Coursearch - a KTH course application

The design and development of an interactive visualization tool for customization and personalization of KTH students' educational paths

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A link to the working application is found below:
LINK - Coursearch

Abstract

There is a wish from KTH to develop a more personalized, adaptive and digitalized education (Karlsson et al., 2017). In today's education, the only possibility for customization are the elective courses and the possibility of finding suitable elective courses is restricted by a deficient course search functionality on the current KTH website. In order to help students at KTH plan and customize their educational path, an application for course search and the possibility of creating a personalized education overview was designed and developed, using interactive visualizations. The design and choice of visual structures were based on results of a pre-study survey and a literature review. The application was developed using React.js and D3.js and resulted in two main features - a course search visualization with filtering options and a study plan for customizing the students' educational path. Possible future work involves conducting user evaluations in order to enhance further customization and improve the user experience of the application.

Sammanfattning

Det finns en önskan från KTH om att utveckla en mer personlig, anpassningsbar och digitaliserad utbildning (Karlsson et al., 2017). Den enda möjligheten till anpassning i dagens utbildning är de valfria kurserna. Möjligheten att hitta lämpliga valfria kurser är begränsad av en bristfällig sökfunktion på den nuvarande KTH-webbplatsen. För att underlätta studenters möjlighet att planera och skräddarsy sin utbildning designades och utvecklades en applikation som gör det möjligt att söka efter kurser samt skapa en skräddarsydd utbildningsöversikt med hjälp av interaktiva visualiseringar. Designen och valet av visuella strukturer baserades på resultaten från en förstudie och en litteraturundersökning. Applikationen utvecklades med hjälp av React.js och D3.js och resulterade i två huvudfunktioner - en visualisering av kurser med filtreringsalternativ och en studieplan där studenterna kan skräddarsy sin utbildning. Förslag på vidareutveckling innefattar bland annat att utföra användartester för att bättre anpassa studieplanen efter varje enskild student samt för att förbättra användarupplevelsen av applikationen.

1. Introduction

1.1. Motivation

Every program at KTH offers the students a number of elective courses, which gives students the opportunity to customize their education by being able to choose courses corresponding to their personal interests. One prerequisite for that type of customization is a platform collecting all available courses and filtering out those that are irrelevant. The current search function on the KTH website gathers all courses but makes it hard for users to find relevant courses due to deficient filtering (see Image 1). Also, there is a maximum value of search hits (see Image 2) resulting in a need for a rather specific search from the user in order to even get a result. This means that the user needs to know specifically what they are looking for, and cannot use the website for the purpose of discovering all course offerings. A survey where 33 KTH students participated found that 46% of the students, who had- or were about to take an elective course, experienced difficulties when searching for courses (see Figure 1 in section 4.1 Prestudy survey).

A project at KTH, KTH Education of Tomorrow, addresses possible scenarios of reforming the programs at KTH in a ten-year future as the world is turning even more digital (Karlsson et al., 2017). The fictitious education catalog describes how all KTH students have a personal AI mentor throughout their whole time at KTH, guiding them to personalized education. The AI mentor is supposed to give advice in ongoing courses and also give long-term advice regarding the selection of courses that meet students' requirements and needs. The focus of the project was for students to be able to design their own educational path, based on interests and competencies in order to get the most out of it (Karlsson et al., 2017). This project shows that there is a wish from KTH to develop a more personalized, adaptive, and digitalized education.

With the above mentioned project as a starting point and inspiration and the fact that the current KTH website for course search is not good enough, this project was conducted to create an application to help students at KTH design their education. Unlike the project KTH Education of Tomorrow (Karlsson et al., 2017), our application will provide students with prerequisites for customization of the elective courses in each program and will be applicable in today's education.

Further, because of the human visual perception ability, a visual representation is often more effective than written text (Mazza, 2009). Therefore, we argue that visual representations can help us understand complex systems, make decisions, and find otherwise hidden information.

However, it has been shown that the educational effect of only observing visualization is surprisingly low meaning that there is a need for "useful visualization". Brusilovsky and Spring (2004) present three approaches to "useful visualization": engaging-, explanatory- and adaptive visualization. By practicing engaging visualization the users become more active and engaged in the educational process and will thus enhance learning. Additionally, users will fail to learn if the visualizations are not understandable and therefore, explanatory visualizations in the form of natural language explanations are needed to complement the visualizations. Users may have different levels of knowledge regarding different parts of a visualization hence the visualization needs to be adaptive. Unnecessary details of information might be a distraction for users and draw focus from the parts where the user has less knowledge.

Thus, since this project aims to help students plan their education and find suitable elective courses among thousands of courses, visualizations will be used in order to represent the offer of courses that KTH provides and a personalized education overview. The visualizations will be interactive to enhance engagement from the users and will be designed to follow the principles of explanatory and adaptive visualization.

1.2 Research question

How can KTH course information be visualized to help students customize their educational path?

2. Related work

2.1 Visual mappings and human perception

Visualization is not solely about the printed visual representation of data, but also about the cognitive processes of understanding an image. People build a mental representation of the world through perceiving visual representations - it is a cognitive activity (Mazza, 2009). A user's efficiency and effectiveness can be directly impacted by how s/he sees details in an image (Healey & Enns, 2012). Thus, human perception plays a large role in how to design visual representations and an understanding of perception can improve the quality of information visualizations (Healey & Enns, 2012).

For this purpose, the use of visual attributes is important. Different graphical properties are perceived differently in the human mind, and visual attributes like color, size, proximity, and movement are processed instantly by the human vision before complex cognitive processes begin (Mazza, 2009). Hence, it is possible to represent different categories of data by mapping them to different visual attributes. If the mapping is well constructed, it can contribute to a faster perception and the possibility of processing several items of information at the same time. Also, it becomes easier to single out the maximum and minimum values of the represented data, the relationships between the data, grouping, trends, gaps, or other interesting values. Hence, the choice of visual attributes is essential for the overall perception of the visualization (Mazza, 2009).

Since the design of visual mappings is important for the perception of the data representation, there are some general principles on how to avoid misinterpretations of the data - the choice and expression of scales should be carefully designed. For example, visual objects are perceived in relation to their surroundings, straight lines are easier to interpret than curves, horizontal lines are easier to perceive than oblique lines, comparisons between items are easier if the items are visually close together than items far apart from each other, and items of equal importance should have the same visual impact (Reuter, Tukey, Maloney, Pani, & Smith, 1990).

Visual features compete for cognitive attention and the order of processing might affect what visual attributes are superior to others (Healey & Enns, 2012). Additionally, the visual system lets a visual hierarchy decide what visual feature is more salient than another. For example, during boundary detection tests to classify preattentive features (features that guide attention in visual search), where people detected a texture boundary between two groups of elements, it was shown that the visual system favors color over shape (Callaghan, 1990). Also, the amount of information the eye can register is not the same as what we actually perceive, hence we may not be able to attend to large sets of items presented in combination (He, Cavanagh & Intriligator, 1997).

The design of visualizations is often supposed to engage the user (Healey & Enns, 2012). Engagement is the second stage in low-level visual attention and encourages the visual system to stay and observe details in a certain location (Healey & Enns, 2012). So, if a visualization manages to orient viewers to an important part of the visualization, the viewer should be engaged at that position which in turn will allow them to go into more detail about the data in that location (Healey & Enns, 2012).

When designing visual mappings, three structures must be defined - the spatial substrate, the graphical elements, and the graphical properties (Mazza, 2009). The spatial substrate is given by the axis, so it can be quantitative (defined by some metrics), ordinal (the axis is defined by something that has a particular order, months for example), and nominal (the region of an axis is divided into subregions without any order). The human eye is sensitive to the properties of the graphical elements and, therefore, these have to be chosen with care (Mazza, 2009). The most common properties are size, orientation, color, texture, and shape, and for perceiving quantitative information, spatial positioning is the most accurate property to use (Mazza, 2009). Regarding the choice of colors as graphical property, colors can be perceived differently depending on culture and other physiological factors such as color blindness. Hence, colors have to be chosen with care. The colors that can be considered primary are black, white, red, green, blue, and yellow, even when regarding cultural differences in color perception (Ware, 2004). If there are more than six category attributes, pink, brown, cyan, orange, and purple can be used for the remaining categories (Mazza, 2009).

2.2 Visual structures

There are many different visual structures to use when representing data, however, the type of data determines what kind of structures are to prefer. According to Mazza (2009), the creation of a visualization is a process of preprocessing data and data transformations, visual mappings, and view creation. Preprocessing of a dataset is needed when dealing with large amounts of data in order to transform the dataset into a manageable data structure. While preprocessing of data is important, one of the key problems in the process is defining which visual structures to use so that it matches the data (Mazza, 2009). The view creation is the last step, which is the result of the mapping of data structures to the visual structures - it is the visual representation of the data that the user can see. This step is challenged by the size of the computer screens, the quantity of data might be too large for the available space. It can be solved by using several interaction techniques such as zooming, panning, scrolling, and overview + details (Mazza, 2009). Zooming lets the user zoom into the visual interface while the overview + details approach means that a detailed part of the view is shown at the same time as the user gets to see a global, less detailed view of the representation - an overview. The positive aspect of using an overview + details technique is that the user gets to dig deeper into the visual representation and is not startled by the amount of data at first sight. Keeping both the detailed view and the overview visible allows for quick interaction and helps users' first impressions and understanding of the structure of the content and provides users with necessary details (Mazza, 2009). Another guideline when designing interactive visualizations is the "information visualization's mantra" mentioned by Ben Shneiderman (1996): overview first, then zooming and filtering, finally details on demand. The mantra became famous among visualization researchers for its simplicity (Mazza, 2009) and describes how it is necessary to provide the users with an information visualization system that supports users in the information searching process. By providing an overview the user gains an understanding of the entire dataset, then the user can filter to focus on specific parts of the dataset that is of particular interest, and then if the user demands it, there are details provided when the user needs them (Mazza, 2009).

When designing visual representations there are some aspects to consider - the problem, the data type, the dimensions, the data structure, and the type of interaction (Mazza, 2009). The data type can be quantitative, ordinal or categorical, the dimensions can be univariate or multivariate, the data structure can be linear, temporal, spatial, hierarchical or a network and the type of interaction can be static, transformable or manipulable.

