes with scope local or global. This makes it easier to fine tune and clearly see the styling each component uses.

Vue components and bootstrap.vue resources have registered events and the components using the resources can handle them or emit events to parent components. The component in which an event is handled usually depends on the data-store of the object that will be modified. This is done in order to maximize the re-usability of data and not having to store multiple items of same data. For example in this app, a list of questions that are specific to a learning unit(video) are stored in questions component, since this data is specific to questions component page i.e where it is displayed. On the other hand, the data of learning unit list of a specific language, like englishVideos is used in two components Videos and Questions and if updated must reflect in both components, it is stored in their parent. Because of this decisions, events need to be emitted to respective components, as explained below.

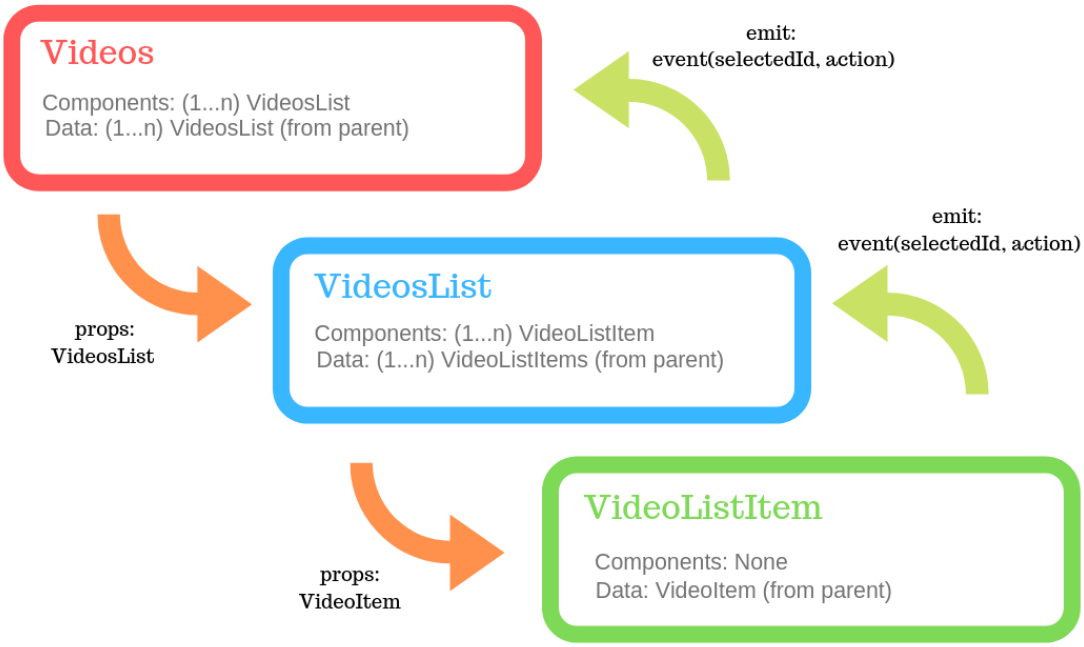

Figure 4.7.: Vue event architecture for Videos class

Vue implementation

To explain the events structure in use, consider the components Videos, VideosList, VideoListItem and Questions, QuestionsList, QuestionListItem. Videos are displayed in VideosList for multiple language groups and are used in two pages. Since the units doesnt change and are used to display both Videos and Questions pages they are stored in common parent. QuestionsList also handles any language based on the selected Video. Figure 4.7 helps in visualizing this structure where Videos component has VideoList components depending on supported languages. VideoList has many VideoListItem components which each display a learning unit irrespective of language. Events are detected at the lowest component but how they are handled is as follows

- To make a component reusable, they are made generic. Since the URL to contact server needs a parameter of language, this cannot be handled inside a generic component which handles all languages. The functionality is removed from VideoListItem and QuestionListItem, instead we emit a event(s) with selected function and additionally selected item-id. In figure 4.9 each QuestionViewItem is individual and if a button is clicked it emits an event to parent with the QuestionId.
- The parents (VideosList, QuestionsList) components capture the events but the component is also reused. VideosList must fit any language of videos, and currently using for two languages as seen in figures 4.8 and 4.9. This means the components get data props from parent to be reusable. And as such we cannot handle the events here and we re-emit them to parent. For QuestionsList too handling the data in Questions is done to make it simple, even though it is not necessary.
- The parent components directly being attached to router-view are Videos and Questions, which have methods to handle events appropriately, based on emitted information, i.e, handling englishVideos and germanVideos, or selected and deleted

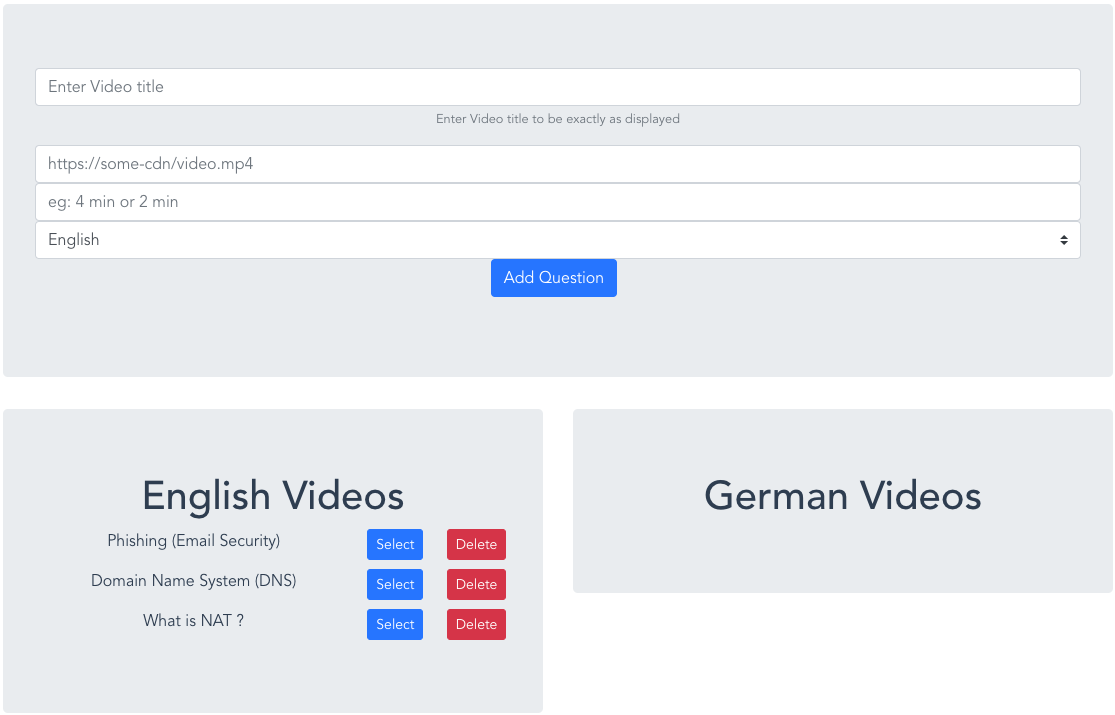

Figure 4.8.: Vue component(s) VideosList being reused with English and German Videos, for the study only English learning units are available and populated

events. For deletion events both Videos and Questions ask for confirmation dialog and send requests to server, following that emit an event to parent to update the data. Additionally in Questions an event for viewing responses generates and attaches a chart with responses to the question.

Chart.js

Chart.js is a visualization framework used to generate beautiful charts [51]. Chart.js is very simple to use and supports many types of visualizations and control over the axis as well as color choices. For this application we mostly used bar charts to depict response rates of the questions. Figure 4.10 shows an example response visualized.

Chart.js works by using a ***Canvas*** element from *HTML5* [51]. In the component Questions, after all the child Vue components an additional Canvas element is added in a *bootstrap modal* (an empty popover). When an event reaches Questions after emitted by child components, then the data of responses is retrieved from servers and a Chart is drawn, attached to modal and made visible. When another question responses are to be seen, a new chart is attached to the same canvas element, making it reusable.

