A User Centric Approach to Visualizing Linked Educational Metadata in The ITC Geo Course Hub.

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JUNE 2024

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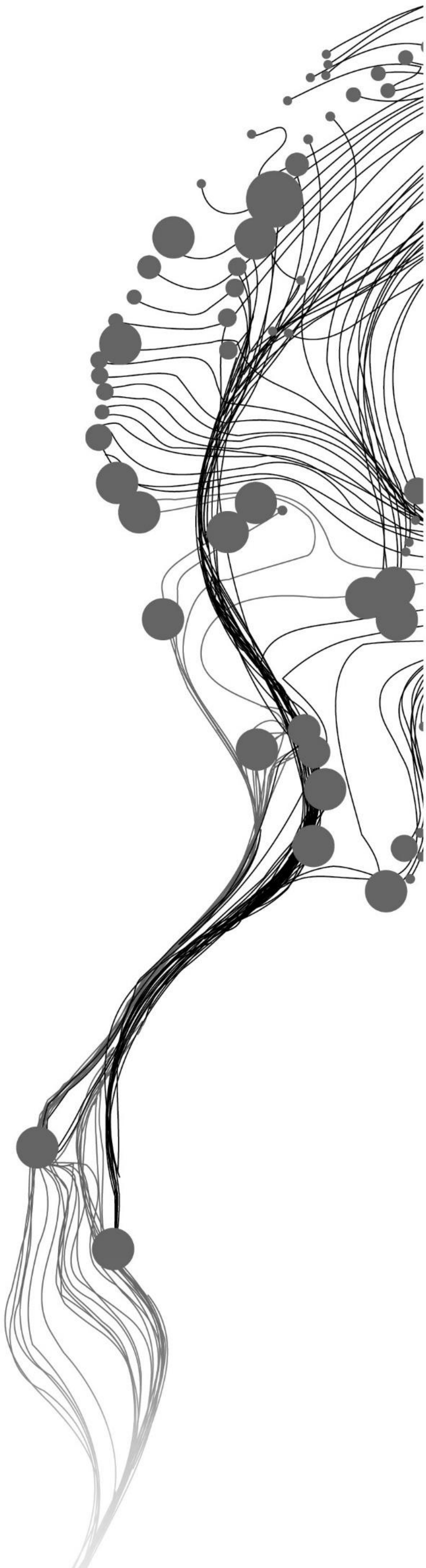

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Abstract:

This study explores the use of various visualization methods to enhance the presentation of linked educational metadata, focusing on creating a user-centric dashboard. The primary objective is to improve user experience and usability by addressing the specific needs of teachers through various visual and systematic techniques. The research involved identifying user requirements, employing different visualization methods, and developing a web-based dashboard followed by the usability study. A comparative usability study was conducted with nine teachers, evaluating both the existing and new Geo Course Hub dashboards. The study employed eye-tracking, think-aloud protocols, and surveys to gather data on user interactions and preferences. The findings revealed that the new GCH significantly outperforms the existing system in terms of effectiveness, efficiency, and user satisfaction. Users were able to access and interpret the linked educational metadata more accurately and quickly with the new dashboard. The study validates the hypothesis that a user-centric design approach enhances the usability and comprehensibility of data visualization systems. By integrating user feedback and applying principles of user-centered design, the research successfully addressed the limitations of the existing GCH. This research contributes to the field of educational data visualization by demonstrating the impact of user-centered design on the effectiveness of data presentation tools. It underscores the importance of involving users in the design process and leveraging their insights to create more functional and engaging visualization systems. Future work may focus on extending the dashboard's functionality, including mobile platform adaptation, and conducting broader usability studies to further refine and validate the system's effectiveness across diverse user groups.

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1. Introduction:

Data visualization refers to presenting data visually to help people comprehend its meaning. It identifies patterns, trends, and connections that need to be more easily noticeable in text-based data. By transforming datasets into visual representations, data visualization facilitates the human brain in understanding and processing information. We frequently encounter data visualizations in the form of charts and graphs, which reveal insights and uncover hidden facts and trends. When executed effectively, data visualizations combine communication, data science, and design principles to offer meaningful and intuitive interpretations of complex datasets (Islam & Jin, 2019).

1.1. Goal:

This research aims to improve and develop educational metadata visualization, specifically targeting curriculum offered in an educational institution within the linked data framework. Curriculum refers to the various courses and their content that are offered to the learners in educational institution like a university. Curricula consist of different guidelines, plans, learning experiences and learning outcomes which are designed by following a systematic construction of knowledge and experiences (Young, 2014). ITC Geo course Hub (GCH) is an online platform that contains information about the variety of Geo-courses, practical sessions, and training programs provided to the students at ITC. By focusing on the ITC GCH, the aim is to contribute to the improvement and development of visualizations where needed. Educational resources in the context of the GCH are the different courses that are present, and the metadata are the information such as description of the courses, course duration, number of staff, learning outcomes, etc. The visualizations seek to provide an understanding of the relationships, patterns, and semantic connections within educational resources and their metadata. This will help in identifying the strengths and weaknesses of individual course and the alignment of the properties such as topics or concepts of one course with another. This will help teachers in creating and examining the course's learning activities, learning objectives, and lessons. The goal is to provide an easier understanding curriculum design by offering user-friendly visualizations that facilitate informed decision-making and promote meaningful insights derived from the interconnected educational metadata within the GCH.

1.2. Problem:

The problem addressed by this research lies in the complexity of analyzing vast amounts of educational data within higher education institutions. Majority of educational institutions utilize databases, either relational or linked database to manage and store their data. These databases provide the facilities which are essential for data manipulation like CRUD (Create, Read, Update, Delete) operations. Acquiring information by using queries require technical expertise and knowledge which all users do not possess. In the context of this research the data is stored in a linked database, while techniques like SPARQL query language is a potent tool for querying linked data, there is a challenge in making this capability accessible to a broader audience. The research identifies the need for a solution that goes beyond the technical proficiency required for SPARQL, posing the question: How can educational metadata, crucial for curriculum, be effectively presented to ensure easier analysis and extraction of meaningful insights? The proposed answer lies in the creation of a visualization dashboard, offering a more user-friendly alternative to SPARQL. Dashboard refers to a place where various type of visual, graphical, tabular, or text-based representation of data is displayed to the end user in combination at the same time (Indeed Editorial Team, 2023)(Figure 4). It presents the end user with the required information in one place to answer the question that the user has in its mind. Dashboards uses charts, graphs, tables, and other visual elements to present the information or data in easy to digest form. Dashboard has several advantages over SPARQL query such as user friendliness, simplified information communication and interactivity. Through this approach, the research seeks to bridge the gap between the richness of educational data and the usability required for informed decision-making within higher education institutions. The aim is to provide a clear picture and meaningful insights, ultimately facilitating informed decision-making and fostering a deeper understanding of GCH Linked Data.

Moreover, Despite the utility of the current visualizations within the GCH, certain limitations hinder their effectiveness, particularly when dealing with extensive datasets and complex relationships. The existing visualizations, such as bar charts and tree maps, excel in presenting quantitative data related to themes like "specialization programs". However, challenges arise when applied to themes with huge data, as seen in "topics covered by the courses."

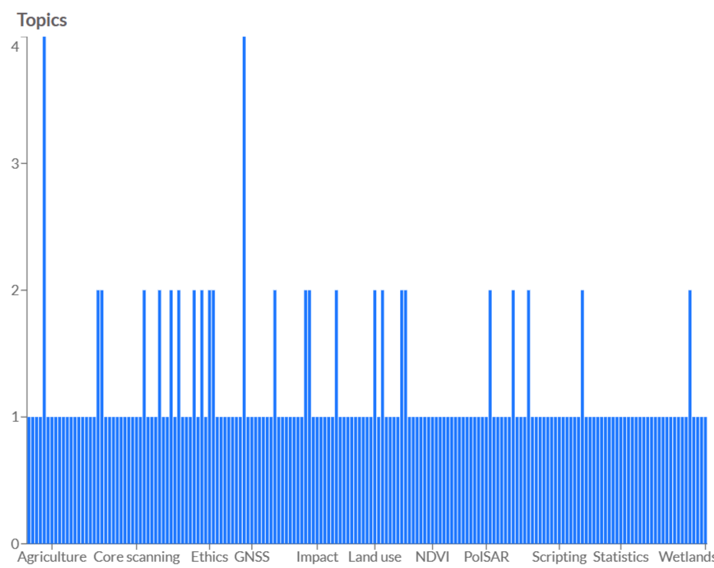


Figure 1 Bar chart in existing GCH.

One prominent limitation is visual cluttering, where the abundance of information makes it difficult for users to discern meaningful patterns. The use of a single color worsens this issue. To address this, proposed solutions involve the implementation of categorization and filtering mechanisms, enabling users to organize and streamline data based on specific criteria.

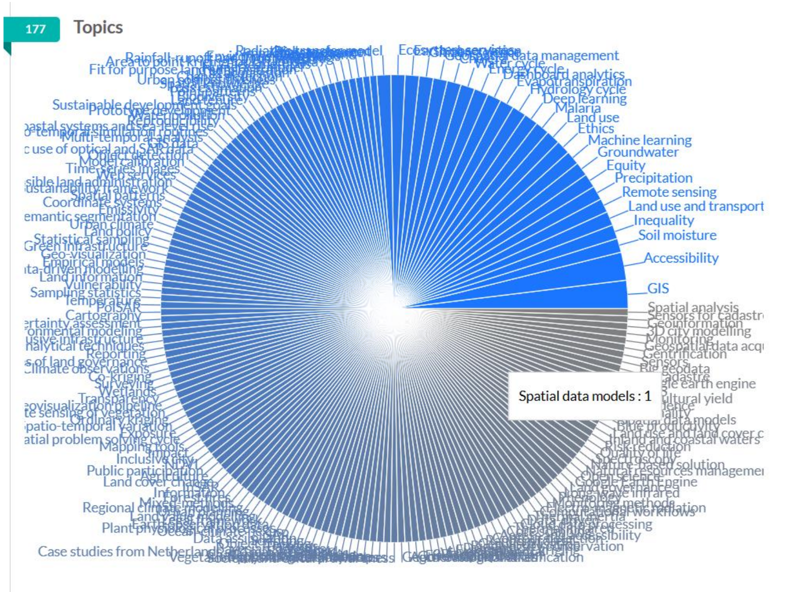


Figure 2 Pie chart in existing GCH.

Another limitation lies in the lack of representation of courses with their properties. Users currently struggle to identify the desired course, their properties, and how courses are interconnected to one another. Introducing various graphs and filtering features aims to enhance the depth of understanding by revealing relationships based on topics, sequential order, or shared specializations. To overcome these limitations, the envisioned GCH dashboard will prioritize user-centric design principles, that aligns with the needs of teachers. The visualizations aim to make a more user-friendly and insightful exploration of educational metadata.

1.3. Research gap:

Information visualization proves helpful in effectively presenting large amounts of data. A potential research area to explore is the potential of information visualization to enhance the accessibility, comprehensibility, and utilization of linked educational metadata. The relationship and connection between data entities in the GCH can be interpreted more easily using various visualization techniques. Visualizing the GCH will help introduce problem comprehension to the existing information or knowledge already present, ultimately enhancing decision-making processes and fostering a deeper understanding of the linked data within educational metadata.

1.4. Importance of research:

In this research, the content of the ITC GCH website will be visualized. The website contains information about the courses that are offered at ITC. The data shown on the website fosters rich interconnection between the different data elements. The research focuses on the critical need to visualize this linked data effectively, providing users with comprehensive, intuitive, and insightful representations. Exploring and enhancing the visualization techniques employed within the GCH will advance the current state of the art by creating a visualization dashboard for the GCH. The aim is to unlock the full potential of GCH resources by strategically using information visualization techniques according to the users mentioned.

Especially today, when a massive amount of data is being collected daily, and connections between these data sets are of utmost importance, it becomes clear to develop an effective way of visualizing this big data (Bikakis & Sellis, 2016). The main aim of visualizing the data is to reduce the cognitive burden on humans, allowing them to subconsciously solve the cognitive task. It can be achieved by using the human visual capacity to identify patterns, process information before conscious awareness, and remember visuals to create an impactful visual representation (Tervakari et al., 2014).

Visualization plays a crucial role in the exploration of linked data, enhancing the capabilities of users to understand its meaning when presented visually to them (Qin et al., 2020). Linked data Visualization can enable discovery and exploration; it allows users to start understanding previously unknown data and better understand the overall dataset. It can also help users focus on specific parts of the dataset, and visualization is likely the only way for users who need more technical skills to grasp the meaning of the content of linked data sources (Po et al., 2020). It can help the user save time and ensure data quality by comprehending the intricate structure of the data, uncovering outliers, and recognizing patterns, clusters, and local trends (Unwin, 2020). It helps the analyst better understand the data and what they are dealing with, making it easier to explore and derive effective results from the linked data.

Linked Open datasets are published in a format designed to be as informative as possible, but this can make them challenging to understand (Helmich et al., 2017). Due to this reason, an expert is always needed to interpret the data and create an understandable view. According to Kuck (2004), the semantic web is a framework that allows the data to be shared and reused across different platforms to make the data machine readable. It is vital to involve more general users to make it easy for them to explore and visualize the world of the semantic web and linked data. This can be done by developing tools and resources that support data consumers in quickly getting visualizations that enable them to explore a dataset (Atemezing & Troncy, 2014). Visualization serves as descriptive summaries of large scale linked data sets, offering users a quick and intuitive way to grasp the essential information and relationships within the data, making linked data more user-friendly for the users (Ghorbel et al., 2017).

1.5. Main Objective and Sub-objectives:

The main aim of the research is to create a data visualization system that can improve the exploration of educational metadata based on linked data, such as GCH while considering the teachers' needs.

1. Design a user-friendly interface tailored to the needs of teachers interacting with the GCH.

   RQ1: How can the dashboard interface be structured to accommodate the specific preferences and queries of teachers?

   RQ2: What visual elements and navigation features would optimize the user experience for teachers exploring linked educational metadata?

2. Incorporate semantic maps or hierarchical charts to reveal contextual relationships among courses, specializations, and courses metadata.

   RQ3: To what extent can semantic maps and hierarchical charts be interchanged in visualizing linked educational metadata within the GCH, and how does this interchangeability impact users' understanding of contextual relationships between courses, specializations, and courses metadata?

3. Implement categorization and filtering options to streamline the display of data, addressing issues of visual cluttering.

   RQ4: What criteria should be considered for the effective categorization of educational metadata to improve visualization clarity?

   RQ5: How can filtering mechanisms be customized to allow teachers to focus on specific aspects, such as topics, quartiles, or specializations?

4. Conduct usability testing sessions to evaluate the overall effectiveness and user satisfaction of the developed dashboard and visualization.

   RQ6: How do teachers perceive the overall usability and functionality of the data visualization system during usability testing sessions?

   RQ7: What specific usability challenges or positive experiences do teachers encounter, and how can these insights inform further refinements to the system?

Hypothesis: The research hypothesizes that implementing a user-centric data visualization system within the GCH will enhance the accessibility and understanding of linked educational metadata, facilitating informed decision-making for teachers.

2. Literature review:

2.1. Information visualization:

Nowadays, a massive amount of data is being collected daily by various organizations ranging from small to large, from corporate organizations to research or educational organizations. Much research is being done in information visualization as it helps gain meaningful insight from data and plays a crucial role in understanding, analysis, and decision-making processes. Data visualization impacts strategic cognition (Eberhard & Wulf, 2023), meaning it motivates the users to assign meaning to their goals and strategies to guide themselves in achieving specific tasks. Visualization improves the visual representation of the data, which leads to the effective communication of information. Maps visualize geographic data, while scatter plots and charts mainly present quantitative data (Li, 2020). Combining artistic thinking with logical data in information visualization design is essential, as it enhances users' memory and improves their experience. These artistic elements provide aesthetics and promote engagement and emotional connection of the user with visualization, whereas accuracy and meaningfulness are ensured using logical data. Combining these two results in visually appealing, memorable, and user-friendly visualizations that effectively communicate complex information (Rui et al., 2023). Link data visualization also rapidly evolves as users and the research community develop new tools and techniques. For example, A web-based tool, LDViz, enables the user to explore and visualize knowledge graphs using SPARQL (Menin et al., 2023). Another is the web browser by the name KGBrowser, which is also for exploring and visualizing linked data (Nečaský & Stenchlák, 2022).

2.2. Dashboard and educational data visualization:

In information visualization, dashboards are powerful tools for visualizing and analyzing large and complex datasets. According to Mazumdar et al., (2014), the dashboard allows its user to explore the linked data through multiple perspectives in a flexible and customizable way because the dashboard has the property to present multiple visualizations to its user, which can enable them to select the appropriate visualization according to their needs and requirements. It lets the user see the big picture by quickly identifying the most relevant and vital information, trends, and general patterns (Few, 2006). The use of dashboards is more frequent because various organizations collect and store more and more data day by day. So, designing an effective and user-friendly dashboard is of utmost importance. Bach et al., (2023)provide an overview of eight design patterns to help dashboard designers create more effective, narrative, analytical, and embedded dashboards. Researchers can also use these patterns to develop new design guidelines and evaluation methods for dashboards. When designing a dashboard, a vital factor to consider is the users who are going to use the dashboard. For the user group that is going to use the GCH, the dashboard will be according to their needs. The most common visualization components used in adaptive dashboards are charts, graphs, and maps, and the standard techniques to make these elements adaptable are filtering, aggregation, organizing the data, and changing the visualization of the data depending on data types and needs of the users (Contreras et al., 2022). Another critical factor is interactivity, as it makes the dashboard more valuable and informative for the users, as users can get more information out of the data. If dashboards are designed carefully, such as if they contain too much data or the user needs to be more skillful to use them effectively, it can waste users' time. To mitigate these challenges, several strategies provided by (Alhamadi, 2020), such as designing a dashboard with a clear focus and purpose to help users understand what information is essential and what they should be looking for, providing the user with a small demo or training on how to use the dashboard effectively. This will aid the user in interpreting visualization and make the dashboard user-friendly.

Over recent years, several tools and techniques have been developed that visualize educational metadata in an informative, engaging manner and are available to various users. However, it is still in the early stages and is currently evolving. Data visualization can help the user explore and browse the content by providing the scope and context of a collection more easily. According to Miller, (2019), visualizing digital collection data positively impacts user participation. It helps users connect the different items, pursue their research interests, and discover new materials. The interactivity of the visualization keeps the user engaged and encourages them to explore the digital collection. It can be used to present the digital collection in innovative manners like interactive narratives, timelines, and maps. The author interviewed the users of digital collection and surveyed them to find out about their experience and satisfaction and collect quantitative data on their use of the visualization. It allows the author to draw firm conclusions about the benefits and challenges of using data visualizations in digital collections. Niemiec, (2020), introduces an innovative approach to curriculum mapping through the application of data visualization techniques. The study emphasizes the limitations of traditional curriculum mapping and underscores the significance of visualizing connections across curricula, particularly in fields like architectural education. Using a Bachelor of Architecture program as a case study, the paper illustrates the potential of visualizations to uncover patterns and connections in a curriculum. Various visualization types, such as alluvial diagrams and contour plots, are employed to examine learning objectives, their distribution, and assignment difficulty over time. The findings support the effectiveness of data visualization in curriculum mapping and suggest future research on optimal visualization types and their correlation with student assessments.

The thesis presents educational data in an efficient way by utilizing different visualizations. The hierarchy of courses within specializations is depicted using a hierarchical chart, which offers an easily understood structure for course organization. The relationships between courses and their different properties are represented by a semantic map, which makes it easier to comprehend how the interconnected data is put together. Furthermore, while descriptive information is communicated through text, tables are utilized to provide concise information, such as the number of credits and the start dates of the courses. The interconnectivity of these visualizations improves the user's capacity to effectively digest and analyze the educational data.

2.3. Usability Study:

Once the dashboard is developed, testing it for the ease of use whether the proposed designed fulfills its goals is an important part of a development phase. In a case study conducted by Ansari, (2024), 20 domain experts participated in paired-user virtual data collecting sessions to determine the specifications needed to create acceptable public health data dashboard. There were three steps in the process, firstly, a survey to score the user experience, secondly an interview with users and use cases and lastly the observed use of an existing dashboard to perform tasks and address usability issues. The analysis encompassed both theme analysis of the audio transcripts and quantitative evaluation of the survey results. Key findings showed that dashboards should use recognizable charts with obvious labels and legends to draw users' attention to the content; they should also arrange charts in an easy-to-understand layout; provide contextual information to help with interpretation; make data limitations clear; and provide guidance to encourage user interaction.

Țichindelean et al., (2021) investigates the usability of various websites to identify the structure, elements, and design features that enhance web page usability. The study employs multiple methods, including eye-tracking, task performance evaluation, and subjective feedback surveys. The eye-tracking method collects detailed data on users' visual attention, generating metrics such as fixation duration, order, locations, rapid movements between fixations, and revisits. This method aims to observe user behaviors and determine which website elements capture the most attention. The second method involves task performance, where users are assigned specific tasks to assess the efficiency and effectiveness of the websites. Lastly, participants complete a survey after interacting with the websites to provide subjective feedback. The study's findings highlight key usability factors that can be incorporated into website design to create more sustainable and user-friendly web pages.

Richter Lagha et al., (2020) conducted a study focusing on the effectiveness and intuitiveness of a clinical dashboard. The study involved virtual observations of participants interacting with the dashboard, utilizing think-aloud moderating techniques. The think-aloud method provided insights into participants' decision-making processes and the difficulties they encountered. The study's findings include identifying functional problems in the dashboard design, improving system usability, and emphasizing the importance of using multiple usability methods. The research suggests that relying solely on questionnaires may obscure certain usability issues, thus advocating for a more comprehensive approach to usability testing.

