Universidade do Minho
Escola de Letras, Artes e Ciências Humanas

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Exploratory visualization of science in an academic context: development of an interface applied to languages

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Professor Bruno Azevedo

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STATEMENT OF INTEGRITY

I here declare having conducted this academic work with integrity. I confirm that I have not used plagiarism or any form of undue use of information or falsification of results along the process leading to its elaboration.

I further declare that I have fully acknowledged the Code of Ethical Conduct of the University of Minho.

Abstract

This work presents a web-based platform developed as part of the DIAL4U project, funded by the Erasmus+ program of the European Union. The project aims to assist foreign language teachers during the challenges posed by the COVID-19 pandemic. It focuses on designing and deploying a web-based interface for delivering multimodal academic content in foreign language education, emphasizing collaborative knowledge creation.

Drawing from Scientific Communication, Data Visualization, and Digital Humanities, this project seeks to create an interactive and multimodal interface to support language educators in adapting their teaching to pandemic scenarios. The platform's concept of data visualization in a hierarchical structure, radial tree layout, as a source of interaction and knowledge discovery enhances user navigation and access to content visually and interactively.

The development process involved creating a medium-fidelity prototype, implementing a radial tree data visualization, designing the web page, and integrating content using HTML, CSS, JS, JSON, and the E-charts visualization library. In addition, the DIAL4U project incorporates a curated podcast series and diverse pedagogical resources to engage the audience. The development used User Interface Design and User Experience.

The project culminated in a workshop designed for foreign language educators to experience the resource and gain a deeper understanding of the intended user base. The workshop provided an opportunity to get educators' feedback and identify issues for further improvement.

Keywords: Information Visualization; Science Communication; Interfaces; Radial tree layout.

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Acronyms

API - Application Programming Interface

COVID-19 - Coronavirus Disease 2019

CSS - Cascading Style Sheets

DIAL4U - Digital pedagogy to develop Autonomy, mediate, and certify Lifewide and Lifelong Language Learning for (European) Universities

DOM - Document Object Model

DSR – Design Science Research

GIS - Geographic Information Systems

HCI – Human-Computer Interaction

HTML - HyperText Markup Language

HTTP - Hypertext Transfer Protocol

INFOVIS – Information Visualization

IO - Intellectual Output

JS - JavaScript

JSON - JavaScript Object Notation

LTTA - Learning Teaching Training Activity

NPM – New Public Engagement

PUS - Public Understanding of Science

TRL - Technology Readiness Level

UMINHO – University of Minho

WHO - World Health Organization

XML - Extensible Markup Language

1. Introduction

This work focuses on creating a resource for science communication. In this sense, this research aims to explore a potential solution to science communication during the COVID-19 (Corona Virus Disease 2019) pandemic to foreign language teachers by creating online resources that facilitate clear, interactive, and accessible communication among university audiences and scientists. This work focuses on creating a resource that addresses the challenge of conveying scientific knowledge in a clear, interactive, and accessible way.

In this realm, science communication has assumed a paramount role in disseminating scientific knowledge to lay and expert audiences. In recent years, academics, researchers, and students have explored the creation of digital and online resources using creative strategies to enhance science communication and knowledge dissemination. As a result of the integration and spread of digital technologies, educational practices, including language teaching and learning, have been undergoing significant changes.

Besides this revolution, the COVID-19 pandemic has significantly impacted the teaching landscape due to the social distance requirements. On March 11, 2020, the WHO (World Health Organization) declared it a global pandemic, obliging organizations and society to adapt to challenging circumstances through innovation and competitiveness. The COVID-19 pandemic has significantly changed education, forcing educators and students to adapt quickly to online teaching and learning environments. As a result, there have been equity, access, and capacity issues in distance learning (Fullan et al., 2020). This disturbance in education is estimated to result in a loss of $10 trillion in earnings over time for the current generation of students (Reimers, 2022).

In this scenario, the DIAL4U (Digital pedagogy to develop Autonomy, mediate, and certify Lifewide and Lifelong Language Learning for (European) Universities) project emerges to help teachers and students deal with the difficulties experienced in the language teaching landscape

as they transition from physical to virtual environments. The project is co-funded by the Erasmus+ program of the European Union and supported by the European Commission.

The DIAL4U objectives include empowering language teachers with digital skills, creating innovative digital tools for language learning, recognizing and validating language learning across contexts, and promoting open educational resources. Furthermore, the DIAL4U project seeks to enhance language learning outcomes, making it more engaging and accessible while enabling learners to take ownership of their learning journey.

As a scholarship recipient (Fundação da Ciência e Tecnologia) and a master's student at the University of Minho, I participated in the project's development in which I was responsible for designing the interface presented in this work, managing data acquisition, and creating resources such as podcasts. The objective of the intellectual output that I worked on was to enhance multimodal language learning and teaching material to develop autonomy.

An interface has been developed to support language educators in adapting to online teaching. This user-friendly tool equips them with essential skills and strategies to improve their teaching methods in traditional and digital environments. Moreover, the interface simplifies scientific communication through data visualization, enabling more profound and effective knowledge exploration and exchange, resulting in better learning outcomes.

1.1. Objectives

The project aims to implement, design, and develop a web interface for communication, visualization, and collaborative creation of educational multimodal and linguistic resources. To reach this goal, it will be necessary:

- Literature review on the state of the art of interactive visualizations.
- Identify the visualization characteristics of topics and contents.
- Develop a medium-fidelity prototype of the web interface.
- Implement the radial structure in HTML, JS, and CSS.
- Conduct a Workshop to experience the interface.

1.2. Benchmarks

To adequately address the identified issue, it is essential to establish criteria for developing the proposed solution. The necessary considerations and requirements include:

- **Contribute to Knowledge Discovery:** A proposed solution must demonstrate its ability to enhance language teaching discovery of practices and methodologies with the potential to contribute to the daily activity of language teaching.
- **Boost Educators:** A practical solution should empower language educators by equipping them with a range of digital skills and resources.
- **User Feedback and Satisfaction:** The solution should be refined based on continuous feedback to meet educators' needs and expectations.

1.3. Motivation

The DIAL4U project has a research framework that powers the development of an interactive and educational web-based resource. The framework is rooted in a user-centric and iterative design approach, emphasizing aligning project objectives with user needs and best practices.

The framework utilizes interactive data visualization techniques to engage and comprehensibly present complex information visually. Hierarchical data structures (see section Hierarchical Structures) organize and navigate the project's content effectively, allowing users to explore the resource at various levels and providing a structured and coherent learning experience.

The research framework emphasizes including multimodal information within the web interface to support science communication and enhance language learning. Textual content, images, and videos are included to accommodate diverse learning styles and preferences.

1.4. Document Structure

This dissertation is structured into five chapters, each providing context and perspectives on the project's main components. The first chapter, "State of the Art," provides a comprehensive

overview of Science Communication and Data Visualisation as a foundational pillar. The link between the fields of Digital Humanities and the role of Science Communication in developing online resources is explored in depth in the next section. With this foundation, we move on to the Methodological Approach chapter, which describes the elements of the solution space and the research process critical to the development of this work.

In the Web Interface Development chapter, we delve into the details of creating the resource. Based on this groundwork, the next chapter describes the workshop, presenting how it was set up and how it takes place, as well as a brief analysis of the results. The final chapter delves into the improvements made to the user experience and the discerned impact of the project and offers recommendations for future endeavors.

2. State of Art

This section comprehensively examines key themes supporting this project's development. It explores the role of Science Communication as a tool for delivering meaningful information to the public and delves into the implications of employing Data Visualization interfaces.

2.1. Science Communication

Science communicators, such as academic institutions, research institutions, or public relations agencies, depend on the knowledge of their audiences to communicate science (Kessler et al., 2022). Whether the audience is scientists, the media, policymakers, or non-scientists (Schäfer et al., 2019), the creation of new resources depends on the ability of science communicators to respect their audience's prior knowledge and thus keep them interested in what will be communicated (Geenen et al., 2020).

In this sense, it’s important to underline that the concept of science communication isn't homogenous (Kessler et al., 2022). Some researchers advocate for a unidirectional flow of scientific information from experts to the public as a suitable approach to science communication. Conversely, alternative models prioritize dialogue and deliberation involving the public, experts, and decision-makers as the preferred method of engaging in science communication (Kappel & Holmen, 2019).