There are several visual structures to use when visualizing hierarchical data. An example of visualizing hierarchical data is showing population data in a so-called space-filling layout (Willis, 2009). Space-filling layouts can be used when there is a variable in the data that can be summed up. In the population data, the population number of countries can be summed upon, for example, a continent level and a world level. The space-filling layout uses area sizes as a visual attribute for indicating the population size (Willis, 2009). Additionally, a treemap layout, where the child nodes are laid on top of the parent node, is a very compact representation of hierarchical data (Willis, 2009) which is the main advantage of that visual structure - it uses all space available with its use of nested rectangles. One of the treemap's largest advantages is the ability to determine not only the position of things in the hierarchy but also the size (Shneiderman, 1996). It was first developed to overcome the difficulty of having a filled hard disk and to determine how and where space was filled in order to find a large file that could be deleted (Shneiderman, 1996). However, one disadvantage of using treemaps is that the hierarchical structure is hard to distinguish since space is mostly used for showing leaf nodes (Van Ham & Van Wijk, 2002).

Wang, Wang, Dai, and Wang (2006) proposes a similar way of visualizing hierarchical data - through circular packing. The child nodes, like in the treemap, are laid on top of its parent node. When circular packing was used to visualize file systems, a user study showed that 67 percent of the users gave the visualization a positive rating and some of the feedback received showed interface satisfaction and the users thought that the visualization provided a bird's view of the whole files and also more information such as directory structures and file attributes. Additionally, the users found the zooming convenient in the sense that it only took one or two zoom-ins to reach a very deep level (Wang et al., 2006).

2.3 Other solutions

In the fictitious education catalog from the project KTH education of tomorrow (Karlsson, et al., 2017), examples of course combinations are presented along with a visualization of expertise and competences. The visualization uses location, size, and color to show the users what kind of engineer the course combination will educate them to be.

Similarly, Ferreira, de Oliveira, Araújo, Dorça, and Cattelan (2019) mentions that personalization and visualization can simplify teaching-learning processes, making it more dynamic and attractive to students and that the integration of Information Visualization tools in educational- and pedagogical purposes can allow for individualized adaptation of educational content (Ferreira et al., 2019). Sharing information between all those involved in the teaching process, i.e. the students and teachers, allows for increased interaction between them and thus enables conversations about improved teaching (Ferreira et al., 2019).

The Danish Technical University, DTU, uses the DTU course base (Danish Technical University [DTU], 2020) where users can broadly search for courses. There are several filtering options such as keyword search, course term-, department-, course type-, and teaching language selection. A course basket is also available where the user can store courses temporarily, then continue searching for more.

3. Method

This project can be divided into two different phases, the design phase and the development phase, and therefore, the method can also be divided in the same way. The design phase includes a literature review to gain theoretical grounds for the design, collecting and analyzing data, user studies, and sketching the visual design according to the literature review. The development phase includes the implementation of the design into a working application.

3.1 Method for the design phase

The design phase was initiated with a literature review and a pre-study survey in order to gain knowledge about the problem and of what tools can be used to solve it.

3.1.1 Literature review

A literature review was conducted in order to find a solid ground for all the design choices and visual structures. This resulted in insights regarding which visual structures to use for different functionalities.

3.1.2 Pre-study survey

A user study was conducted with the aim to gain insights about the users' thoughts of the current course-website (see Image 1 & 2). The target group for this project is all students at KTH, but for this user study only students from the program Media Technology participated. The reason for only having Media Technology students was that we had easy access to the participants, i.e. convenience sampling. The user study was initially thought to be in the form of think-aloud usability tests of the current KTH website followed by a semi-structured interview to gain insight about the user needs to set up requirements for the design.

However, due to the current situation regarding COVID-19, physical meetings were restrained and the tools for a digital solution were not available to us at the time. A quantitative method was therefore used in the form of a survey that was sent out to the KTH students via groups on Facebook where all members were students at KTH in different grades (see Attachment 1 - Pre-study survey questions).

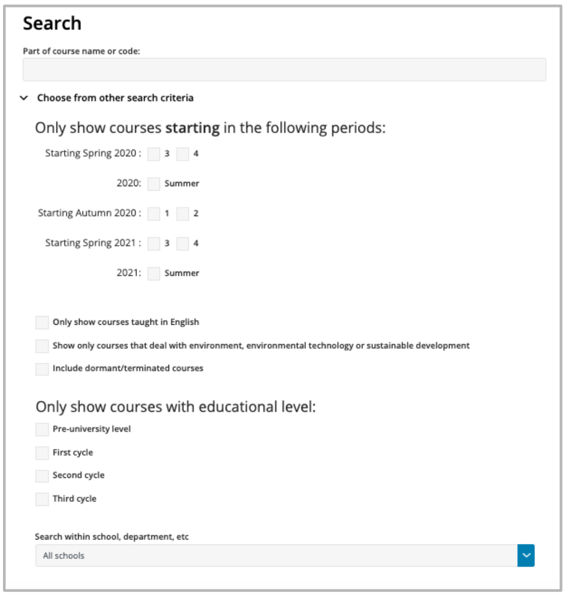

Image 1 *- The search function in the current KTH website*

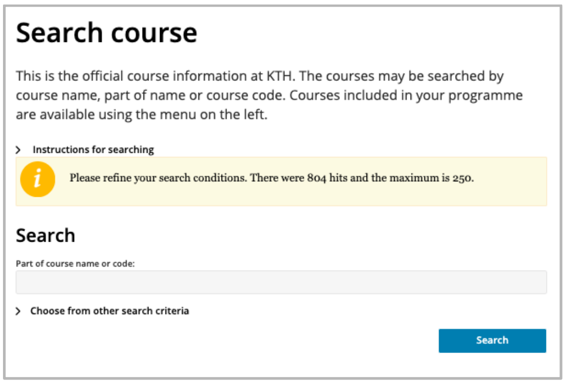

Image 2 *- There is a limit of 250 search hits that can be shown then searching for courses on the KTH website*

33 students participated in the survey. The survey let the students elaborate on what difficulties they had faced when trying to find courses via the current KTH website. The answers played a big part in the later design choices as they revealed the participants' needs. The answers were analyzed and grouped together into three main requirements (see Attachment 2).

3.1.3 Sketching

When all data from the pre-study was collected and analyzed, we had a brainstorming session to figure out the best way to solve the issues that arose in the pre-study. The "best way" was based on previous research in the field of information visualization and the brainstorming was in the form of concept sketching (Digital Society School, n.d.) with the purpose of generating a lot of ideas. The design was created in Figma and was based on the answers from the survey, the insights from related work, visualization theory and the sketches made during brainstorming (see Image 3, 4 & 5).

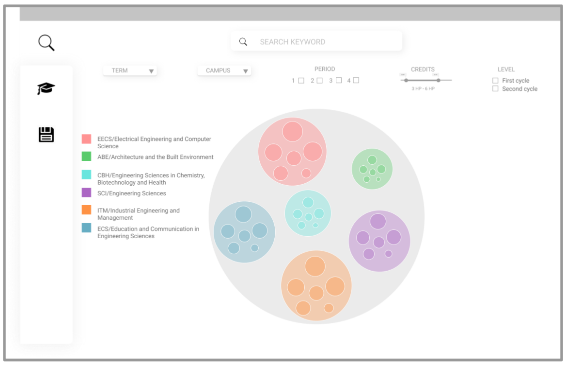

Image 3 *- The design of the search page, created in Figma*

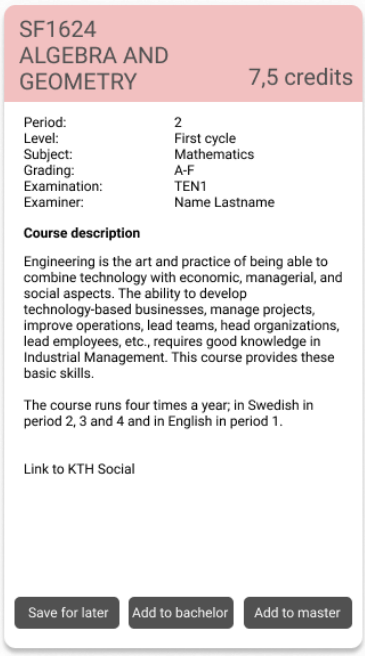

Image 4 *- The design of the details appearing when clicking on a course at the search page, created in Figma*

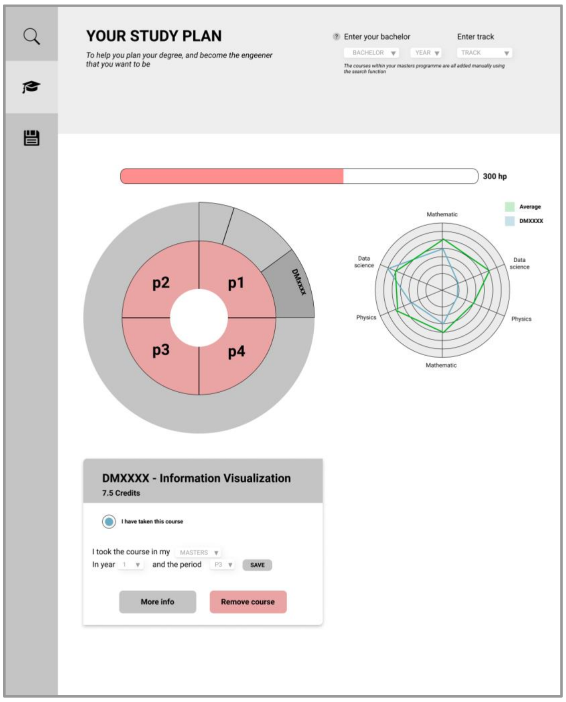

Image 5 *- The design of the study plan, created in Figma*

3.2 Method for the development phase

As previously mentioned, the development of this application had to be conducted remotely due to the situation with COVID-19. The meetings were held via Zoom and the workload was evenly distributed among the group members. A backlog with todos was conducted in Trello and GitHub was used for collaboration.

The working application was developed using React.js, a javascript framework for building interactive user interfaces, and the visualizations were built with D3.js. D3.js is a javascript library using SVG, HTML and CSS to represent data visually. The interactions were made by integrating D3 components into a react application and using built-in D3.js functions.

As for state management, Reach Hooks was used. React does not have a solution to “attach” reusable behavior to a component and the hierarchical structure has the ability to only pass data as props downwards in the hierarchy. By using React Hooks as state management it was possible to reuse logic and behavior without having to change the hierarchical structure of the component. Data was shared globally using the context-hook and the same data was manipulated from any component with the reducer-hook (React.js, 2020). A custom hook for fetching data from an external API was written which could be reused whenever an API call had to be made.