The proposed methodology for the usability study in this research involves a combination of think-aloud protocols and eye-tracking techniques. At the end of each session, participants are requested to complete a questionnaire related to specific aspects of the dashboard and the overall usability experience. Each method illuminates different facets of the study, and the results from all three methods complement each other, helping to identify issues that might be missed when using a single method. This multifaceted approach ensures a more comprehensive evaluation of the dashboard's usability.

3. Methodology:

The methodology developed for this research is a process that includes data consideration and collection, analyzing requirements, designing, developing, and conducting usability tests. This methodology is based on user-centric design principles and incorporates insights from teachers about a data visualization system that not only fulfills the needs of educators but also substantially improves the exploration of connected educational metadata within the GCH.

3.1. Dataset:

The dataset for this research consists of educational metadata sourced from the original GCH website. This metadata includes various details related to courses, such as the specialization in which the course is offered, the concepts covered, and the learning outcomes. The data utilized in the creation of the dashboard for this research is obtained from the Platform "Linked Data Netherlands" (PLDN) database. The data acquisition process will be explained in a subsequent section. The Figure 3 illustrates the structure of the data:

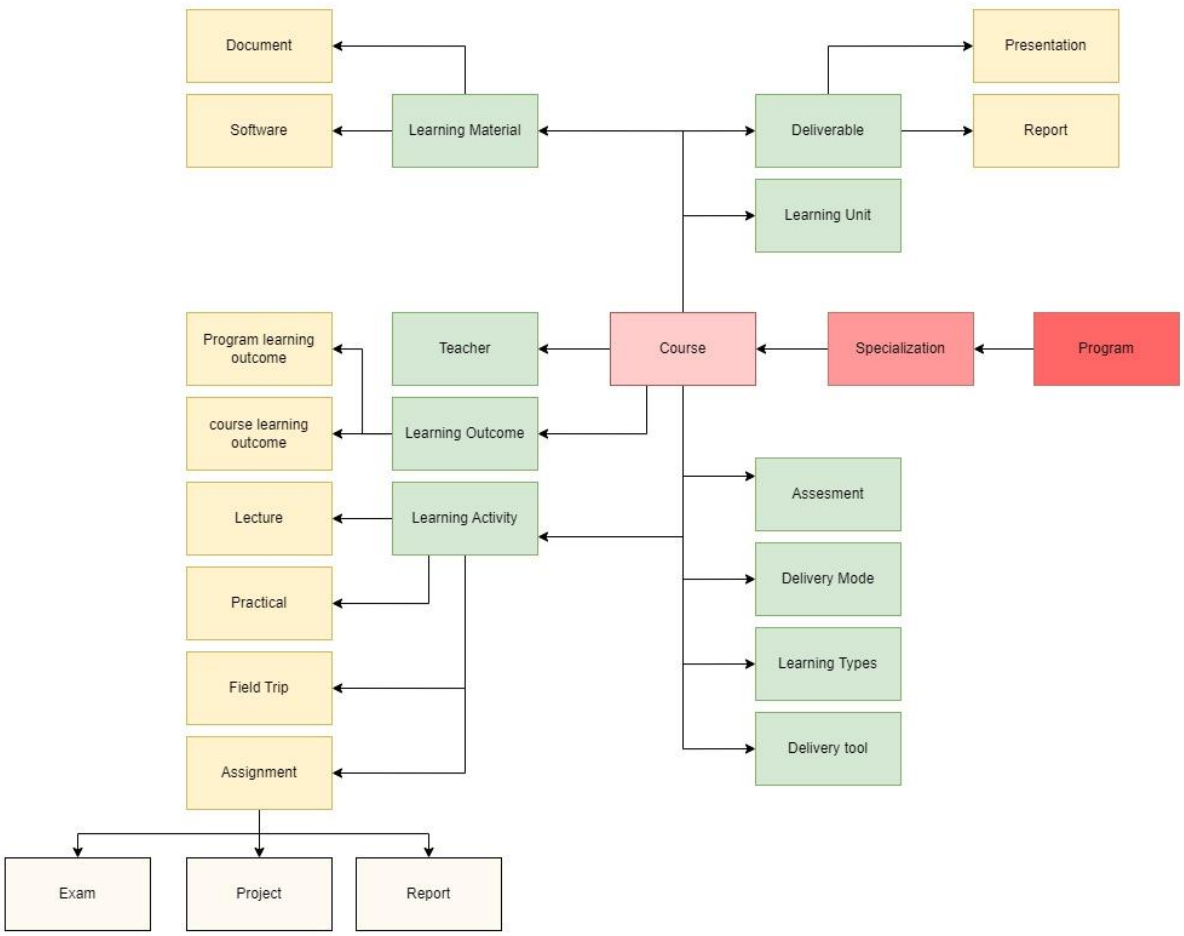


Figure 3 Structure of the metadata of a course.

Figure 3 includes information on Programs, representing broader academic categories; Specializations, indicating focused tracks within programs; Courses, providing details on individual academic offerings. Assessment records encompasses evaluation methods, while Delivery Mode and Learning Type outline how courses are presented and the nature of the learning experience. Delivery tools denote the technologies employed in course delivery. Teacher entities represent the educators associated with courses. Learning Outcomes are delineated into Program Learning Outcomes and Course Learning Outcomes, highlighting course-specific educational objectives. Learning Activities encompass instructional methods, such as Lectures, Practical, Field Trips, Assignments, Exams, Projects, and Reports. Learning Materials encompass documents, software, deliverables, presentations, reports, and learning units.

Unfortunately, not all the GCH data is utilized in this thesis research due to the incomplete nature of the information available for each course. Some courses lack details on learning units, while others are missing information related to concepts or prerequisite courses. Only one course, "From Data to Geo-information for Natural Resources Management," contains mostly complete information compared to the other courses. This course includes learning activities and their allocated times, but it also contains redundant information that required preprocessing before it could be used for visualization. The incompleteness of the data is attributed to the early stages of the GCH's development. As the project progresses, it is anticipated that the dataset will become more comprehensive, with missing information being added for all courses and the data will be made standardize to avoid redundancy. Information related to the sub-concepts of a main concepts like “narrower concepts” was added to the database upon request by the author to the creator of the GCH database to illustrate related concepts and identify concepts not covered in any course.

To create a meaningful and valid dashboard, data selection became a crucial step. The dashboard must present data that is comprehensive and consistent across all courses to ensure validity. The selected data should meet user needs and requirements, as outlined in the methodology's user section. With these considerations in mind, it was decided to present course-related data based on specializations and concepts for the first view of the dashboard. Courses categorized under concepts represent elective courses, while those under specializations represent core courses. Core courses should also be included under concepts since they contain relevant concepts; however, this integration is limited by data availability in the database. For the second and third views of the dashboard, various course-related data such as learning outcomes, prerequisite courses, and comments are displayed. The choice of data for these views also depends on its availability across all courses to maintain consistency. However, some courses lack certain data, and the approach to handling these gaps is detailed in the Implementation (sub-section 3.4.2.3) section of the methodology. The selected datasets form the foundation of this research, enabling the exploration of Linked educational metadata within the GCH dashboard. Understanding the relationships between these entities is essential for comprehending the curriculum and educational outcomes, which are crucial for developing an effective data visualization system to assist users.

3.2. User and user requirements:

3.2.1. Users:

In this research, the user group is teachers within the educational context of the ITC GCH. As the facilitators of the learning experience, teachers play a pivotal role in curriculum development, course design, and the overall educational process. The focus is to understand and cater to the specific needs and expectations of teachers as they engage with the linked educational metadata within the GCH dashboard.

Teachers as users, seek valuable insights into the courses, learning outcomes, and concept covered by a course. They may be interested in analyzing the strengths and weaknesses of the current curriculum, identifying areas for improvement, Identifying the concept which is not covered in a course or identifying a common concept between the course to avoid overlap in the lectures, and aligning the courses with educational goals and learning objectives. Additionally, teachers may want to explore new possibilities for course creation, updating existing content, or discovering relevant learning out-comes.

Creating visualizations and the overall dashboard to meet the requirements of teachers is important. This involves a requirement analysis to understand the requirements for their queries and preferences. The visualizations should empower teachers to efficiently navigate through the interconnected educational metadata, providing them with a holistic view that aids in decision-making, curriculum planning, and the enhancement of the overall teaching and learning experience. This will ultimately lead to creating visualizations that are not only informative but also practical and user-friendly for educators. The success of the visualization dashboard hinges on its ability to seamlessly integrate with the workflow of teachers, making the exploration of linked educational metadata a seamless and beneficial endeavor within the GCH.

3.2.2. Use case scenarios:

During the requirement analysis phase, use case scenarios were developed to capture and address the specific needs and interactions of the teachers with the GCH dashboard. Dr. Hanif, a university professor who is expert in visualization, intends to develop a course titled "Application of Visualization in GIS." Upon recommendation from his colleagues, Dr. Hanif discovered the Geo-course Hub dashboard. As illustrated in Figure 4, upon accessing the dashboard, the initial view presented is the "General Overview." This view allows users to choose between exploring a concept or a specialization. Interested in the concept of "Visualization," Dr. Hanif selects the concept option from the left-hand menu.

Following his selection, he can search for the concept “visualization” using the search bar or browse through the options. By clicking on the concept, a hierarchical chart, as detailed in the Visualization section of the methodology, appears. This chart displays narrower sub-concepts at the top, the primary concept in the center, and the relevant courses covering this topic at the bottom. Additionally, the top right corner of the chart includes a legend for reference. Below the chart, a table provides additional information related to a course such as course start and end dates, quartile, and course number.

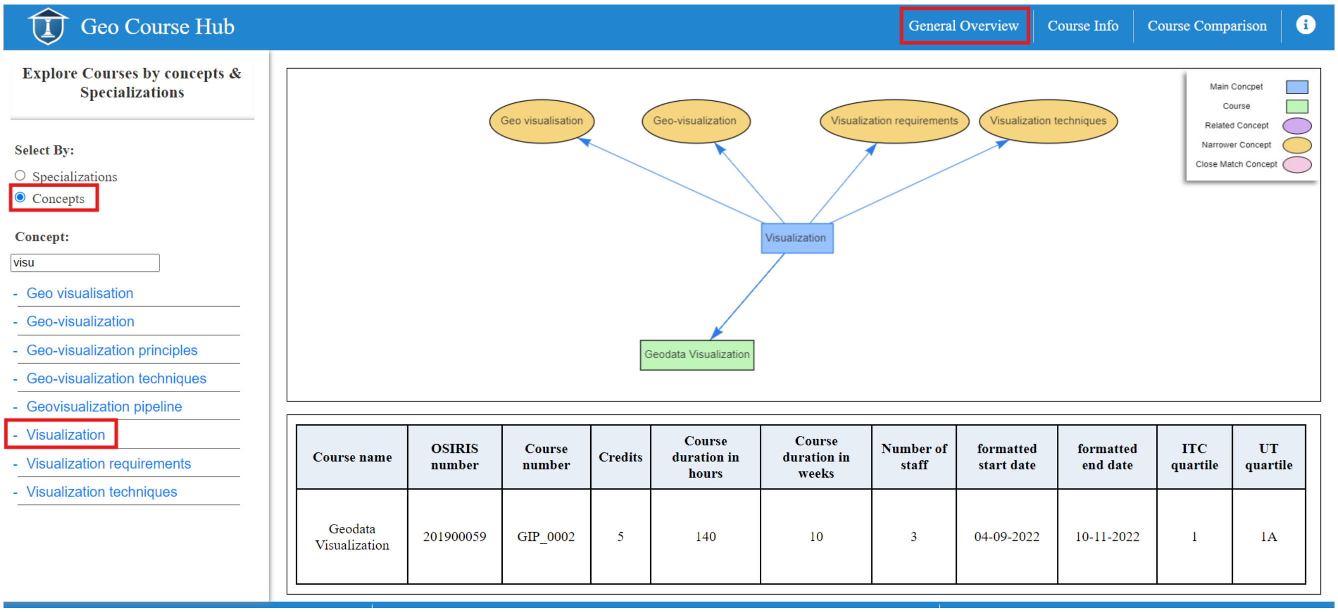


Figure 4: Hierarchical chart of the concept.

To gain more insights into the course "Geodata Visualization," Dr. Hanif navigates to the "Course Info" tab, as depicted in Figure 5. Like the "General Overview" tab, he can select the course by either searching for it or browsing through the list on the left-hand side. Upon selection, a semantic map detailed in the Visualization section of the methodology, illustrates the course and its attributes, such as concepts and learning outcomes.

Below the chart, a table provides additional information about the selected course. Dr. Hanif can click on any node within the semantic map to view detailed information about that specific component on the right side of the dashboard. This allows him to access the course description by selecting the name node of the course or identify which concepts are covered in the course by selecting the respective concept node. Additionally, he can further explore related concepts by clicking on them, as shown in Figure 6.

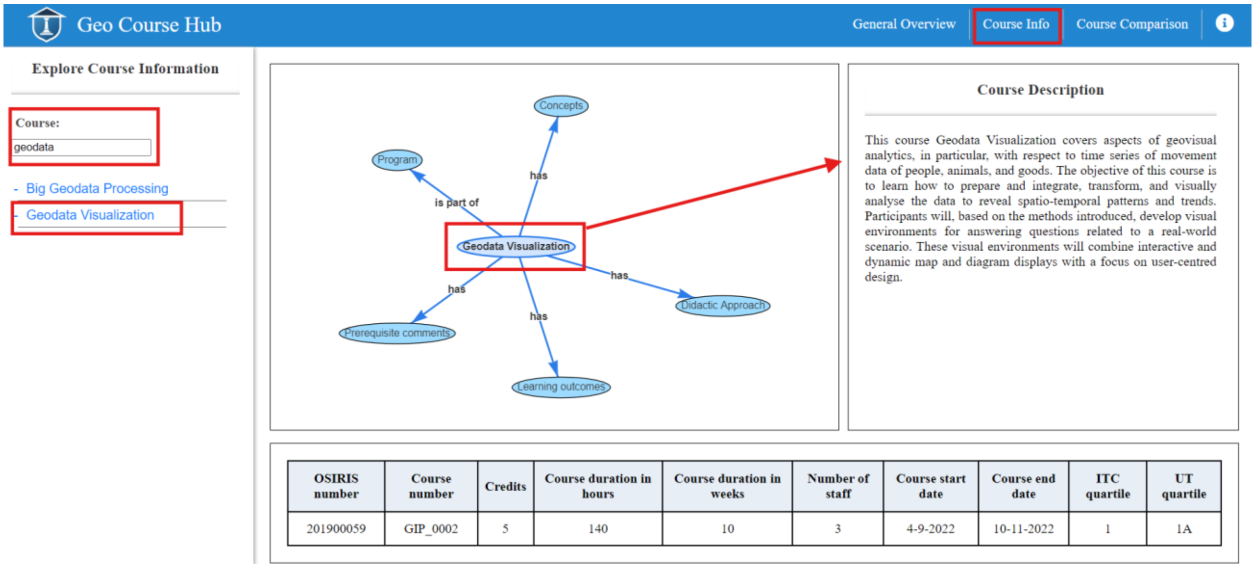


Figure 5 Semantic map of a course.

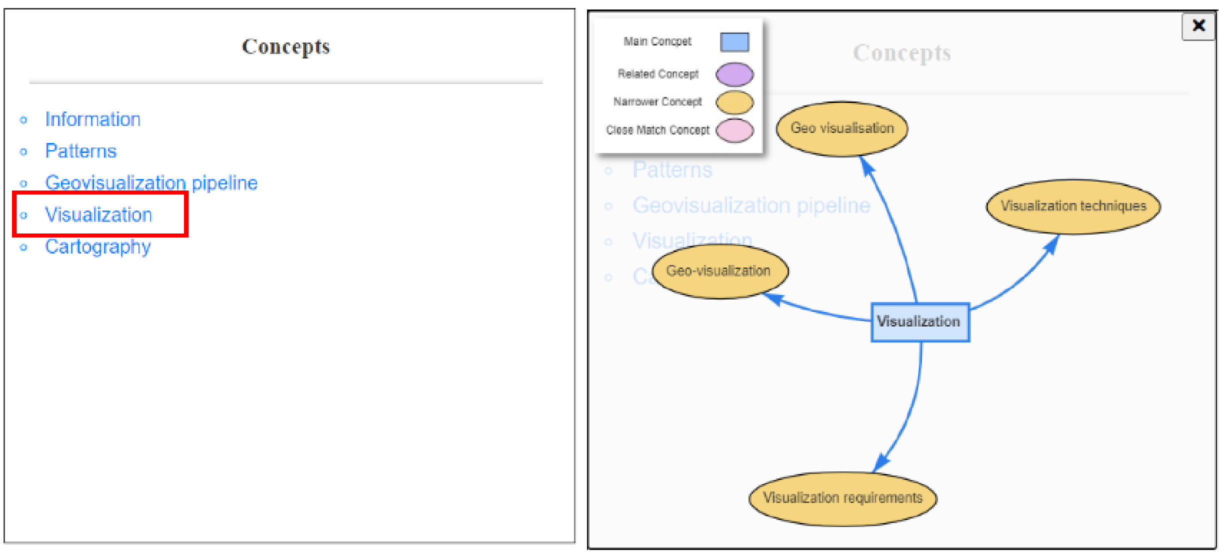


Figure 6 Semantic map of the sub-concept related to the main concept of the course.

In another scenario, Dr. Hanif seeks to compare two courses: "Big Geodata Processing," which he is currently teaching, and "Advanced Image Analysis." He aims to determine whether these courses share common concepts. If students have already completed the "Advanced Image Analysis" course, Dr. Hanif can focus less on the concepts that overlap between the two courses. Additionally, he might consider adding some concepts to his own course from the "Advanced Image Analysis" course.

To facilitate this course comparison, Dr. Hanif navigates to the third view of the dashboard. Using the sidebar, he selects the two courses from the respective drop-down menus. This action generates two semantic maps displayed side by side. By clicking on any node within these maps, detailed information about the specific properties of each course is revealed below the corresponding chart, as illustrated in Figure 7. This feature enables Dr. Hanif to efficiently compare the content and structure of the two courses.

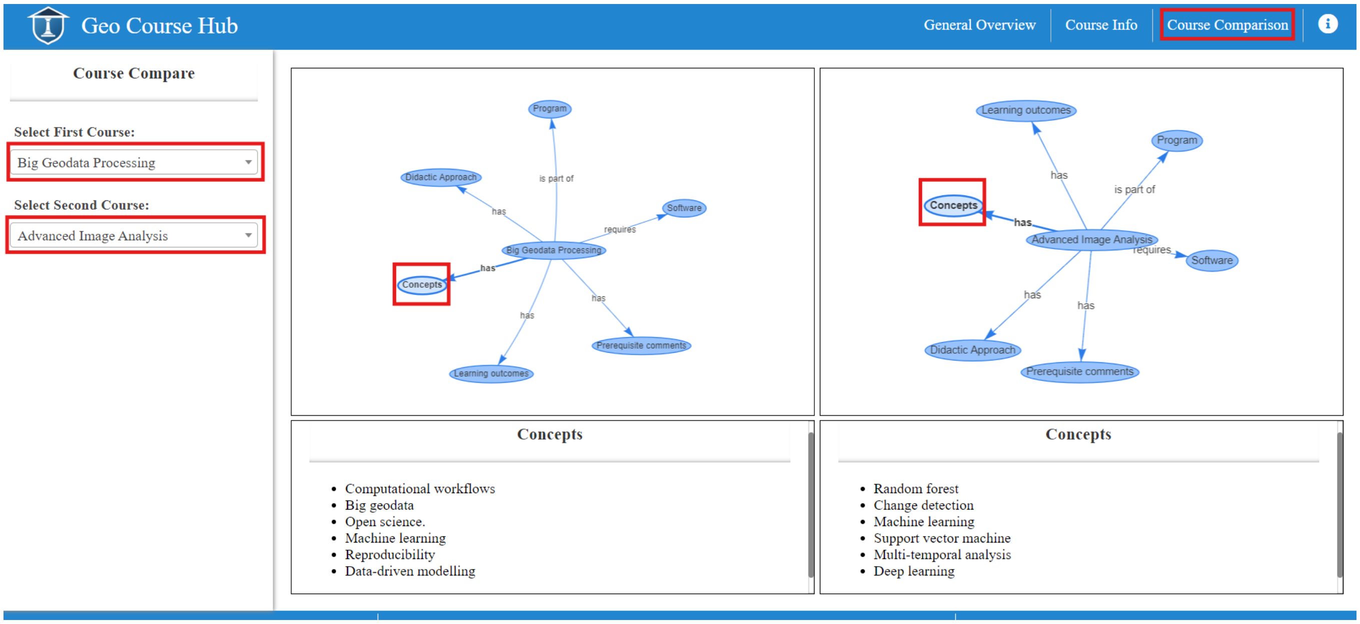


Figure 7 Course comparison view of dashboard showing the comparison of the two courses.

3.2.3. User requirements:

The user requirements for the Geo-course Hub dashboard are derived from user stories, which are detailed in use case scenarios. To ensure the dashboard meets user needs, these requirements become an integral part of the development phase (Martin et al., 2002). User requirements describe the qualities, functionalities, characteristics, and features that the dashboard must possess to satisfy and fulfill user needs. Collecting user requirements is beneficial as it ensures the project's success, reduces rework, and costs, and provides a clear understanding of the project scope.