The timeline of these models begins with the Deficit Model in the 1960s, which, during the 1980s and 1990s, shifted to the Public Understanding of Science (PUS) paradigm (Entredas, 2021). Both models assumed that a lack of knowledge among the public needed to be addressed. Despite the decline in the popularity of the deficit model and its lack of empirical support, a deficit approach still prevails in science communication. The PUS paradigm assumes that increasing lay knowledge about science will lead to more significant public support for science. The longevity of the PUS approach can be attributed to the simplicity of implementation. Moreover, it views science communication as a one-way dissemination of knowledge, hindering public influence on scientific discourse (Kessler et al., 2022).

After the 2000's, a new model called Public Engagement with Science (PES) emerged, aiming to facilitate a two-way dialogue between science and the public. The focus shifted from merely creating public awareness of science to encouraging citizen engagement and dialogue among various stakeholders (Bucchi & Trench, 2014). Non-scientists' involvement in scientific research and knowledge generation, such as citizen science, gained importance (Haklay et al. 2021). The goal of science communication now includes establishing a dialogue with the public and enabling their participation. This approach promotes discussions and interactions as equals between science and society.

A third model, Strategic Science Communication, has gained prominence in the last decade, emphasizing the legitimation of science and its protagonists. For example, scientific institutions and academics lead to strategic communication with instrumental goals like reputation-building, especially regarding communications as publications. On the individual level, academics are pressured to compete for limited positions, publish extensively, secure funding, and strategically use public communication to their advantage (Kessler et al., 2022).

The New Public Management (NPM) ideology is centered on the premise that institutional communication responds to the era of 'academic capitalism' (Entradas, 2022) and the competitive environment driven by NPM. Current research has delved into the shifting landscape of science communication, highlighting the evolving role of science journalism and the ascending influence of strategic communication by science organizations (Marcinkowski et al. 2014). This transformation is witnessed through two distinct types of studies: those focusing on structural aspects and those using analytic instruments or strategies. On the structural element, it is possible to see the increase in institutionalization and professionalization of science communication professionals, and this work relies on this.

2.1.1. The Dissemination Paradigm

Models within the dissemination paradigm perceive science communication as effectively conveying information from scientific experts to the public. Prominent perspectives assume this transmission occurs through formal education or mass media, including various media formats like books, documentaries, magazines, blogs, and websites (Kappel & Holmen, 2019). Including

scientific journalism, popular science channels, open lectures, and social media fosters public trust in science and extends engagement beyond the scientific realm (UNESCO, 2021). And social media, such as Twitter, due to the potential to promote public engagement (Guenther et al., 2023).

When it comes to evaluating science communication, both individual context and context diversity have a significant impact. Some dissemination models acknowledge the importance of social diversity and how it can affect people's responses to communication efforts. These models recognize that an individual's information processing is influenced by various factors, such as social, psychological, experiential, and cultural factors. Considering these different factors makes it possible to understand better how to effectively communicate scientific information to a diverse audience (Kappel & Holmen, 2019).

2.1.2. The Public Participation Paradigm

Most models within the public participation paradigm prioritize enabling interactive communication—dialogue and, at times, deliberation—among the public, experts, and policymakers (UNESCO, 2021). Numerous methods have been proposed, varying from traditional approaches like public hearings and referendums to less familiar methods such as Science Shops, Scenario Workshops, Citizens Juries, Planning Cells, Deliberative Polling, and more (Kappel & Holmen, 2019).

One of the most prominent models of this paradigm is Citizen Science, a participatory approach that involves public members in scientific activities, contributing to research and data collection (Haklay et al., 2021). This model leverages the collective power of individuals to assist scientists in addressing complex questions and conducting various projects across diverse fields. Participants engage in data collection, observation, and analysis tasks, often aided by digital technologies and online platforms. Citizen Science empowers individuals to contribute meaningfully to scientific endeavors and fosters a sense of ownership and connection to research outcomes, promoting a deeper public engagement with science (Kappel & Holmen, 2019).

Notably, journals specific to science communication, such as Science Communication (SC), Journal of Science Communication (JCOM), and Public Understanding of Science (PUS), have

increased the number of publications between 1976 and 2016 (Schäfer et al., 2019). This results in investigating diverse science communication topics among bioscientists, political scientists, and social scientists; however, it's important to point out the lack of quantitative studies (Kessler et al., 2022).

At the same pace, it's notable that the internationalization of the field, besides the notable discrepancy between the number of productions of English writing in the Western world and other languages and countries, is also noteworthy. The diversification in language matters is a challenge that needs to be addressed in this field. It's also significant for the diversification of study subjects and the increase of resources used to communicate (Schäfer et al., 2019) the support of institutions such as museums, universities, and public relations companies that hosted the research or were a communication channel.

On the other hand, social media communicators have approached science through the roles of curators, conveners, intellectuals, and civic educators, facilitating interaction with the public by using multimodality (Schäfer et al., 2019). The presence of these speakers, who may become influencers, occasionally generates tensions with more traditional academic communicators (Bucchi & Trench, 2021).

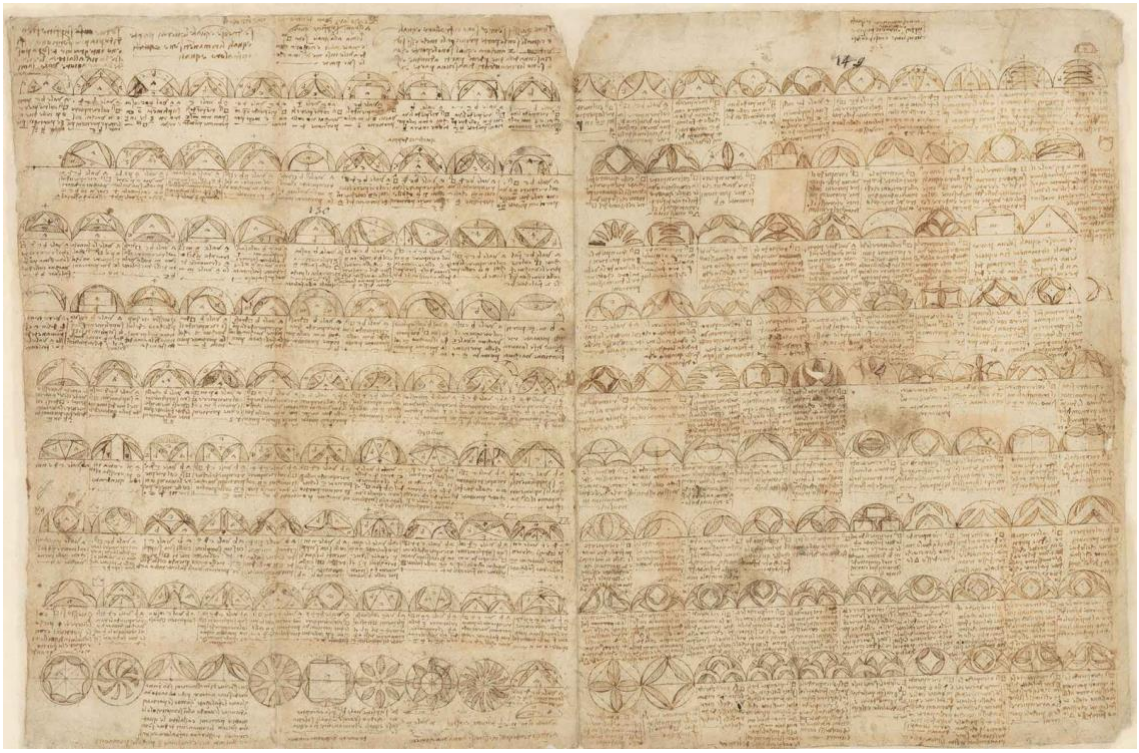
This is influenced by how communication is carried out in institutions such as museums, which use a centralized communication channel. This project creates a web interface focusing on language teaching data, thus forming a resource of scientific content created by participants, whether connected to the project or not. It also emphasizes the multimodal dissemination of knowledge, aiming to make the content more appealing to the public.

2.1.3. Data Visualization and Science Communication

Data visualization is a tool that facilitates the dialogue between the scientific fields and the public, including peers and/or the lay public (Silic & Lowry, 2020). Being a powerful tool in the information society (Norris, 2012)—enabling the presentation of data in an attractive, interactive, and easy-to-understand way (Zentner et al., 2020)—motivating the public interest in science and pursuing knowledge through discovering and discerning relationships between elements that emerge from large and complex data sets (Arce-Orozco et al., 2019). Synthesizing knowledge in a

visual representation as done by Leonardo Da Vinci (1480/1482)[1] (Figure 1) with his research through graphic representations (Silic & Lowry, 2020), that is, the synergy between text and image (Unwin, 2020).