Data of courses at KTH was given by the KOPPS API V2 for courses, containing information about courses, programs and departments. The API provided information about courses in each program, and which school and department that was responsible for each course. It also contained detailed information such as subjects, examination form and a recruitment text for each course.

The development of the application was based on the design and started with the development of a MVP, minimal viable product, covering the requirements established in the design phase (see Attachment 2). When the MVP was developed, two user tests were conducted. The idea was initially to conduct more than two tests at this point but due to the restricted social gatherings, the number of tests had to be reduced but longer and deeper. This round of user tests focused less on what content and information to show since that had been done in earlier tests, and instead it focused on where to show it and how to access it. The user tests were in the form of unstructured interviews, the user tested the application and thought out loud. It was unstructured in the way that questions were not prepared but the interviewer had guidelines to always ask:

- What information do you expect to get when clicking on X?
- What information do you want to get when clicking on X?
- Why?

4. Result

Below is the result of the pre-study survey, the user tests, and the final delivery.

4.1 Pre-study survey

The survey showed that 46% of the participants who had- or were about to take an elective course, experienced difficulties when searching for courses (see Figure 1).

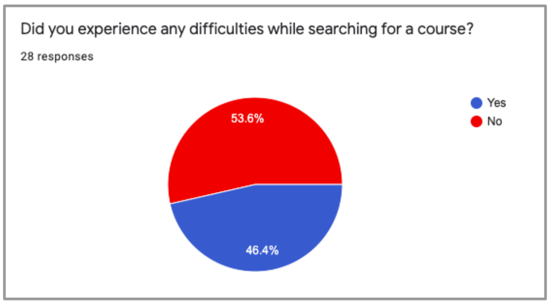

Figure 1 *- Survey answers of the question: "Did you experience any difficulties while searching for a course?"*

The survey further showed that 16 people (57%) looked at other programs' curse lists when searching for courses, 15 people (53%) found courses based on recommendations, and 13 people (46.6%) used the search function on the KTH website. Two people found courses among the recommended courses in their program, and one person claimed to have looked through all courses given, for all five years, in his program (see Figure 2).

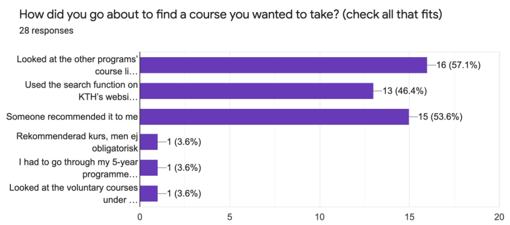

Figure 2 *- Survey answers of the question: "How did you go about to find a course you wanted to take? (check all that fits)"*

The criteria rated most important were the subject of the course (ranked with a mean value of 4.5 out of 5), the period it was given in (ranked with a mean value of 3.86 out of 5) and the number of HP (ranked with a mean value of 3.5 out of 5). The less important criteria were the educational level (ranked with a mean value of 3.14 out of 5) and the examination set (ranked with a mean value of 2.64 out of 5) (see Figure 3).

Other criteria that were important to the users were the location of the lecture, the schedule, how fun and interesting it seemed, responsible lecturer and examiners, and if the content of project-based courses are applicable outside of school.

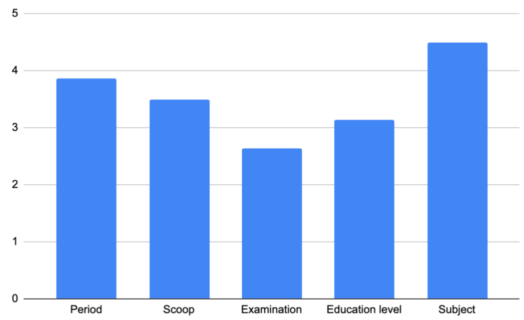

Figure 3 - *Survey answers of the question: "What criteria were most important for the course you were looking for? Please rank below the criteria after how important they were. (1 = Not important, 5 = very important)"*

13 people (46.4%) had experienced difficulties while searching for a course, the problems were mainly that it was hard to get an overview of all courses and the inability to filter out unrelated courses. The participants mainly wanted to filter on the periods the courses were given in to ensure that courses would not collide. They also wanted to be able to filter on course subjects (see Attachment 2). The answers gave rise to three main requirements:

1. Ability to filter on when the course is given
2. Ability to easily get a hold of the subject area or filter according to the subject
3. A clear overview of the courses

4.2 User test on MVP

The navigation and interaction with the packed circles' diagram for the courses confused the users as it was unclear how to both zoom in and go back once you had zoomed. Further, it was perceived that the zooming was inconsistent in the way that it sometimes zoomed many levels at a time. The information in the details card was appreciated and there was no mention of anything missing. The feature of choosing a bachelor to add all courses to the study plan was a bit unclear and in need of some onboarding or further guidelines. One user wished to be able to connect the study plan to Ladok (a student information platform) in order to get all the finished courses added to the study plan automatically. The ability to remove or move a course to another time was appreciated and the users could see an area of use for the feature. Further, the users would expect the progress bar and radar chart to update when zooming, however, it was not clear to the user that the sunburst was interactive.

4.3 Final delivery

The final application consists of two main features, the search feature and the study plan feature (see Image 6 & 7).

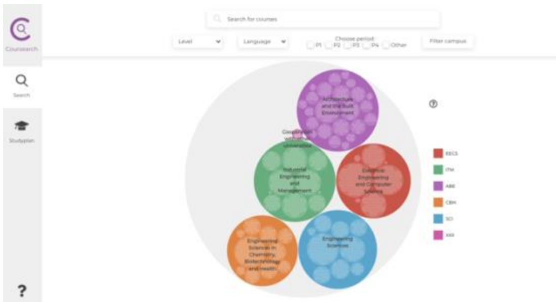

Image 6 - *Course search visualization with filtering options*

Image 7 - *Study plan with added bachelor courses from the program Information and Communication Technology*

The search feature shows all courses available at KTH in a packed circle diagram (see Image 6), each course belongs to a department that belongs to a school at KTH. The diagram is interactive and the user can zoom one level at a time, when clicking on a school, all departments show up and so on. The user can search for course names or the course codes, filter on periods, language, educational level, and campus. When clicking on a course node, a details card shows up next to the diagram containing more details and a button labeled “add to study plan” (see Image 8). The details are divided into three sections, one containing practical information such as course credits, one with the recruitment text describing the course, and one with information about the examination and grading.

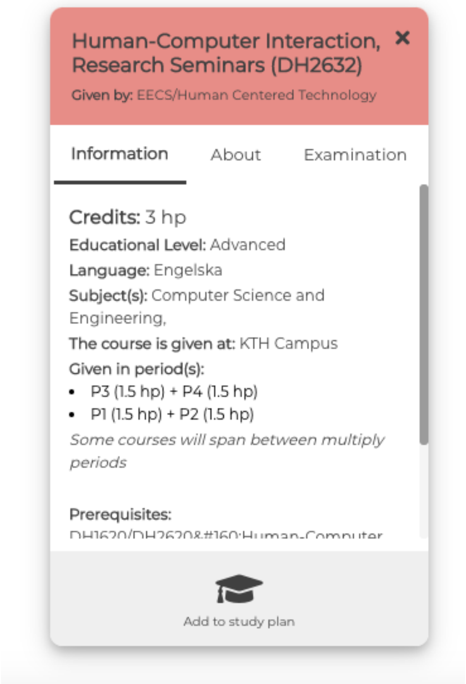

***Image 8** - Details card showing up when user clicks on a course in the search view*

When adding a course to the study plan, the user gets to choose a year and period when the course will be taken. The course then appears in the sunburst diagram in the study plan feature (see Image 7). The courses in the sunburst all belong to a period in a certain year, the year belongs to either the bachelor or the master. To avoid having to add all bachelor courses manually, the user can choose a bachelor program and a starting year to add all courses from that bachelor program as well as remove all bachelor courses if needed. Next to the sunburst, a radar chart appears showing the division of subjects for all courses in the study plan (see Image 12 in section 5.2 Data processing and API restrictions**)**. For example, the user might have read 30 credits in mathematics and 6 credits in electrical engineering. A progress bar shows the summed amount of credits in the study plan, where the maximum is 300 credits, the number of credits in a 5-year master program at KTH. Both the radar chart and the progress bar are updated when zooming the sunburst. When clicking on a course node, a similar detail card as in the search feature shows up. The card has buttons for moving the course to another time or removing it from the study plan.

5. Discussion

Below follows a discussion on the design of visual structures, restrictions in the data and future work.

5.1 Design of visual structures

The choice of using visualizations for representing the KTH course data was based on the fact that different graphical properties are perceived differently in the human mind, such as color, size and proximity - they are processed instantly before any complex cognitive processes can take place (Mazza, 2009). Additionally, visual representations can help us make decisions and find otherwise hidden information (Mazza, 2009), which is essential when students design their education and decide what courses to take. Integrating visual representations, together with interactive tools such as the filtering functionality and the detailed information about the courses, can thus help the students find suitable courses among all the thousands of courses KTH offers. The pre-study (see section 4.1 Pre-study survey) showed that there is a need for an overview of all courses given at KTH, something that can be provided through visualizations. The visual representations can help students perceive the data more rapidly and provide them with the possibility of processing several items of information at the same time (Mazza, 2009). The course search visualization represents over 5000 courses, and since the human perception system makes it hard to attend large sets of items in combination (He et al., 1997), the visualization was designed so that the courses are only displayed when zooming and their respective detailed information is accessible only on demand using the overview + details on-demand approach (Mazza, 2009). Having all courses and their information displayed at once would have been difficult for the user to perceive. Moreover, the overview + details on-demand approach follows the principles of adaptive learning (Brusilovsky & Spring, 2004) as it offers users the opportunity to get more details about parts where they need it. Adapting the visualizations to the users will also reduce the cognitive overload caused by too much information at once (Mazza, 2009).

Further, as Reuter et al. (1990) point out, the design of visual mappings is important for the perception of the data representation, and this was constantly regarded throughout the development of the application. For example, as items of equal importance should have the same visual impact (Reuter et al., 1990) we reduced the use of color in other places of the application where the color did not have any meaning other than for esthetic reasons. The sidebar, the filter component, and the top bar in the study plan were all of less importance than the visualizations themselves.