User stories collected by the developers of the ITC Geo-course Hub play a crucial role in forming the foundation of these user requirements. These user stories encompass various scenarios and situations users might encounter while interacting with the platform. They offer a detailed account of a user's goals, motivations, and expected outcomes within the system, thereby shaping the development to align with real user experiences and expectations.

The availability of course data was pivotal in shaping both the user requirements and the design and visualization of the dashboard. It is essential for the dashboard to present visualizations that are coherent and applicable across all courses. While minor differences may exist, each course should consistently include elements such as concepts and learning outcomes. This consistency ensures that the dashboard effectively supports user needs and provides meaningful and uniform visualizations for all courses. By standardizing these core elements, the dashboard can offer a more streamlined and user-friendly experience, facilitating easier comparison and analysis across different courses.

3.3. Visualization:

Building on insights gained from user requirements and available data, the goal was to create visualizations suitable for presenting each type of data. These visualizations needed to fit within the provided space and remain visually clear, while prioritizing a user-friendly interface tailored to the context of educational metadata. The implementation of these visualizations is detailed in the following section of this chapter.

3.3.1. Hierarchical Chart:

In Figure 8, a hierarchical chart is utilized to present the data to the user. A hierarchical chart is a graphical representation where entities are arranged from top to bottom, with lines indicating connections or subsequent levels (Elmqvist & Fekete, 2010). This type of chart effectively illustrates the hierarchy or relationships among various entities. The hierarchical chart is employed because the data represented follows a hierarchical structure. The chart aids users in comprehending the organization and relationships within the information presented. For instance, the initial view displays courses based on the user's selection of either "specialization" or "concepts." At the top, the main entity, such as specialization, is shown, followed by the core courses offered within that specialization.

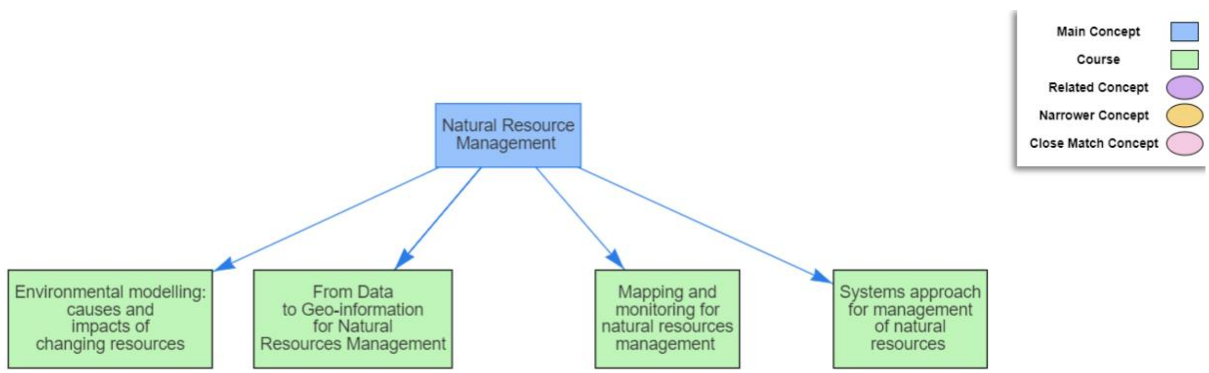


Figure 8 Hierarchical chart showing the core courses offered in a specialization.

3.3.2. Table:

Additional information, such as course number, start and end dates, and other details, is displayed in the table below the charts. When a user clicks on one of the courses in the chart, the corresponding row in the table is highlighted, as illustrated in Figure 9. The use of a table for this type of data is advantageous because it allows for the clear and organized presentation for such kind of information. Tables facilitate quick comparison and easy access to specific details, enhancing the overall user experience by providing easy navigation through the course information.

Course name	OSIRIS number	Course number	Credits	Course duration in hours	Course duration in weeks	Number of staff	formatted start date	formatted end date	ITC quartile	UT quartile
Big Geodata Processing	**201900064**	**GIP_0001**	**5**	**140**	**10**	**3**	**04-09-2022**	**10-11-2022**	**1**	**1A**
Advanced Image Analysis	201900065	EOS_0003	5	140	10	4	04-09-2022	10-11-2022	1	1A

Figure 9 Shows other miscellaneous information related to a course.

3.3.3. Semantic Map:

Another visualization utilized in the dashboard is the semantic map. A semantic map illustrates the associations between different entities, showing how they are connected based on their semantic meaning and relationships (Georgakopoulos, 2019). Nodes represent course and properties, while links depict the connections between these nodes based on their meanings. The decision to use this type of chart is influenced by two main factors: the nature of the data and the available space for the chart. The semantic map is used to visualize various properties related to each course, such as learning outcomes, software used, and concepts covered. Unlike hierarchical data, these properties do not possess any hierarchy, and the number of properties can vary for each course. Therefore, the semantic map is an optimal choice for visualizing this data, as it allows for clear and readable representation within the confined space available. This is due to the undirected nature of the semantic map which efficiently utilizes the surrounding empty space. Figure 10 illustrates a semantic map of a course and its properties, with the central node representing the course and the arrows radiating towards other nodes representing the course properties.

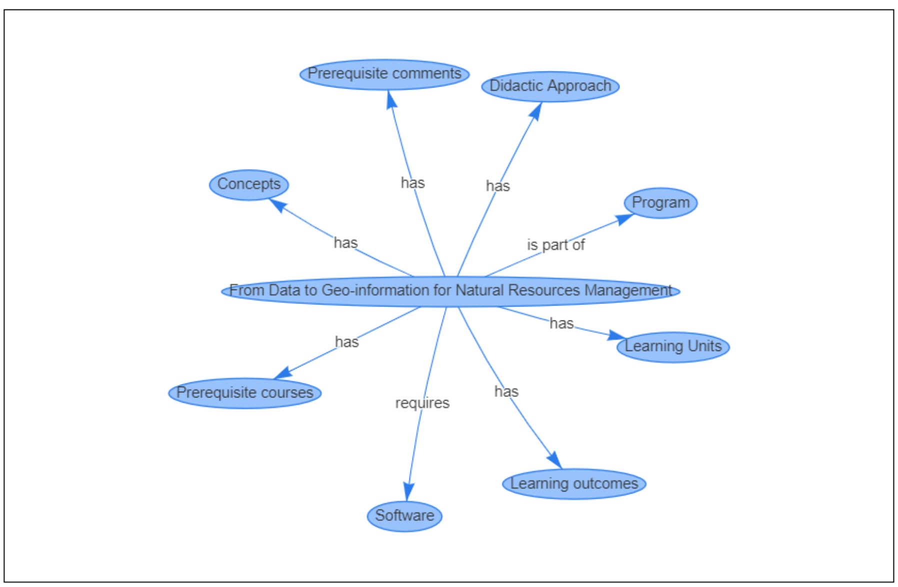


Figure 10 The semantic map of a course.

3.3.4. Descriptive information:

Users can click on any node of their preference within the semantic map to access information related to that specific node. In the "course info view," the description is displayed on the right side of the semantic map, providing users with immediate access to detailed information. Similarly, in the "course comparison view," the description appear below the semantic maps, allowing users to compare information across courses with ease. Figure 11 visually illustrates this functionality, demonstrating how users can interact with the semantic map to access relevant information based on their selections.

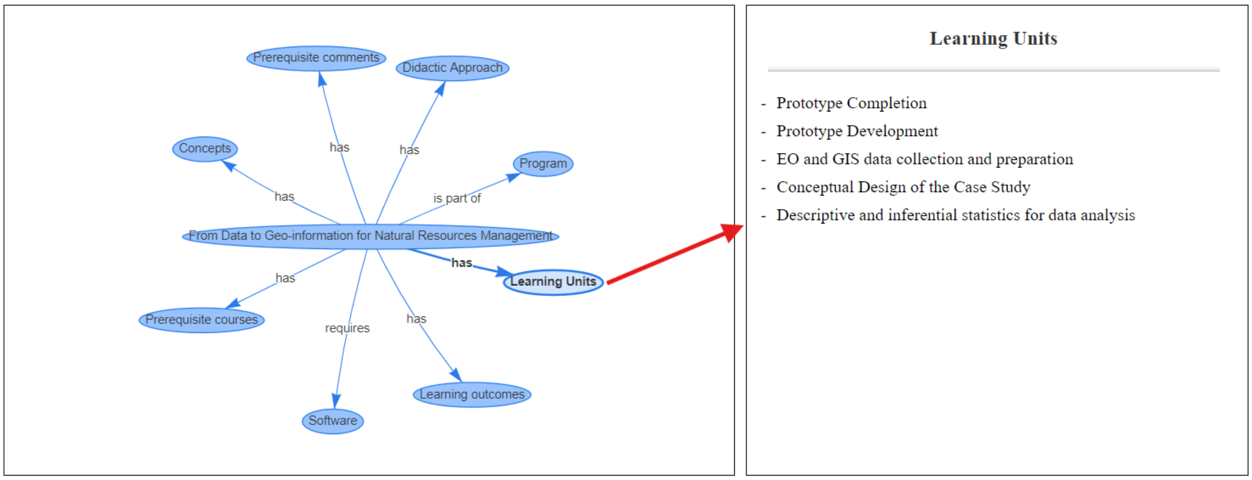


Figure 11 the node description can be seen once the user clicks on a node.

3.4. Implementation of the dashboard:

3.4.1. Technologies Used:

Web technologies such as HTML, CSS, and JavaScript are utilized to create the GCH dashboard. HTML (Hypertext Markup Language) for structuring web content. CSS (Cascading Style Sheets) for the customization of web page aesthetics, such as colors, fonts, and layout design. JavaScript, for dynamic interactions and functionalities within web pages. Moreover, the dashboard uses the Vis.js library for generating hierarchical and semantic maps. It is a browser-based visualization library, adept at managing extensive dynamic data and enables easy manipulation and interaction with datasets (Vis.Js - Network Documentation., 2023.). Additionally, jQuery AJAX (Asynchronous JavaScript and XML) is used to facilitate asynchronous web requests for SPARQL queries. This integration allows the dashboard to seamlessly fetch and display data without necessitating a full page reload (Jingjing Li & Chunlin Peng, 2012). For data retrieval from linked database, the dashboard utilizes SPARQL (SPARQL Protocol and RDF Query Language), a query language for querying and manipulating data stored in RDF (Resource Description Framework) format. RDF, a standardized model for data interchange on the web, utilizes subject-predicate-object triples to represent information. SPARQL like SQL serves as a standardized means to query RDF data (Hogan, 2020).

The decision to develop the web page using HTML, CSS, JavaScript, and jQuery was primarily motivated by familiarity with these technologies and the abundance of available resources. Furthermore, the dashboard the will be deployed on the ITC server so it will be easily accessible to the users that connected with the ITC network. Given that the data is structured as Linked data and stored within a linked database, SPARQL emerged as the natural choice for querying this dataset. Moreover, the decision to use the Vis.js library stemmed from its minimal learning curve, making it an accessible choice. Additionally, the library's compatibility with JSON data played a pivotal role in its selection, as the data is requested in JSON format.

3.4.2. Implementation:

Figure 12, illustrates the fundamental structure of the GCH dashboard, detailing the primary components and their interactions that enable the dashboard's functionality. This schematic representation provides an overview of the essential elements involved in the operation of the dashboard, offering insights into its architectural framework.

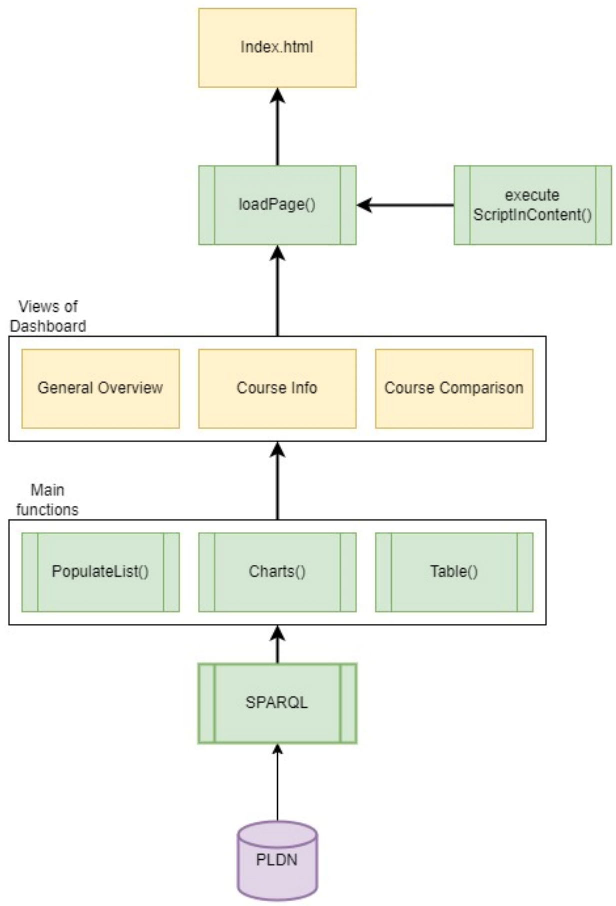


Figure 12 Structure of the GCH dashboard.

Examining the diagram, the database storing educational metadata is located at the bottom. Data retrieval is conducted using SPARQL query language via an AJAX function. Once the data is obtained in JSON format, it is processed through three primary functions: “populateList()”, “charts()”, and “Table()”, which are integral to all views of the dashboard. To combine the three views within a single index page, the “loadPage()” function and “executeScriptContent()” function are employed.

3.4.2.1. Index Page

As illustrated in Figures 4, 5, and 7, the index page features a consistent layout comprising a fixed sidebar on the left and a menu bar positioned at the top, which persists across all views of the dashboard. However, the remaining layout of the index page dynamically adjusts to accommodate the loading of each respective view. A fixed sidebar positioned on the left side of a web page offers several advantages that enhance both functionality and user experience. This layout ensures consistent and immediate access to navigation links, tools, and important information as users scroll through the content, which significantly improves site usability. The left-side placement aligns with natural reading patterns in many cultures, facilitating intuitive navigation (Shrestha et al., 2007). It also allows the main content area to remain uncluttered, enhancing readability and focus. Additionally, a left-fixed sidebar can effectively house search functions and links, promoting user engagement and maintaining an easy access, which can lead to higher user satisfaction and retention.

Positioned within the menu bar at the top left corner is the dashboard's logo and name, secondly, at the top right corner there is an "i" button, providing a guide for users when needed. Additionally, adjacent to the "i" button, tabs corresponding to the various views of the dashboard are displayed. To make these tabs functional, an "Click" event listener is incorporated, enabling the execution of the "loadPage()" function upon user interaction. This implementation is explained in Figure 13, the code is designed to dynamically load and execute content on an index page, enhancing user interactivity without requiring a full page reload. The "loadPage()" function fetches the HTML content from a specified URL using the Fetch API and inserts it into a designated HTML element with the ID "content". Upon successful content insertion, the "executeScriptsInContent" function ensures that any embedded scripts within the fetched HTML are also executed. It does this by creating a temporary element to parse the HTML and extract the scripts, which are then appended to the document body either as external scripts (if they have a "source" attribute) or as inline scripts. This approach maintains the functionality of dynamically loaded content and enhances the overall responsiveness and interactivity of the web application.

```
function loadPage(pageUrl) {
fetch(pageUrl)
    .then(response => response.text())
    .then(html => {
        document.getElementById("content").innerHTML = html;
        executeScriptsInContent(html);
    })
    .catch(error => console.log('Error loading page:', error));
}

function executeScriptsInContent(html) {
const temporaryElement = document.createElement("div");
temporaryElement.innerHTML = html;
const scripts = temporaryElement.querySelectorAll("script");
scripts.forEach(script => {
    const scriptElement = document.createElement("script");
    if (script.src) {
    scriptElement.src = script.src;
    } else {
    scriptElement.textContent = script.textContent;
    }
    document.body.appendChild(scriptElement);
});
}
```

Figure 13 The load Page and execute strip function to load the content of the views.

3.4.2.2. General overview (view 1):

Once the dashboard is loaded, the general overview (view 1) is shown to the user. As explained above the menu bar and the side bar remains the same, but the content of the side bar changes as shown in figure 4. Two radio buttons by the name “specializations” and “concepts” are given to the user. The user can make use of these to update the content of the list provided below as per their need. The provided JavaScript code in figure 14, is designed to populate list menu with options based on user selection between two radio buttons: "specialization" and "concepts". Upon user interaction with the radio buttons, the “populateOption()” function is invoked. This function first retrieves references to the radio buttons from the Document object model (DOM). It then constructs SPARQL queries (query_special and query_topics) to be executed based on the selected radio button. If the "specialization" radio button is checked, the query_special query retrieves distinct specialization names from the linked dataset. Conversely, if the "topics" radio button is checked, the query_topics query retrieves distinct concept names from the linked dataset. The appropriate query URL (queryUrl_menu) is then constructed by appending the query and format parameters to the base API URL. Subsequently, an AJAX request is made to the SPARQL endpoint specified by the query URL. Upon successful retrieval of JSON-formatted data, the function extracts the relevant information (e.g., specialization or concept names) and populates a list of options for the list menu. Finally, the populated list is passed to the populateTopicList() function for rendering in the dashboard.

```
var url = "https://api.data.pldn.nl/datasets/GeoCourseHub/GCH/sparql";
function populateOption(){
    document.getElementById("searchInput").value = '';
    var specializationRadio = document.getElementById("specialization");
    var topicsRadio = document.getElementById("topics");
    var query_topics = 'PREFIX skos: <http://www.w3.org/2004/02/skos/core#>\
                        PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>\
                        PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>\
                        PREFIX gch: <http://gch.utwente.nl/ontology#>\
                        PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>\
                        select distinct ?name where {\
                        ?s ?p skos:Concept;\
                            rdfs:label ?name.\ }'
    var query_special = 'PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>'+
                        'PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>'+
                        'prefix gch: <http://gch.utwente.nl/ontology#>'+
                        'prefix xsd: <http://www.w3.org/2001/XMLSchema#>'+
                        'SELECT distinct ?name WHERE {'+
                        '    ?course gch:isPartOfSpecialisation ?special.'+
                        '    ?special rdfs:label ?name.'+'}';
    var queryUrl_menu;
    if (specializationRadio.checked) {
        document.getElementById('topic-name').innerText = 'Specialization:'
        queryUrl_menu = url + "?query=" + encodeURIComponent(query_special) +
"&format=json";
    } else if (topicsRadio.checked) {
        document.getElementById('topic-name').innerText = 'Concept:'
        queryUrl_menu = url + "?query=" + encodeURIComponent(query_topics) +
"&format=json";}
    $.ajax({
            dataType: "json",
            url: queryUrl_menu,
            success: function (data) {
                var serach_list = [];
                for(let i=0; i<data.length;i++){
                    serach_list.push(data[i]['name']) };
                populateTopicList(serach_list); }});
```

Figure 14 The JavaScript code for retrieving the data for the list menu from database.

Now to render the specialization or concepts name in the dashboard the code in figure 15, shows "populateTopicList()" function. This function populates a list element on a webpage with "specializations" or "concepts" provided as input. Upon execution, it retrieves the list element, clears existing items, and sorts the data alphabetically. For each data, a new list item is created with a corresponding event listener attached to handle clicks. So, that the name can be passed to other two functions for creating the table and the chart. This functionality enhances user interaction by allowing them to select topics of interest within the dashboard.

```
function populateTopicList(topics) {
    var topicList = document.getElementById("topic-list");
    // Clear existing list items
    topicList.innerHTML = "";
    // Sort topics alphabetically
    topics = topics.map(item => item.trim())
    topics.sort();
    // Populate the list
    topics.forEach(function(topic) {
        var listItem = document.createElement("li");
        var span = document.createElement("span"); // Create a <span>
element
        span.textContent = topic; // Set the text content of the span
        listItem.addEventListener("click", function() {
            handleListItemClick(topic);
        });
        listItem.appendChild(span); // Append the span to the list item
        topicList.appendChild(listItem);
    });
}

function handleListItemClick(topic) {
    network_graph(topic);
    get_table_data(topic);
}
```

Figure 15: The code to populate the list menu on the side bar in the dashboard.

So once the user clicks on something from the menu another two functions are executed namely "network_graph()" and "get_table_data()" these two functions retrieve the data for the "specialization" or concept name selected. The data is retrieved the same way by using the SPARQL query and AJAX call. Once the data is available it is than passed to another two functions called "create_table()" and "create_network_graph()" respectively.

Firstly, the create_network_graph()" function utilizes Vis.JS library, the sample code for which is provided in figure 16.

```
var nodes = new vis.DataSet(I
    { id: 1, label: 'Concept 1' },
    { id: 2, label: 'Concept 2' },
    { id: 3, label: 'Concept 3' },
    { id: 4, label: 'Concept 4' }
    ]) ;
// Create an array of edges
var edges = new vis.DataSet([
    from: 1, to: 2 }, from: 1, to: 3
}
    from: 2, to: 3
    from: 3, to: 4
    }
    1);
// Create a network
var container = document .getElementById('mynetwork');
var data = {
nodes: nodes, edges: edges
var options = (};
var network = new vis.Network(container, data, options);
```

Figure 16 Sample code for creating a network graph by utilizing Vis.JS library.

The "create_network_graph()", serves to generate a network graph visualization based on input JSON data representing relationships between "concepts" or "specialization" with their related entities. Initially, the function identifies the target container element within the HTML document where the graph will be rendered. Subsequently, the function iterates through each object in the input JSON array, processing and transforming the data into nodes and edges that constitute the graph structure. Various properties of nodes and edges, including labels, colors, and shapes, are dynamically defined based on the characteristics of the corresponding entities in the dataset. These entities for "concept" include concept names, narrower concepts, close concepts, and related concepts, and for "specialization" include name of the specialization and courses name. Each entity represented as nodes in the network graph. The resulting graph data, consisting of nodes and edges, is then encapsulated into a format compatible with the vis.js library, which facilitates the creation of interactive network visualizations. Additional options, such as layout configuration and physics simulation parameters, are specified to customize the appearance and behavior of the graph. Event listeners are registered to enable user interaction. Specifically, when a node in the graph is clicked, the corresponding label is retrieved, and a function is invoked to highlight the relevant row in an associated table, enhancing cross-referencing between the graph and tabular data within the dashboard.