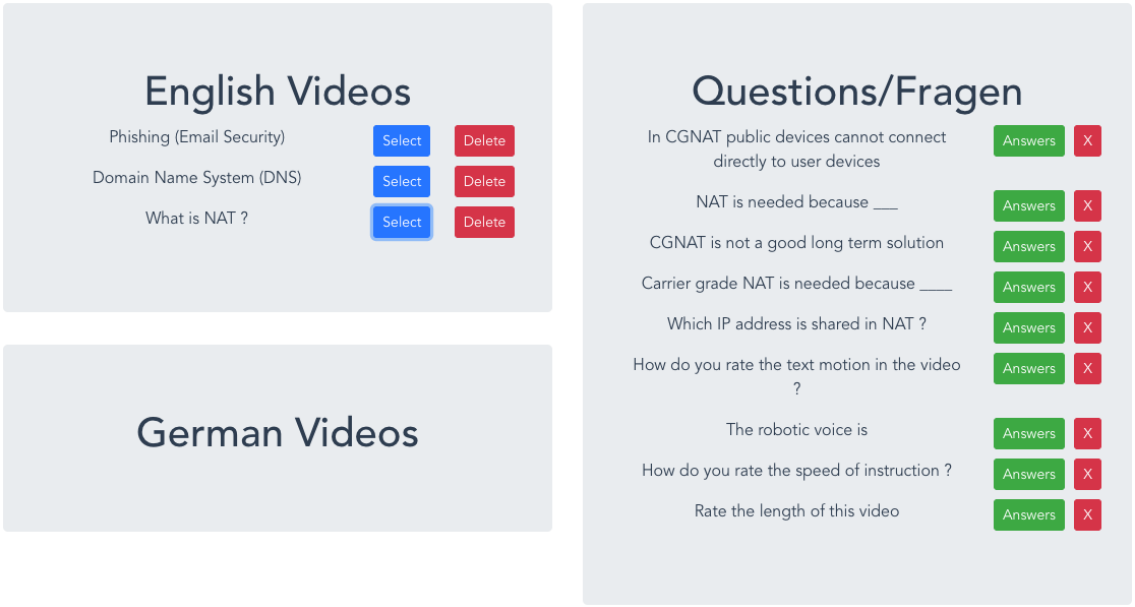

Figure 4.9.: Vue component(s) VideosList and QuestionsList displaying Questions for a selected Video

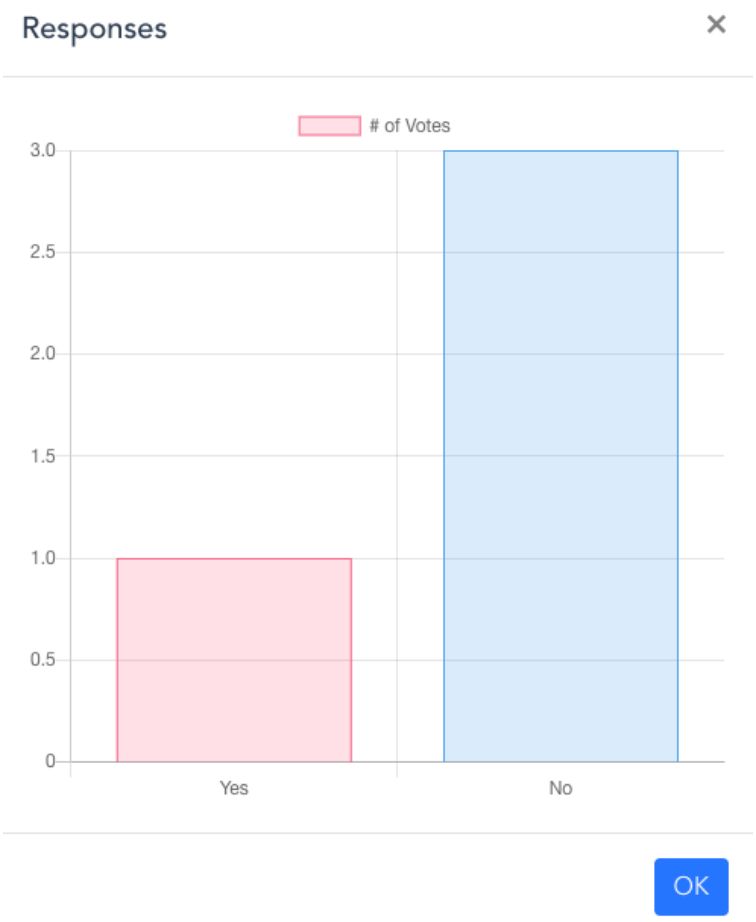

Figure 4.10.: An example response of a question visualized by Chart.js

4.3.2. Android App

The Android app is the most important component as the only component facing users. The design goals are that it must be intuitive and simple to use, be modular and support multilingualism. The app User Interface (UI) must support multiple languages, and for the learning unit content to be displayed it must be language agnostic. To keep the app simple, it only has one function, to show learning units videos and gather feedback from questions. None of the data is stored locally and all processing happens in the server 4.2. This makes the app usable without recompilation, as long as the URL of server and JSON data model remains the same.

It was decided early on to settle with Android API level 23 as the minimum supported level. This is simply to make sure the tablet(s) available are all compatible. Another decision was to select between widely used Java as the programming language or newer but officially supported Kotlin. Kotlin was selected in part as a future advantage, and also it's null safety and type checking capabilities resulting in fewer crashes. Moreover Kotlin is compiled to run on the same Java Virtual Machine(JVM) and is inter-operable with Java classes [52].

Data Access

Firebase Firestore was the initial choice in prototype, as it allows for reliable and highly available database that also is not rigid SQL [40]. Firestore libraries were used and directly access the application data. The libraries provided an API to add, retrieve or delete data in collections or documents and handle all the asynchronous communications. While this made the app very stable and easy to implement, it created a very hard dependency of adding access data into project library. When the firestore admin credentials are changed to another firebase account, the app must be updated and compiled again to connect with new account. This is an unacceptable compromise with design goals of modularity, and also a security risk if the app is de-compiled and the access keys are retrieved.

To solve this an interface layer, middle plane (see 4.2) is added to relay information to and from datastore to users. This removed the dependency of app relying on a database, but now relies on a JSON data-model. The application does not need to know what is being used to store the data, it only needs to know the URL to get the data from and all the data structuring is moved to node.js server [43]. This also meant library handling asynchronous communications is not used, and a library to handle custom tasks is needed. **Axios** is the library used for async tasks and handles on a background thread. Android for security reasons, allows modification of User interface to a main thread, and so when UI modifications are needed we need to manually switch to UI thread [52].

One more design goal initially was to provide some user behavioral statistics like, if a user stopped watching video after few seconds or minutes and if the user replays video and so on. This was part of the objective to provide behavioral statistics to find out problems in video content and improve the lecture units. After quick prototype development, a small evaluation is done in order to check the feasibility of the software for the user study. The implementation of user-drop-off statistics is in android lifecycle

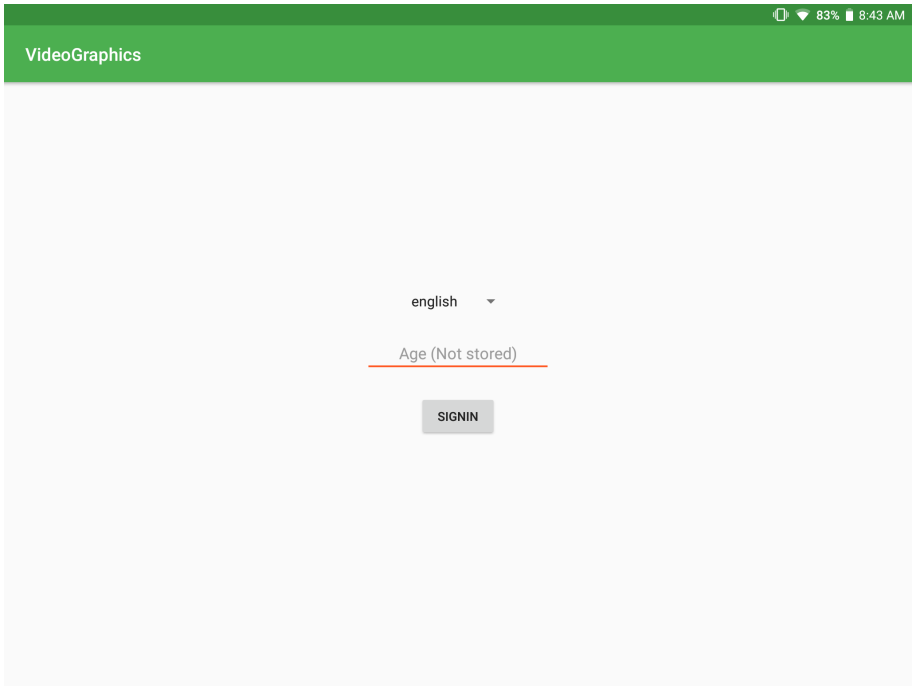

Figure 4.11.: Login screen which stores user language and uses the age to put in one of the target groups

method onStop() where it makes a server call when the intent activity is closed. In slow networks, due to network latency the app reaction is slow while it waits for the response to finish making the users impatient and start pushing back button again and registering multiple entries of drop off requests. One poswible solution is to have a background service that can be called from lifecycle methods and continue the main thread. Later this was pushed back to future work as it takes more time and opted for user response with questionnaires.
The figure 4.11 shows the login screen of the app, and only asks for non-identifiable information. A random uuid is generated and stored on the server after signing in and once the user logs out, the data is anonymized permanently. Figure 4.12 shows the welcome screen after logging in and displays all the available learning units for the selected language. Clicking on one of the units takes user to video playback screen as shown in figure 4.13. To give feedback user must click on the feedback button and is taken to figure 4.14 and 4.15 screens depending on the question types. At anytime user can stop the session if they are uncomfortable and use the menu settings to delete all the user data as shown in figure 4.16.