In the pre-study, it was shown that the courses' subjects were an important aspect when selecting courses to take (see section 4. Result). In our course search visualization, the schools represent different subject areas and their respective departments represent more specific subject areas, it was important to clearly divide these in the visualization. In line with the fact that the visual system favors color over shape (Callaghan, 1990), the grouping of schools and departments were made by using colors. The schools got one color each to represent the overall subject area, however, since there is a limited number of colors to use (Ware, 2004; Mazza, 2009) the departments and courses belonging to each school were grouped by using position and hue (based on their school's color). The color then represents the overall subject area of the course.

The colors used were chosen based on the idea of primary colors, which are not perceived differently depending on culture (Ware, 2004), and the additional colors that can be used for categorization (Mazza, 2009). The different schools have the colors of red, green, purple, orange, blue, and pink.

Spatial positioning is the most accurate property to use for perceiving quantitative information (Mazza, 2009), and this was regarded when designing the visual mappings in the study plan of both the progress bar showing the sum of credits and the radar chart showing what subjects are represented in the courses in the study plan. Both visualizations use position in order to show credits (the quantitative data).

The idea of developing a study plan functionality in the application was, as mentioned, based on the project KTH Education of Tomorrow (Karlsson et al., 2017), not only is there a need for a better way to find suitable courses, but there is also a need for planning and building a more personalized education where students get to customize the education as much as possible to fit their own interests and competences. In today's education at KTH, this customization is possible only with the elective courses and therefore the study plan functionality was developed to enhance this customization and make it more accessible. The study plan is supposed to make it easier for students to get an overview of the courses they have taken and possibly will take, the composition of subjects represented in these courses and also the possibility to know how many credits these courses sums up to - in a period, a year, the whole bachelor or masters or the whole education.

The choices of all visual structures to represent the data were based on the data types, which in the case of this project were categorical and/or quantitative, the data structures that were hierarchical and linear. Since there was a lot of data to present, a transformable interaction type was implemented. For the course search visualization, a lot of data had to be represented on one screen, it had to indicate the different subject areas and be categorized by school and department. A typical hierarchical visual structure to use would have been a treemap whose main advantage is that it uses the space on the screen efficiently (Willis, 2009) and that it is easy to determine the position and size of items in the hierarchy (Shneiderman, 1996). However, one limitation of the KOPPS API used for collecting all courses was that it did not have the information on how many credits each course was worth, something that could have been represented by the size of a rectangle in a treemap. Since there was no such data to map to the size, the advantages of using a treemap were fewer. Instead, a packed circle diagram was chosen as a visual structure for representing the courses. The packed circles showed a better overview of all courses since the different schools and departments were more separated than they would have been in a treemap, so it had the advantage of clearly distinguishing hierarchical structures which a treemap does not (Van Ham et al., 2002).

Furthermore, the choice of visual structures for the study plan had somewhat different requirements - it was not nearly as much data to represent as in the course search visualization. All information could be shown at the same time to get the full overview, and there was a variable in the data that could be summed up - the credits. When adding courses to the study plan, more data from the KOPPS API was fetched to complement the data in the packed circles visualization. This data contained the credits for each course, enabling mapping the size of a course depending on its credits. Thus, a space-filling layout, a sunburst, was best suited for the purpose (Willis, 2009) and was therefore used for visualizing the courses a student has taken or will take. Additionally, the sunburst provides the user with both details and an overview, which allows for quick interaction and understanding for the structure of the content (when the courses were taken or are to be taken) at the same time as necessary detailed information (the courses) is provided (Mazza, 2009). An additional visual structure was developed in order to provide the user with information about what subjects are covered in their study plan - a radar chart. This visual structure was chosen because of its possibility to present multivariate, quantitative data. The subjects constitute the axes, and the sum of the credits belonging to each subject is then mapped to the axes. This creates an area that represents the total subject area. Additionally, when zooming in the sunburst, the radar chart creates a new area based on the courses visible in the zoomed-in sunburst while keeping the total subject area fixed (see Image 9). This enables a comparison between the zoomed-in courses' subject area and the total subject area - for example, the first year of the education might have covered a lot of mathematics courses while the total education might cover more of interaction design and human-centered technology.

Image 9 *- The visual representations in the study plan when zooming to Year 1 in the sunburst*

However, there are some difficulties using visual structures for data representation - the interaction can be tricky to develop and for users to manage. The learning curve for the application might be high. When developing the packed circles visualization, the navigation was shown to have some difficulties (see section 4.2 User test on MVP) - depending on where it was clicked, it zoomed in to different levels in the hierarchy and this was not consistent. This was solved by allowing users to zoom in solely one step at a time. To deal with this constraint of the visual structures, additional explanation texts and a step-by-step section describing how the application works (see Image 10) were added as a complement to the visualizations in the application, following the principle for explanatory visualization (Brusilovsky & Spring, 2004).

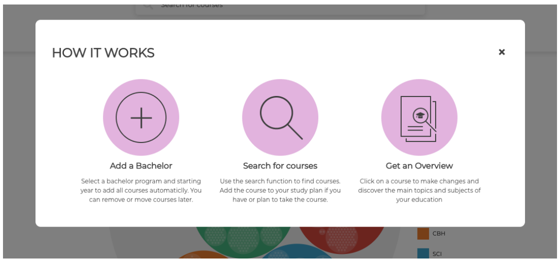

Image 10 *- a step-by-step section describing how the application works*

5.2 Data processing and API restrictions

According to Mazza (2009), preprocessing data is the first step in the creation of visualization when dealing with large amounts of data. All data used in the D3 components needed some preprocessing in order to fit into the data structure, mainly into hierarchical structures. However, the data was continuously fetched from the KOPPS API and was therefore processed every time after a fetch was made in the application. Both the fetching of data and the processing took unnecessary time, time that could have been reduced if the data was processed once into a JSON file with the desirable data structure. However, the data had to be dynamic as the course rounds are constantly changing, and therefore fetching the API continuously was necessary.

The data in the KOPPS API was divided into several smaller data structures with different endpoints, meaning that several fetches of different URLs had to be made and combined in order to get all desired data. For instance, the endpoint for course offerings used to fetch all courses did not contain information about credits. In order to get that information, the endpoint for course-details containing more details about every single course had to be fetched for each course. One compromise that had to be made was that we could not represent the size of each course in the visualization with the number of credits. That would have required fetching the API with an endpoint for course-details once for each course directly when entering the page, which would have increased the loading time severely. Instead, the details were fetched once a course was clicked by the user as details on demand (Mazza, 2009).

The KOPPS API that was used for the radar chart to show course subjects, contained information about the main subjects for each course. However, the subjects seemed to not always be accurate and reliable as the subject in many cases was only "technology" which is a very broad and uninformative subject. Since almost every course had the subject "technology", it took up a large space in the radar chart, leading to almost neglecting the other subjects (see Image 11). Therefore, the subject “technology” was excluded from the radar chart (see Image 12). This means that the radar chart works more as a proof of concept and is something that can be further developed if the KOPPS API would update more accurate subjects.

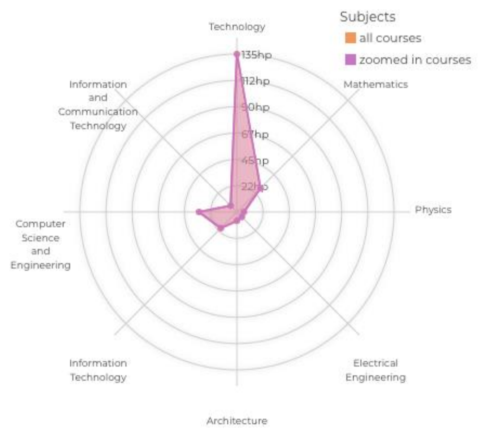

Image 11 *- The radar chart before excluding the subject “technology”*

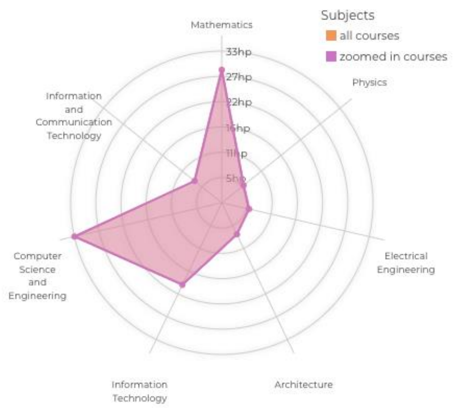

Image 12 *- The radar chart after excluding the subject “technology”*

5.3 Future work

There are several possible future developments for the application. To begin with, no user evaluations of the final delivery have been conducted, and therefore it is unknown how the application, and the visualizations, are experienced by users. In line with Healey and Enns (2012) idea of that visualizations should engage the user, our application would benefit from high user engagement where the user is oriented to important parts of the visualizations and thus be engaged enough to dig deeper and look for more detailed information in the data (Healey & Enns, 2012). If the user would understand, by solely looking at the visualizations, how to interact with them it would make the data exploration process more accessible. However, in order to gain knowledge about the user engagement of the visualizations, it would be necessary to conduct user evaluations and studies.

Additionally, conducting user tests on the final delivery would increase the knowledge of how users interact with the application - both as a whole and in the visualizations. It could also provide an insight into what users expect to get out of the application and what they are missing or not understanding. The two user tests that were conducted gave some insights, but in order to know if the insights are reliable, it would be necessary to conduct more user tests. Conducting more qualitative think-aloud user tests of the application is therefore also a possibility for future work.

As one user mentioned in the user test (see 4.2 User Test of MVP), one possible technical development would be to allow users to log in with their KTH username and in that way connect the application to the users' personal Ladok-accounts. That would give the application access to information about what courses the users have taken, which courses the users are currently taking, and their grades. That would contribute to a better user experience, and a more customized study plan, as it would reduce the manual work of adding master-courses, courses that are track specific, or various elective courses that belong to the bachelor programs. Getting access to personal information about students from Ladok would require collaboration with the IT department at KTH, and is therefore not possible for us to develop at the moment. However, a possible compromise would be to allow users to add their master's program in the same way as they can add the bachelor's. The technical solutions for that would not be an issue since the information is available in the KOPPS API. The reason for not implementing it in the final delivery was that the master's programs do not in general contain as many mandatory courses as the bachelor's and therefore manual work would still be required from the users for adding the elective courses. Adding only a few courses automatically and the rest manually might feel inconsistent and would perhaps confuse the users. In order to know if it is desirable to implement such functionality, a user evaluation first has to be conducted.