Secondly, The "create_table()" function in figure 17, is designed to dynamically generate an HTML table based on input data provided in the form of an array of objects. Initially, the function creates a “<table>” element and appends it to the designated container element within the HTML document. Subsequently, the function iterates through the keys of the first object in the input data array to generate table headers, excluding the "concept" and "course" columns. For each key, a “<th>” element is created and after replacing underscores with spaces, the corresponding key name is set as the heading of a column. After creating the table headers, the function proceeds to populate the table rows. For each object in the input data array, a new row “<tr>” is created within the “<tbody>” element. Within each row, cells “<td>” are generated for each key-value pair in the object. The cell content is set to the corresponding value from the object. Upon completion of table generation, the function manipulates the visibility of certain elements within the HTML document. Specifically, any existing table within the designated container element is removed to ensure the display of only the newly generated table.

```
function create_table(data) {
    var table = document.createElement("table");
    var thead = document.createElement("thead");
    table.appendChild(thead);
    var headerRow = thead.insertRow(0);
    for (var key in data[0]) {
        if (key !== "concept" && key !== "course") {
            var headerCell = document.createElement("th");
            headerCell.textContent = key.replaceAll('_', ' ');
            headerRow.appendChild(headerCell);}}
    var tbody = document.createElement("tbody");
    table.appendChild(tbody);
    for (var i = 0; i < data.length; i++) {
        var row = tbody.insertRow(i);
        for (var key in data[i]) {
            if (key !== "concept" && key !== "course") {
                var cell = row.insertCell();
                cell.textContent = data[i][key];}}}
    var container = document.getElementById("table-data");
    var elements = container.querySelectorAll('.initial-text');
    for (var i = 0; i < elements.length; i++) {
        elements[i].style.display = 'none';}
    var tableElement = container.querySelector('table');
    if (tableElement){
        container.removeChild(tableElement);}
    container.appendChild(table)}
```

Figure 17 Shows the create table function, which dynamically create the table from JSON data.

Both the “create_table()” and “create_network_graph()” functions are integral components of the dashboard's functionality, facilitating the dynamic generation of tables and network graphs from JSON data. These functions are designed to be reusable across multiple views within the dashboard, minimizing code duplication and promoting maintainability. While primarily utilized in the initial view of the dashboard, slight modifications were made to the “create_network_graph()” function to adapt it for use in generating semantic maps in subsequent views. Specifically, layout properties were omitted from the semantic map code to produce the desired graph visualization.

3.4.2.3. Course info and Course comparison View (View 2 & 3):

As discussed in the previous section on View 1, the course info view and course comparison view share the same layout regarding the sidebar and menu bar, as shown in Figures 4, 5, and 7. However, the course info view displays a course list in the sidebar, whereas the course comparison view features two dropdown menus in the sidebar, allowing users to select two courses for comparison. In the course info view, the table is positioned below the chart, while the course comparison view does not include a table. The area designated for the chart in the course info view is divided into two sections: the left section displays the semantic map of a course, and the right section provides a description of the node or property selected by the user. In the course comparison view, the total area is divided into four sections: the top two sections display the semantic maps of the two courses being compared, and the bottom two sections provide node or property descriptions for each course respectively.

The function that creates the table in the course info view is the same as that in View 1. However, the difference lies in the creation of the network graph. Both maps are generated using the Vis.JS library, but while the “General Overview” view employs custom layout properties, the course info and course comparison view utilizes the default layout properties of Vis.JS, which naturally generate a semantic map layout for the network graph. As discussed in the dataset section of the methodology, the data is not consistent across all courses. Therefore, creating an adaptive semantic map based on data availability becomes a critical task. For instance, if a course includes information on learning units, a corresponding node will be created. Conversely, for courses lacking such information, no node will be created. To achieve this adaptability, the SPARQL query must check for each course whether it contains information on various properties, such as concepts or learning units, and then return a Boolean result indicating the presence or absence of these properties. Figure 18 illustrates the SPARQL query used for this purpose.

```
var query_nodes =  'Prefix skos: <http://www.w3.org/2004/02/skos/core#>\
                   PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>\
                   PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>\
                   prefix gch: <http://gch.utwente.nl/ontology#>\
                   prefix xsd: http://www.w3.org/2001/XMLSchema#\
                   SELECT distinct ?name\
                   (COALESCE(?Didactic, false) AS ?Didactic_Approach)\
                   (COALESCE(?LearningOutcomes, false) AS ?Learning_outcomes)\
                   (COALESCE(?LearningUnit, false) AS ?Learning_Units)\
                   (COALESCE(?Prerequisite, false) AS ?Prerequisite_comments)\
                   (COALESCE(?PrerequisiteCourse, false) AS ?Prerequisite_courses)\
                   (COALESCE(?Softwares, false) AS ?Software)\
                   (COALESCE(?Programs, false) AS ?Program)\
                   (COALESCE(?Concept, false) AS ?Concepts)\
                   WHERE {\
                   ?course rdfs:label "'+course_name+'"@en, ?name.\
                   OPTIONAL {\
                       ?course gch:hasDidacticalApproachComment ?approach.\
                       BIND(IF(BOUND(?approach), true, false) AS ?Didactic) }\
                   OPTIONAL {\
                       ?course gch:hasLearningOutcome ?loutcome.\
                       BIND(IF(BOUND(?loutcome), true, false) AS ?LearningOutcomes)}\
                   OPTIONAL {\
                       ?course gch:hasLearningUnit ?lunit.\
                       BIND(IF(BOUND(?lunit), true, false) AS ?LearningUnit)}\
                   OPTIONAL {\
                       ?course gch:hasPrerequisiteComment ?preqcom.\
                       BIND(IF(BOUND(?preqcom), true, false) AS ?Prerequisite)}\
                   OPTIONAL {\
                       ?course gch:hasPrerequisiteCourse ?preCourse.\
                       BIND(IF(BOUND(?preCourse), true, false) AS ?PrerequisiteCourse)}\
                   OPTIONAL {\
                       ?course gch:requiresSoftware ?soft.\
                       BIND(IF(BOUND(?soft), true, false) AS ?Softwares)}\
                   OPTIONAL {\
                       ?course gch:isPartOfProgramme ?pro.\
                       BIND(IF(BOUND(?pro), true, false) AS ?Programs)}\
                   OPTIONAL {\
                       ?course gch:hasSubject ?sub.\
                       BIND(IF(BOUND(?sub), true, false) AS ?Concept)}}\;
```

Figure 18 SPARQL Query, checking the existence of a property for a course.

The SPARQL query in figure 18, is designed to retrieve detailed information about a specific course based on its label. In the first few lines the query uses various prefixes to reference RDF vocabularies and the custom GCH ontology. It selects distinct course names, to avoid duplication and employs the COALESCE function to check for the presence of several optional properties related to the course, such as didactic approach, learning outcomes, learning units, prerequisite comments, prerequisite courses, software requirements, program affiliations, and associated concepts. Each optional block uses the BIND function to assign a Boolean value indicating the presence or absence of the respective property.

Following data retrieval regarding the properties associated with each course, the Vis.js library is employed to generate the semantic map. Furthermore, a function named "node_description()" is utilized to access and display Properties descriptions. In the course info view, these descriptions are presented on the right side of the semantic map, while in the course comparison view, they appear below the charts. This function operates by receiving the name of a node, such as "software", and subsequently passing it to a SPARQL query for data retrieval from the database in JSON format. The resulting data is then presented to the user.

In the course info view, an additional functionality entails the display of sub-concepts for main concepts. Upon clicking the node labeled "concept", on the right side of the chart, a list of related concepts is presented to the user. These concepts are interactive, allowing users to click on them for further exploration. If sub-concepts are available for a main concept, a chart is displayed. In this chart, the main concept occupies the center position, with arrows radiating towards its sub-concepts, as illustrated in Figure 6. Conversely, if no sub-concepts are available for a particular concept, a message indicating "no information available" is presented to the user. This functionality is done by using the function named “get_concept_info()” as shown in figure 19.

The “get_concept_info()”, is designed to retrieve additional information about a specific concept selected by the user in the course info view. Upon selection, this function dynamically creates a container element to display the retrieved data. It first constructs a graphical user interface element, which includes a close button for dismissing the displayed information. Subsequently, it queries the database using the SPARQL query to fetch relevant data related to the selected concept. Depending on the retrieved data, the function either generates a network graph illustrating the relationships between the concept and its sub-concepts or displays a message indicating the absence of additional information. Additionally, if data is available for visualization, the function includes a legend image for reference.

```
function get_concept_info(con) {
    var concept_graph = document.createElement('div');
    concept_graph.id = 'concept-graph';
    var top_div = document.createElement('div')
    top_div.id = 'concept-graph-close-btn'
    var close_btn = document.createElement('button');
    close_btn.id = 'close-btn';
    var close_button = document.createElement('i')
    close_button.className = 'fas fa-times';
    close_btn.appendChild(close_button);
    top_div.appendChild(close_btn);


    concept_graph.appendChild(top_div)
    $(close_btn).on('click', function() {
        document.getElementById('sub-lower').removeChild(concept_graph); });
    var bottom_div = document.createElement('div');
    bottom_div.id = 'concept-graph-figure'
    concept_graph.appendChild(top_div);
    concept_graph.appendChild(bottom_div);
    var data_content = document.getElementById('sub-lower');
    data_content.appendChild(concept_graph);
    var query_course =  'Prefix skos: <http://www.w3.org/2004/02/skos/core#>\
                        PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>\
                        PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>\
                        prefix gch: <http://gch.utwente.nl/ontology#>\
                        prefix xsd: <http://www.w3.org/2001/XMLSchema#>\
                        SELECT distinct ?concept ?close_concepts ?related_concept
?narrower_concept WHERE {\
                        ?course gch:hasSubject ?topic.\
                        ?topic rdfs:label "' + con.textContent + '"@en, ?concept.\
                        optional{  ?topic  skos:related ?close.\
                        ?close rdfs:label ?related_concept. }\
                        optional {  ?topic  skos:closeMatch ?mat.\
                        ?mat rdfs:label ?close_concepts. }\
                        optional {  ?topic skos:narrower ?narrower.\
                        ?narrower rdfs:label ?narrower_concept. }\}';
    var queryUrl_course = url + "?query=" + encodeURIComponent(query_course) +
"&format=json";
    $.ajax({
        dataType: "json",
        url: queryUrl_course,
        success: function (data) {
            var create_legend = false
            data.forEach(function(item) {
```

```
                if (item.close_concepts === null && item.related_concept === null &&
item.narrower_concept === null) {
                    var no_data_para = document.createElement('div')
                    var no_data_text = document.createElement('h3')
                    no_data_text.innerText = 'No Additional Information for this concept';
                    no_data_text.className = 'initial-text'
                    no_data_text.style.opacity = 0.8
                    no_data_para.id = 'no-data-para'
                    no_data_para.appendChild(no_data_text)
                    bottom_div.appendChild(no_data_para);
                } else {
                    create_legend = true
                    create_network_graph(data);}});
            if (create_legend){
                var legend_img = document.createElement('img')
                legend_img.src = "Assets/legend_concept.jpg"
                legend_img.id = 'legend-image'
                legend_img.className = 'legend-image'
                legend_img.style.display = 'block';
                concept_graph.append(legend_img);}}});
```

Figure 19 shows the function that creates chart of the sub-concepts for the main concept of a course.

In addition to the core functionalities, several supplementary features have been integrated into the dashboard to enhance user-friendliness. A tutorial section is included to provide users with guidance, while a “user guide” pop-up appears for five seconds upon loading the website to inform users about the guide's availability. Various other pop-ups provide descriptions for different page views. A filtering mechanism allows users to choose between "specialization" and "concept," updating the list menu accordingly. Both charts and tables are dynamically generated based on the selected properties. In the "course info" and "comparison" views, charts and tables are specifically created for the selected courses, and node descriptions are displayed only for the selected nodes. Additionally, a chart for the main concept is generated upon user selection in the course info view. Each view has a dedicated CSS file to enhance visual appeal. The white and blue theme was chosen for its readability, complementary aesthetics, and professional appearance, although user preferences may vary. Handling missing data is achieved through user prompts indicating the absence of specific information or by verifying the presence of data for each course. Visualizations are generated exclusively for courses with available data, as previously discussed.

3.5. Usability Study:

To test the hypothesis, Usability testing of the dashboard will be undertaken, guided by the ethical considerations. Usability testing of the GCH dashboard will involve the evaluation of effectiveness, efficiency, and user satisfaction as the user interacts with the visualizations (Ferreira et al., 2020). The aim is to discover any design flaws, usability challenges, or any other issue related to the navigation or interaction of the user with the dashboard. Here are some of the critical dimensions of usability testing (ISO 9241-11, 1998).

Effectiveness: how the user can complete tasks accurately when interacting with the dashboard. For example, if the user wants to zoom in or wants a filter or search option, the dashboard should provide those functionalities to enable them to complete the task or achieve their goals without error and confusion.

Efficiency: It measures how efficiently the user can complete the task. For example, how long does a user find relevant information or functionalities to achieve their desired goals?

Satisfaction: It measures to what extent the user's needs, expectations, and preferences are met by using the dashboard.

3.5.1. Method of usability study:

Following are the methods that are used in the usability study of a dashboard.

Eye tracking: involves an instrument that tracks and records the user's eye movement when interacting with an interface or product. The main aim of this test is to understand how long the user looks at a specific element of the interface and the pattern of their gaze. It provides quantitative data related to user eye movements, area of focus, etc (Djamasbi et al., 2010).

These methods provide valuable insights into user interactions with the dashboard. They capture user behavior and decision-making processes while interacting with the application. The new GCH proposes charts and tables to visualize educational metadata. By utilizing Tobii Pro Lab, areas of interest can be defined within the dashboard. This allows for the collection of gaze data, such as the frequency with which users look at specific elements like charts, text, or tables. Analyzing this gaze data can reveal if users are particularly drawn to certain elements, such as charts, indicating their interest. Eye-tracking can also help identify design flaws in the dashboard. For instance, developers might assume the logical placement of buttons or tabs, but users might struggle to find them. Observing the gaze patterns or paths that users follow to locate these elements can provide crucial insights for improving the dashboard's design.

Think-aloud: The participants are motivated to verbalize their thoughts, actions, and decisions when interacting with the product or system. It is a powerful usability testing method that provides qualitative insight into the user's usability challenge and overall experience (Ruckpaul et al., 2015).

The think-aloud method complements eye tracking by providing immediate verbal feedback from users as they perform specific actions. This technique offers insights into the functionality of the dashboard from the user’s perspective. Users can quickly comment on the placement of elements, such as suggesting that a particular item might be better positioned on the left side of the menu bar rather than the right. They can also provide unique suggestions, such as having images zoom in when hovered over, which developers might not have considered. The think-aloud method helps identify user interpretations of various elements. For instance, while developers might use an "i" button for the user guide, users might respond better to a question mark symbol. During the think-aloud sessions, users often provide numerous suggestions for enhancing the dashboard's functionality. Although many of these suggestions may reflect personal preferences, it is the developer's responsibility to identify and implement the most common and beneficial recommendations to improve the overall design. Throughout the think-aloud process manual notes were made so as to aid the results section of the research.

Survey: a systematic method for collecting data from a predetermined group of respondents. This method involves the use of structured questionnaires or interviews to gather quantitative and/or qualitative information about specific topics of interest (Story & Tait, 2019).

The survey should include well-crafted questions that yield precise and measurable results. In this study, the survey offers scale-based questions to the users. Respondents are asked to rate various aspects, including the design functionality and the overall user-friendliness of the dashboard. This approach ensures that the data collected is quantifiable, facilitating the analysis and interpretation. The reason for using the scale-based questions is to enhance the reliability and validity of the survey by reducing the ambiguity often associated with open-ended questions. Respondents can express their views more precisely, leading to more accurate and consistent data. It simplifies the statistical analysis process, allowing for the application of various quantitative techniques to compare and interpret the results.

In addition to scale-based questions, the survey includes several open-ended questions to gather additional insights about the dashboard. These open-ended questions allow users to elaborate on their ratings, explaining why they might rate one aspect higher than another or prefer a specific feature. This qualitative data provides a deeper understanding of user preferences and experiences, offering valuable context to the quantitative findings.

The survey form comprises seven sections, each focusing on a specific aspect of the usability study. The first section gathers general information about the participants, such as their years of teaching experience and familiarity with the programs. The second section addresses questions related to user-friendliness and the dashboard interface. The third section evaluates the effectiveness of the visual elements and navigation features utilized in the dashboard. The fourth and sixth sections examine dashboard features related to the filtering of educational metadata and the comparison of two courses within the GCH, respectively. The fifth and seventh sections solicit general feedback regarding the overall usability of the dashboard.

3.5.2. Technology, users, and setup:

After the completion of the dashboard designed for teachers, it was crucial to test its usability with real users to evaluate its performance. According to Jakob Nielsen's usability research (Bevan et al., 2003), testing with just five users is typically sufficient to uncover most usability issues. This approach is cost-effective and practical, providing valuable insights without requiring extensive resources. Testing with a larger number of users is necessary when a complex system is being tested. For this usability study, nine teachers participated in the evaluation of the dashboard. The number of users is enough for producing a statistical insight from the data. The usability testing was conducted in the VISUSE lab at the University of Twente. Despite the lab's capabilities to minimize external noise, some distractions were present due to the two large windows. However, the testing was scheduled during the afternoon when the number of people outside was minimal, reducing potential distractions.

Upon entering the user was asked to sit in an immoveable chair so that the user cannot move around much as the eye-tracking test was conducted by fixed X60 eye-tracker as shown in figure 20.

Figure 20: X60 Eye-tracker, used in usability study.

The Tobii X60 eye tracker is a device designed for detailed eye-tracking research. It features a sampling rate of 60 Hz, which allows for accurate tracking of eye movements. The device is compatible with various software platforms, including Tobii Pro Lab, which supports a wide range of experimental setups and data analysis methods. The device uses infrared illumination to track the corneal reflection and pupil center, allowing for precise data capture.

Key specifications of the Tobii X60 include:

- **Sampling Rate**: 60 Hz.
- **Accuracy**: 0.5° to 1.0° of visual angle.
- **Tracking Distance**: 50 to 80 cm.
- **Gaze Recovery Time**: Less than 100 ms.
- **Data Output**: Gaze data, pupil data, and other eye-related metrics.

The primary reason for selecting this device is its availability. Additionally, the user will test the dashboard on a computer or laptop, resulting in minimal head movement. The device's sampling rate of 60Hz is sufficient to accurately capture the user's eye movement patterns while interacting with the dashboard. Additionally, a Microsoft HD camera, mounted on the monitor, records video of the users at a resolution of 1920x1080p. A Samson omnidirectional microphone is used to capture user comments during the think-aloud sessions, where users articulate their thoughts while performing tasks. These devices are connected to a computer equipped with an Intel Xeon(R) CPU and 64 GB of RAM, ensuring the system's robust performance and data processing capabilities.

The Tobii Pro Lab software was selected for the usability study due to its compatibility with the Tobii X60 eye-tracker and features for designing recording sessions. This software allows researchers to configure their recording setups by selecting preferred devices, including the microphone, camera, and eye tracker. Such flexibility ensures that the experimental design can be tailored to meet specific user requirements and preferences, facilitating comprehensive data collection and analysis.

The usability testing was conducted in three parts. The first two parts involved eye-tracking and think-aloud protocols, while the third part required participants to complete a survey. Two distinct designs were utilized for the eye-tracking and think-aloud sessions. In the first design, participants interacted with the newly developed GCH dashboard, and in the second design, they interacted with the existing GCH dashboard. This approach aimed to evaluate whether the new dashboard offered improvements over the existing one. To mitigate bias, the order of dashboard interaction was alternated: if one participant used the new GCH first, the next participant used the existing GCH first. After completing their sessions, participants were asked to fill out a survey. This survey captured their feedback and responses to specific questions about their experience.

Each participant received an introduction explaining the purpose of the usability study, the tasks they would perform, and the specific aspects they would be testing. Following this introduction, each participant was given a consent form (Appendix 2), which outlined the study's purpose, their rights as participants, and the details to which they were consenting. After signing the consent form, participants were provided with a task sheet (Appendix 1) detailing the tasks they needed to complete on both the new and the existing GCH dashboards.

The tasks were designed based on the user stories outlined in section 3.2.2 and the user requirements detailed in section 3.2.3. The first task evaluates whether the user can utilize the first view to locate a course within their specialization. In a subpart of this task, the user is required to find course information such as concepts and prerequisites, assessing their ability to navigate to the next dashboard view and their response to this transition. The second task also pertains to course information retrieval. The third task involves course comparison, where the user is asked to identify a common concept between two courses, thus testing the ease with which the user can locate shared concepts. User feedback is collected at this stage. The subpart of the third task focuses on the user's ability to backtrack in the dashboard to the first or second view, examining how easily the user retains knowledge of where specific information can be found. In this subtask, users are asked to identify sub-concepts of the main concept.