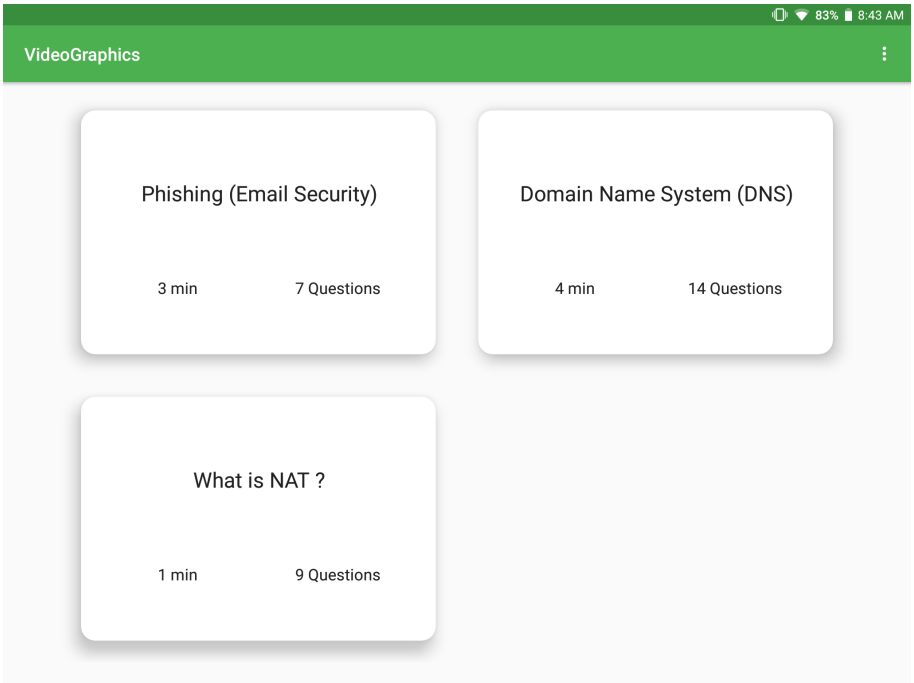

Figure 4.12.: Dashboard shows the learning units available for the user preferred language

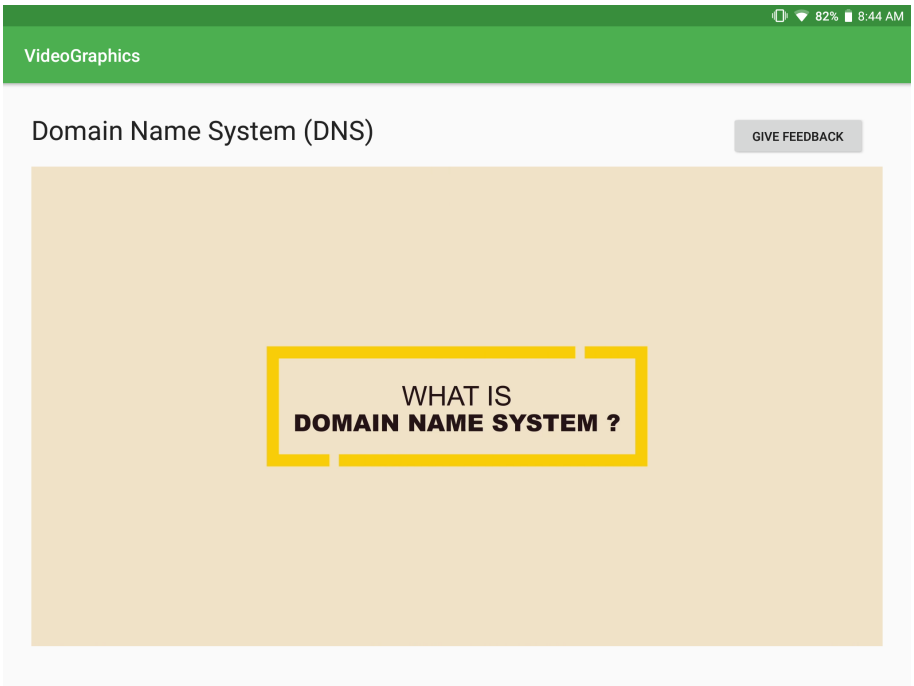

Figure 4.13.: Video player streams the video learning unit and provides basic playback controls

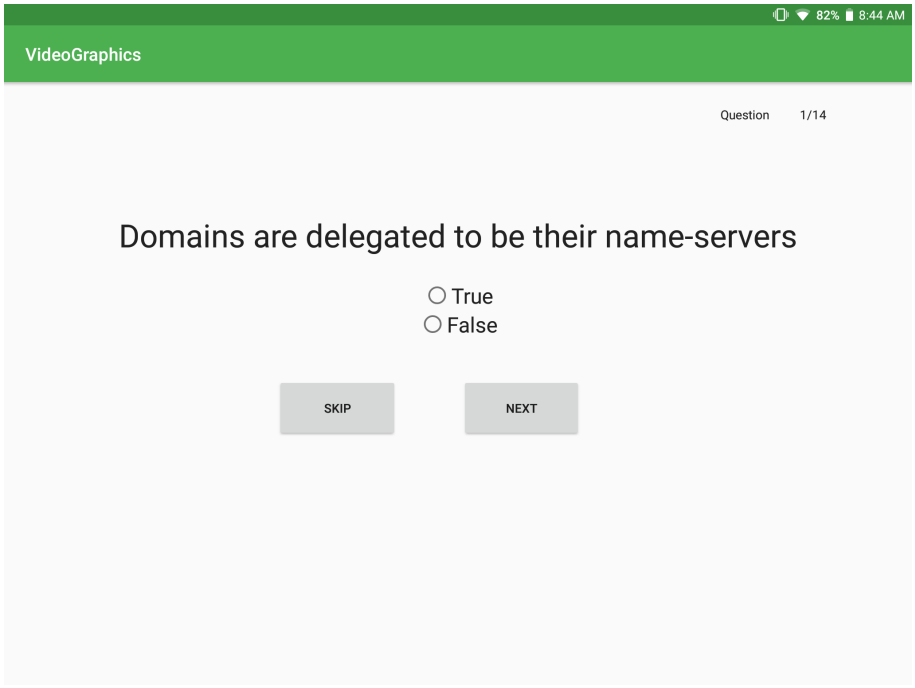

Figure 4.14.: Type1 question example supported by app, a two-choice type

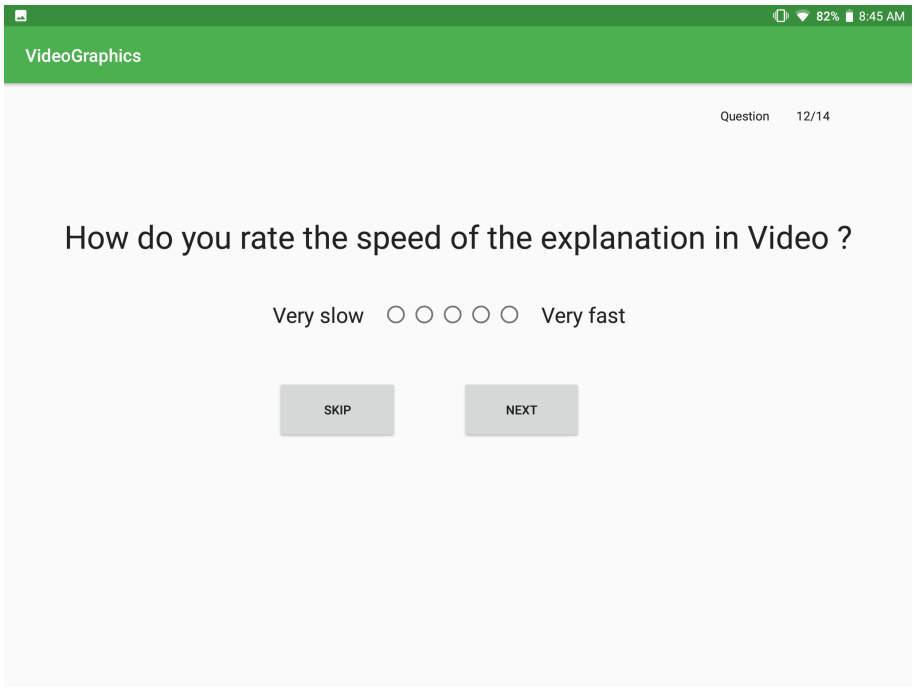

Figure 4.15.: Type2 question example supported by the app, a likert scale of measurements