Figure 1. Atlantic Codex (Codex Atlanticus)—Leonardo da Vinci: Geometrical drawings dealing with the transformation of curvilinear surfaces into linear surfaces and vice versa.



Note. By Da Vinci (1480), drawing, pen, ink, and wash on paper are located at Veneranda Biblioteca Ambrosiana.

Information visualization is the result of the combination of science, art, and visual design (Silic & Lowry, 2020) that makes it possible to improve the ability to perceive visual patterns, trends, and outliers (Idrissov, 2021). Data visualization uses technologies—artifacts such as the clock, compass, abacus, or map—that transform how people relate to reality (Cairo, 2020) by making complex data more accessible to understand than tabular data (Geenen et al., 2020).

[1] Available on Google Arts & Culture.

InfoVis (Information Visualization) is a complementary tool to scientific writing and plays a strategic role in clarifying the information presented in the text (Unwin, 2020). Using graphic forms, it is possible to communicate objectively with a broad and diverse audience (Gai et al., 2022) and promote the dissemination of scientific knowledge (Cavaller, 2021). However, when presented ineffectively, these graphics can leave viewers needing clarification in terms of navigation and interpretation (Franconeri et al., 2021).

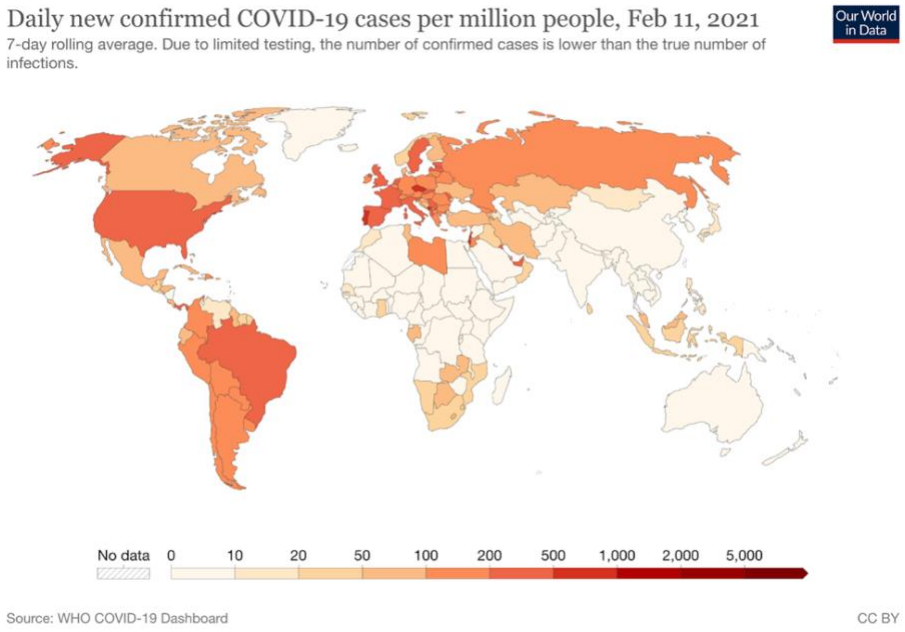
Visualization principles are the basis for building compelling visualizations and are influenced by several areas, such as epistemology, sociology, semiotics, history, ethics, critical theory, and philosophies of science, statistics, art, and technology (Cairo, 2020). From an approach that maximizes obtaining reliable, replicable, and representative results by analyzing history, assumptions, conventions, and practices in observational, descriptive, hermeneutic, normative, and critical approaches (Meyer & Dykes, 2020).

Both academic and civil society institutions (Zentner et al., 2020) use information visualization to communicate with their audiences (Unwin, 2020) through projects that emphasize three aspects of scientific communication: Dissemination of scientific knowledge, dissemination of scientific experience, and dissemination of the scientific community (Yansong et al., 2020). Examples include The COVID-19 Pandemic: Visualizing the Global Impact[2] (Figure 2) from the University of Oxford, which presents data on the COVID-19 pandemic around the world through the dissemination of scientific knowledge (Mathieu et al., 2020), the same perspective as Mapping Antibiotic Resistance[3] (Figure 3), which uses interactive maps to display the levels of antibiotic resistance around the world (Criscuolo et al., 2021); and the Palladio[4] (Figure 4) project from Stanford University (2021), which created an interface in which users develop visualizations

[2] Available on Our World in Data.
[3] Available on Resistance Bank.
[4] Available on Palladio Project.

from historical data related to their research (Edelstein et al., 2017), in an attempt to combine graphical interfaces with humanistic methods (About, n.d.).

Figure 2. Daily confirmed COVID-19 cases per million people, Feb 11, 2021

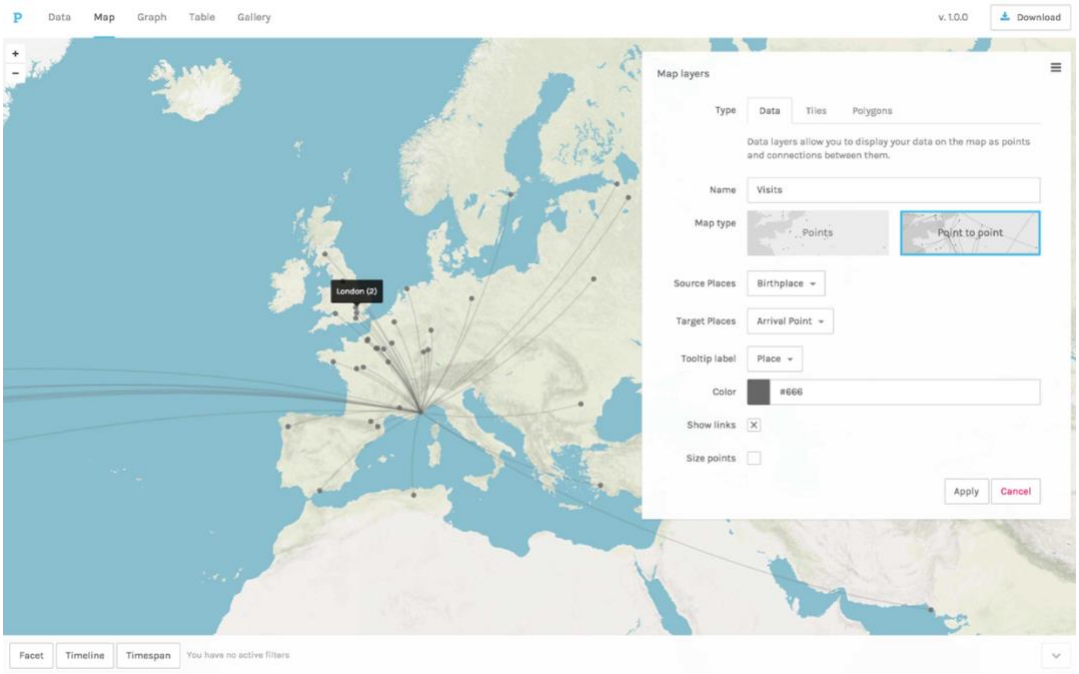


Note. Heatmap of new confirmed cases of COVID-19 ON February 11, 2021 (Mathieu et al., 2020).

Figure 3. Global Antimicrobial Resistance Cases

Note. Global heatmap of antimicrobial resistance cases (Criscuolo et al., 2021).

Figure 4. Historical Data Visualization



Note. From Palladio [image] by Edelstein et al. (2017), webpage, https://hdlab.stanford.edu/palladio/

2.2. Hierarchical Structures

Trees are a collection of nodes linked together to form a hierarchical structure. Each node represents a singular unit. A classification element is the context in which each node is inserted based on its relationship with the surrounding nodes, such as a parent, child, or sibling node (Burch, 2020).

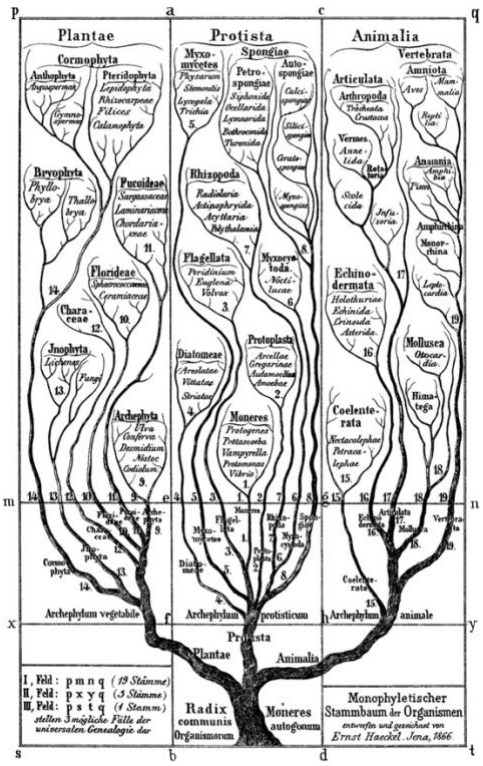
A sub-tree is a subset of nodes and links in a tree dataset that preserves all the properties of a tree. An additional way of defining a subtree is in terms of the node: from any node, there is a set of descendant data, which form a subtree (Pandey et al., 2021).