3.5.3. Analysis of the Result:

Upon completion of the usability study, three types of results were obtained: eye tracking data, think-aloud and survey responses. For the eye tracking test, nine videos were recorded from each user while they interacted with the dashboard. These videos were segmented into custom intervals based on the specific tasks assigned to the users. Intervals represent periods on the recording timeline between a start event and an end event, with events serving as multipurpose markers to identify significant occurrences on the eye tracking recording's timeline (Albert & Tullis, 2023). The primary objective was to monitor users' eye movements during task performance to determine whether they focused on the intended areas or were distracted by other elements on the dashboard. In this research, the stimulus was a website, necessitating the creation of custom events for each task, as the software could not generate them automatically. This customization was crucial for accurately tracking and analyzing user interactions with the website.

Once the intervals are defined, the next step is to create the Time of Interest (TOI). TOI in Tobii Pro Lab provides the user with the flexibility to analyze eye tracking data based on the start and end events. Using the defined intervals, TOI for each view of the dashboard is created by specifying the start and end points of these intervals using events and identifying the snippet for which the data needs to be analyzed. Thus, for each task, an interval is defined, which is then used to create the corresponding TOI. These TOIs filter the data to include only that which is relevant to the specified interval, facilitating analyses such as gaze plots and other metrics. The data can be visualized on the snippets in the form of heat maps, scan paths, or bee swarms, depending on user preferences. It is crucial that these snippets correspond to the defined intervals to ensure meaningful analysis. In this research, heat maps were generated to observe participants' visual attention across the defined intervals. Additionally, other visualizations such as scan paths were produced to identify areas for improvement in the proposed visualizations.

The data gathered from the survey form was downloaded in csv format where the results were analyzed by creating various charts and tables using Excel software. The charts and tables created were to focus on different aspects of the dashboard's usability, complementing other data analysis results to address the research questions proposed in this thesis. The survey data helps in evaluating the effectiveness of the dashboard, assessing whether the proposed elements were useful in conveying information to the users. Additionally, the time taken by users to complete each task was recorded, and charts were generated to compare performance of the existing and new GCH. This analysis helped determine the efficiency of the new dashboard. In the think-aloud sessions, common themes such as challenges, suggestions for improvements, and compliments were noted. Combined with responses to open-ended survey questions, this data helped assess user satisfaction with the new GCH dashboard. Insights from the think-aloud sessions also contributed to the improvement of the dashboard, as discussed in the Results and Discussion section of this thesis.

The result obtained from these methods are validated by their complimentary nature. The eye tracking data quantitatively demonstrates user focus on the proposed elements of the dashboard, providing objective metrics on visual attention. Objective metrics are quantifiable measurements that are based on observable and verifiable data, that can be consistently measured and evaluated. Concurrently, the think-aloud sessions offer qualitative insights, clarifying the users' perspectives and experiences. Common themes and comments identified in the think-aloud sessions are also evident in the eye tracking and survey results, highlighting a consistent pattern of user behavior. This triangulated approach to validation confirms the observed patterns and thus enhancing the reliability of the findings.

3.6. Ethical considerations:

The usability study was conducted in accordance with established ethical guidelines and regulations(University of Twente, 2023.). Participants were fully informed about their rights, the nature of the study, and its purpose through a detailed consent form. This form explained the objectives of the study, the methods of data collection, and assured participants of their right to withdraw from the study at any time. Additionally, participants were debriefed on the study's objectives, results, and any relevant follow-up actions. Consent was explicitly obtained for the recording of audio and video during the sessions. To ensure confidentiality, the privacy of participants was protected, with access to the data restricted to the research personnel and their supervisors. All personal information and test data were scheduled for destruction upon the completion of the research study, ensuring that sensitive information was not retained beyond its necessary use.

4. Result:

This section presents the findings that were obtained from the usability study. The types of finding include are quantitative from eye-tracking and survey data and qualitative findings from think aloud session. The user test both the existing and new Geo curse hub. The aim of this section is to answer the research questions that were posed in this study by presenting the result obtained from these methods. The primary goal of the usability study was to find out how easy was it to use the Proposed dashboard. Therefore, the results will be presented in the light of three usability components which are effectiveness, efficiency, and satisfaction.

4.1. Effectiveness:

During the usability study, participants evaluated both the existing and new versions of the GCH (GCH) and rated the overall structure, placement of visual elements, and navigation features of the two dashboards. Overall, the visual elements received an average effectiveness rating of 7.4 as illustrated in table 1, which shows the rating given by each user. The highest rating is 9 while the lowest rating is 7. Figure 21 illustrates the average ratings given by users for three key components: "Menu tabs, Search Bar," "Course Navigation," and "Clarity & organization of info." In the bar chart, the blue bars represent the new GCH, while the orange bars represent the existing GCH. As shown, the new GCH consistently received higher average ratings across all components. Specifically, the new GCH scored 7.3 for "Menu tabs, Search Bar" compared to 5 for the existing GCH, 7.7 for "Course Navigation" versus 5.8, and 7.2 for "Clarity & organization of info" against 5.2. These results are also summarized in Table2. The graphs and tables comparing these three components for both the existing and new GCH across each user are provided in the Appendix section 3.

Users	**Effectiveness of Visual elements (Tables, semantic map, hierarchical chart etc.) New GCH**
1	7
2	7
3	7
4	7
5	9
6	7
7	8
8	8
9	7
Average	7.4

Table 1: Average rating given by the users to overall visual elements.

	New GCH	Existing GCH
Menu tabs, Search Bar	7.3	5
Course Navigation	7.7	5.8
Clarity & organization of info	7.2	5.2

Table 2: Average rating given by the user for each of the three components for both new and existing GCH.

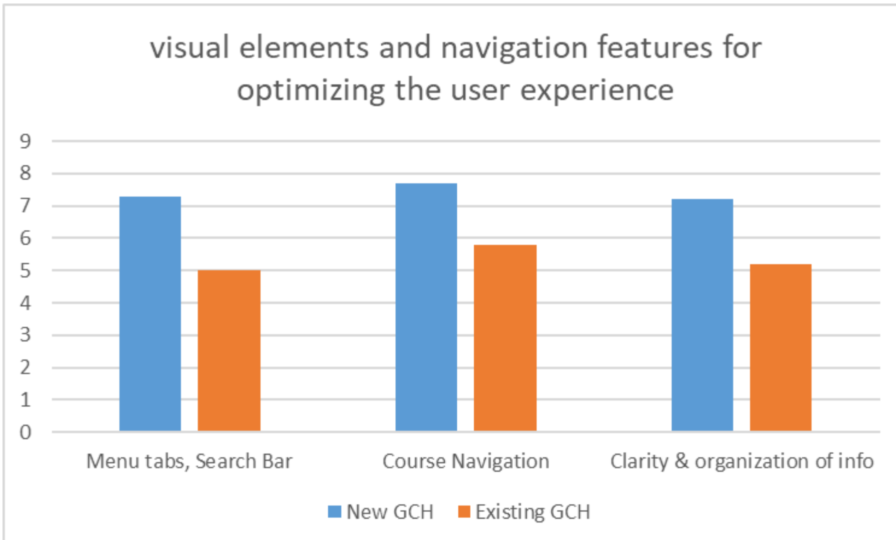


Figure 21: Average rating given by the user to overall structure of the two dashboards.

In the new GCH (GCH), linked educational metadata is presented using both hierarchical and semantic maps to evaluate their impact on user understanding of the relationships between specializations, courses, and other related information. The average ratings given by users for the hierarchical and semantic maps were 7.1 and 7.4, respectively. Figure 22, a bar chart, illustrates the effectiveness of these two maps in conveying information to users, with green bars representing the hierarchical chart and yellow bars representing the semantic map. The chart indicates that both map types similarly affect users' understanding of educational metadata. This trend is further supported by Figure 23, which shows user preferences: 56% of users favored the hierarchical map, while 44% preferred the semantic map. The detailed table is given in the appendix section 4.

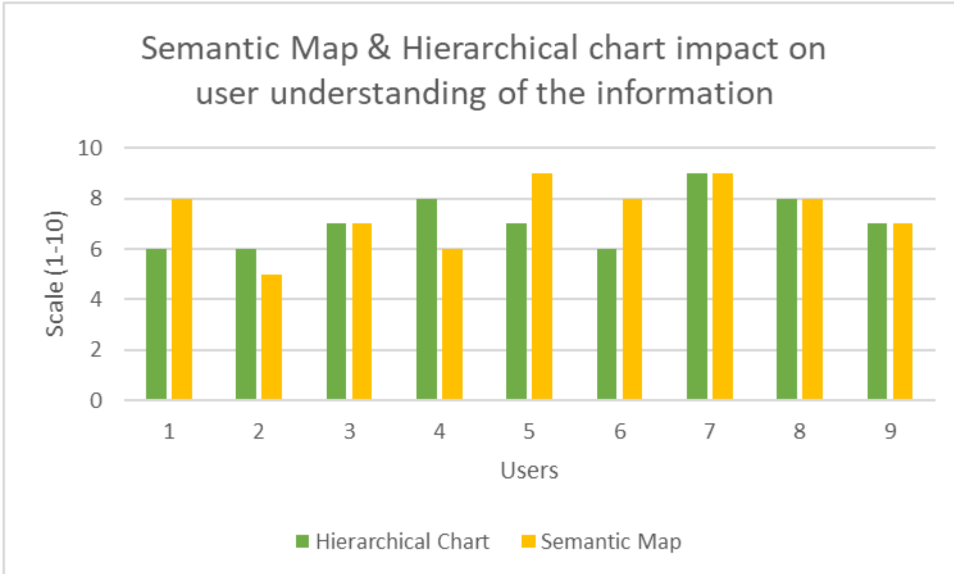


Figure 22: Bar graph, showing the impact of both the charts on user understanding of educational metadata.

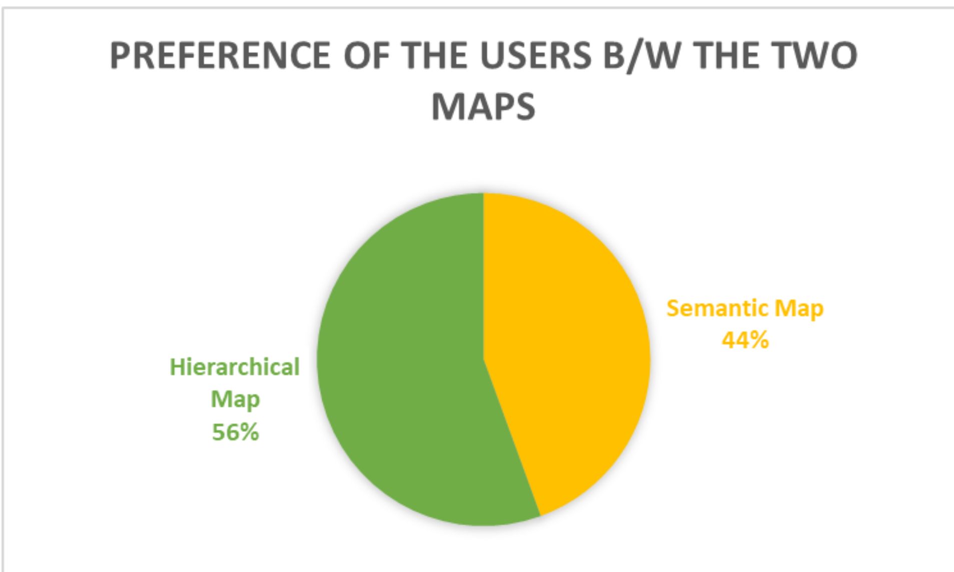


Figure 23: Pie chart shows the users preference of one graph over the other.

Table 3 and Figure 24 illustrates user ratings for the filtering options of both dashboards, revealing that the new GCH generally outperformed the existing GCH. This trend is further substantiated by the average visual clarity ratings, with the new GCH scoring 7.2 compared to 5.2 for the existing GCH, as shown in Table 2. Additionally, Figure 25 presents a heat map for Task 3 (comparing the two courses) performed using the new GCH, highlighting user eye fixation on areas containing relevant information. The color gradient ranges from green (indicating less user concentration) to red (indicating higher user concentration), demonstrating the effectiveness of the new dashboard in directing user focus to critical information areas. Other heat maps for different tasks are provided in the Appendix section 5.

Users	Effectiveness of the filtering option new GCH	Effectiveness of the filtering option Existing GCH
User1	8	6
User2	6	7
User3	7	5
User4	7	5
User5	10	6
User6	8	4
User7	7	8
User8	8	5
User9	4	3
Average	7.2	5.4

Table 3: Average rating given by the users for filtering options used in both dashboards.

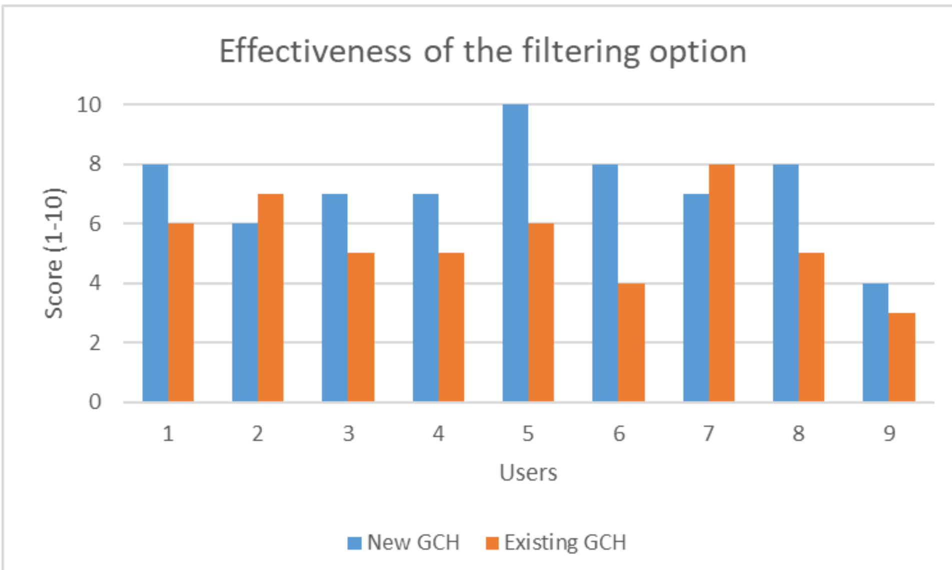


Figure 24: Effectiveness of the filtering options used in the dashboard for visualization clarity.

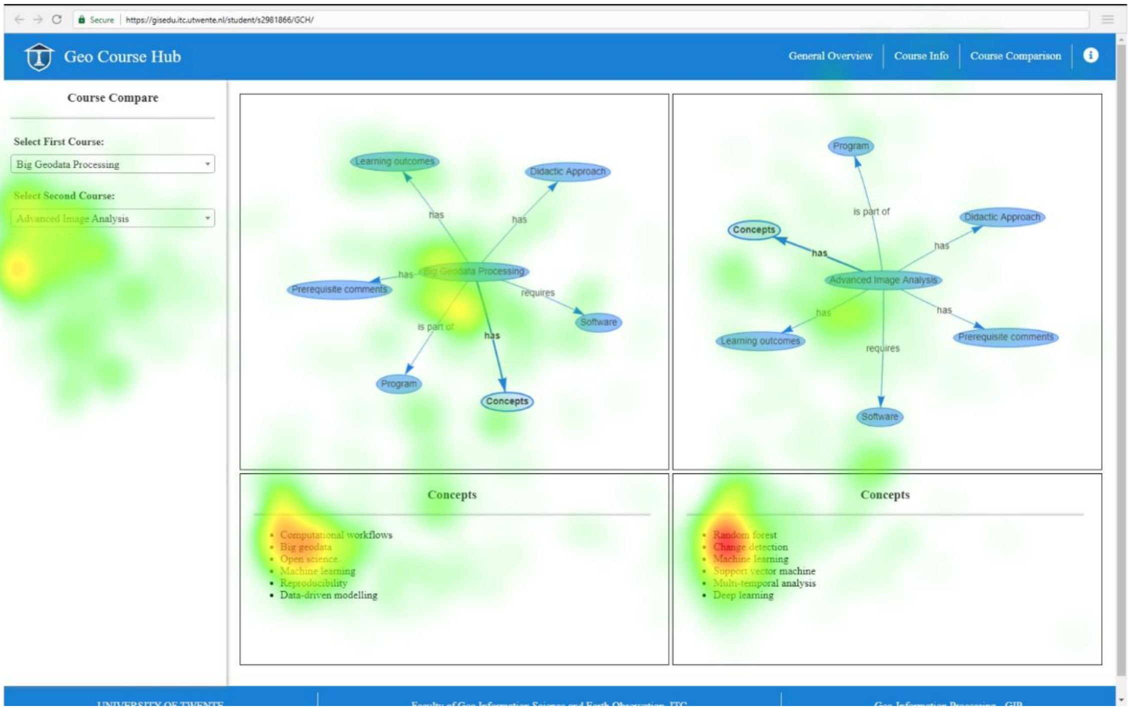


Figure 25: Heat map, showing the fixation of the user eye indicating high and low area of user fixation.

The figure 26 shows box and whisker plot of the user ratings for the course comparison view, reveals several key insights. The median score is 8, indicating that the central tendency of user ratings is quite high. The interquartile range (IQR), spanning from 7 to 9, shows that 50% of the ratings are closely clustered around this high median, reflecting a generally positive user experience. The minimum and maximum scores are 6 and 10, respectively, with no outliers detected, suggesting consistent feedback across the board. Overall, the plot indicates that the course comparison feature is well-received, with most users rating it favorably. The detail table is given in the appendix section of this thesis report.

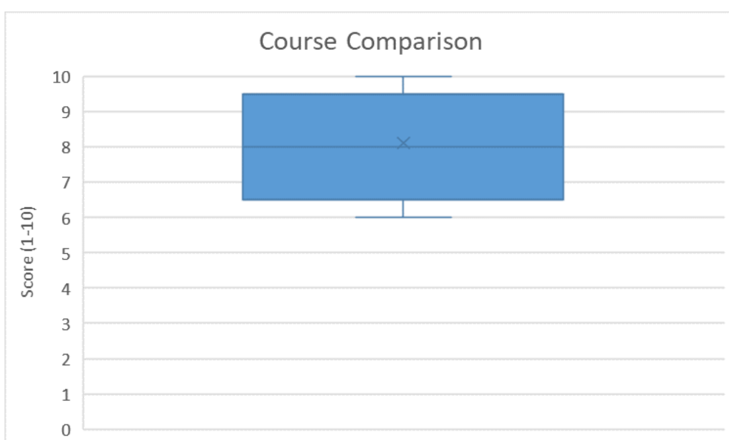


Figure 26: Box and whisker plot showing the visualizing the result for course comparison view.

The box and whisker plot for the user ratings on the ease of finding sub-concepts within a concept, with scores ranging from 1 to 10, reveals several insights. The median score is 6, indicating a moderate central tendency, suggesting that users generally found it somewhat easy to locate sub-concepts. The interquartile range (IQR) spans from 5 to 7, showing that 50% of the ratings are concentrated within this range, reflecting moderate satisfaction among users. The score of 1 is a noticeable outlier, indicating that at least one user found it extremely difficult to find sub-concepts. The detailed table showing each user score is given in the appendix section 6.

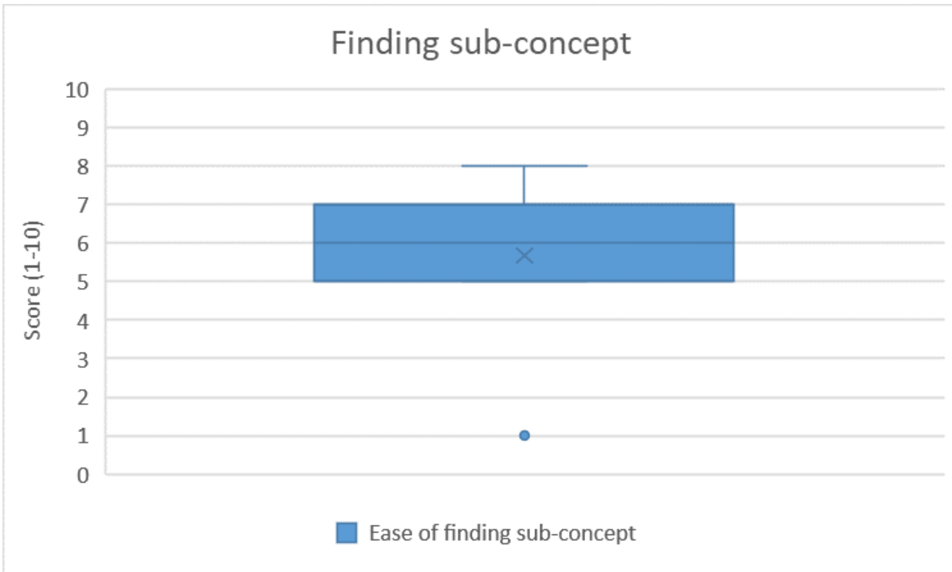


Figure 27: Box and whisker plot for finding the sub-concept of a main concept.

4.2. Efficiency:

The table 4 below presents the average time, in minutes, taken by users to complete various tasks on both the new and existing GCH (GCH) dashboards. The user tasks are mentioned in Appendix 1. As depicted, the new GCH generally facilitates quicker task completion across the board. The bar graph shown in figure 28 further illustrates this trend, with blue bars representing the new GCH and orange bars representing the existing GCH. In Task 1, users spent an average of 1.3 minutes on the new GCH compared to 1.9 minutes on the existing GCH. Task 1a showed a slightly different pattern, with the new GCH taking 1.9 minutes versus 1.1 minutes on the existing GCH. Task 2 demonstrated a clear advantage for the new GCH, with users completing the task in 0.9 minutes, faster than the 1.3 minutes on the existing GCH. Task 3 showed the most substantial improvement, with the new GCH reducing the average time to 1.7 minutes from 3.2 minutes on the existing GCH. For task 3a the users took an average time 1.6 minutes. The detailed table of the time that each user took to complete the tasks, along with the bar graphs for comparing the time, are provided in the (Appendix section 7).