Additionally, visualization of students' study plans and covered subjects could, in line with the idea of that integration of Information Visualization tools in educational- and pedagogical purposes can allow for individualized adaptation of educational content (Ferreira, et al., 2019), be used for communication purposes. Information about students' educational paths could be shared with teachers and possibly enable the development of programs into more personalized and customized educational paths.

The functionality to be able to save a course without adding it to the study plan was in the initial design but had to be excluded due to time constraints. The inspiration for such a feature came from the DTU course search (see 2. Related Work) and would be used as an interstage between the search and the study plan, to lower the threshold for saving courses since adding courses to the study plan might be too big of a commitment. Again, this would require a deeper evaluation in order to understand the need for such a feature.

Lastly, the application would require some optimization as the fetching and data processing is currently of high complexity which makes the application slow.

6. Conclusion

The project aimed to develop an application for students at KTH in order to assist them with the possibility to plan their education and find suitable elective courses. Several interactive visualizations were developed using React.js and D3.js. It resulted in an application visualizing all courses at KTH with filtering options and the possibility to create a study plan. The study plan provides an overview of the courses a student has taken or will take along with the composition of subjects represented in these courses and the possibility to know how many credits these courses sums up to - in a period, a year, the whole bachelor or masters or the whole education. Possible improvements involve conducting user evaluations in order to enhance customization and improve the user experience of the application.

References

Brusilovsky, P., & Spring, M. (2004). Adaptive, engaging, and explanatory visualization in a C programming course. In *EdMedia+ Innovate Learning* (pp. 1264-1271). Association for the Advancement of Computing in Education (AACE).

Callaghan, T.C. (1990). Interference and Dominance in Texture Segregation. *In Visual Search, Taylor & Francis*, pp. 81-87.

Danish Technical University. (2020). DTU course base. Retrieved 2020-06-02 from https://kurser.dtu.dk/search?CourseCode=&SearchKeyword=design&SchedulePlacement=E1A&CourseType=&TeachingLanguage=

Digital Society School. (n.d.). Concept Sketch. Retrieved 2020-06-02 from https://toolkits.dss.cloud/design/method-card/concept-sketch-2/

Ferreira, H., de Oliveira, G.P., Araújo, R., Dorça, F. & Cattelan, R. (2019). Technology-enhanced assessment visualization for smart learning environments. S*mart Learn. Environ. 6, 14*. DOI:https://doi.org/10.1186/s40561-019-0096-z

He, S., Cavanagh, P., & Intriligator, J. (1997). Attentional Resolution. *Trends in Cognitive Science*, vol. 1, no. 3, pp. 115-121.

Healey, C. & Enns, J. (2012). Attention and Visual Memory in Visualization and Computer Graphics. *IEEE Transactions on Visualization and Computer Graphics*, 18(7). 1170–1188. DOI:https://doi.org/10.1109/TVCG.2011.127

Karlsson et al. (2017). KTH education of tomorrow. *Unpublished fictitious catalogue.*

Mazza, R. (2009). Introduction to Information Visualization (1st. ed.). *Springer Publishing Company, Incorporated*.

React. (2020). Hooks API References. Retrieved 2020-06-02 from https://reactjs.org/docs/hooks-reference.html

Reuter, L.H., Tukey, P., Maloney, L.T., Pani, J.R., & Smith, S. (1990). Human perception and visualization. In Proceedings of the 1st conference on Visualization ’90 (VIS ’90). *IEEE Computer Society Press*, Washington, DC, USA, 401–406.

Shneiderman, B.(1996). The eyes have it: A task by data type taxonomy for information visualizations. In *Proceedings of the 1996 IEEE Symposium on Visual Languages*.

Van Ham, F. & Van Wijk, J.J. (2002). Beamtrees: Compact visualization of large hierarchies, In Proc. Information Visualization 2002, IEEE, 31–39.

Wang, W., Wang, H., Dai, G., & Wang, H. (2006). Visualization of large hierarchical data by circle packing. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI ’06)*. Association for Computing Machinery, New York, NY, USA, 517–520. DOI:https://doi.org/10.1145/1124772.1124851

Ware, C. (2004). Information Visualization: Perception for Design. *Morgan Kaufmann, San Francisco, CA*, 2nd edition.

Wills, G. (2009). Visualizing Hierarchical Data. In Encyclopedia of Database Systems, Springer US, Boston, MA, USA, 3425-3432.

Attachment 1 - Pre study survey questions

The survey asked the following questions:

1. Have you ever taken, or will take, an elective course at KTH (not mandatory within your program)?
2. How did you go about to find a course you wanted to take? (check all that fits)
3. What criteria were most important for the course you were looking for? Please rank below the criteria after how important they were. (1 = Not important, 5 = very important)
    a. What period it was given
    b. The scope (how many HP)
    c. Examination set
    d. Educational level
    e. Subject
4. Any other criteria that were important? (if not, leave blank)
5. Did you experience any difficulties while searching for a course?
6. If yes, please describe which difficulties (if no, leave blank)

Attachment 2 - Analysis of qualitative answers

Survey answers	**Our comments**
The problem is not to find a course but to be aware of all the courses you can take.	- overview
I tried the search function on KTH's website several times, with different key words, to find a class in a specific area/subject I needed more credits in. I spent a lot of time searching without finding a suitable course. Later on I found a course that fit perfectly on another programme's list of courses. The title of the class matched the key words of my previous searches very well so it should have showed up.	- if a specific area is needed for credit - bortfall av kurser som man var intresserad av
Det var väldigt svårt att se vad det fanns för kurser, vad de handlade om och när dem gick (i vilken period). Jag hittade någon lista över kurser som fanns inom de olika skolorna men det var jätte oklart om det var alla kurser som fanns på KTH, och man visste inte vilken typ av kurser som skulle finnas på varje skola. Vissa kurser som fanns gick inte ens längre så man visste inte vad som gick eller vilka som hade blivit skrotade. Det var generellt väldigt svårt att hitta kurser som man var intresserad av, då man inte visste vart eller vad man skulle söka på/efter eller vart man kunde hitta dem.	- filter on period - filtrera på skolor är inte helt tydligt - man vet inte Vilken typ av kurser som ges av varje skola - man får upp kurser som inte längre går
Many courses that are elective and interesting can clash in the schedule or be in periods that is already full of mandatory courses.	- filter on period
There are duplicates, old versions of courses and generally incomplete information on KTH's website.	- man får upp kurser som inte längre går eller dubbletter av kurser
No Easy way to compare courses. It was very hard to get a proper overview as well.	- ability to compare courses - overview
So many different course names and it is hard to distinguish what each is.	- not intuitive to filter on name - to not collide → filter on period

I used mostly the search and it was difficult to find courses that match my interests. Also, finding courses that do not collide was hard	
My main criteria was to find an interesting course and that was quite difficult	- level of the course important - subject area important → filter
Difficult to get a complete overview, I discovered some courses by incident or too late	- Overview of courses, controlled search in order to not only find courses by incident
Which I could apply for was unclear	- confused about subject area? - unsure of how many credits? - outside the scope?
Had a hard time understanding wheither I would be able to include the credits for my degree or not	- confused about subject area? - unsure of how many credits? - outside the scope?
Don’t know a good place to look	- need for a collected place

Top 3:

- Overivew: 7/12
- Filter on period (aviod collisions)
- Filter on subject area

Conclusion:

the three main requirements:

1. Ability to filter on when the course will take place
2. Ability to easily get a hold of the subject area or filter according to the subject
3. A clear overview of the courses