Any node in a tree with a child node is called an internal node. A particular type of internal node is the root node, which is the starting node of the hierarchy and does not have a parent

node. Those nodes outside the hierarchy that do not have child nodes are called external nodes or leaves (Pandey et al., 2021).

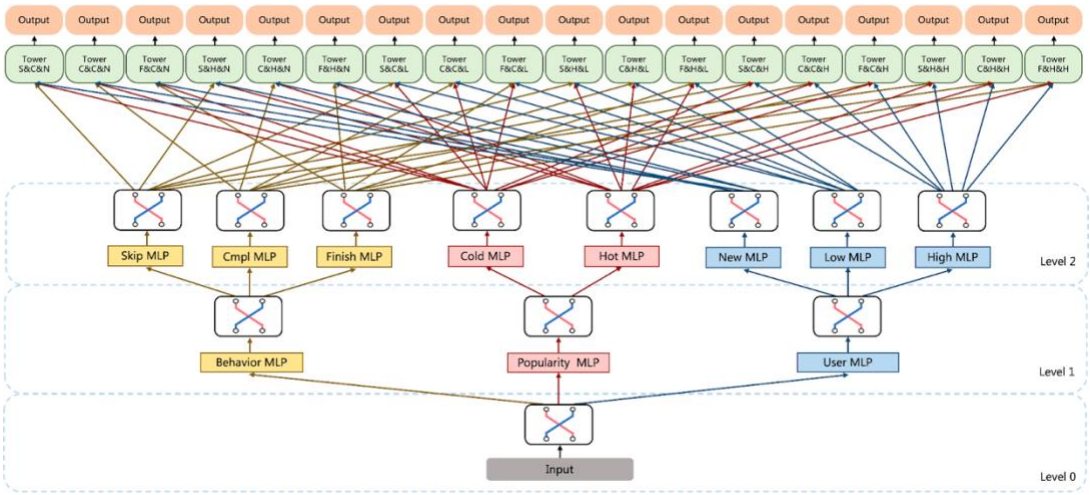
The visualization of hierarchies can be applied to the organization of codes, the explanation of decision models, the representation of natural phenomena, and the exploration of genetic evolution data (Figure 4). This type of visualization is used in various fields, such as software engineering, machine learning (Figure 5), linguistics (Figure 6), finance, and biology (Pandey et al., 2021). Composing these visualizations is based on at least four central visual metaphors: grouping, stacking, indenting, or explicit linking (Burch et al., 2022).

Figure 5. The first monophyletic tree of organisms was drawn by Haeckel in 1866.



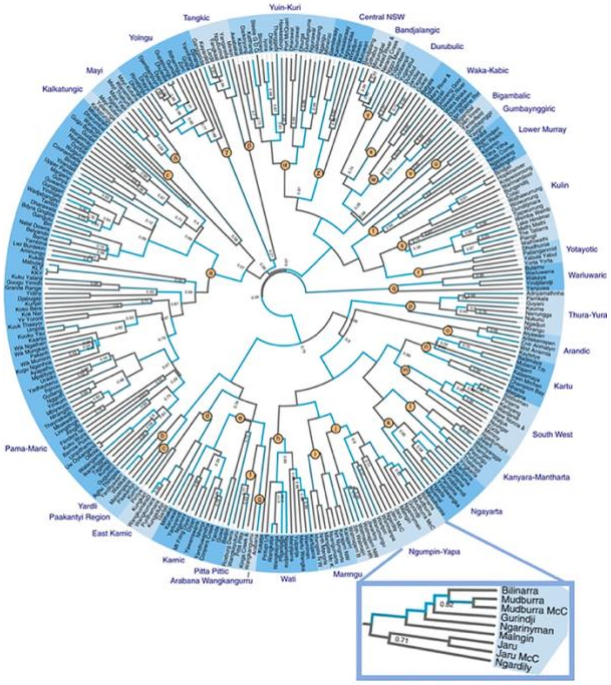
Note. The Generelle Morphology der Organismen from Haeckel (1866) is available on Gontier (2011).

Figure 6. Hierarchical MTL (H-MTL) Model



Note. The image describes the MFH model, composed of multiple nested H-MTL trees. The switcher network learns the task relationship between two facets and branches out to the facets' MLPs. Each tower network combines the hidden outputs from two paths and outputs the predicted score for a task. Junning et al. (2022).

Figure 7. Phylogeny of the Pama-Nyungan family of languages from Australia. Inset highlights detail within the Ngumpin subgroup.



Note. The Pama-Nyungan language family phylogeny from Australia. Inset highlights the Ngumpin subgroup. Numerical values on nodes represent branch support. Orange letters mark subgroups. Blue branches imply higher migration rates under the biogeographic model. from Bromham (2022).

2.2.1. Visual Encoding in Trees

There are five distinct categories of visual coding: encoding, manipulation, arrangement, filtering, and aggregation (Burch et al., 2022). Such categories are essential for most visualization tasks, as they define how data is initially represented visually. Manipulation/interaction techniques modify the existing visualization elements and involve interaction and visual coding (Li et al., 2020). Layouts refer to the spatial organization of the elements of a visualization, and filtering methods adjust the criteria for excluding and including the elements in the visualization. Finally, aggregation methods change the granularity of the elements in the visualization, allowing users to adjust the scale or aggregate elements into a tree (Brehmer & Munzner, 2013).

2.2.1.1. Properties

The purpose of hierarchical visualization is to understand the structure and attributes of hierarchical data represented in nodes and links. Structural tree levels categorize structural attribute information as shown by categorical attributes, while numerical values are represented by quantitative data (Pandey et al., 2021). Space-filling representations, such as tree maps, use numeric values to fill the viewing area, making the layout the best use of space (Burch et al., 2022).

The tree layout's exponential growth of the number of nodes is a disadvantage of this representation, resulting in overlapping nodes (Kavaz et al., 2023) and uneven distribution of space (Gai et al., 2022). To overcome such challenges, the technique of parent-child alignment (enclosure, indentation, adjacency), layout (linear, radial), dimensionality (2D and 3D), the coordinate system (Cartesian, Hyperbolic) is commonly used (Pandey et al., 2021).

The Multi-Level Task Typology Visualization (MLTT) supports high-level task abstraction tree visualization. Typology supports the abstraction of "targets" from trees into "topology," "path," and "attribute" (Pandey et al., 2021). Node link diagrams represent the most relevant visualization layout for relational data (Burch, 2021).

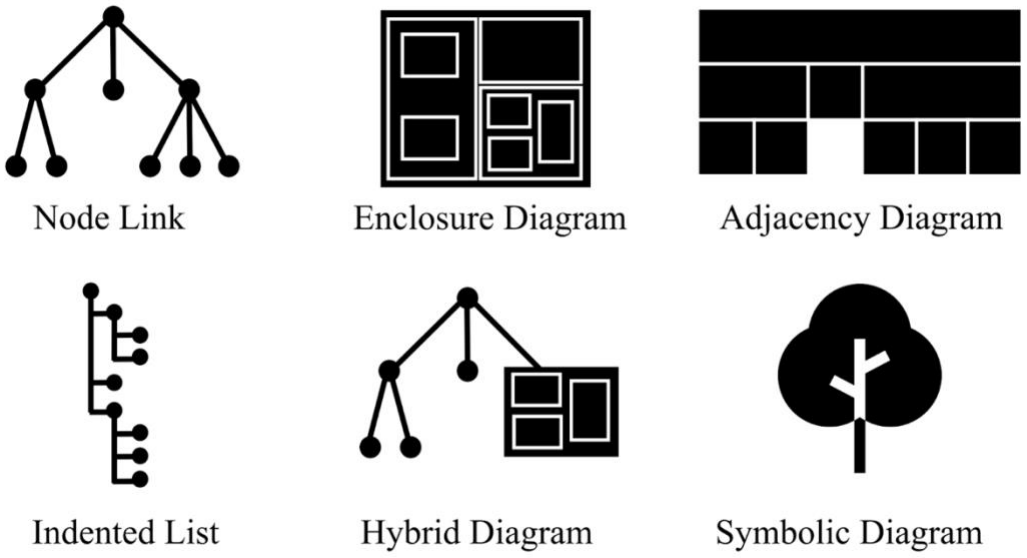
2.2.1.2. Layout

The main challenge of dynamic visualization is maintaining the viewer's mental map as they inspect changes in the visualization (Azevedo et al., 2023). Consequently, user research aims to find the best representation to preserve the users' mental map in dynamic visualization. At the same time, following aesthetic criteria and application requirements is essential, which may conflict with protecting the cognitive map (Burch et al., 2022).