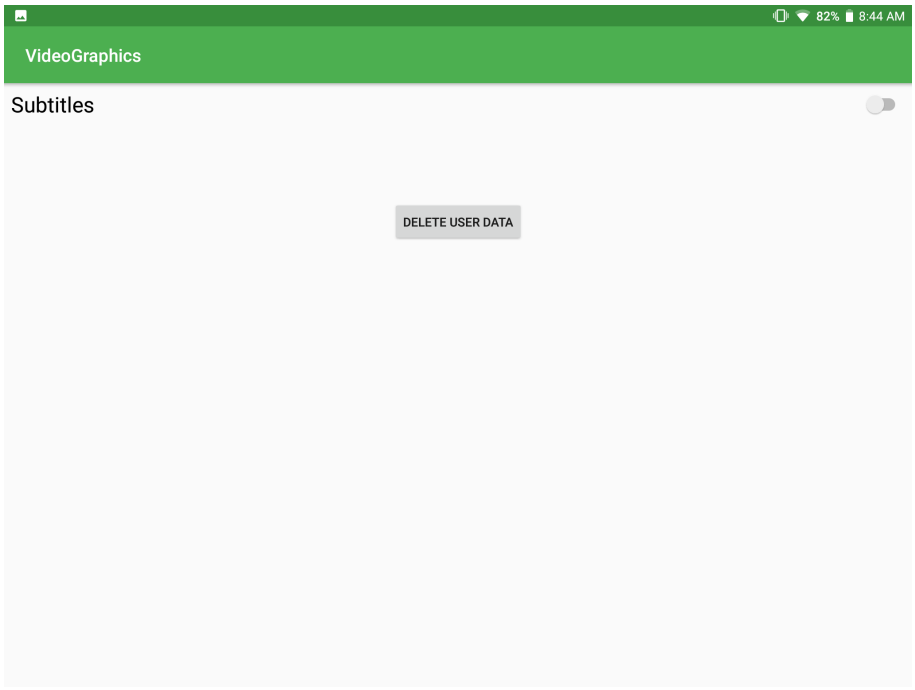

Figure 4.16.: Subtitle functionality is disabled, and delete user data in case user wants to stop the session

Chapter 5 Evaluation

For the duration of the thesis, there are two cycles of evaluation. The first cycle is a semi-informal pilot study done after rapid prototyping the learning unit with basic information and process, as well as the development of a deployment service through an Android app. This is done to evaluate the feasibility of the design and is discussed in section 5.1. After the first cycle, from the evaluation results as inputs, a formal user evaluation was done towards the end of the thesis. This is discussed in section 5.2.

5.1. Prototype feasibility evaluation

For the thesis the initial assumptions were to collect behavioural statistics that allows collection of data like status of user's tasks, user drop off rates for a learning units and replays of learning units. This kind of behavioral data will help gain insights when the users are bored of a video and drop off the task, as well as replays of a learning unit signifying some difficulty in comprehension. And as such, the initial prototype app was built with user authentication using username and password, and user statistics with task status and task dropoff counter(s).

Using the previously identified list of learning units, a learning unit Network Address Translation is developed following the steps from 3.4. The number of users are 3 (n=3), all performing the same task. Users signup using email, perform tasks in a informal location. The prototype app uses Activity lifecycle to detect drop off points as well as completion of the tasks, and a server call was made in the onStop() method of the player activity [42]. This caused problems when network calls taking some time in poor network situations and impatient users using back button multiple times. User statistics is unreliable data, with multiple duplicate entries.

From this evaluation it was clear that to obtain user behavioural data and statistics, a complex application with background service threads must be developed, and also a complex database structure to ensure each user has reliable statistics [42]. This compromises the modularity objective and it was decided to push user statistics into future developments and develop a system that directly queries the user about the quality of learning units.

5.2. Evaluation

After the feasibility study, it is established that the process of producing content and deploying through an app and getting feedback is possible, with some modifications on how to get the feedback. With this knowledge changes are made to the software including, adding middle layer and replacing behavioural statistics with user reported questions. After the learning units are ready and the app was tested to work without crashing, the user evaluation was planned and carried out based on the inputs from [53].

Experiment Design

For this evaluation, three learning units are prepared. To compare the results and establish an improvement, the results must be compared to accompanied 3 text with illustration counterparts. Each learning unit is to be repeated twice.

So No of Tasks (3) x Repetitions (2) = 6 participants are needed.

Participants

It is important to understand the impact of different learning techniques on different ages of population, and since the motivations are in accordance with retraining people due to automation it is necessary to test the learning units on different population ages. One other constraint is to find people who speak English in multiple age groups and those who (preferably) does not have computer science topics explained in the learning units to reduce prior knowledge bias.

For this two groups, Adults aged 18-49 and Elders aged 49+ are selected. All 12 participants (6 per group x 2 groups) are comfortable in English and work in Cologne, Germany. No data other than their names on consent form are taken and all data is stored with random identifiers.

Tasks

There are 3 video and 3 text tasks. It is observed to not allocate the same video and text tasks to same user to counter learning/knowledge bias. For this the text tasks are numbered 1,2,3 and video tasks 4,5,6 below them. Using a cross-cross lines the pairs of tasks are determined as (1,5), (2,6), (3,4), (4,2), (5,3) and (6,1). These pairs are then fed into a random list generator twice and generated a list of pre-determined test allocations. Whoever participates first in the experiment gets the first set and so on.

Devices and room lighting.

The experiments are conducted in a mini conference room, with plenty of sunlight. The networking is provided by a separate router other than the institutions wireless network to ensure no interference. Cola, apples and cakes are available for the users participating and at any time there is only one user evaluated. For text part of the test, a highlighter, and two pens are provided to make any notes or highlight information.

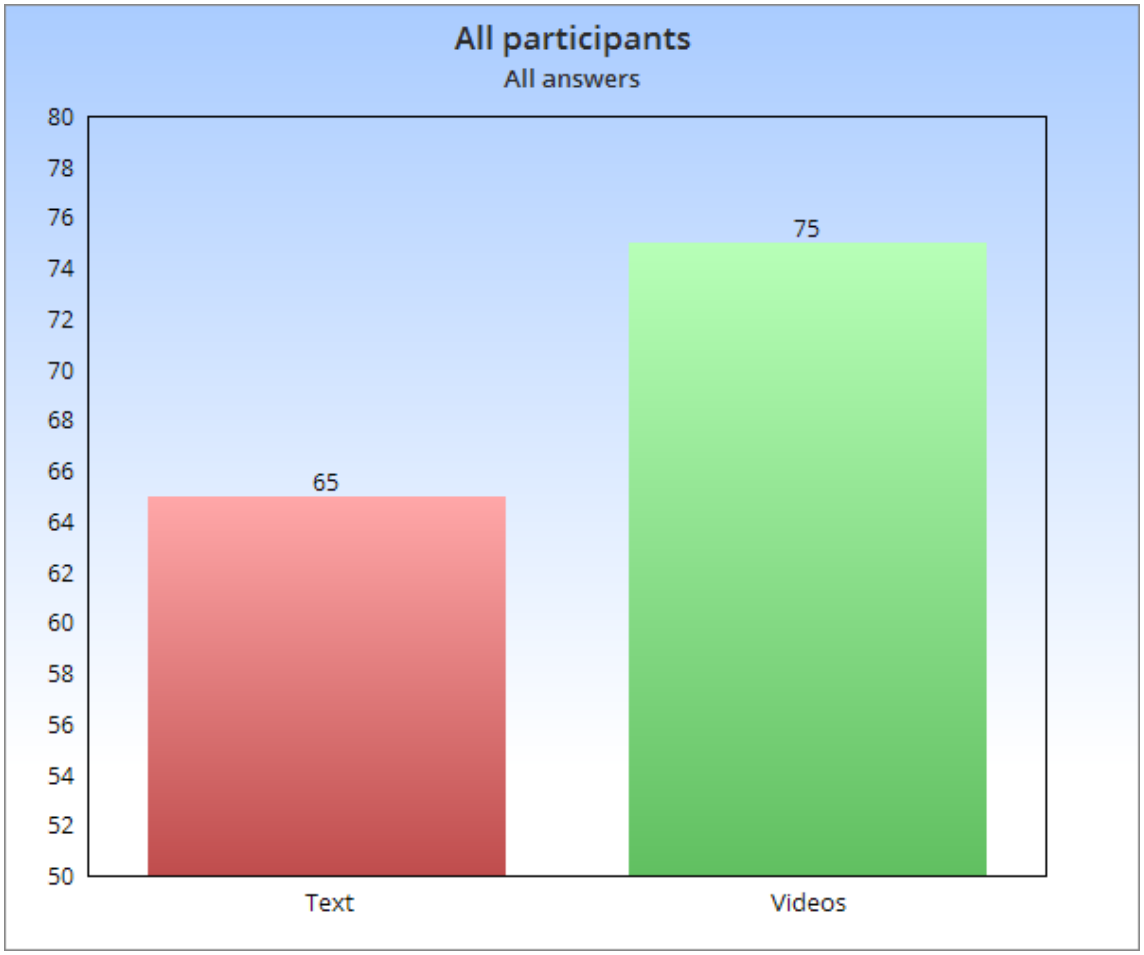

Figure 5.1.: Correct Responses of all participants on all the learning units

Hypothesis

Null hypothesis H0: There is no difference in perceived comprehension when using video-infographics compared to textual information.
Alternative hypothesis H1: There is improvement in perceived comprehension when using video-infographics compared to textual information.

5.3. Results

The dependent variables of the evaluation is the perceived user comprehension, and is measured as the number of questions correctly answered. For the first result 5.1, All participants on all tasks are combined to give an overall comprehension scores. This result shows there is significant improvement in comprehension when topics are explained using video infographics.