Attachment 3 - Images

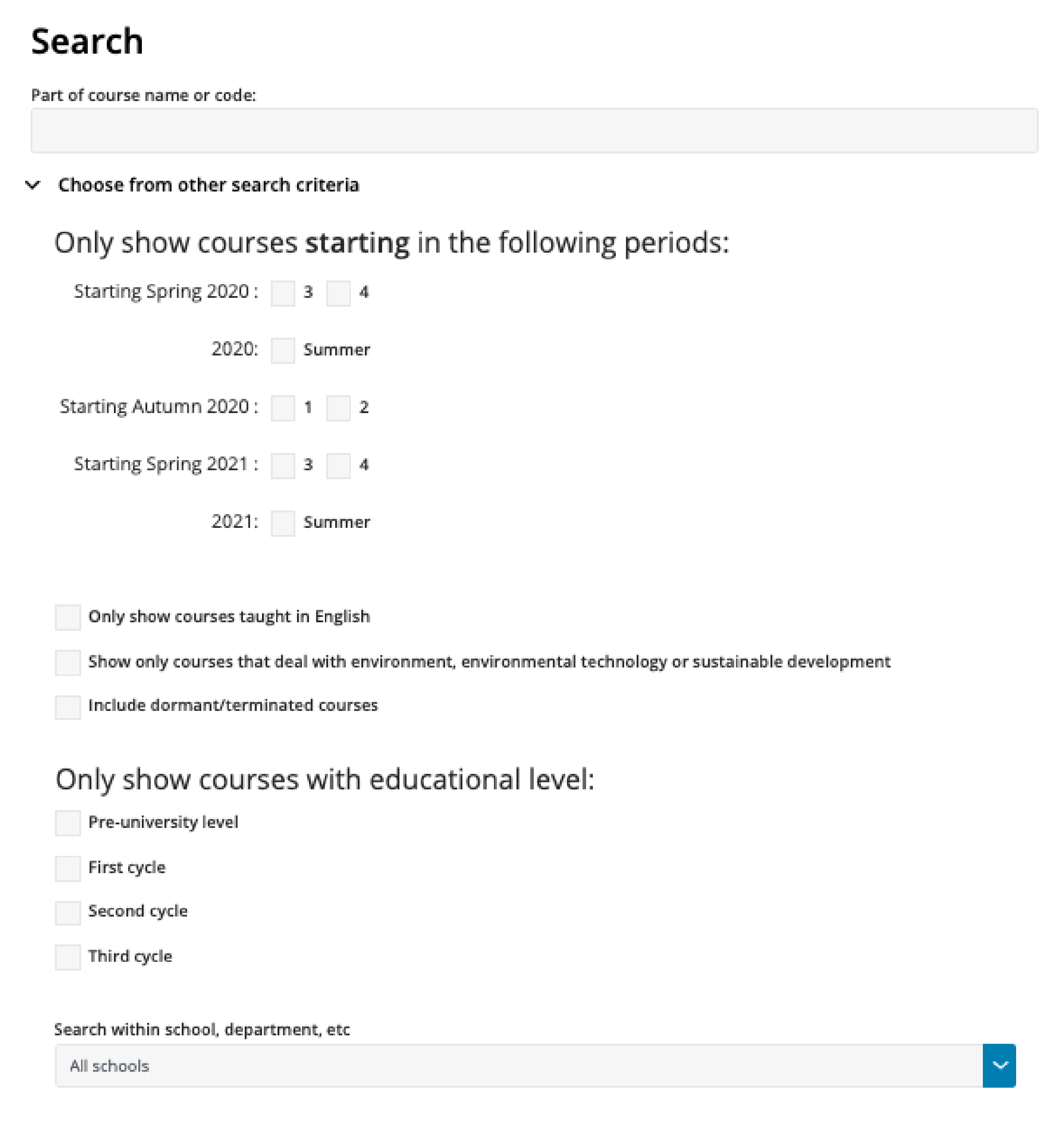

Image 1 *- The search function on the current KTH website*

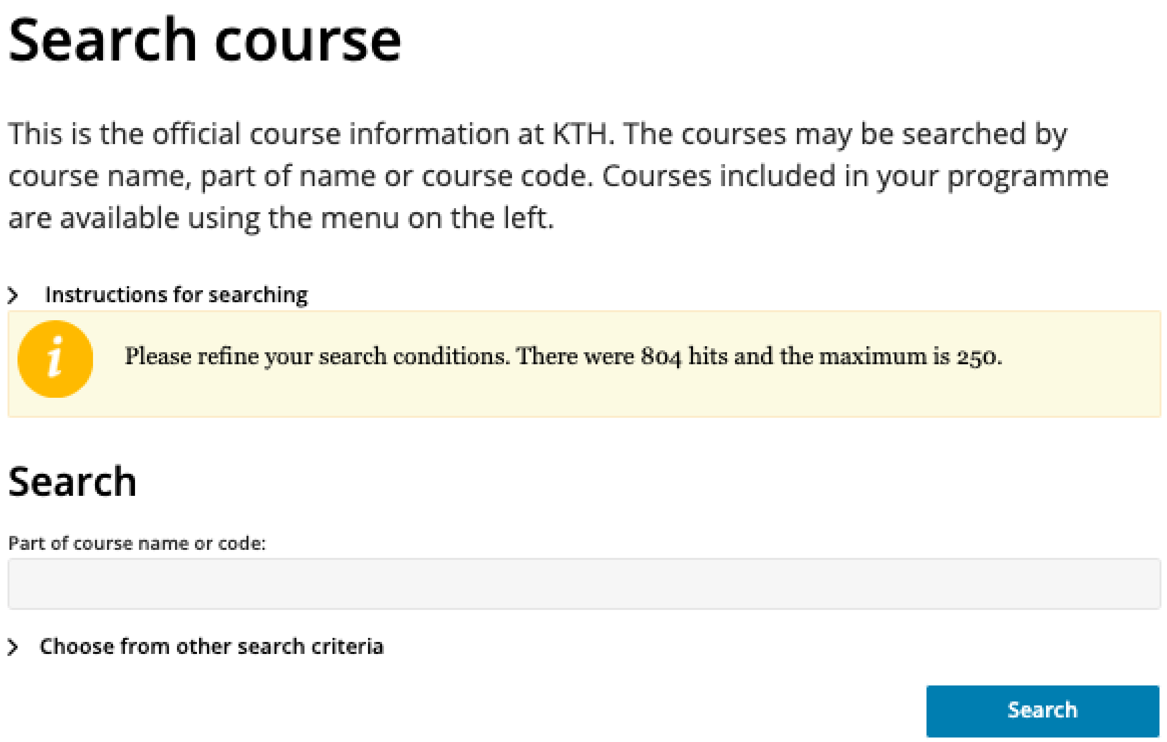

Image 2 *- There is a limit of 250 search hits that can be shown then searching for courses on the KTH website*

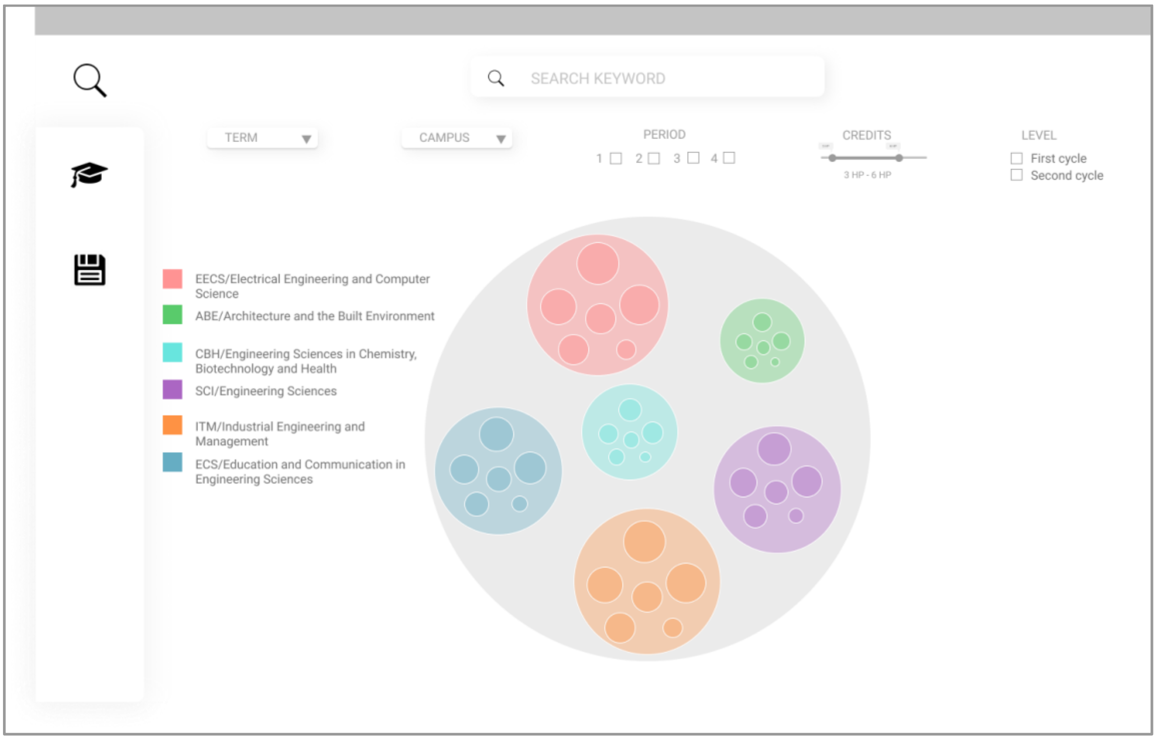

Image 3 *- The design of the search page, created in Figma*

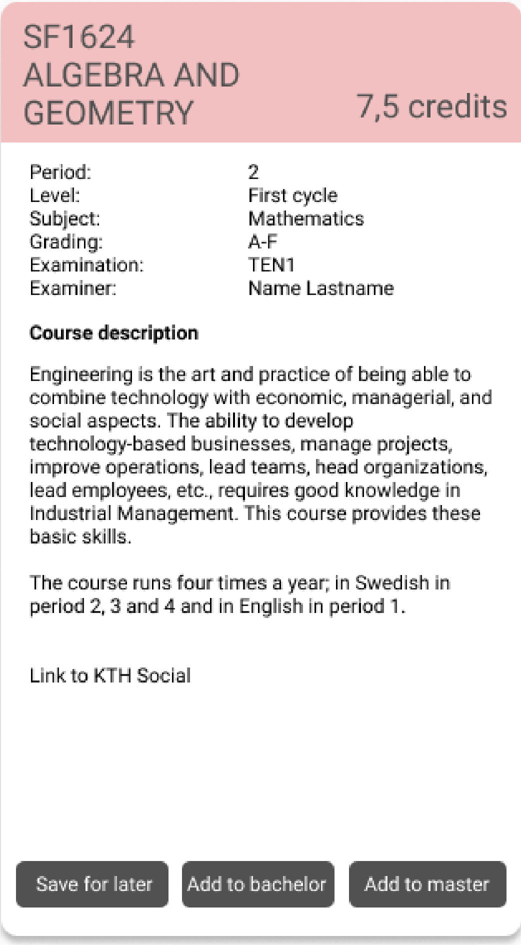

Image 4 *- The design of the details appearing when clicking on a course at the search page, created in Figma*