Choosing the proper layout when using node-link diagrams influences the aesthetics of the visualization and the effectiveness of performing tasks. There are various vertex layout options, such as radial, circular, hierarchical, and others (Burch et al., 2021). From the user's point of view, tree visualization performs different tasks, such as locating a known or unknown object (node) for comparison, identification, or summarisation purposes (Pandey et al., 2020).

The diagrams linking nodes can be classified into different diagrams distinguished by the nature of the organization between these elements.

Figure 8. Viewings of common trees grouped by parent-child coding.



Note. Image from Pandey et al., 2021.

There are various types of diagrams for visualizing trees (Pandey et al., 2021):

- Node-link diagram: the nodes are distributed in space, and the links are lines. It can be 2D or 3D and can also use hyperbolic surfaces.
- Enclosure diagram: the hierarchy is represented through spatial delimitation. It helps get an overview of a tree but can be challenging to read in terms of depth.
- Adjacency diagram: adjacency and alignment create the tree structure, which can be vertical or horizontal. The top-level nodes have a larger area, and the children's area is limited to the extent of the parent's area.
- Indented diagram: uses indentation in vertically spaced lines to make parent-child relationships explicit. It is commonly used in interfaces such as Windows File Explorer.
- Hybrid diagram: intersperses two or more tree visualization encodings to take advantage of each method.
- Symbolic diagram: has the characteristics of biological trees to represent a data set. It uses trunks and branches to define links between different entities.

This work uses a specific category of node link diagrams, known as radial tree layout, to effectively convey hierarchical information structures to users as a source of knowledge. Emphasizing the hierarchical nature of data to illustrate these structures makes it a powerful tool for visually representing organizational relationships within data (Azevedo et al., 2023).

2.2.1.3. Task

Visualization techniques can impact the choice of the most effective method for that specific task. The task to be performed by the user corresponds to the medium in which the graphics are presented, as well as the means of interaction with the user (Pandey et al., 2021). In addition, the task to be performed can impact the choice of the most effective visualization technique for that specific task. Tasks are equally crucial for interpreting, memorizing, and creating graphs (Burch, 2020). Analyzing the tasks is essential for evaluating visualization in observational studies. Understanding the tasks is critical to successful visualization behavior (Zeng & Battler, 2023).

Although there are many general taxonomies of tasks in visualization, such structures often lack the specificity needed to support task abstractions in specific datasets, such as temporal and spatio-temporal graphs, networks, and trees. A formal task abstraction framework for trees is required to properly design and evaluate tree visualizations (De Luca et al., 2019).

2.3. Digital Humanities

Over the last few decades, the Digital Humanities have significantly impacted several areas of knowledge, including science communication. The rise of the internet and the growing amount of online information has dramatically changed how science is communicated to the public. In this context, Digital Humanities emerged as a multidisciplinary approach that aims to apply advanced computational techniques, such as data analysis, to knowledge production in humanistic areas (Semerikov et al., 2021). The term Digital Humanities was coined at the beginning of 2001 to wrap up new methods of analyzing humanities data using computing procedures (Berry, 2022).

Digital Humanities only comprehended the field as a discipline in the 2000s until now; notably, there hasn't been a consensus regarding the connection between the new discipline and information science. Some researchers believe that in the future, the name Digital Humanities will be presented as Humanities (Luhmann & Burghardt, 2022).

Digital Humanities focuses on applying digital technologies to support humanities research (Münster et al., 2019). Besides the lack of consensus on the definition of DH, the researchers agree that DH is the application of digital techniques in humanistic research (Müenster & Terras, 2020b). This new discipline was born on the practice of text-driven humanistic disciplines, such as linguistics, and spread to art and architectural history, museology, and archaeology (Münster et al., 2019).

Communicating historical and cultural outputs became more understandable by linking data into space frameworks. Consequently, the user's engagement is exploited in depth (Münster et al., 2019).

Visualization models encompass diverse forms of tangible representation, including hierarchies, timelines that synthesize written content, and 3D models. These modes have facilitated the widespread communication of cultural information and applied research. However, embracing a new perspective isn't solely reliant on updated communication; the shift is also driven by information and communication technologies (ICT) transforming how humanities engage. Digital humanities have initiated this transformation, altering cultural information production and innovating every stage, including co-creating knowledge (Münster et al., 2019).

This movement bridges content producers with users, necessitating interdisciplinary research and expertise to transcend data representation and communication. Additionally, digital humanities extend beyond spatial and temporal cultural information visualization, propelling diverse data representation and management systems. These advances introduce new scholarly customs for collecting and sharing data (Münster et al., 2019).

Technology development has enabled scientists and science communicators to produce more accessible and engaging materials for the public. This includes creating resources such as infographics, animations, videos, and other types of media (Vohland et al., 2021) and contributing to creating online resources aimed at disseminating scientific research (Yansong et al., 2020). Platforms such as blogs, podcasts, and social media offer an easy and effective way to communicate scientific information to a broader audience. In addition, they also allow scientists to interact with the public about their research. This work intends to take advantage of this dynamic to promote the dissemination of information.

It concerns the relationship between Digital Humanities and Visualization; Munster & Terras (2020a) advocate for the existence of a branch named Visual Digital Humanities. This "umbrella term" (Münster & Terras, p.367, 2020b) is anchored in a spectrum of emerging visual digital humanities encompassing intricate visual data analysis, semantic enrichment of collections, and contextual imagery creation. This spans areas like "(...) image analysis (e.g., the pattern analysis of large-scale image collections, computational vision), perception-based techniques (e.g., the visuospatial analysis of architectural objects), spatial modeling (e.g., 3D

reconstruction of historical architecture, GIS modeling) and visualization (e.g., sketching for visuospatial reasoning)" (Munster & Terras, p.1, 2020a).

2.4. Related Work

Within the framework of the projects related to this initiative, we were directly inspired by the Strategic Alliance[5] launched by the World Economic Forum. This innovative tool is designed to give leaders the ability to crack the intricate global dynamics and to facilitate well-informed strategic decision-making. The purpose is to promote strategic dialogues and simplify the understanding of complex interconnections in the ever-evolving global landscape. A comprehensive exploration of more than 250 distinct thematic areas[6], providing users with the means to identify relevant multimodal content such as publications, videos, data, events, initiatives, and key players in each domain. In addition, on the paid version of the Strategic Alliance, the platforms offer access to customized content and the flexibility to build personalized visualizations.

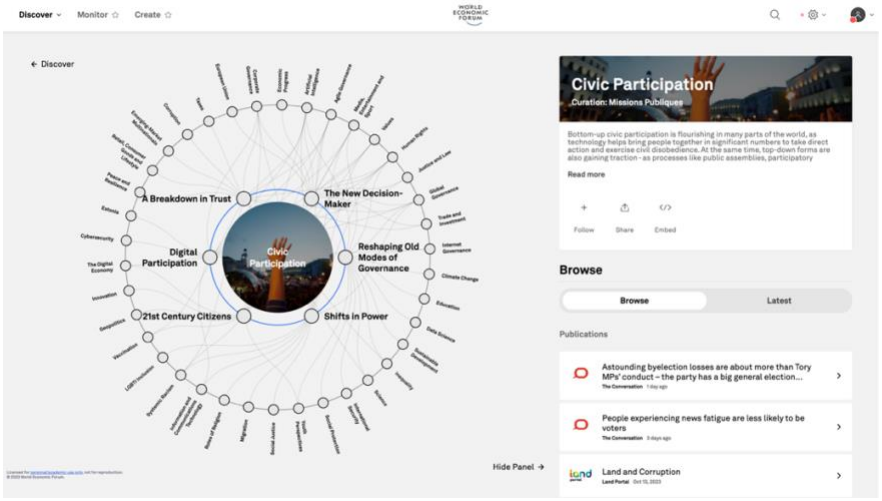
Each Transformation Map has a continuously refreshed feed incorporating the most up-to-date research and analyses from esteemed research institutions and global media outlets. These interconnected maps function as centralized hubs for comprehending each topic from various perspectives and offering diverse pathways for exploration. It is important to note that the visualization framework employed is reminiscent of a radial tree layout. However, it should be emphasized that the visualization consists of three primary components: the root, parent, and leaf/child nodes. As users interact with each node, the corresponding information dynamically appears in the right sidebar, adjusting instantaneously in response to user interactions.