However Figure 5.2 shows the differences in the responses for adults group only. Of the 10 point difference in overall statistics 5.1, 7 points are from this group, which is a significant margin over the Elders group with only 3 point different from Figure 5.3. The explanation for this is not found but the speculation about reduced attention spans is one of the possibility. From this data it can be inferred that, ***video infographics are more helpful for adults(18-49) over elders(49+).***

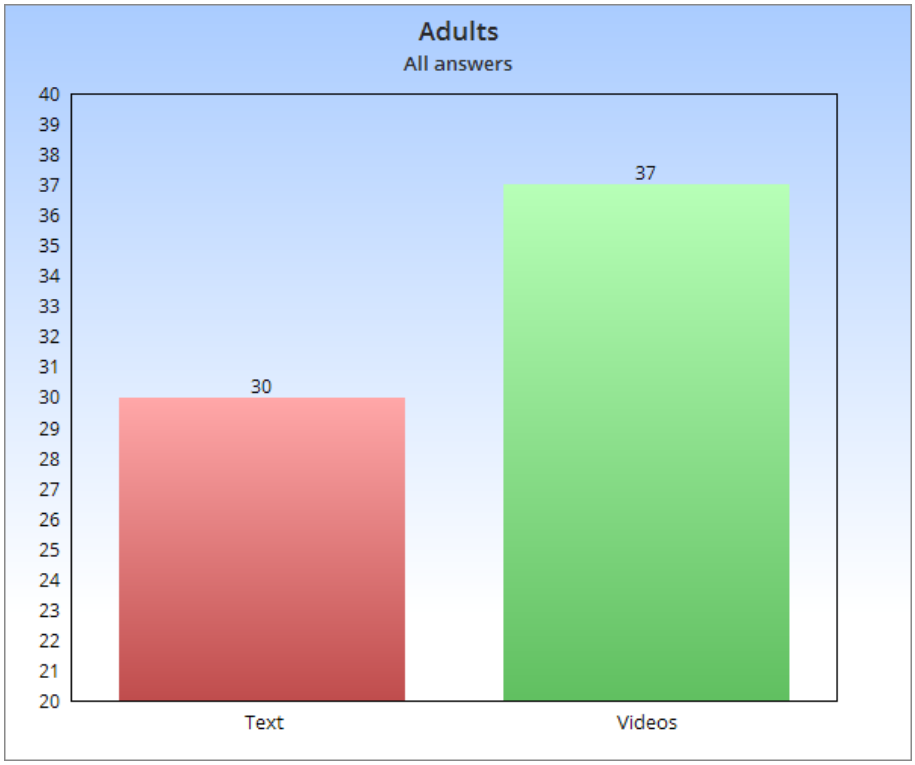

Figure 5.2.: Correct Responses of adults group on all the learning units

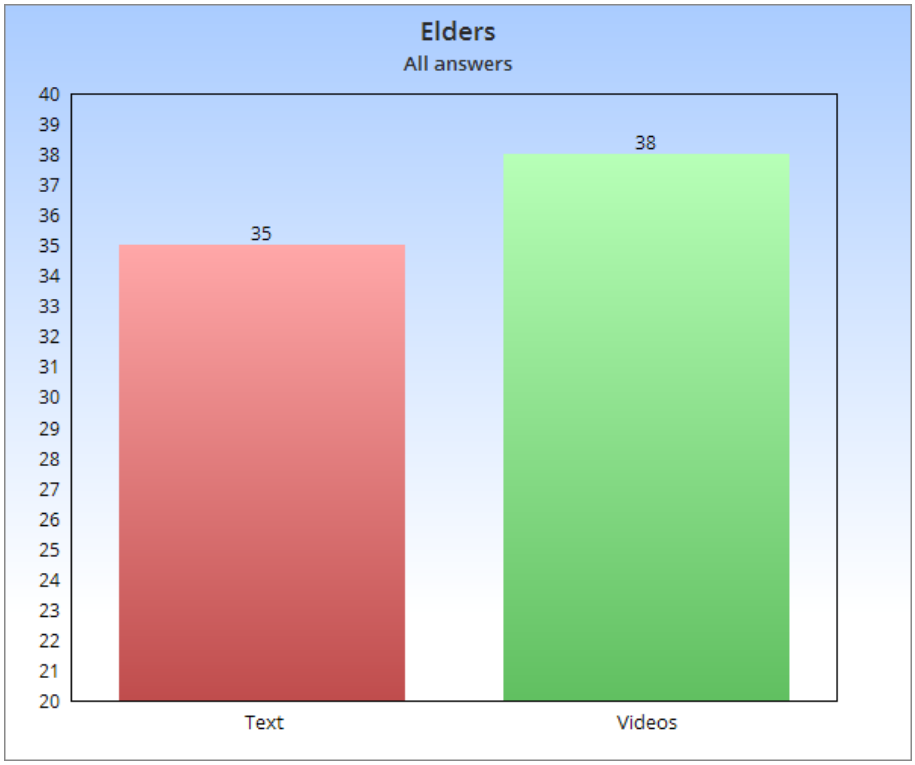

Figure 5.3.: Correct Responses of elders group on all the learning units

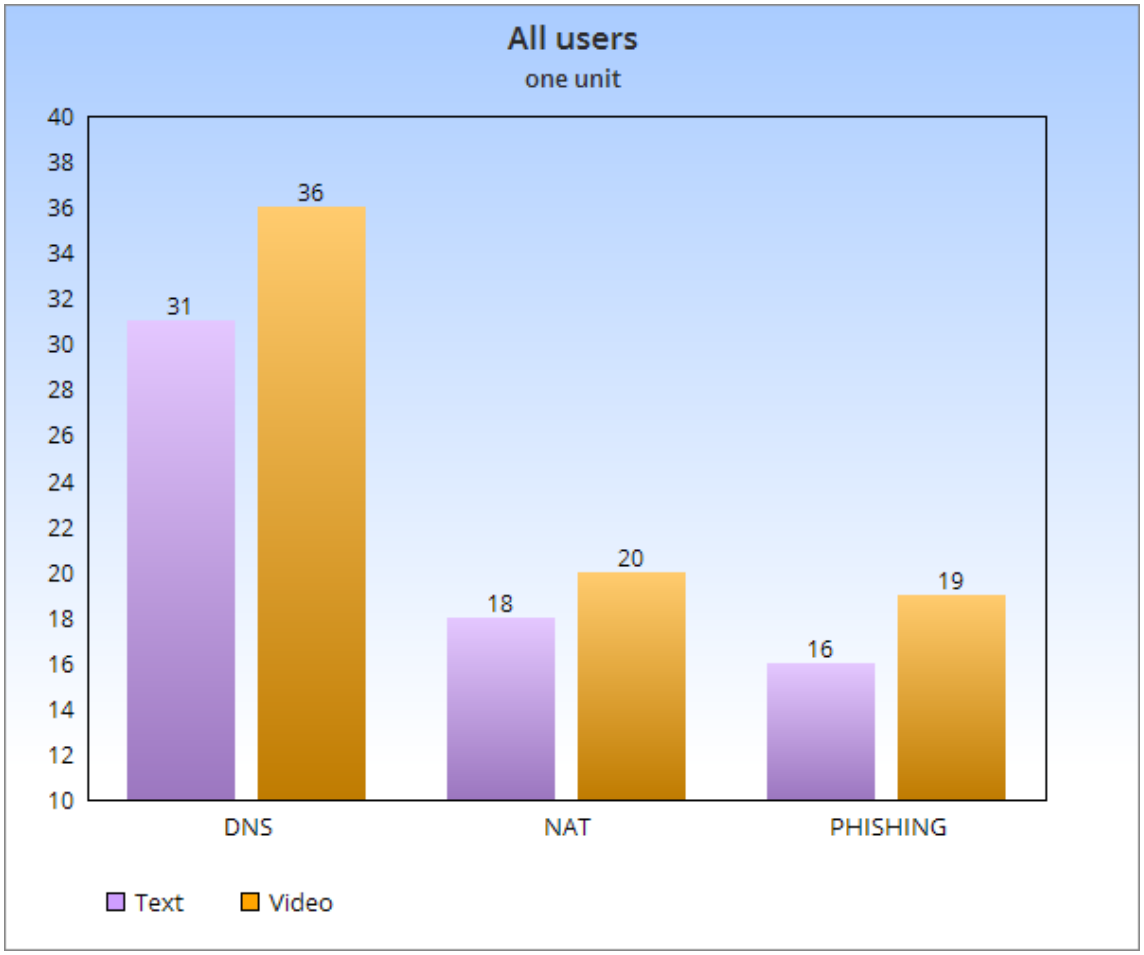

Figure 5.4.: Correct Responses of all participants per each learning unit

The individual difference between the learning units style are visible in Figure 5.4. The DNS learning unit focuses on appeal and comprehension and is a longer topic overall. It shows there is non-negligible difference in comprehension with video infographics pulling a little ahead. In another learning unit NAT which is very short and focuses on comprehension, retention over appeal, the difference in comprehension is too small and within margin of error. Finally in the last learning unit phishing which focuses on appeal and retention has larger difference in responses than the NAT learning unit.