	New GCH	Existing GCH
Tasks1	1.3	1.9
Task1a	1.9	1.1
Task2	0.9	1.3
Task3	1.7	3.2

Table 4 Shows the average time taken by users to complete the tasks.

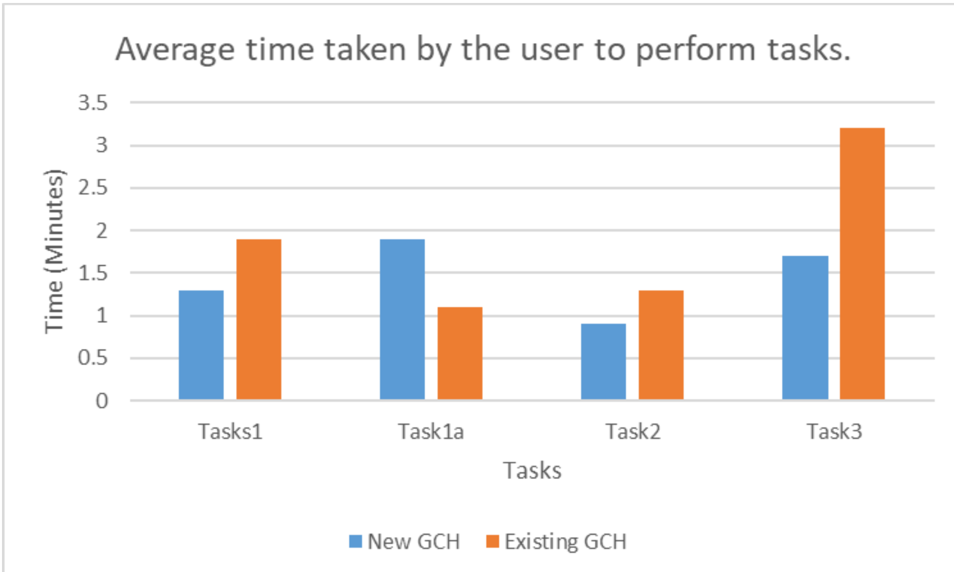


Figure 28: Bar graph showing the average time taken by the user to complete each task.

4.3. Satisfaction and user friendliness:

This section focuses on the overall usability and user satisfaction with the new GCH (GCH). The user satisfaction ratings for the filtering options in both the new and existing GCH were analyzed and compared. The new GCH received an average rating of 7.3, significantly higher than the 5.1 average rating of the old GCH. The table 5 presents user ratings on a scale of 1 to 10, with the new GCH consistently receiving higher scores, ranging from 4 to 10, whereas the existing GCH ratings range from 3 to 8. This clear disparity indicates a general preference for the new GCH. The bar graph (Figure 28) visually represents these ratings, with blue bars indicating the new GCH and orange bars representing the existing GCH. The higher and more consistent scores for the new GCH suggest a substantial improvement in user satisfaction, reflecting enhanced overall usability and a better user experience.

Users	Satisfaction with filtering options in new GCH	Satisfaction with filtering options in Existing GCH
1	8	6
2	5	4
3	7	5
4	7	7
5	10	6
6	8	3
7	8	8
8	9	4
9	4	3
Average	7.3	5.1

Table 5: The table shows the rating given by each user for the filtering option available in both dashboards.

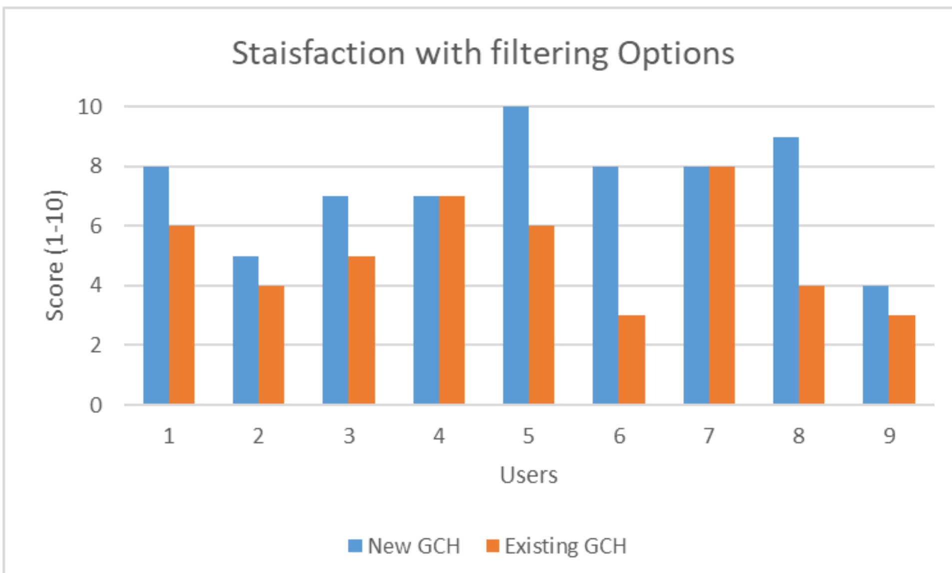


Figure 29: Bar graph shows the ratings given by the users for the filtering option in both new and existing GCH.

The bar graph in Figure 30 compares the user-friendliness ratings of the existing GCH (GCH) with the new GCH. Each user rated both versions on a scale from 1 to 10. The graph shows that the new GCH consistently received higher ratings across all users. Specifically, the new GCH achieved an average rating of 6.9, whereas the existing GCH received an average rating of 5.1. The detailed table which shows the individual user rating is given in the appendix section 8.

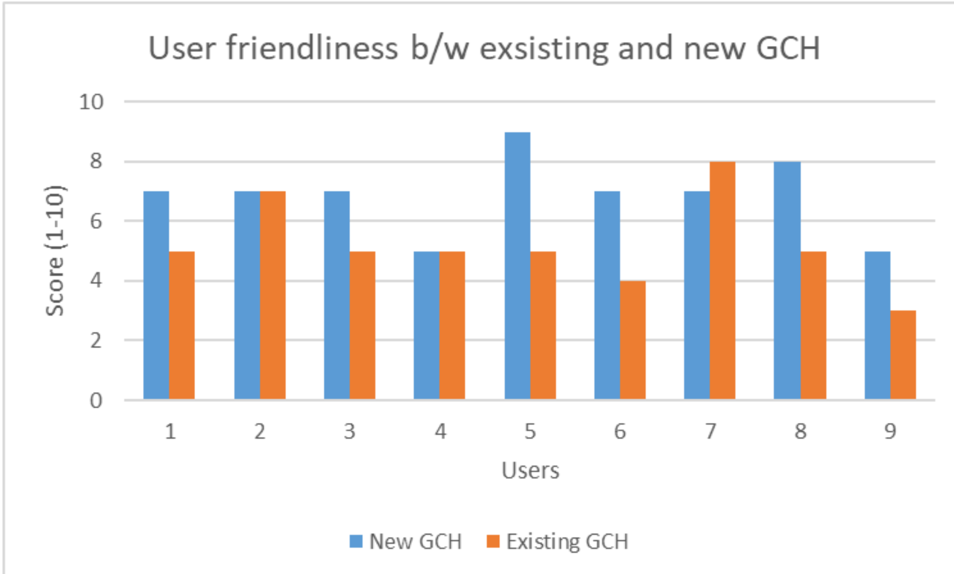


Figure 30: Shows the ratings given by the user for both new and existing GCH.

User feedback during the think-aloud sessions reveals user's satisfaction with the new GCH (GCH) interface. One key advantage is the integration of charts and knowledge about sub-concepts for a main concept, which enhances users' understanding and navigation through educational metadata. This feature helps users avoid feeling overwhelmed by data, allowing them to selectively view information based on their specific interests and needs. Additionally, the course comparison functionality within the new GCH is particularly beneficial for users when choosing courses. It provides a clear and concise way to evaluate different courses side-by-side, aiding in informed decision-making. Following are the summary of common compliments provided by the users.

- "The charts are highly effective in conveying information clearly and the knowledge about sub-concepts of main concept is helpful to know."
- "The new GCH allows data to be accessed upon request. This feature makes it easier to digest information without feeling overwhelmed."
- "The course comparison view is useful for identifying commonalities between courses. It also aids in the course selection process."

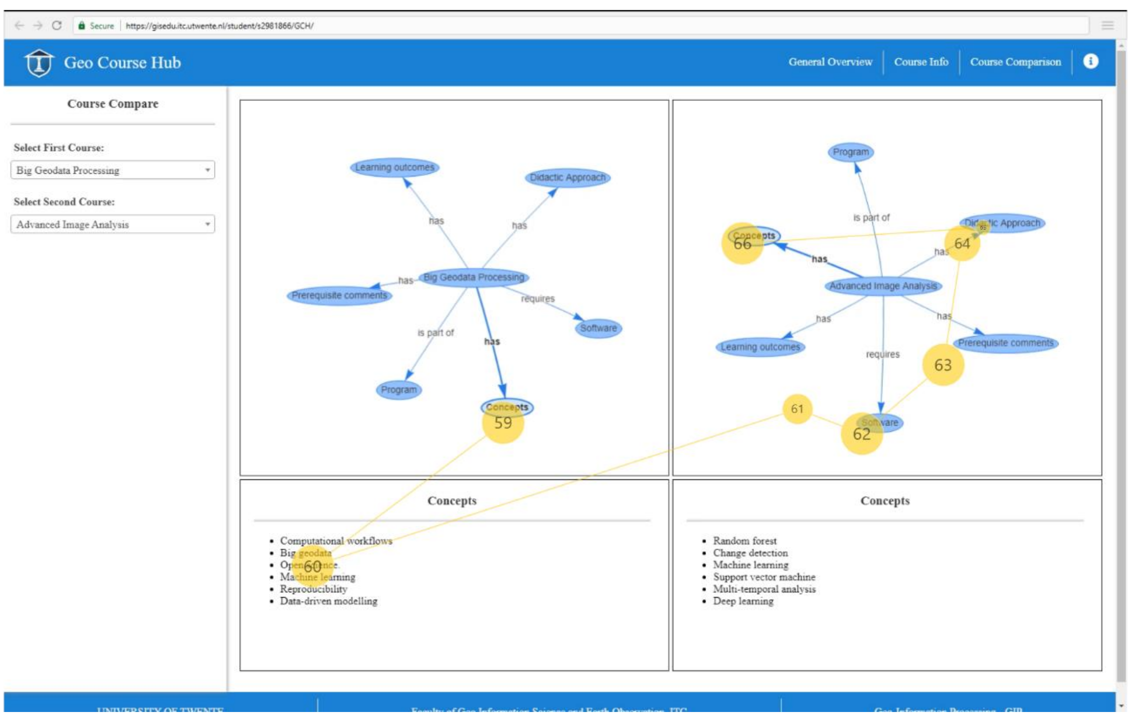
4.4. Users feedback and improvements:

This section presents user feedback collected during the think aloud sessions. Table 6 summarizes the users' comments on areas for improvement in visualizations, including the semantic map, hierarchical map, and overall dashboard. These comments represent common themes and suggestions shared by all users who tested the new GCH (GCH), highlighting areas where further enhancements are needed to optimize user experience and satisfaction. The following table shows the user comments and whether they were addressed in the New GCH.

User Comments	Solved
The position of the nodes should be static in semantic map.	✓
Make the central node different from the rest in semantic map.	✓
Nodes should be highlighted on mouse hover in both maps.	✓
The legend text should be visible.	✓
The common concept should be highlighted in course comparison.	✓
Pop-ups for the menu-bar tabs to explain what each Tab is about	✓
Change the location of the Menu buttons to the left	-
Lists items inside bar or in visualization should be ordered alphabetically.	✓

Table 6: Improvements made to the visualization based on user comments.

Figure 31 depicts the user navigation path when interacting with the course comparison view to click on specific concept nodes for two different courses. The nodes for each course are generated in distinct, non-overlapping locations within the visualization. This illustration demonstrates that once a user identifies and clicks on a concept node in one course chart, they must actively search for the corresponding node in the second course chart. The figure supports the comment made by the users which indicates potential area of improvement in semantic map, to make the node placements static. The navigation path shows sequence of eye fixations.



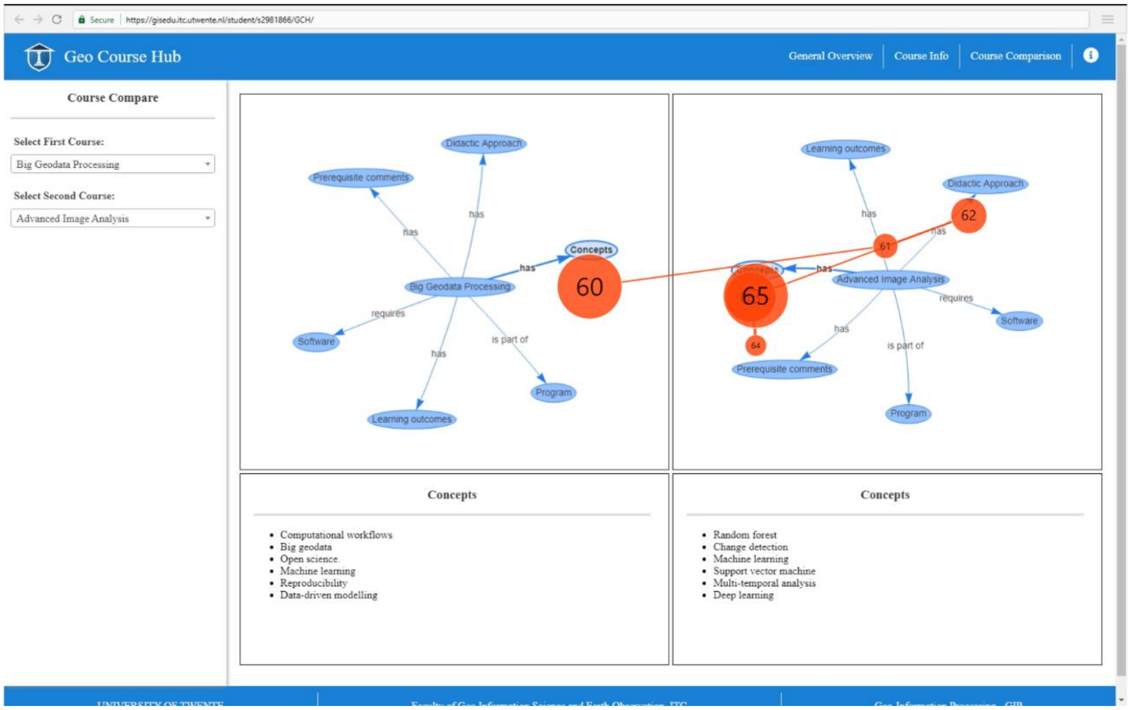


Figure 31: shows the path followed by the user to click on the same concept node.

Figure 32 displays a heat map illustrating the fixation points of the user's eye movements while navigating different views of the GCH (GCH) dashboard. The green areas represent regions with fewer fixations, while the red areas indicate regions with a higher concentration of fixations. This visualization helps in understanding the user's focus and interaction with the dashboard elements.

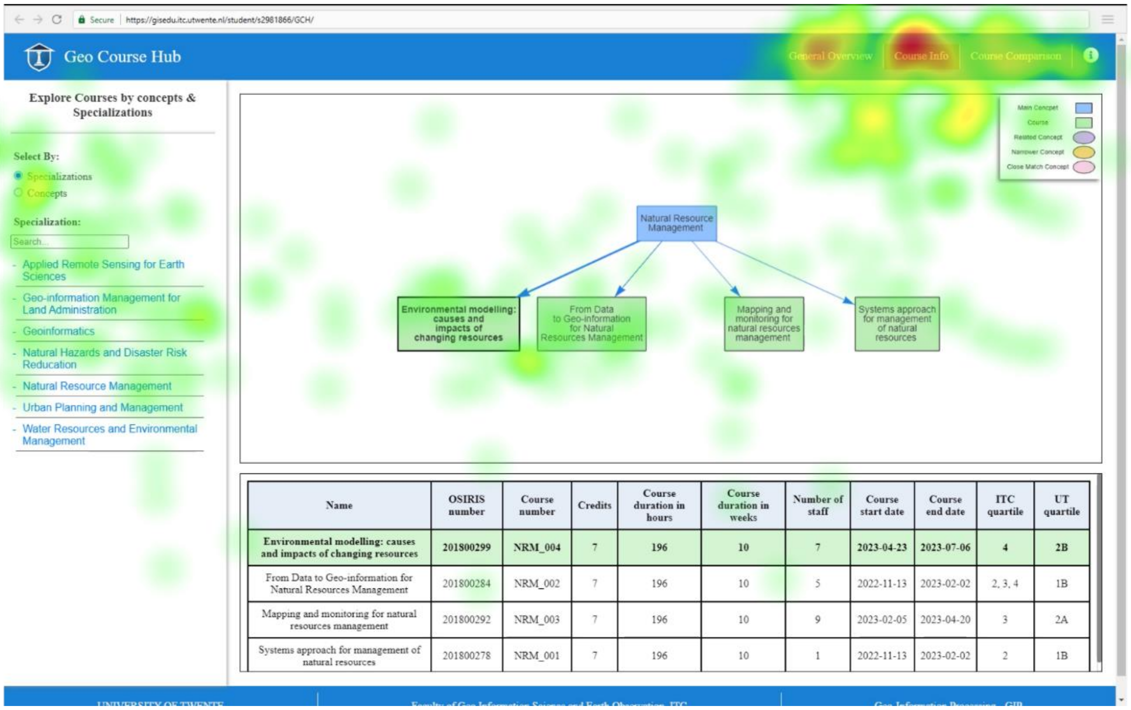


Figure 32: Heat map of the users' eye fixation when changing the view of the dashboard.

5. Discussion:

The research revolves around two things firstly, introducing a new GCH dashboard which improves upon the existing GCH and the second thing, this research focusses on is the visualization of linked data. Therefore, the research aims to develop a data visualization system for teachers to enhance their understanding of educational metadata such as GCH using a user-friendly interface. The system will include semantic maps and hierarchical charts to reveal contextual relationships, categorization, and filtering options to streamline data display, and usability testing to evaluate effectiveness, efficiency, and satisfaction. The hypothesis is that implementing a user-centric system will improve accessibility and understanding of linked educational metadata, enabling teachers to make informed decisions.

5.1. Discussion over effectiveness results:

The first objective and its related research questions revolves around the structure of the dashboard and the use of different visualization and navigation feature. The structural elements are menu tabs, side bar and all the navigation options available to the users. These elements play a crucial role in making a system user friendly. The findings from table 1, table 2, and figure 21 reveals a marked improvement in user experience with the new GCH significantly outperforming the existing version in several key areas. Participants rated both new and existing GCH in terms of overall structure, placement of visual elements, and navigation features. The new GCH received higher scores for "Menu Tabs, Search Bar," "Course Navigation," and "Clarity & Organization of Information." This indicate that the redesign effectively addressed previous deficiencies, resulting in a more user-friendly interface and contribute to the higher user satisfaction. This implies that the user finds the new dashboard easier to use as compared to the existing GCH, meaning the efficiency and the productivity of the user is increased.

The second objective and its corresponding research question focus on the introduction and evaluation of semantic and hierarchical maps, examining how these two can show the relationships among specializations, courses, and associated metadata. Figure 23 highlights user perceptions of these two charts and their impact on understanding linked metadata. The average ratings for both charts were nearly identical, indicating that they are equally effective in conveying information. Individual user ratings revealed that preferences between the two charts were largely influenced by their modes of information presentation. Users who favored the hierarchical map appreciated its static nature and consistent element placement, as well as its use of hue to distinguish different information categories. Conversely, some users rated the semantic map lower due to its dynamic element placement and lack of hue differentiation, though this issue was addressed in the end and the position of the nodes was made static after the user's comments. However, some users preferred the semantic map for its ability to clearly depict the relationships between the central node and its elements, which they found particularly insightful. Users were also asked to indicate their preference between the two charts. Although this is not a fair comparison as both charts were showing different information, but the preference were mostly related to how each chart appear like making use of hue. As depicted in Figure 24, the results were nearly split, with 44% preferring the hierarchical map and 56% favoring the semantic map. This near-even distribution suggests that both charts are valuable for conveying information, with no strong consensus favoring one over the other.

The third objective and its corresponding research questions focus on the filtering options available in the dashboard and how these options help categorize information to minimize visual clutter and enhance the dashboard's clarity. The categorization of information is based on use case scenarios detailed in the methodology section 3.2.2. Figure 24 demonstrates that the filtering options in the new GCH (GCH) were better received by users compared to the existing GCH, indicating a significant improvement in user experience. This improvement ultimately enhances the dashboard's effectiveness, enabling users to locate the information more easily they need, thereby increasing the overall efficiency of the dashboard. Effective filtering also impacts how information is presented to the user. Figure 25 shows user eye fixation patterns, indicating that users' attention was directed precisely to the areas of interest when tasked with finding common concepts between two courses. This finding underscores the improved clarity of the new GCH, as it successfully guides users in addressing their queries, making the dashboard a more effective tool for users.

The new GCH (GCH) introduced two significant functionalities: the course comparison view and the identification of sub-concepts within a main concept. Figures 26 and 27 present box and whisker plots of user ratings for these functionalities. Overall, the course comparison view was highly appreciated by users, facilitating easier comparison between courses. This indicates that the new functionality successfully enhanced the overall effectiveness in performing course comparison tasks.