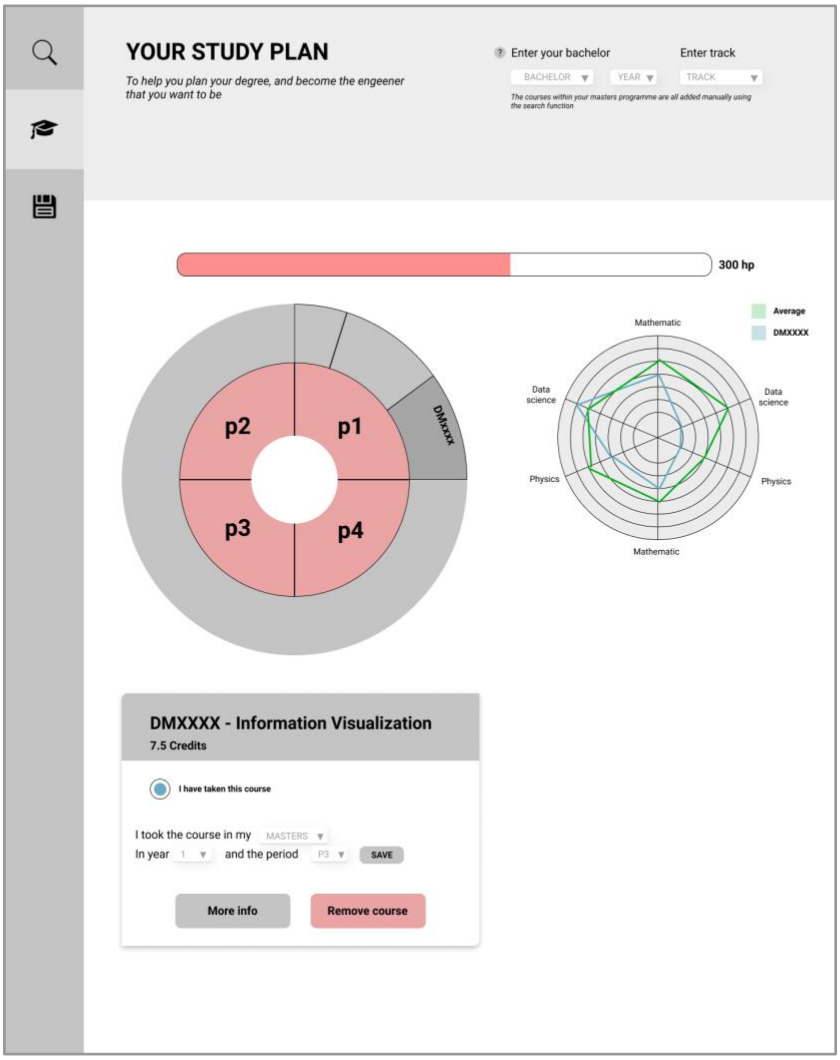

Image 5 *- The design of the study plan, created in Figma*

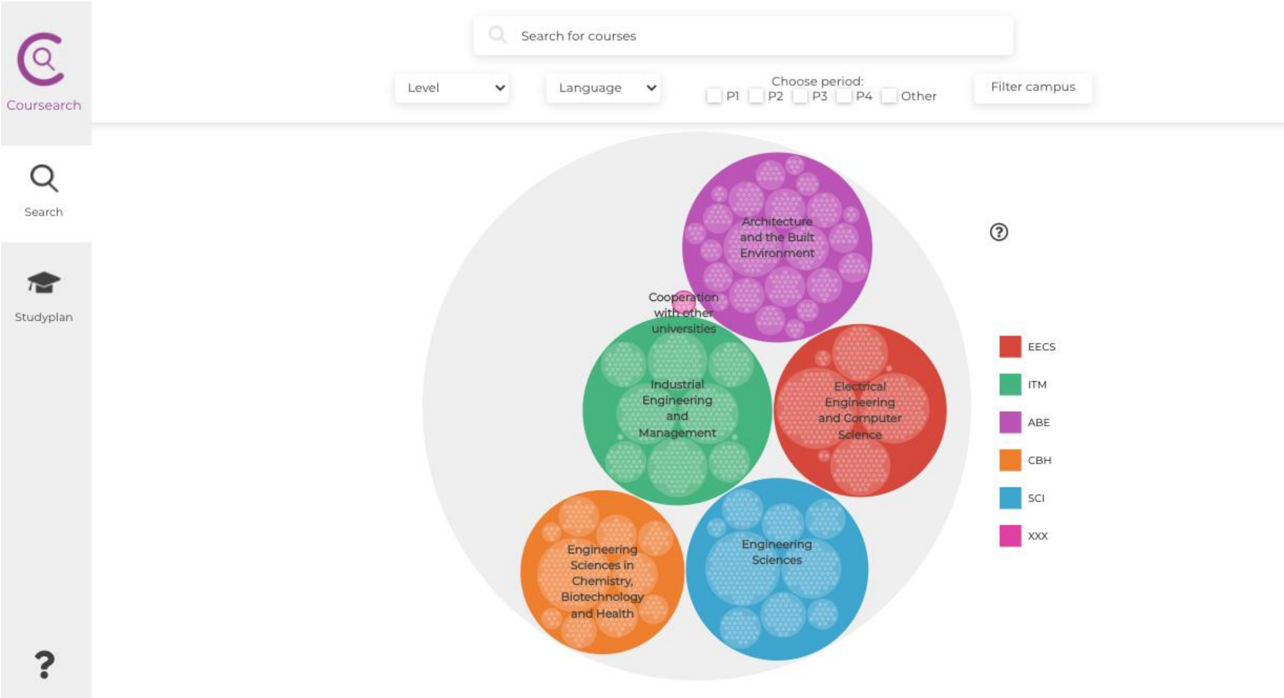

Image 6 *- Course search visualization with filtering options*

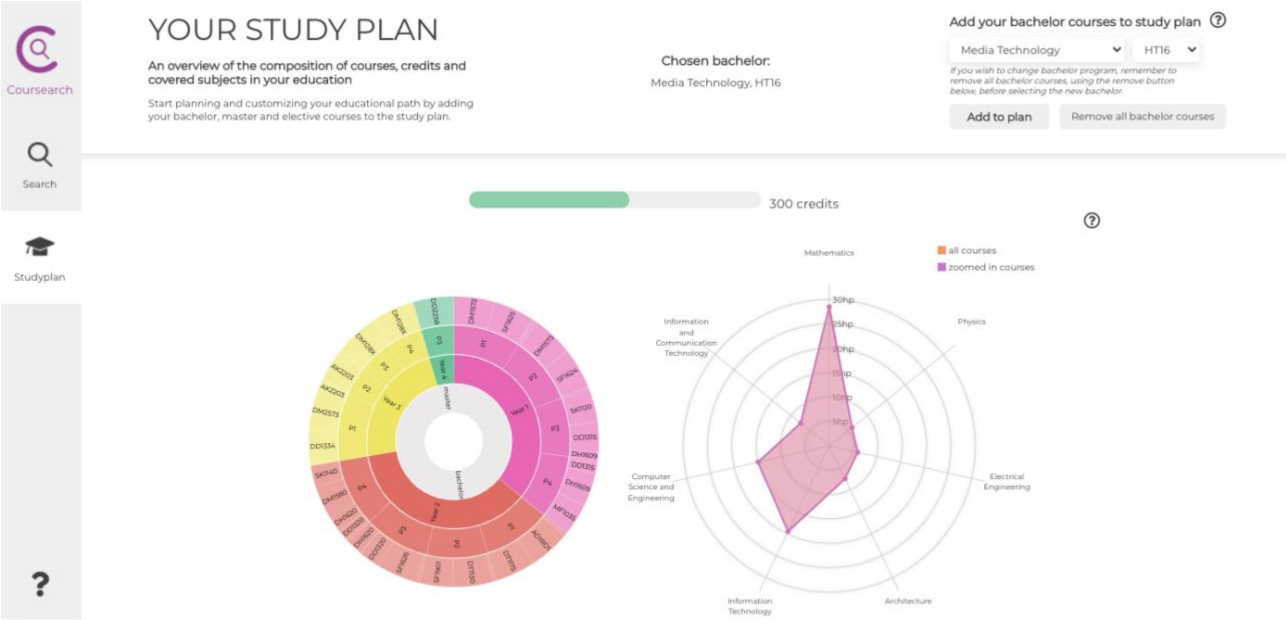

Image 7 *- Study plan with added bachelor courses from the program Information and Communication Technology*

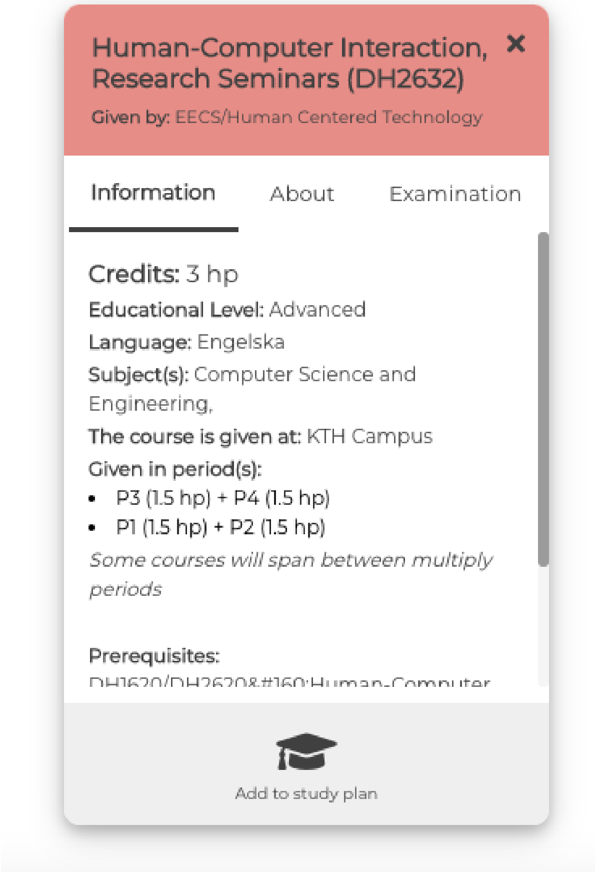

Image 8 *- Details card showing up when user clicks on a course in the search view*

Image 9 *- The visual representations in the study plan when zooming to Year 1 in the sunburst*