Separating the each learning unit responses by age groups is not useful, as each task is done only by two participants from one group compared to two participants from the second group. That may lead to significant skew in statistics and has limited validity. For this reason, only statistics with a minimum of 4 participants are reported. Theerefore, the ***null hypothesis is rejected***, and ***alternative hypothesis is accepted.***

All of the statistics reported so far are only type 1 questions. These questions are to answer the research question. There are other questions that only appear in learning video units, and these are used to improve the infographics by asking user feedback. These statistics are discussed in section 5.4.

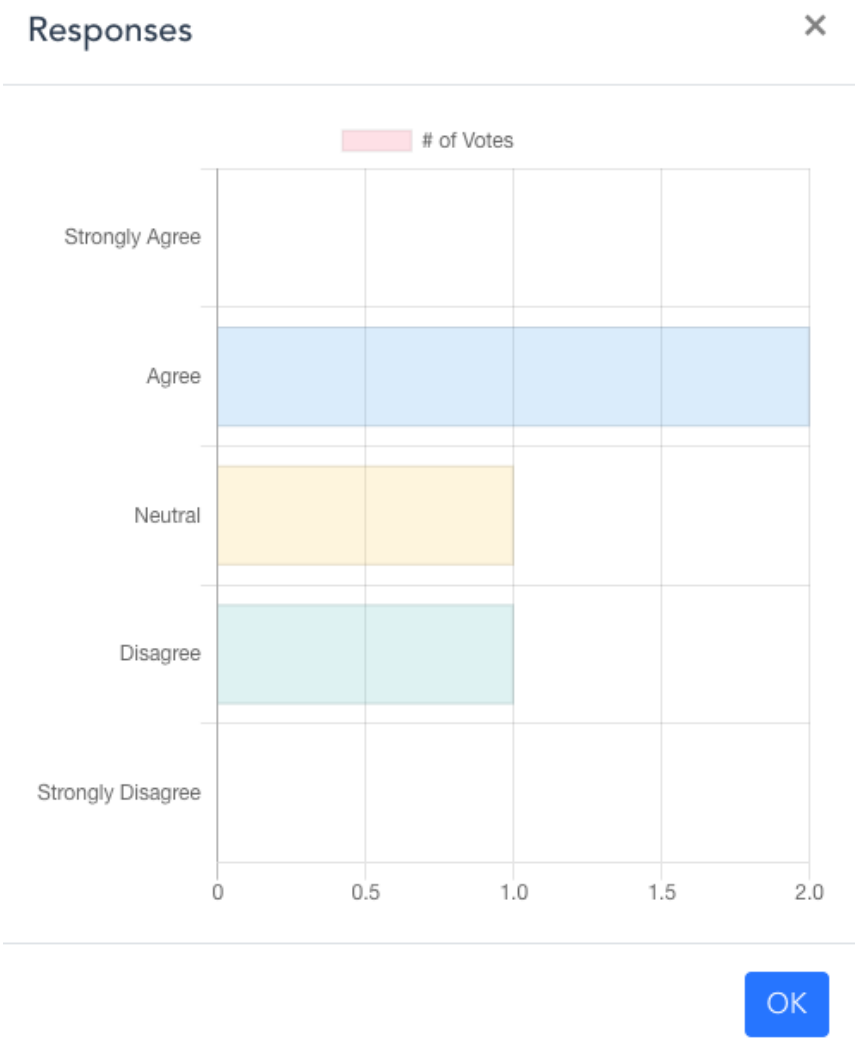

Figure 5.5.: Ratings to speed of the instruction, auto-generated from Admin Interface 4.3.1

5.4. Feedback evaluation for learning units

The set of questions type 2 (likert scale [54]) are made to retrieve user feedback on the quality of video, audio or explanations of a concept and speed of the explanations. In the evaluation study some of the questions of type 2 were given to users but to ensure they do not interfere with the primary objective, the type 2 questions are sorted towards the end of the questionnaire. However, since the sample size of each learning unit is only 4 users, the feedback received is not actionable and serves as a proof of concept. Figure shows some of the responses to learning unit DNS about the speed and clarity of instructions.

Chapter 6 Conclusion

In this chapter the implications of this work are discussed in , limitations and future work are discussed in

6.1. Discussion

Based on the results from user evaluation, and the continuous trends of higher number of correct answers in each case when comparing video infographics to text based learning 5.3, it can safely be said that ***Video Infographics improves basic computer science competences.***
Factors influencing the video infographics like appeal and comprehension must be preferred over retention, because everything can be looked up when needed in modern internet connected world.

6.2. Limitations

While the primary goal is achieved and proven, the other goals of developing a process to streamline video production that allows for content modification without hassle, and an application to continuously deliver content and get feedback are not properly tested. It is proven the method to get feedback works, however due to lack of enough variation in feedback due to lower participants per learning unit means the data collected is not actionable. On the other hand the process of video production is tested multiple times during the making of learning units, changes to content and pitch are continuously made and edited back into the output, without much hassle.

6.3. Future work

Future work based on the initial feasibility test is to add support for behavioural data collection. The prospects of the telemetry that shows how many users attempted to watch a learning unit and how many completed compared to how many left before the video ended is huge. This allows to shorten your videos if necessary or add breaks in between.

Additionally the app must be extended to have it's own object server that serves the video content, by syncing with your production local folders to provide seamless updates. Running the database instance behind the Apache proxy with local or same domain urls will fix the cors open policy currently implemented and lock down requests to only authorized clients [48] [46].

On the video production side, characters must be developed across a whole range of courses and allows people, specially younger ones to attach to characters and help them concentrating on the content [10].

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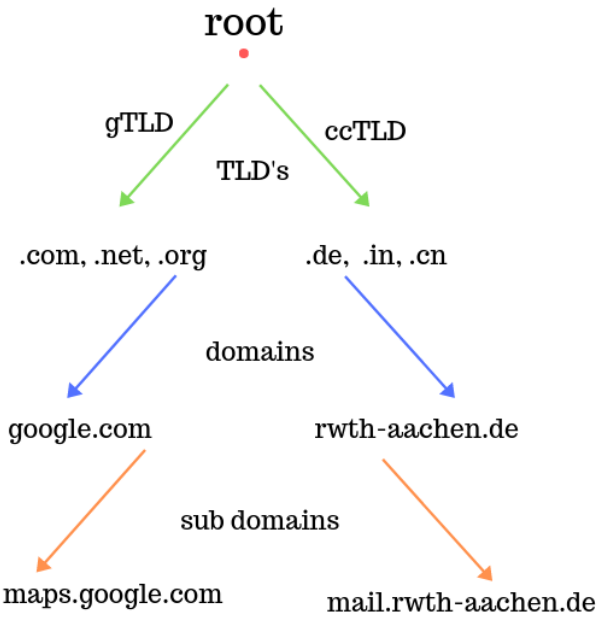
A.1. Evaluation protocol, consent form, texts and questionnaires

Domain Name System (DNS)

The Internet works using IP addresses, where each device connected must be given a unique address. This address is used to communicate with other devices. To reach a device one must know the remote device's IP address. If a user has to communicate with multiple devices, they will have to remember multiple unique addresses. So in order to make remembering the destinations easier, an additional layer is added, which stores and translates strings to addresses. Humans can easily remember strings of words.