Similarly, the functionality for identifying sub-concepts within a main concept received positive feedback. Despite many users not utilizing the provided tutorial, they were still able to locate the sub-concepts effectively. This suggests that the new GCH's design is intuitive and user-friendly, allowing users to navigate and access information without guidance. The minimum score of 1 and the maximum score of 8 show a wide range of user experiences. The lower whisker extends to 1, highlighting at least one user's significant difficulty in finding sub-concepts, which is an outlier. The upper whisker extends to 8, showing that some users found it considerably easier.

5.2. Discussion over efficiency results:

To evaluate the impact of the new design on user task performance, the average time taken by users to complete each task in both the new and existing GCH (GCH) dashboards was analyzed, as shown in Table 4 and Figure 28. For Task 1, users performed better with the new GCH because all relevant information was accessible on a single page. In this task, users were asked to find a course under a specialization and determine its quartile. In the new GCH, users could quickly locate the course using the hierarchical map and view the quartile information in the table below. In contrast, the existing GCH required users to navigate through a list of courses and pages, increasing the time needed to find the desired information. For Task 1a, the existing GCH outperformed the new GCH. Users needed to find course information, and in the new GCH, this required navigating to another tab, which sometimes delayed the process. The existing GCH had users already on the course information page, leading to quicker task completion. In Task 2, the new GCH again outperformed the existing. This task involved finding specific course information, and the new GCH's design consolidated all course information on one page, facilitating quicker retrieval. Conversely, the existing GCH required users to navigate back and forth between pages, hindering efficiency. Task 3, the final task, demonstrated a significant improvement in the new GCH due to the dedicated course comparison view. Users could easily compare two courses side by side, enhancing their performance. In the existing GCH, users had to individually gather information on each course, resulting in longer completion times. In task 3a the users on average took 1.6 minutes to find the sub-concept of a main concept. This task cannot be performed in existing GCH, therefore, there is no benchmark to test the performance of new GCH in this task. Overall, the new GCH proved to be more efficient and user-friendly compared to the existing GCH, significantly enhancing task performance and user satisfaction.

5.3. Discussion over satisfaction and user friendliness results:

The fourth objective of this thesis relates to the usability study of the GCH (GCH) dashboard. The first research question investigates the overall user-friendliness of the dashboard. Analyzing Table 5 and Figure 29, which compare user satisfaction with filtering options between the new and existing GCH, reveals that users found the filtering options in the existing GCH satisfactory. This indicates that these options effectively filtered information according to user preferences, enhancing the overall user-friendliness of the dashboard. This finding is further supported by the bar graph in Figure 30, which shows user ratings for each dashboard's user-friendliness, with the new GCH outperforming the existing version. Notably, one user rated the existing GCH higher, likely due to their familiarity with it, as indicated during the think-aloud session.

User feedback further underscores the user satisfaction and user-friendliness of the new GCH. Comments highlighted key improvements over the existing GCH, such as the addition of semantic and hierarchical maps, a course comparison view, filtering options to display information on request, and the ability to show sub-concepts of main concepts. Overall, the new GCH is more user-friendly, enabling users to find information easily and efficiently.

5.4. Discussion Over user feedback and improvements:

The second question of the fourth objective addresses user feedback, focusing on positive experiences and suggestions for further improving the new GCH design. Table 6 documents user comments gathered during think-aloud sessions and survey feedback. These comments were reviewed and integrated to enhance the new GCH. As highlighted in Table 6 and Figure 31, one significant issue was the non-static positioning of nodes in the semantic map. Each time the semantic map was generated, nodes appeared in random locations, requiring users to repeatedly search for the same node. This inefficiency was rectified by modifying the Vis.js function, as demonstrated in Figure 33.

The JavaScript code now arranges nodes in a consistent circular layout around a central node. It begins by defining the total number of nodes and a radius for their placement. The central node is positioned at the origin (0,0), and surrounding nodes are positioned using polar coordinates, which are then converted to Cartesian coordinates. Adjustments are made to avoid overlap for nodes near the horizontal axis, ensuring that nodes are evenly spaced around the central node. This adjustment improves both the clarity and usability of the visual representation, making it easier for users to navigate and understand the semantic map consistently as shown in figure 34.

```
var numNodes = trueKeys.length;
var radius = 200;
// Add central node
nodes.push({ id: 0, label: data.name, x: 0, y: 0});
// Calculate positions for each true node
trueKeys.forEach(function(key, index) {
       var angle = (index / numNodes) * 2 * Math.PI;
       var x = radius * Math.cos(angle);
      var y = radius * Math.sin(angle);
       if ((y >= -30 && y <=30) && (x > 0)){
         x = x + 80
          y = y + 80
       }
       if ((y >= -30 && y <=30) && (x < 0)){
          x = x - 80
            y = y + 80}
```

Figure 33: x-y point is given to each node so that their position is always remains the same and avoid overlap.

Another issue identified by users was the use of the same hue for all nodes in the semantic map. This problem has been addressed by differentiating the lightness of the central node from the surrounding nodes, as illustrated in Figure 34. Additionally, node interactivity has been enhanced; nodes now highlight when the user hovers the mouse over them, indicating that they are clickable, as shown in Figure 35. The legend has also been enlarged, and the text made bold to improve visibility. Improvements were also made to the course comparison view. Previously, users had to manually read through lists to find common concepts. Now, these common concepts are highlighted, allowing users to easily identify them, as demonstrated in Figure 36. Furthermore, pop-ups have been added to the view change tabs in the menu bar, providing more information to users upon hovering. To improve the organization, lists for concepts, specializations, courses, and other course-related information are now arranged in alphabetical order.

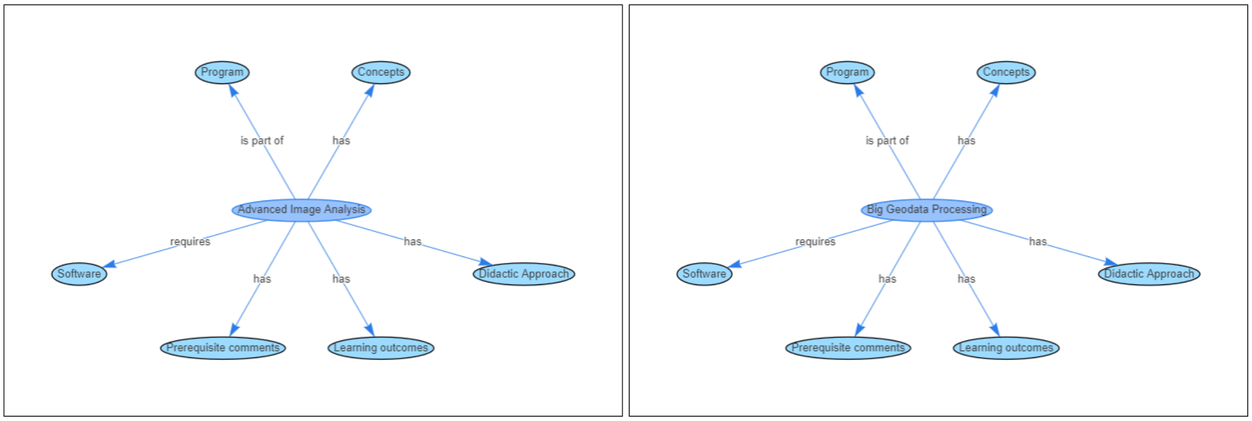


Figure 34: The node positions are made static, and the external nodes were given different lightness.

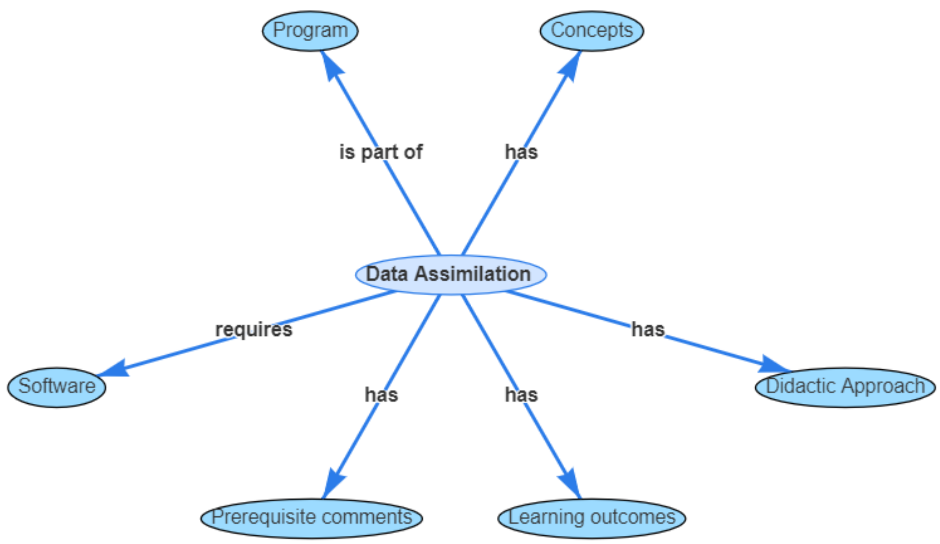


Figure 35: show the highlighted central node as the user hover over it.

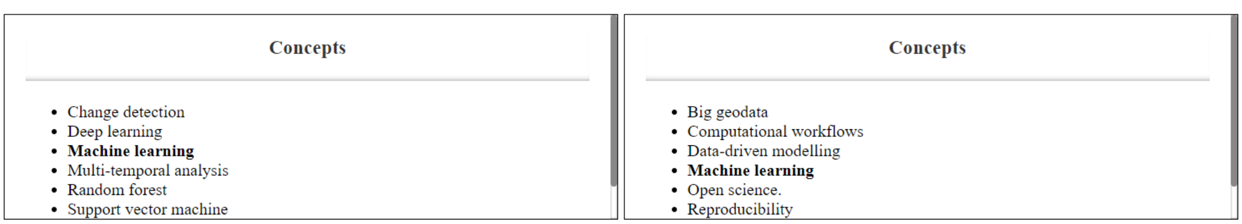


Figure 36: The common concept is highlighted, in course comparison view.

The position of the menu buttons in the menu bar was kept constant based on eye-tracking data, as shown in Figure 32. This data clearly indicates that users consistently fixate on the correct areas when needing to change the dashboard view. Maintaining the menu buttons' positions ensures that users can reliably find and interact with these tabs. Overall the comments made by the users highlight the areas that need to be improved in the dashboard, which results in the improvement of efficiency, effectiveness and user friendliness of the dashboard.

5.5. Implications:

The results of the study underscore the critical importance of a user-friendly interface tailored to accommodate user queries and preferences. As demonstrated in Table 1 and Figure 21, the GCH received significantly higher ratings for structural elements such as menu tabs, course navigation, clarity, and organization of information. This indicates that the new GCH adheres effectively to user-centric design principles. These findings are consistent with prior research, which highlights that well-designed dashboards enhance comprehension and navigation (Few, 2006; Mazumdar et al., 2014).

The study's findings on the use of hierarchical and semantic map, alongside other visual elements such as tables and text, provides valuable insights into the visualization of linked educational metadata. The visualization methods received high ratings, meaning users were able to understand the information easily. This is also supported by the literature that advocates for the use of interactive and dynamic visual elements to enhance data comprehension (Eberhard & Wulf, 2023; Rui et al., 2023).

Moreover, the positive user feedback regarding the overall usability of the new GCH underscores the significance of employing user-centered design principles in developing effective data visualization systems, as also emphasized by Bach et al., (2023). The enhanced user-friendliness ratings for the new GCH, compared to the existing version, validate the hypothesis that a user-centric approach significantly improves the accessibility and understanding of linked educational metadata. This improvement also translates to increased user efficiency in task performance, as evidenced by the reduced time taken by most users to complete tasks using the new GCH.

These findings contribute to the existing body of knowledge on educational data visualization by demonstrating the importance of user-centric design principles in enhancing dashboard usability, efficiency, and satisfaction. The study also highlights the effectiveness of various visualization methods and the importance of the filtering options in the introduced in new GCH dashboard, which play a crucial role in the development of an effective dashboard.

5.6. Limitation and recommendations:

The limitations of this research primarily stem from time constraints. Due to the limited time frame, user requirements were derived from pre-existing user stories of the current GCH (GCH) dashboard, and there was no opportunity to conduct preliminary surveys or interviews with the ITC teachers, the intended end-users, who were constrained by their busy schedules. The project also faced challenges with the data quality on the platform, as it was in its initial phases, leading to numerous missing entries and repetitive information across various courses, which made developing a coherent and consistent dashboard difficult. The usability study, conducted with only nine teachers due to their limited availability and was further impacted by an unsuitable study environment, with distractions from external noise and movement. Technical issues with the Tobii Pro Lab software, which crashed twice during sessions, led to the loss of initial user responses, as participants had to repeat tasks. Additionally, some users did not read survey questions thoroughly, affecting task completion times and feedback accuracy. Furthermore, the feedback provided by the users paved the way for improvements, but unfortunately another study can not be conducted to see how much these modifications has improved the usability of the new GCH.

Despite the identified limitations, the results obtained from this study are valid and provide significant insights for answering the research questions. The user requirements, although derived from pre-existing user stories, were relevant and applicable to the current user base, ensuring the new GCH (GCH) addressed the needs of ITC teachers effectively. The usability study, despite its small sample size and environmental challenges, yielded consistent and meaningful data on the interface's effectiveness, efficiency, and user satisfaction. This validity is further proved by the convergence of results across multiple methods. For instance, the survey results, eye-tracking data, and think-aloud sessions consistently highlighted the same usability issues and strengths.

The GCH (GCH) can be significantly enhanced by incorporating additional aspects of the courses, such as detailed learning activities per learning unit and the time allocated to each activity. Future iterations could also link each course to its associated materials, thereby providing users with direct access to relevant resources. While the current GCH includes related sub-concepts for main concepts, it would be beneficial to delineate which sub-concepts of a main concept, such as machine learning, are covered in specific courses. Future studies should prioritize conducting initial surveys and interviews with users to gather comprehensive requirements based on the available data and interface design. This approach will help determine which visualizations or charts are most suitable for user needs. Expanding the usability study to include a larger sample size would enhance the generalizability of the results. Moreover, research should explore adapting the dashboard for student use, starting with an initial usability study to identify necessary improvements, followed by the development of an optimized design tailored to student needs. Future work should also explore the adaptation of the GCH (GCH) for mobile platforms, potentially developing it into a user-friendly mobile application.

6. Conclusion:

This research aimed to develop a linked educational metadata visualization dashboard that improves upon the existing GCH (GCH) by incorporating diverse visual materials while addressing user needs. The central hypothesis was that a user-centric data visualization system enhances users' ability to understand, and access linked educational metadata. The following sub-objectives and research questions were addressed in this study:

1. Design a user-friendly interface tailored to the needs of teachers interacting with the GCH.

RQ1: How can the dashboard interface be structured to accommodate the specific preferences and queries of teachers?

RQ2: What visual elements and navigation features would optimize the user experience for teachers exploring linked educational metadata?

The research answered RQ1 and RQ2 by creating a dashboard that prioritizes user needs. Users efficiently located the information they sought, as evidenced in Section 4.2 of the results. The optimized user experience, compared to the existing GCH, was achieved by adopting intuitive navigation features, validated through the data presented in Tables 1 and 2 and Figure 21 from Section 4.1. Thus, Objective 1 was successfully met.

2. Incorporate semantic maps or hierarchical charts to reveal contextual relationships among courses, specializations, and courses metadata.

RQ3: To what extent can semantic maps and hierarchical charts be interchanged in visualizing linked educational metadata within the GCH, and how does this interchangeability impact users' understanding of contextual relationships between courses, specializations, and courses metadata?

RQ3 was addressed through the data in Tables 1 and Figures 22 and 23 in Section 4.1. Both hierarchical and semantic maps effectively conveyed information, receiving similar user scores and preferences. These charts improved upon the existing GCH, fulfilling Objective 2

3. Implement categorization and filtering options to streamline the display of data, addressing issues of visual cluttering.

RQ4: What criteria should be considered for the effective categorization of educational metadata to improve visualization clarity?

RQ5: How can filtering mechanisms be customized to allow teachers to focus on specific aspects, such as topics, quartiles, or specializations?

The criteria for categorizing educational data were well-received, as shown in Table 2 and Figure 2. Users appreciated the clear presentation of information, facilitated by effective use of space and filtering options, as evidenced by Figures 24 and 29. These findings addressed RQ4 and RQ5, thereby completing Objective 3.

4. Conduct usability testing sessions to evaluate the overall effectiveness and user satisfaction of the developed dashboard and visualization.

   RQ6: How do teachers perceive the overall usability and functionality of the data visualization system during usability testing sessions?

   RQ7: What specific usability challenges or positive experiences do teachers encounter, and how can these insights inform further refinements to the system?

RQ6 was answered in Section 4.3, where users expressed satisfaction with the filtering options and rated the new GCH higher in user-friendliness compared to the existing version. Table 6 highlighted that both experienced and novice users could effectively use the new GCH. RQ7 was addressed in Section 4.4, which detailed user feedback and areas for improvement that informed the new GCH design. Thus, Objective 4 was achieved.

The research methodology employed in this study involves the development of a new GCH (GCH), incorporating the proposed visualizations detailed in Subsection 3.3 to effectively present linked educational metadata to users. The dashboard was designed to present the information onto a single page using multiple visualization techniques. Developed using web technologies, it is accessible via the university server, ensuring broad accessibility. The chosen usability methods illustrate the significant enhancements of the new GCH over its predecessor. These methods are complementary, revealing consistent patterns in the collected data across various usability evaluations, thereby reinforcing the reliability and validity of the results obtained.

The new GCH can be enhanced in future by adding detailed learning activities per unit, linking courses to their materials, and specifying which sub-concepts are covered in each course. Future research should include initial surveys and interviews with users to determine the most suitable visualizations. Expanding the usability study with more participants will improve result generalizability. Additionally, adapting the dashboard for student use through initial usability studies and subsequent design optimization is recommended. Future work should explore the adaptation of the GCH (GCH) for mobile platforms, potentially developing it into a user-friendly mobile application.

The research achieves its primary objective by developing an enhanced visualization system tailored to explore linked educational metadata while addressing user needs. Additionally, the findings support the hypothesis that dashboards designed with user-centric principles significantly improve users' ability to effectively utilize the system and comprehend the presented information. This study bridges a critical gap by representing linked educational metadata through a combination of tables, text, and maps within a dashboard format. Furthermore, the research advances the current GCH (GCH) by resolving the issues identified, thereby providing a more efficient and user-friendly interface.

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Appendix:

1. User tasks:

User tasks:

1. Assume You are a new teacher and who has been asked to teach a course, let's say "Environmental impact assessment". You heard there is course like this which is offered in "Natural resource Management" Specialization. Can you find that course and tell me its name and in which quartile the course is offered.

    a. Now, you want to know what **concepts** this course covers and what are the **pre-requisite comments**. Can you find the **concepts** and **pre-requisites comments** for this course and where you will go in the dashboard.

2. Now can you find the course **"From Data to Geo-information for Natural Resources Management"**. Now can you tell me what the **prerequisite courses** of this course are, can you find it.

3. Imagine you are going to teach a course called "**Big Geodata processing**" and you already know that the students have taken or taking the "**Advanced image analysis**" course. So, you want to know about the **concept** the student will already know about. Can you **find the common concept** for the two courses mentioned.

    a. Now, you want to find narrower concepts of the common main concept that you found. Can you tell me the name of the those two.

4. Now, use the dashboard freely and once you are ready you can fill out the survey form.

2. Consent form:

Consent Form

Project Title: **A User Centric Approach to Visualizing Linked Educational Metadata in The ITC Geo Course Hub.**

Faculty of Geoinformation science and Earth Observation, ITC, University of Twente.

Introduction:

You are being invited to participate in a research study titled "A User Centric Approach to Visualizing Linked Educational Metadata in The ITC Geo Course Hub.". This study is being done by a master student Hafiz Muhammad Amin Shah from the University of Twenty Faculty ITC, supervised by Dr. Paulo Raposo, and Dr. Ronzhin Stanislav. The purpose of the research study is to check the efficiency and effectiveness of the dashboard visualizing the educational meta-data of ITC Geo Course Hub. The study will take approximately 40 minutes to complete. The data gathered will be used to check whether the proposed dashboard fulfils the users' needs and will be used in modification and optimization of the dashboard, and in the research report. The study will contain the eye-tracking test which will record your eye movement and a think aloud process where you need to express your thoughts verbally. You will be asked to solve certain task related to the dashboard and will give your opinion and feedback at the end about the proposed visualization. Your participation in this study is entirely voluntary and you can withdraw at any time.

Participant Consent:

By agreeing to participate in this study, you acknowledge that:

1. You have read and understood the information provided in this consent form.
2. You voluntarily agree to participate in the user testing session for the Geo Course Hub dashboard.
3. You understand that your participation will involve interacting with digital visualization tools and providing feedback on your experience.
4. You understand that your participation will involve the recording of audio, video, and screen activity for research purposes, and you consent to the use of such recordings for data analysis and reporting.
5. You understand that any information collected during the study will be kept confidential and will only be used for this research project.
6. You understand that your identity will be kept anonymous in any reports or publications resulting from this study, and only aggregate data will be presented.

Participant Rights:

1. Your participation in this study is entirely voluntary, and you may withdraw at any time without penalty.
2. You have the right to refuse to answer any questions or perform any tasks that make you feel uncomfortable.
3. You have the right to ask questions about the study before, during, or after your participation, and these will be answered to the best of the researchers' ability.