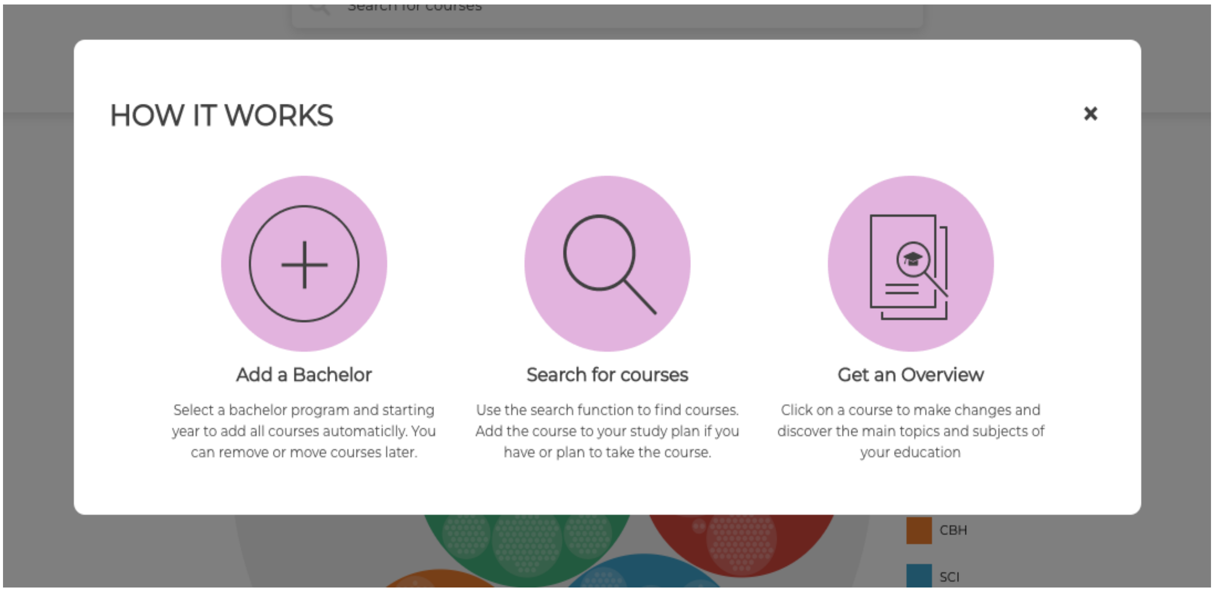

Image 10 *- a step-by-step section describing how the application works*

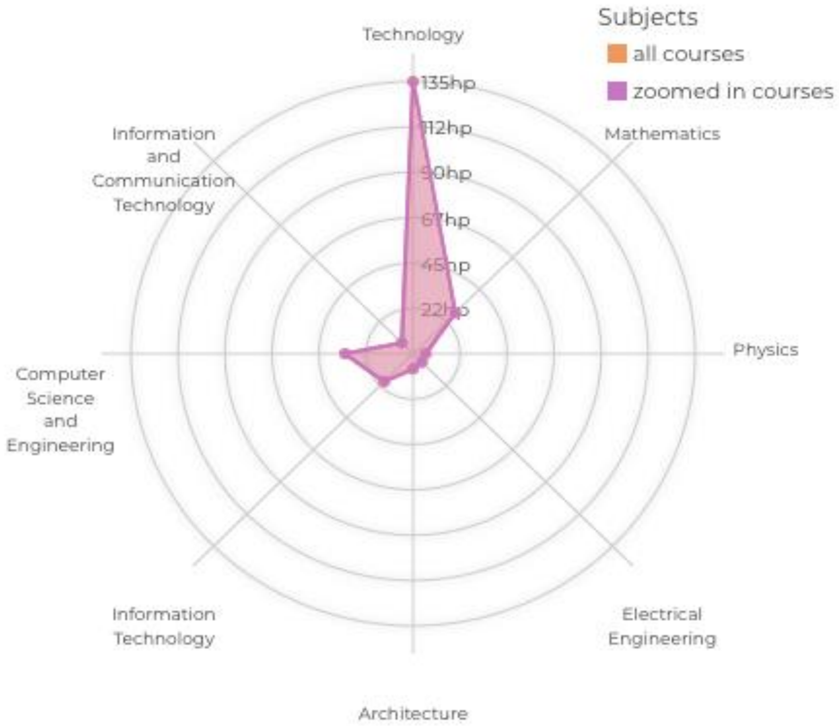

Image 11 - *The radar chart before excluding the subject "technology"*

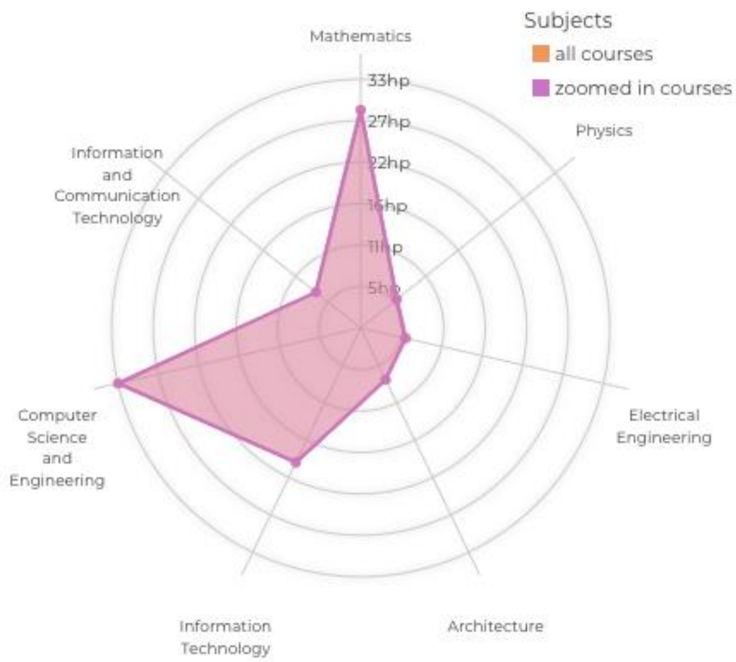

Image 12 - *The radar chart after excluding the subject "technology"*

Attachment 4 - Figures

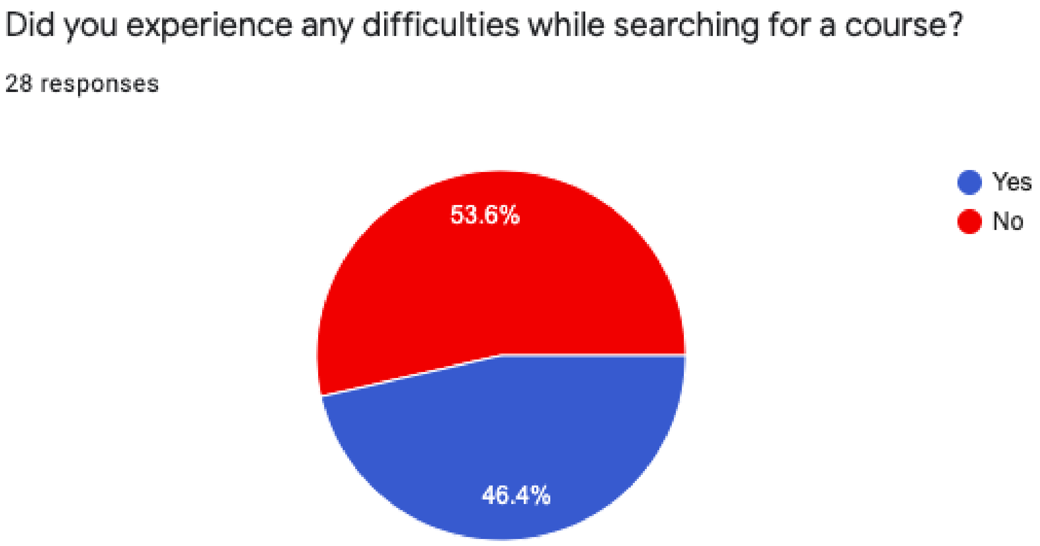

Figure 1 - *Survey answers of the question: "Did you experience any difficulties while searching for a course?"*

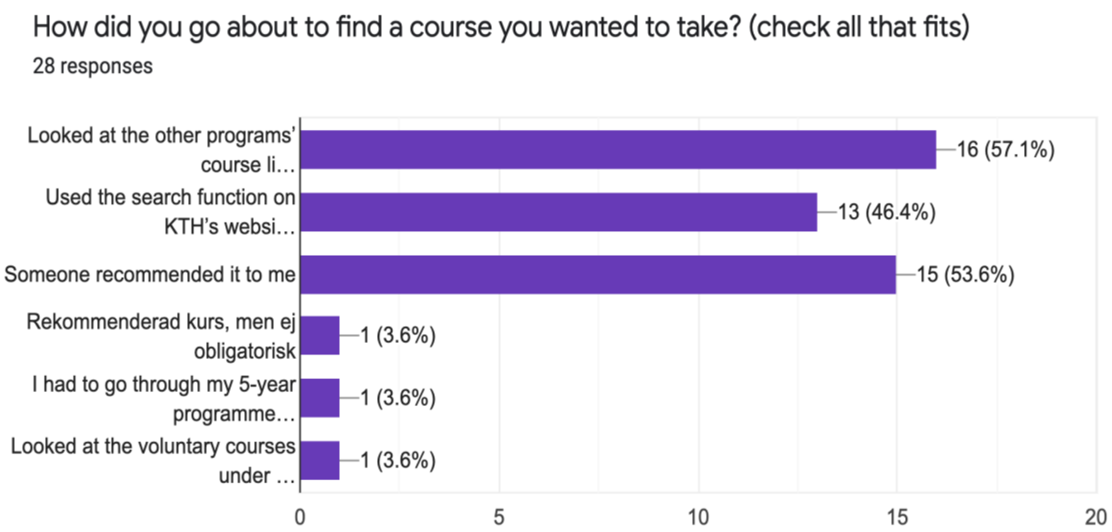

Figure 2 - *Survey answers of the question: "How did you go about to find a course you wanted to take? (check all that fits)"*

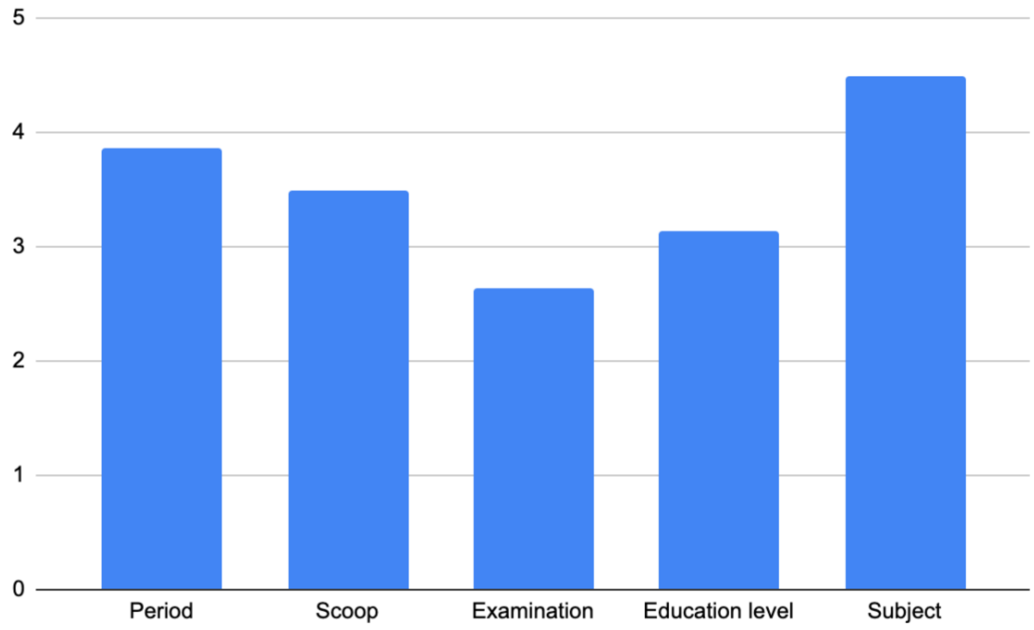

Figure 3 - *Survey answers of the question: "What criteria were most important for the course you were looking for? Please rank below the criteria after how important they were. (1 = Not important, 5 = very important)"*