Each leaf node has the potential to serve as the root node for other visualizations within the system. When a user selects a leaf node, it triggers a new visualization with a similar structure,

[5] Available on Strategic Intelligence webpage.
[6] Available on the Strategic Intelligence About page.

all adhering to the same user interaction model. This approach effectively transforms the complex, hierarchical information structure into a series of smaller radial tree layouts with only two levels of depth. A further look at the platform suggests "(…) a network of "systems maps" across a range of interrelated topics, tracing linkages amongst them and identifying pathways of transformation" (London School of Economics and Political Science, n.d.), which increases the simplification and improves user interaction by breaking down information into more manageable segments while ensuring an informative and facilitated experience.

Figure 9. Strategic Alliance Transformation Map

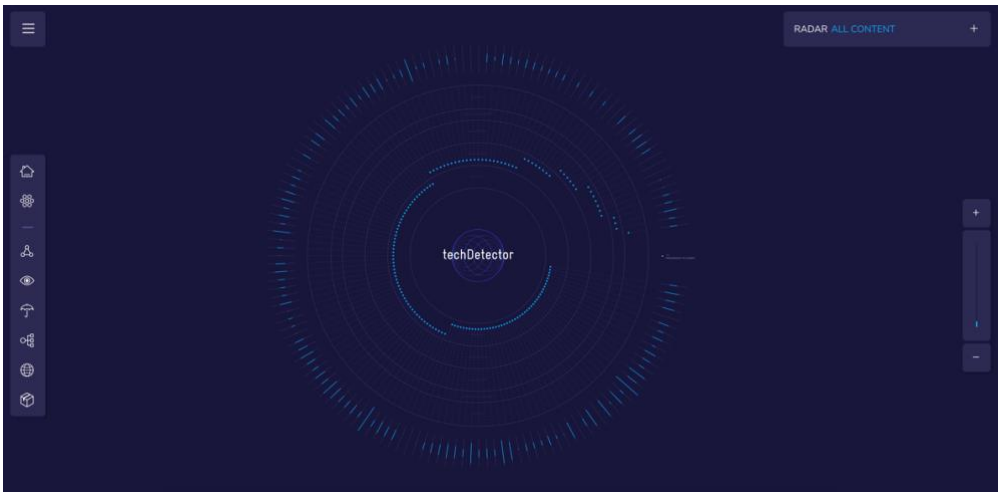


Note. From Strategic Alliance [image] by World Economic Forum, 2023, webpage, https://intelligence.weforum.org/

Although the Strategic Alliance is a source of inspiration for this project, it is essential to note that these two ventures' objectives and target audiences differ. While the Economic Forum project primarily focuses on equipping leaders with tools to understand global forces, the goals of this project revolve around improving access to language teaching practices, especially in virtual environments. And the Target audiences also differ.

TechDetector (Envisioning, n.d.), a collaborative project between research institutes Envisioning[7] and GIZ[8], focuses on simplifying the understanding and evaluation of emerging technologies within the context of sustainable development. Launched in 2019, it compiles a wide range of technology applications, subject to assessments based on technological maturity (Technology Readiness Level—TRL assessment) and sustainability criteria.

Figure 10. Tech Radar Radial Tree



Note. From techDetector [image], by Envisioning, 2023, webpage, https://techdetector.de/.

The techDetector employs a radial tree layout that considers the representative value of technologies based on their Technology Readiness Level. Each resource's position within the hierarchical structure is determined by the TRL value and is distributed in clock order from Prototype to Concept. The circle's border features lines that fulfill the same purpose while utilizing a distinct encoding method.

Replicability is the main characteristic of techDetector; both the interface and data were used to foster new projects with the objective of future foresight. Like Innovation Map[9], a project financed by the Austrian Economic Chamber aimed at business mapping. Strategic Foresight of

[7] Enviosining research institute webpage available on: https://www.envisioning.io/
[8] Giz company webpage available on: https://www.giz.de/en/html/index.html
[9] Available on innovationmap.at

Ukraine[10] maps are based on information from the United Nations Development Programme to create the radial tree layout with 160 trends with the potential to impact the Ukrainian and global future.

3. Methodological Approach

The DIAL4U Project adopts a research approach deeply rooted in Design Science Research (DSR) principles. DSR is a research paradigm that emphasizes crafting innovative artifacts to address practical challenges (vom Brocke et al., 2020). This approach is especially suitable for initiatives looking for solutions to face the constantly evolving innovation landscape. In the context of DIAL4U, the project's focal point is squarely on creating transformative artifacts intended to address the pressing issues encountered by foreign language educators.

The interaction between science and technology is dynamic in that one influences the other and contributes to both knowledge domains (Li et al., 2020). Science employs the scientific method, gradual paradigmatic changes, and empirical evidence. On the other hand, the technology leverages this knowledge to design artifacts. Science-oriented research, focused on descriptive knowledge, elucidates the nature of the phenomena underlying technology. This knowledge is essential for technological innovation beyond trial and error (Drechsler & Hevner, 2022). Design-oriented research, which cultivates prescriptive understanding, is concerned with practical technological advances in projects that often mix both genres, enriching knowledge bases (Adam et al., 2021).

The iterative nature of DSR ensures that user feedback and needs guide the journey to reassessment (Peffers et al., 2007). This alignment reflects the project's overall goal of supporting language teachers as they navigate the complexities of digital teaching with the support of multimodal content.

[10] Available on https://www.foresightua.com/

The core of this research approach revolves around creating a fundamental artifact: a personalized interface for language educators—a digital tool designed to respond to the challenges identified with a reactive digital structure. Developing this interface is characterized by several iterative cycles covering design, implementation, evaluation, and refinement. That led to the resource's first interaction with users through a workshop. Based on the analysis of the data collected at the workshop, it was possible to make refinements and improvements.

The Knowledge Base of the DIAL4U Project is an integral component. The project relies on a spectrum of tools and technologies to facilitate its research and development efforts:

- **JavaScript**: JavaScript[11] is a versatile language for developing interactive digital artifacts and resources. It enables dynamic and responsive elements within the project's solutions, promoting user engagement.
- **HTML**: HTML[12] is the backbone for structuring and presenting digital content. It ensures the accessibility and readability of the project's online resources, particularly in virtual and multimodal educational settings.
- **CSS:** CSS[13] complements HTML by governing the visual presentation of web pages. It ensures a cohesive and user-friendly interface, enhancing the overall user experience.
- **DOM:** DOM[14] manipulation enables the project to create interactive, data-driven visualizations. This capability is crucial for effectively representing complex language education data.

As a strategy to reach a broader audience in terms of multimodal content (Yasong et al. 2020), the following resources were used:

[11] JavaScript definition by Mozilla. The Mozilla Developer Network (MDN) is a resource for web developers, offering detailed documentation and educational materials on various web technologies. This open-source initiative supported by Mozilla encompasses critical areas, which makes it an essential platform for developers.
[12] HTML definition by Mozilla.
[13] CSS definition by Mozilla.
[14] DOM definition by Mozilla.

- **Anchor:** Anchor is a platform for hosting and sharing multimedia content, such as podcasts and videos. It supports the project's dissemination of scientific knowledge to a broader audience. Recently, the name changed to Spotify for Podcasters[15].
- **Spotify:** Spotify[16] is a digital audio streaming platform that enhances accessibility to language education materials. It offers a convenient channel for delivering audio content, complementing traditional teaching methods.
- **Notion:** Notion[17] is a tool for sharing and communicating, serving as an alternative and supplemental source to access information.

3.1. Investigation Process

With a comprehensive understanding of the problem and its context, the objectives may encompass quantitative and qualitative outcomes. To define these objectives, an examination of existing solutions is imperative. In this context, an analysis of related literature revealed existing solutions employing information visualization for accessing academic content. However, these solutions did not cater specifically to language teaching or multimodality. Based on this knowledge, the project outlined the following objectives for the solution:

- Optimal Visualization Approach: The radial tree layout was identified as the most suitable visualization method for achieving the project's communication objectives. It must be interactive so users can easily access the information they want. Returning to the starting point of the view must be done in a single click. The layout must avoid overlapping labels. To be a flexible resource, it must allow the user to zoom in and pan.