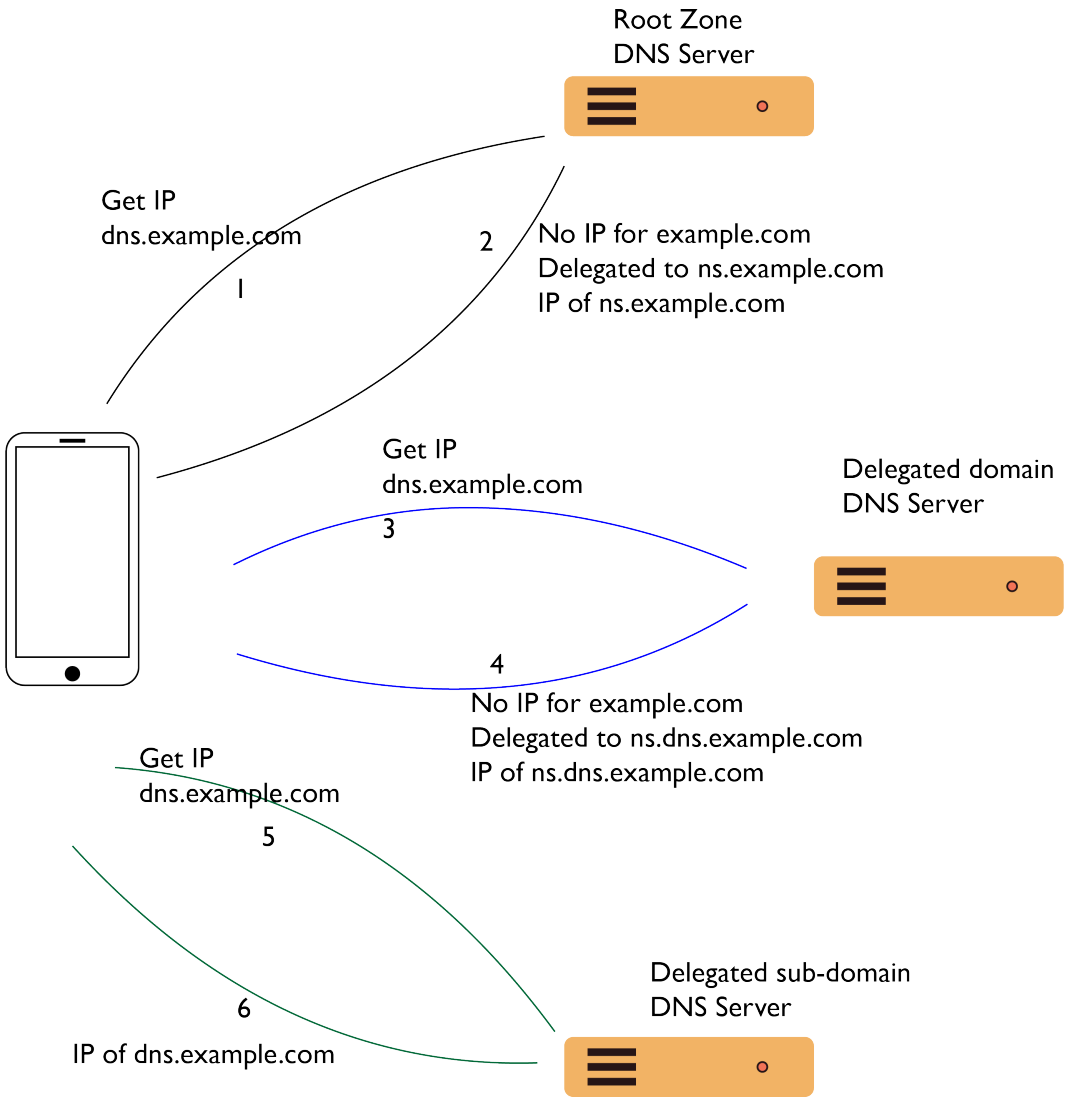
DNS Hierarchy & resolving

DNS is structured so that it can be decentralised and not be a single point of failure, and as such it is split into multiple domain spaces where each domain can effectively be its own authoritative server. It means a domain controls all the sub-domains and their addresses. The top most point is root (.) which is not needed when using, under that there are various *Top Level Domains (TLD's*). Under each TLD can have a unique domain name, attached to the TLD, and a subdomain has a domain name and TLD attached to it. This allows for delegating the domain zone to the child domain. TLD's are classified as Generic Top Level Domains (gTLD's) and Country code Top level domains (ccTLD's).



So when a request is made by a client resolver, it first reaches the root zone, which are server instances deployed worldwide with hardcoded IP addresses. Here if the domain name is present in the root zone list, it responds with authoritative name-server listed and name server's IP address. Then the resolver requests the new name-server about the url, which responds with a record type requested, or if present a child name-server for the resource. This process is repeated until the record is found or further resolving is not

possible. Delegation makes the root-zone less complicated and allows for domain controllers to have their own server and allows for faster changes in records.



Problems in DNS:

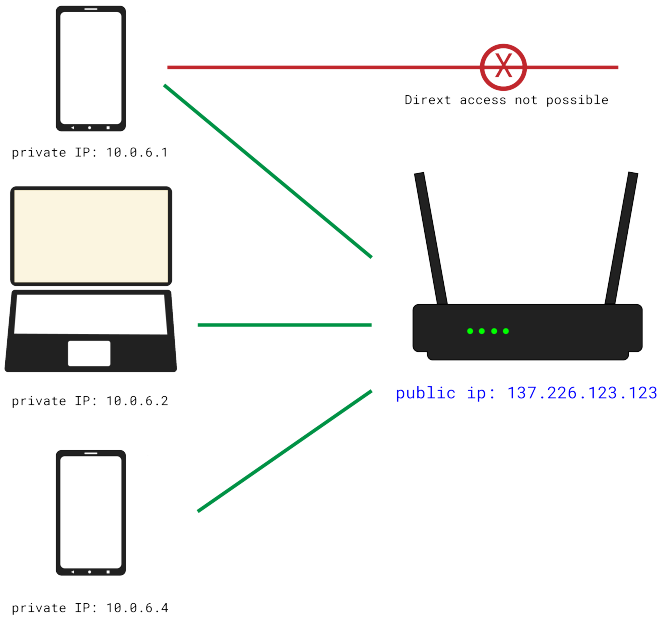
No Encryption: DNS is standardised in 1990's, and uses UDP. No significant changes were made to DNS implementation since then, to keep it compatible with all legacy systems. After a while encryption has become more common on the internet but the DNS resolving is not encrypted, and so anyone with access to communication medium (wifi, ethernet) can listen and know what servers are being queried/resolved. Although the content cannot be seen as it is encrypted, the servers connected are visible. This is a serious issue to privacy.

No authentication: There is no authentication mechanism to verify if the records are official, and we need to trust the responding name server. This allows for a Man-In-The-Middle attack, where someone can pose as a name server and redirect users to fake websites in attempt to steal information like passwords or credit cards.

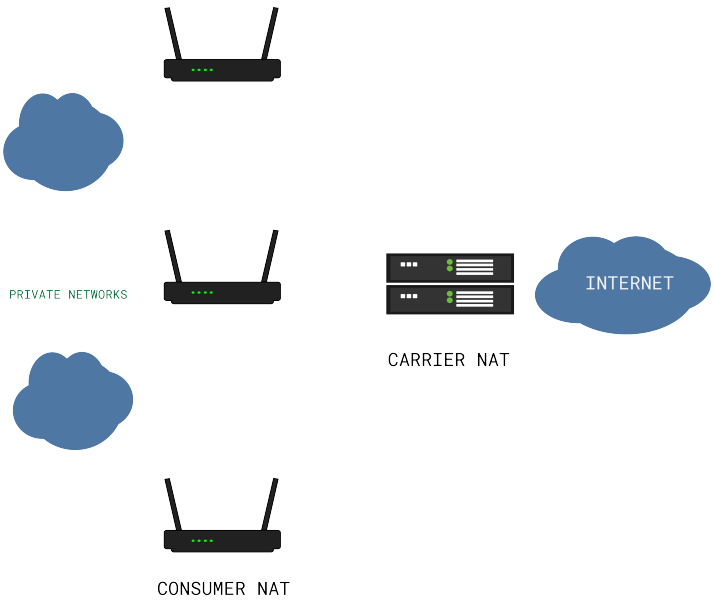
Network Address Translation (NAT)

NAT is one of the important modifications done to IP Addressing system, that made it survivable without sufficient IP Addresses available. With the exponential growth of internet, it was realised that it's not possible to assign every end device with an IP address. So NAT system is proposed and accepted to be implemented.

NAT is a concept of having multiple end-devices hide behind one public IP address. Especially with Home subscribers where each device like computers, tablets, or phones does not need to be reached from interned and are primarily consumers of data. So the router hides these devices by assigning them private IP addresses, and carefully translates requests from private IP addresses to public IP addresses and vice-versa.



But this only worked for a while, and then the IP address space is running out again. So another iteration of NAT is added by Internet service providers called as Carrier Grade NAT(CGNAT). In this the consumer router doesn't get a public IP address, but a private IP address that's unique under the carrier. Now a request is once translated by consumer's router, and then again by carrier's router, leading to complex double NAT.



This too worked for a while and now we are looking at massive internet of connected things where many sensor networks, automobiles, and electricity-meters etc must be connected, even Carrier grade NAT may not be sufficient. We need to look at alternatives like IPV6, which has much larger Address space.

Phishing (Security)

Phishing is a process of stealing passwords or credentials to bank accounts, social network accounts or any privileged information by misleading unsuspecting users into giving up their credentials by pretending to be legitimate.

By far the most common method in use today is email phishing, where unsuspecting users receive an email that contains alarming or threatening content forcing users to check it immediately, where they are misled into fake websites looking official and catches the passwords that user enters. Trust is achieved by pretending to be an official consultation from the financial institution or a colleague.

How to detect a phishing email ?

- Check email address sent from.

  Even if the email appears to be from someone you know, check the email address. Sometimes the hackers use real names but emails originate from a slightly different address.

  Eg. Your colleague uses, daniel@emag.ro as their email address, but the hackers use a fake email address daniel@emaag.ro

- Open email but do not click any links

- Check the greeting, sometimes hackers send generic emails addressed to as *'Dear customer'* instead of *'Dear <yourname>'*

- Be careful when urgent or threatening language is used like *'change password now or your account will be suspended'*

- Banks and other institutions will not ask for your passwords by email, instead whenever needed directly access websites by entering url.

- Finally, never download any attachments without knowing what they are. Phishing scams always try and push users to install malware or virus, which are far more dangerous than phishing. These malware can access passwords, modify or delete data and even spy on you.

Improve basic computer science competences using video infographics

Experiment Title

Evaluating difference in comprehension when a computer science topic is presented as Video-infographics compared to Textual reading.