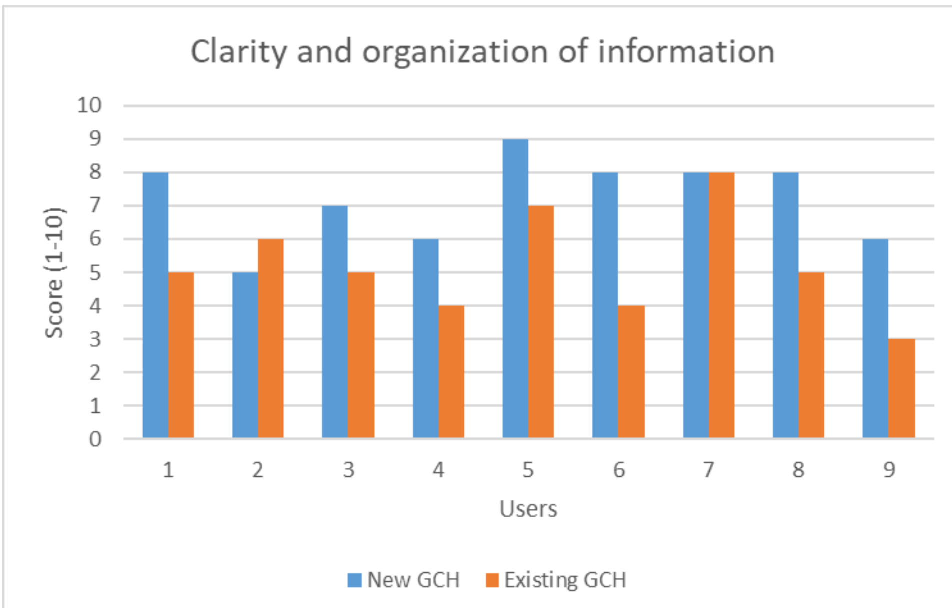
Consent: By providing your signature below, you indicate that you have read and understood the information provided in this consent form, and voluntarily agree to participate in the user testing session for the Geo Course Hub.

Participant Signature:

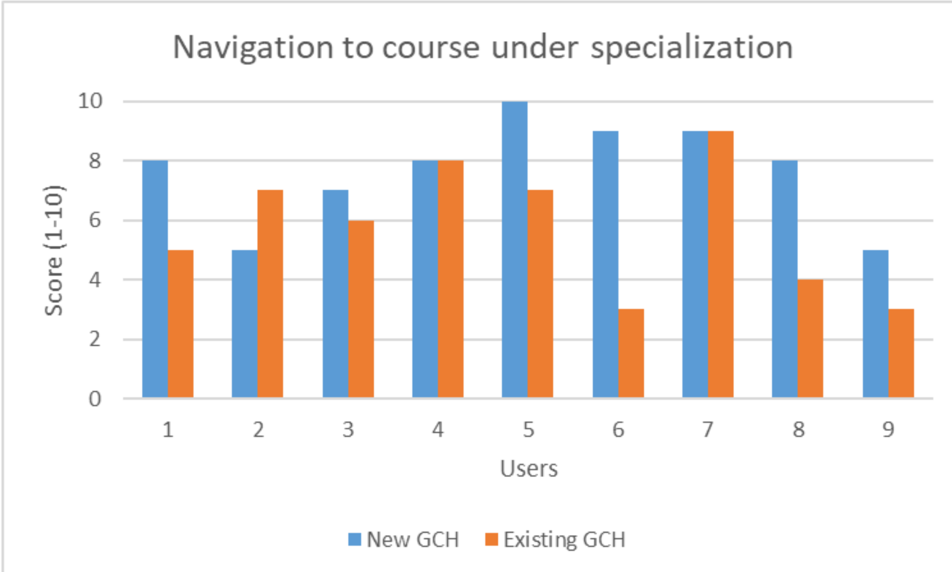
UNIVERSITY OF TWENTE. | ITC

3. Details of result of table 2 and figure 21

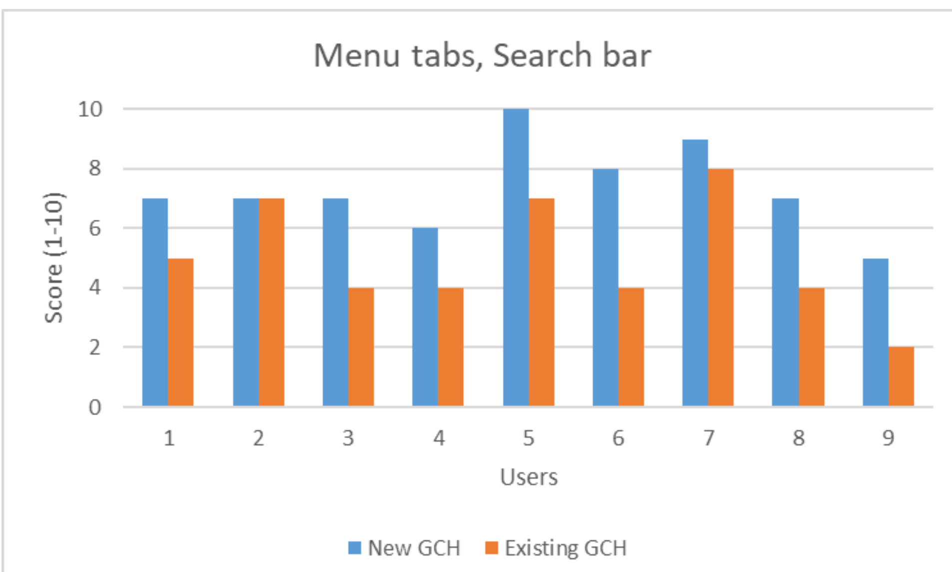
Users	Clarity and organization of information in new GCH.	Clarity and organization of information in existing GCH.
User1	8	5
User2	5	6
User3	7	5
User4	6	4
User5	9	7
User6	8	4
User7	8	8
User8	8	5
User9	6	3
Average	7.2	5.2



Users	Nvigate to a course in a specialization new GCH	Nvigate to a course in a specialization old GCH
User1	8	5
User2	5	7
User3	7	6
User4	8	8
User5	10	7
User6	9	3
User7	9	9
User8	8	4
User9	5	3
Average	7.7	5.8



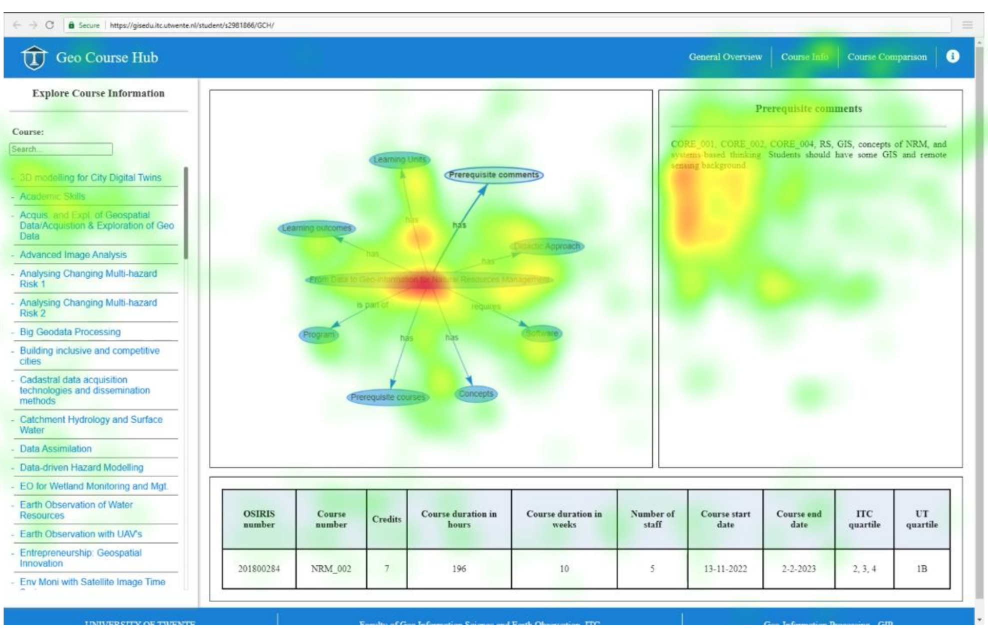
Users	Navigation(Menu tabs, Search) in New GCH	Navigation(Menu tabs, Search) in exsisting GCH
User1	7	5
User2	7	7
User3	7	4
User4	6	4
User5	10	7
User6	8	4
User7	9	8
User8	7	4
User9	5	2
Average	7.3	5.0

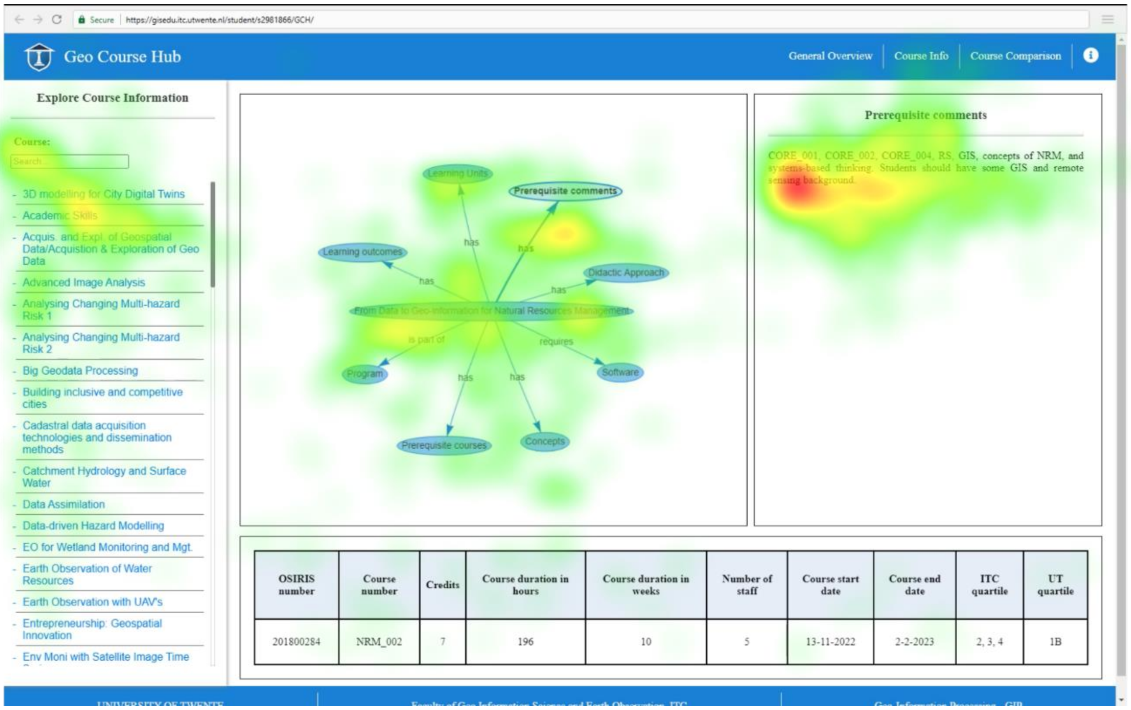


4. Details Result of figure 22 & 23:

Users	Effectiveness of Hierarchical chart	Effectiveness of Semantic Map	Preference between semantic map and hierarchical chart
User1	6	8	Semantic Map
User2	6	5	Hierarchical Map
User3	7	7	Hierarchical Map
User4	8	6	Hierarchical Map
User5	7	9	Semantic Map
User6	6	8	Semantic Map
User7	9	9	Hierarchical Map
User8	8	8	Hierarchical Map
User9	7	7	Semantic Map
Average	7.1	7.4	

5. Heat Maps of different tasks:




https://gisedu.itc.utwente.nl/student/s2981866/GCH/
Geo Course Hub
General Overview
Course Info
Course Comparison
Explore Course Information
Course:
3D modelling for City Digital Twins
Academic Skills
Acquis. and Expl. of Geospatial Data/Acquistion & Exploration of Geo Data
Advanced Image Analysis
Analysing Changing Multi-hazard Risk 1
Analysing Changing Multi-hazard Risk 2
Big Geodata Processing
Building inclusive and competitive cities
Cadastral data acquisition technologies and dissemination methods
Catchment Hydrology and Surface Water
Data Assimilation
Data-driven Hazard Modelling
EO for Wetland Monitoring and Mgt.
Earth Observation of Water Resources
Earth Observation with UAV's
Entrepreneurship: Geospatial Innovation
Env Moni with Satellite Image Time
Learning Units
Prerequisite comments
Learning outcomes
Didactic Approach
From Data to Geo-information for Natural Resources Management
has
is part of
requires
Program
Software
Prerequisite courses
Concepts
Prerequisite comments
CORE_001, CORE_002, CORE_004, RS, GIS, concepts of NRM, and systems-based thinking. Students should have some GIS and remote sensing background.
OSIRIS number | Course number | Credits | Course duration in hours | Course duration in weeks | Number of staff | Course start date | Course end date | ITC quartile | UT quartile
201800284 | NRM_002 | 7 | 196 | 10 | 5 | 13-11-2022 | 2-2-2023 | 2, 3, 4 | 1B


https://gisedu.itc.utwente.nl/student/s2981866/GCH/
Geo Course Hub
General Overview
Course Info
Course Comparison
Explore Courses by concepts & Specializations
Select By:
Specializations
Concepts
Concept:
machine
Machine learning
Main Concept
Course
Random forest
Support vector machine
Machine learning
Big Geodata Processing
Advanced Image Analysis
Course name | OSIRIS number | Course number | Credits | Course duration in hours | Course duration in weeks | Number of staff | formatted start date | formatted end date | ITC quartile | UT quartile
Big Geodata Processing | 201900064 | GIP_0001 | 5 | 140 | 10 | 3 | 04-09-2022 | 10-11-2022 | 1 | 1A
Advanced Image Analysis | 201900065 | EOS_0003 | 5 | 140 | 10 | 4 | 04-09-2022 | 10-11-2022 | 1 | 1A

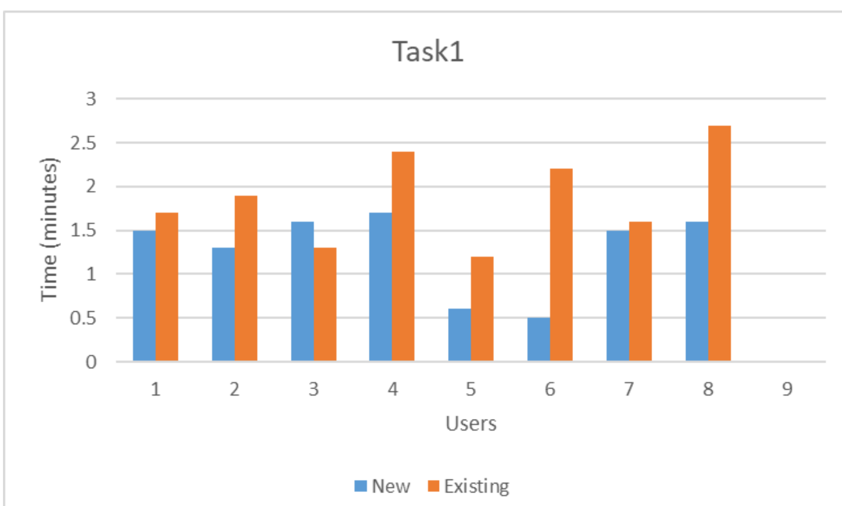
6. Details Result of figure 26 & 27:

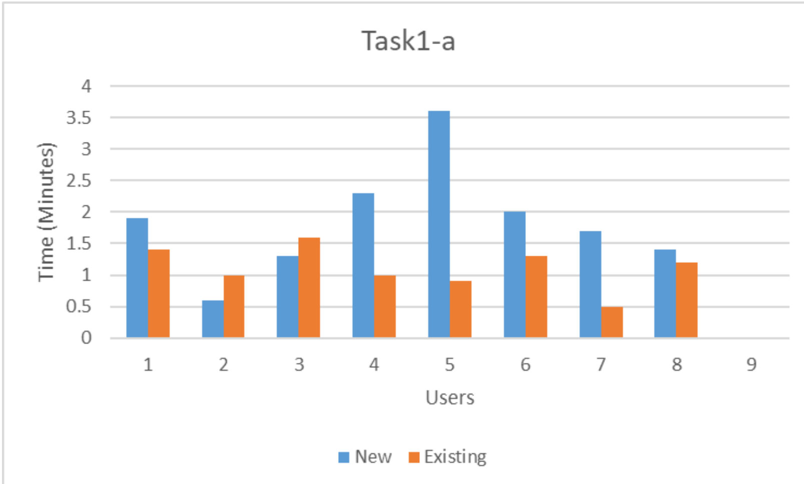
Users	Comparing the concepts of two courses	Ease of finding sub-concept
User1	8	7
User2	6	6
User3	6	5
User4	8	5
User5	10	6
User6	9	6
User7	9	7
User8	10	8
User9	7	1
Average	8.1	5.7

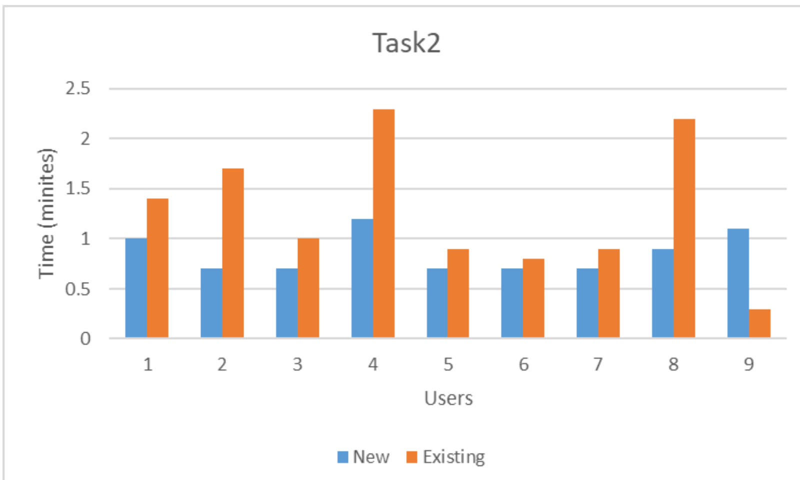
7. Detail result of table 4 and figure 28:

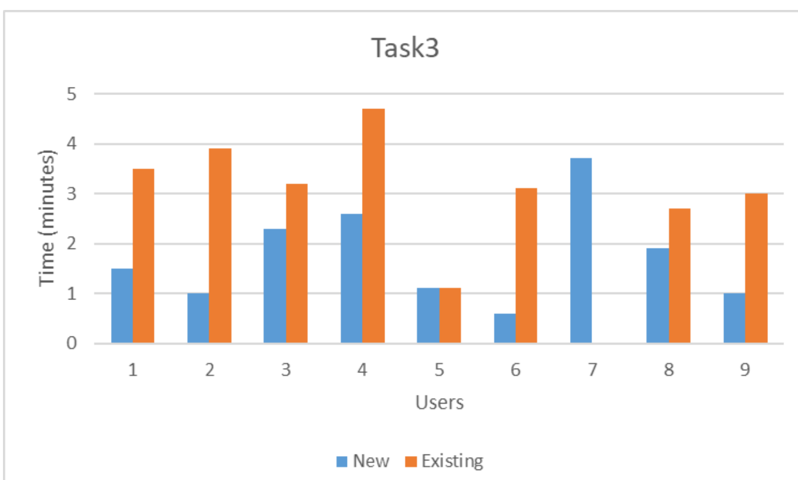
Time is calculated in minute.

Users	Time of task 1		Time of task 1a		Time of task 2		Time of task 3		Time of task 3a	
	New	Existing	New	Existing	New	Existing	New	Existing	New	Existing
User 1	1.5	1.7	1.9	1.4	1	1.4	1.5	3.5	1	NA
User 2	1.3	1.9	0.6	1	0.7	1.7	1	3.9	2.2	NA
User 3	1.6	1.3	1.3	1.6	0.7	1	2.3	3.2	0.4	NA
User 4	1.7	2.4	2.3	1	1.2	2.3	2.6	4.7	3.1	NA
User 5	0.6	1.2	3.6	0.9	0.7	0.9	1.1	1.1	4	NA
User 6	0.5	2.2	2	1.3	0.7	0.8	0.6	3.1	1.7	NA
User 7	1.5	1.6	1.7	0.5	0.7	0.9	3.7		0.5	NA
User 8	1.6	2.7	1.4	1.2	0.9	2.2	1.9	2.7	0.5	NA
User 9					1.1	0.3	1	3	0.7	NA
Average	1.3	1.9	1.9	1.1	0.9	1.3	1.7	3.2	1.6	NA




Task1-a
Time (Minutes)
4
3.5
3
2.5
2
1.5
1
0.5
0
1 2 3 4 5 6 7 8 9
Users
New
Existing


Task2
Time (minites)
2.5
2
1.5
1
0.5
0
1 2 3 4 5 6 7 8 9
Users
New
Existing


Task3
Time (minutes)
5
4
3
2
1
0
1 2 3 4 5 6 7 8 9
Users
New
Existing

Details Result of figure 30 & Table 6:

Users	User firendliness of New GCH	User firendliness of Existing GCH
User1	7	5
User2	7	7
User3	7	5
User4	5	5
User5	9	5
User6	7	4
User7	7	8
User8	8	5
User9	5	3
Average	6.9	5.2

Details Result of figure 30.

Users	Years of teaching	Fimiliarity with program	User firendliness of New GCH
User1	5	8	7
User2	35	10	7
User3	20	8	7
User4	30	10	5
User5	3	6	9
User6	6	8	7
User7	9	5	7
User8	10	8	8
User9	4	7	5

Details Result of Table 6.