[15] Spotify for Podcasters, formerly known as Anchor, is a podcasting platform that allows content creators to create, distribute, expand their audience, and monetise their podcast effortlessly, directly through Spotify's app or website, all at no cost.
[16] Spotify music and podcast streaming platform.
[17] Notion is a comprehensive digital workspace that allows users to brainstorm, take notes and manage projects efficiently. It also offers the ability to oversee a company's operations, providing a flexible and customisable environment for working and sharing information.

- Workshop with language teachers: The final product should undergo a workshop inviting users to try out the interface and access its content. This will enable preliminary information to be gathered about the interface and thus improve it.

The selection of appropriate technologies and tools is a pivotal aspect of this proposal phase. Outstanding technologies were chosen based on their alignment with the project's overarching goals.

3.1.1. Development

The development phase unfolds with the creation of innovative digital tools, resources, and artifacts designed to tackle the identified problem. The process follows an iterative approach, enabling continuous refinement based on user feedback. The refinement efforts are conducted in collaboration with University Jaume I teachers and DIAL4U partners, both of whom consist of foreign language teachers. This iterative process ensures that the solutions are effective and adaptable, catering to the evolving needs of language educators and learners.

3.1.2. Analysis

The analysis phase considered the workshop held during the LTTA1 event. This event brought together 33 foreign language teachers who were actively involved with the product in person. A comprehensive description of the workshop can be found in the Workshop Chapter. The evaluation was carried out with a focus on feedback from workshop participants.

In the final phase of the process, the project synthesizes the insights gleaned throughout its journey, including the analysis of the workshop feedback. The project culminates with the dissemination of knowledge through academic publications, presentations, and resource sharing within the broader language education community. This knowledge dissemination strategy extends the project's influence beyond its original scope.

4. Web Interface Development

In the upcoming chapter, I will describe the journey involved in creating and advancing the interface, beginning with the initial conceptualization of web pages and InfoVis and covering the collection of crucial data from various sources, including publications, web content, and videos. The resources created as part of the project, such as the podcast, map of experts, and glossary, were utilized to communicate science through the interface webpage. Later in the section, I will present the webpage's test development and results.

The project's inception was marked by a preliminary meeting that convened members from Minho University and Jaume I University. This meeting served as a foundational step, driven by the partnership of both universities on this project deliverable. Especially to respond to the evolving needs highlighted by the project coordinators at the University of Lille, who are foreign language educators in a digital scenario related to the COVID-19 scenario. The primary aim was to assess the project's prerequisites comprehensively, recognizing the requirements to empower teachers once they "(…) are key persons in multilingual education" (UNESCO, 2022) and facilitate the development of language skills among their learners.

One key realization from this collaborative dialogue was the need for multimodal content that would serve as a dynamic resource uniquely designed to accommodate a diverse array of multimedia information. Its vision extended far beyond static content, envisioning an interactive environment where mediation interaction played a pivotal role in foreign language information acquisition.

Objective[18] of both universities provided teachers with an innovative and interactive interface. This interface would empower them to navigate the intricacies of language education within a digital and multimodal context. This collaborative effort laid the foundation for

[18] IO-3 description on the DIAL4U webpage.

developing a comprehensive and user-centric interface that would address the challenges of modern language instruction and resonate with the dynamic nature of digital education.

4.1. Resources Creation

In the contemporary landscape, multimodal content has emerged to enhance the communication experience. This section provides a comprehensive overview of the strategies employed in developing a diverse set of multimodal content elements in digital pedagogy and language education. These elements include podcasts, a map of experts, publications set, and a comprehensive glossary, each strategically designed to engage users and foster a dynamic and inclusive educational environment.

4.1.1. Podcast

As part of our collection of multimodal resources, a podcast was created. This podcast series features expert educators invited by our partners to record brief episodes, each limited to a concise 90-second duration. In these episodes, the experts succinctly elucidate their language teaching practices, providing users with insightful overviews. The podcasts are available on Spotify[19], Google Podcasts[20], and Amazon Music[21] to reach a wider audience by making the content available on these popular platforms.

I directly linked to these experts' bios to enhance user engagement and foster connections with them. These links, personally selected by the experts themselves, serve as gateways for users to access the researchers' extensive work and immerse themselves in their ongoing research endeavors.

[19] DIAL4U podcast on Spotify.
[20] DIAL4U podcast on Google Podcasts.
[21] DIAL4U podcast available on Amazon Music.

4.1.2. Glossary

Glossary[22] was designed to be comprehensive, encompassing key concepts across various interface sections, making essential content-specific terms easily accessible. Users can access the glossary as a user-friendly list hosted on Notion, providing a tabular structure. The glossary terms were aggregated to the layout on the node "Glossary," providing a more interactive experience; it is also available as an intuitive radial tree visualization on a webpage, offering a visual representation of the interconnected concepts.

4.1.3. Library

Library[23] is a set of publications curated to provide users with educational materials that delve into the scientific literature related to their areas of interest. Within these publications, users will discover a collection of carefully selected articles about each topic covered in this interface. Notably, the publications in this set may be authored by our esteemed partners or feature contributions from other accomplished writers, ensuring a diverse and comprehensive range of perspectives.

The curatorship of the publications was the responsibility of the experts involved in the project and the researchers who recorded the podcast. These researchers are specialists in language teaching. Along with much of the material in the DIAL4U project, the library is staffed by multilingual publications.

4.1.4. Map of Experts

The interactive map[24] featured within the DIAL4U interface is a dynamic tool designed to provide users with insights into the diverse origins and work locations of the experts who have contributed to the project. These contributions can be through content development, podcast recording, or other forms of participation.

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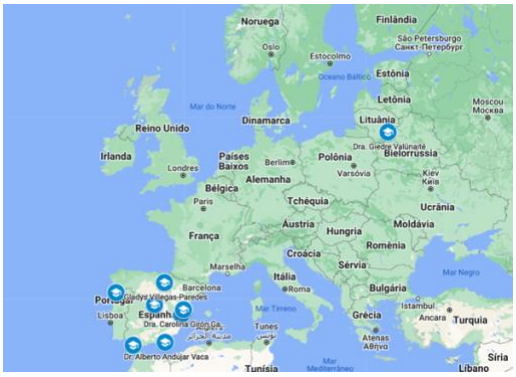
[22] Notion DIAL4U Glossary.
[23] Notion DIAL4U Library.
[24] DIAL4U Map of Experts on Google Maps.

Figure 11. Map of Experts Overview



Note. Map of Experts interactive made with Google Maps.

The centerpiece of this interactive map is its geographic localization feature. By interacting with the map, users can pinpoint the precise locations associated with these experts, gaining a deeper understanding of their regional affiliations and the geographical distribution of their contributions.

4.2. Data Structure

The language teaching experts from the University of Minho and the University of Jaume I were responsible for collectively creating the logical content of the radial tree, focusing on specific facets of digital pedagogies and related topics. This approach ensured that the interface would offer users a rich repository of information and resources organized in a rational and accessible manner.

The first step in structuring this information involved creating a spreadsheet document to transform it into a JSON data format subsequently. JSON, known for its flexibility and compatibility with data visualization, was chosen as the ideal format to support the interactive features. JSON is a text-based data format used for data exchange between systems, including client-server and mobile applications. It was incorporated into the JavaScript language with ECMAScript version 5. JSON is widely supported across programming languages and is favored for its lightweight nature compared to XML. It is being recognized as a solution where data is structured as a collection of name-value pairs or an ordered list of values.

Within the spreadsheet, the content was delineated into 'Levels,' each level corresponding to a node in the data hierarchy starting at Level 0, representing the root node (DIAL4U project) and extending to Level 5 (leaves). The structure provided a clear organizational framework. While 'Level' may not be the most precise terminology, it served as a common reference point for communication and understanding among the experts, establishing a shared concept of what a node entailed within the visualization.

Table 1. Spreadsheet Data Structure of the document done by the experts. Each cell represents a node on the tree.

Level 0	Level 1	Level 2	Level 3	Level 4	Level 5
DIAL4U Project					
	Skills and Strategies				
		Skills			
			Understanding		
				Written	
				Oral	
			Expression		
				Written	
				Oral	
			Interaction		
				Written	
				Oral	
			Mediation		
				Written	
				Oral	
		Strategies			
			Cognitive		
			Metacognitive		
			Linguistic		
			Communicative		
				Understanding	
					Written
					Oral
				Expression	
					Written
					Oral
				Interaction	
					Written
					Oral
				Mediation	
					Written
					Oral

Note. Spreadsheet with a data structure that makes up the radial tree of the DIAL4U project.