Context

To cope with technology, the world is facing a battle against automation and lack of high skilled labor. To train or retrain adults and elders some newer teaching techniques are needed. Video-Infographics is considered a good way of presenting complex information using the audio-visual route and helps in mentally visualising a concept. With the continuous improvement in networks, today it is possible to use Video-based learning ubiquitously. It allows for a serious upgrade to the way of teaching with massive reach for a well-made video. A video can be made once and be used for teaching worldwide (as per the language reach). Video-based learning is judged using three main factors, (i) Appeal of video, if the video is well made and visually appealing it generates interest among audience (ii) Comprehension of the content, if the video content is clear, concise and helps in visualising a concept, and (iii) Retention, usually checked after a few days/weeks is about how much of the concept is still understood/ remembered by the user.

Hypothesis:

H0: There is no difference in perceived comprehension when using Video-infographics compared to textual information.

H1: There is improvement to perceived comprehension when using Video-infographics compared to textual information.

Protocol

Participants: 6 participants from the age group 18-49 with little or no knowledge of computer science topics and comfortable in English. Additionally another 6 participants with age of 50+.

Tasks: There are 3 Video tasks and corresponding 3 Text tasks. Participants will be randomly assigned 1 video task and 1 Text task, care must be taken as to not assign the same set of Text and Video tasks to the same participant.

Experiment Design: Participants needed= 2 (repetitions) x 3 (task-sets) = 6 (participants per group)

Devices: An android tablet with API Level >23 installed with *Vinfographics* app. Also ensure that the API-server running.

Procedure:

- The operator must be present at least 15 minutes before the scheduled time of the participant. The operator must ensure, (plain)water/cola and snacks are available.
- Operator must ensure 50% or more charge available in test device, headphones available, and internet connection is available.
- The subject will be greeted and welcomed into the experiment location. The subject will be briefed about the experiment and the use of data. Then they will be asked to sign a consent document. The subject will also be briefed about their participation is voluntary and can leave at any time.
- The subject will be given the next set of tasks from the list, and the first task will depend on the list.
- If the task is Video, the operator starts the experiment with logging in using the test device with the necessary options. Then the subject is directed to use the headphones and to finish the video task. Complete silence should be maintained by the operator during the video session. If necessary the subject can repeat the task for unto 5 times. If the subject is not comfortable with the headphones, they are removed audio is maxed.
- Following which the operator directs subject to the questionnaire part and asks the subject to answer them. The subject will be informed that there is no time limitation and allowed to skip questions. The subject cannot go back to the video after starting the questionnaire.
- If the task is Text reading, the operator will hand over a printed, legible and tidy piece of paper containing the task to the subject and will be asked to read the topic. The maximum time allowed is limited to 15 minutes. The subject must be informed about the time.
- Following this, the text-task will be taken from the subject and will be presented with a questionnaire. The subject must be informed about no time limits and allowed to skip questions.

The questionnaire must be collected upon completion.

(If less than 3/4 questions are answered the test is not considered for analysis.)
(If the participant does not want to continue then the operator must thank the subject for their time and use delete data button in the settings menu of the app to remove stored data, and also destroy the consent form.)

- The subject will be very graciously thanked and offered a beverage, or cookie or whatever snacks are available.
- The test device must be logged out, and put back to charge if needed.
- The consent form and user response form are scanned or photographed for extra safety and stored into the file safely.

Prepare for the next participant.

Operationalisation

Independent Variables:

- Task type (Video or Text)
- Age group (18-49 or 50+)

Dependent variables:

Comprehension based on responses - No of questions correctly responded in Video task vs Text task averaged for all users in a group. This is done to every task set to show any difference in comprehension.

(Additional video quality questions only for Video task, not part of study)

Informed Consent Form

Improve basic computer science competences using video infographics

PRINCIPAL INVESTIGATOR Prudhvee Nalluri
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Email: prudhvee.nalluri@rwth-aachen.de

Purpose of the study: The goal of this study is to find any difference in comprehension levels when a computer science topic is explained using Video-Infographics compared to Text reading.

Procedure: Participation in this study will involves two tasks. One Video task and one text reading task, the order of the tasks is random and pre-determined. For the Video task questions will follow after the task is finished. Videos will be viewed and questions are to be answered in Android App on an Android based Tablet.

For the text task, you'll be given a paper to read and after reading is finished you will be provided with a questionnaire and asked to answer the questions based on text. The questionnaire is not labelled and does not have any identifiable information.

Benefits: The results of this study will be useful for improving learning techniques and help in preparing people to learning advanced technologies easily

Alternatives to Participation: Participation in this study is voluntary. You are free to withdraw or discontinue the participation at anytime.

Cost and Compensation: Participation in this study will involve no cost to you. There will be snacks and drinks for you during and after the participation.

Confidentiality: All information collected during the study period will be kept strictly confidential. You will be identified only through random identifiers. No publications or reports from this project will include identifying information on any participant. If you agree to join this study, please sign your name below.

_____ I have read and understood the information on this form.
_____ I have had the information on this form explained to me.

Participant's Name	Participant's Signature	Date
	Principal Investigator	Date

Domain Name System (DNS)

1. **Humans need DNS because**
   Mark only one oval.

   - ◯ Hard to remember IP addresses
   - ◯ To manage domains

2. **DNS is not a part of IP Addressing**
   Mark only one oval.

   - ◯ True, It is an essential additional layer
   - ◯ False, it is an essential part

3. **The top most level in DNS is**
   Mark only one oval.

   - ◯ root level (.)
   - ◯ .com

4. **Is fs.example.com a fully qualified domain name (FQDN) ?**
   Mark only one oval.

   - ◯ Yes
   - ◯ No

5. **Domains are delegated to be their name servers**
   Mark only one oval.

   - ◯ True
   - ◯ False

6. **How does DNS reach root-servers ?**
   Mark only one oval.

   - ◯ They have hard coded IP addresses into resolver software
   - ◯ root servers broadcast their location

7. **what happens if there's no requested record found in the domain zone ?**
   Mark only one oval.

   - ◯ looks for any other domain or sub-domain name servers
   - ◯ resolving stops

8. **DNS is not encrypted because**
   Mark only one oval.

   - it breaks legacy compatibility
   - DNS will slow down

9. **Lack of DNS encryption causes**
   Mark only one oval.

   - privacy risk
   - security risk

10. **DNS authentication issue is**
    Mark only one oval.

    - privacy risk
    - security risk

11. **Additional comments**

Network Address Translation (NAT)

1. **NAT is needed because**
   Mark only one oval.

   - ◯ Insufficient IP address space
   - ◯ Secure private devices by blocking direct access

2. **Which IP address is shared in NAT ?**
   Mark only one oval.

   - ◯ Public IP Address
   - ◯ Private IP Address

3. **Carrier Grade NAT is needed because**
   Mark only one oval.

   - ◯ Internet grew too big
   - ◯ ISP's didn't want to buy more costly IP address space

4. **In CGNAT public devices cannot directly connect to user devices**
   Mark only one oval.

   - ◯ True
   - ◯ False

5. **CGNAT is not a good long term solution**
   Mark only one oval.

   - ◯ True
   - ◯ False

6. **Additional Comments**

Phishing (Email security)

1. **Phishing is used to**
   Mark only one oval.

   - ◯ steal credentials or passwords
   - ◯ damage the network infrastructure

2. **You receive an email from your bank that says you are credited €100 and click to check balance, you will**
   Mark only one oval.

   - ◯ enter your bank url or open your bank app and check for balance
   - ◯ click link to check balance

3. **You get an email saying your bank had a database accident, and asks you to reenter your passwords to save them. You will**
   Mark only one oval.

   - ◯ ignore it
   - ◯ try contacting your bank

4. **You receive an official looking email asking to login and renew your account before it expires, you will**
   Mark only one oval.

   - ◯ Click link to renew
   - ◯ go to site and renew

5. **You get an email from your colleague, who says they are stranded and lost their wallet and asks you to paypal some money, you will**
   Mark only one oval.

   - ◯ click link and send some money
   - ◯ try contacting them

6. **Additional commentary**

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   _____

Eidesstattliche Versicherung

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Name, Vorname Matrikelnummer (freiwillige Angabe)

Ich versichere hiermit an Eides Statt, dass ich die vorliegende Masterarbeit mit dem Titel

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*Nichtzutreffendes bitte streichen

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§ 156 StGB: Falsche Versicherung an Eides Statt
Wer vor einer zur Abnahme einer Versicherung an Eides Statt zuständigen Behörde eine solche Versicherung falsch abgibt oder unter Berufung auf eine solche Versicherung falsch aussagt, wird mit Freiheitsstrafe bis zu drei Jahren oder mit Geldstrafe bestraft.

§ 161 StGB: Fahrlässiger Falscheid; fahrlässige falsche Versicherung an Eides Statt
(1) Wenn eine der in den §§ 154 bis 156 bezeichneten Handlungen aus Fahrlässigkeit begangen worden ist, so tritt Freiheitsstrafe bis zu einem Jahr oder Geldstrafe ein.
(2) Straflosigkeit tritt ein, wenn der Täter die falsche Angabe rechtzeitig berichtigt. Die Vorschriften des § 158 Abs. 2 und 3 gelten entsprechend.

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