For each node created in the table, experts were required to provide a brief description and relevant links. These links point to publications, videos, podcasts, or images associated with the content related to the respective node. These links served as the source data, contributing essential information such as title, date, authorship, and content type, particularly influencing the data composition within the JSON structure.

Table 2. Content spreadsheet filled out by experts.

Level 1	Level 2	Level 3	Level 4	Level 5	Description	Link	Link	Link

Note. The first line of the spreadsheet is used to help experts add the data or not see the labels.

Transposing this structured data into a JSON format required some adjustments to facilitate visualization and the implementation of click triggers. Each node adhered to a fundamental structure, including the 'name' attribute, representing the node's display name in the visualization. Introducing a 'children' attribute in an array format within each node allowed for creating leaf nodes within the hierarchy.

Listing 1. Basic JSON structure to create the tree layout.

```
{
"name": "Modalities",
"description": "",
"have_pub": "",
"have_pod": "",
"have_video": "",
"have_profile": ""
}
```

Furthermore, binary attributes such as 'have_pub,' 'have_pod,' 'have_img,' 'have_video,' and 'have_profile' were integrated, where '0' indicated the absence of a particular content type within a node, while '1' signified its presence. Each of these attributes possessed its associated properties, contributing to the intricate structure of the JSON format.

The dataset in the DIAL4U JSON file comprises 132 entries, categorized as follows: 93 entries contain publications, 26 entries house videos, 15 entries feature profiles, and 22 entries include podcasts.

- **Publication**

The publication entity comprises three essential elements: the publication link, the title, and the year of publication. These components were chosen as metadata because they enable users to quickly gauge whether the content is of interest to them or not.

Listing 2. JSON Publication

```
    "publication":
    [{
    "link":"https://instructionalcontinuity.georgetown.edu/ho
me/teaching-modalities/",
    "title": "Teaching Modalities",
    "year": "2020"
    }],
```

- **Podcast**

The podcast entity comprises the embedded podcast link obtained through the Anchor platform. Additionally, include the option to include a podcast description if desired or necessary.

Listing 3. Podcast JSON structure

```
    "podcast":
    [{
    "link":
"https://anchor.fm/dial4u/embed/episodes/Ted-Talks---Edgar-Ber
nad--Spanish-e1rhfjj",
    "description": ""
    }],
```

- **Video**

The video entity includes the embedded YouTube video link, the video title, and the year of video publication.

Listing 4. Video JSON Structure

```
"video":
[{
"link": "https://www.youtube.com/embed/kvqF6-Sx2A8",
"title": "Day of the mother tongue",
"year": ""
}]
```

- **Profile**

As previously stated, the profile entity was designed to accommodate content from experts invited to create podcasts. Each expert has a dedicated profile containing essential details, including their photograph, name, affiliated university, ORCID identifier, and a link to a webpage of their choice.

Listing 5. Profile JSON Structure

```
"profile":
[{
"photo": "Podcast/andujar.png",
"name_researcher": "Alberto Andujar",
"university": "University of Almería - Spain",
"orcid": "https://orcid.org/0000-0002-8865-9509",
"link":
"https://www.researchgate.net/profile/Alberto-Andujar"
}]
```

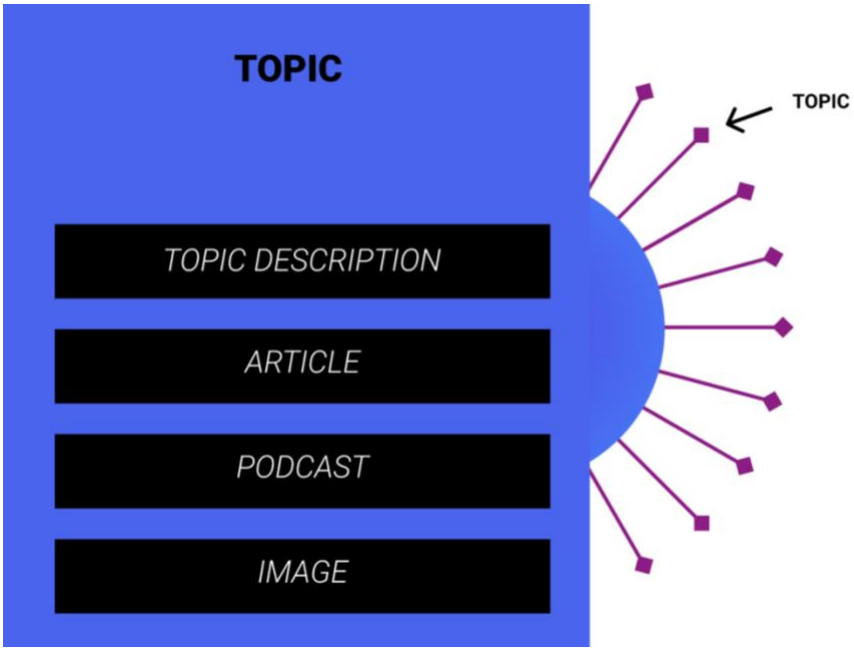
Note. Elaborated by the author.

4.3. Interface Prototype

To ensure the delivery of an improved and easy-to-use browsing experience, a design approach focused on the layout structure of the web page was adopted, and the prototypes were made with Figma. This design's primary structural feature involves dividing the webpage into two columns. The left column is dedicated to presenting an exploratory structure, serving as a visually engaging and interactive visual component. Concurrently, the right column is designated for the retrieval and display of content, offering users a responsive interface that dynamically responds

to their interactions with the InfoVis. This dual-column layout strategy maximizes usability, enabling users to access content corresponding to their interactions with the InfoVis elements, enhancing their overall engagement with the web page.

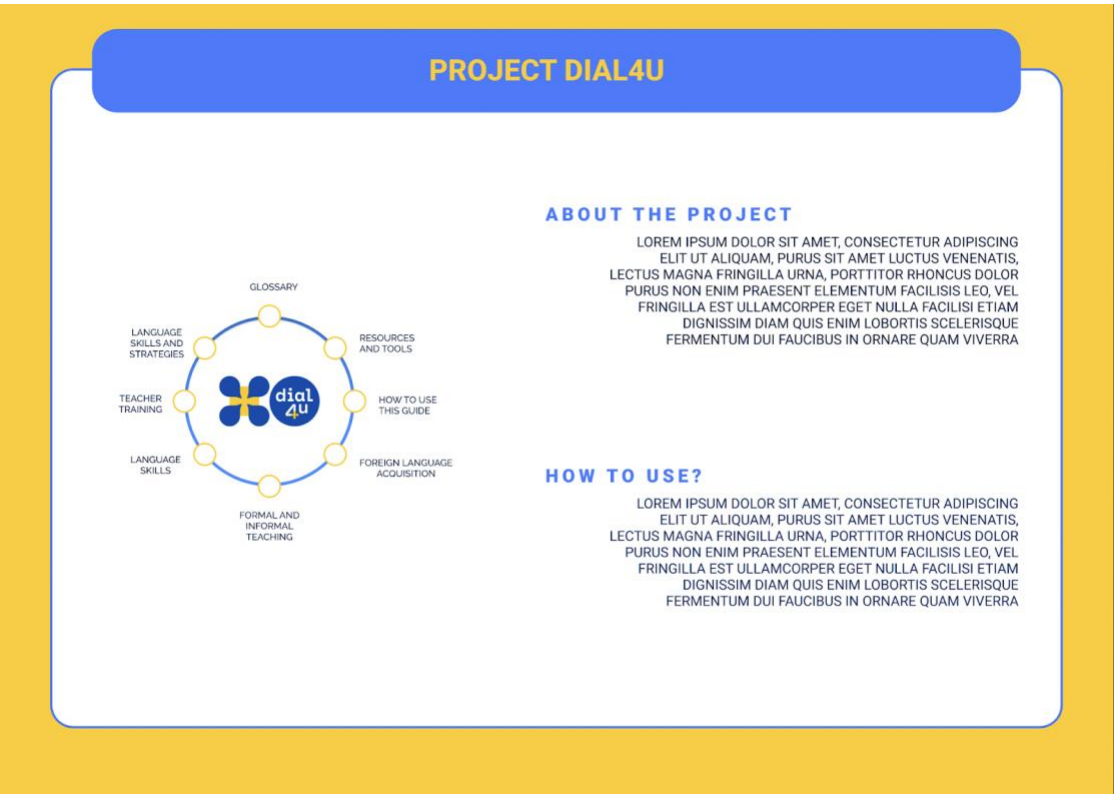
Figure 12. Initial wireframe with the InfoVis as a radial tree and the multimodal content



In this initial prototype[25] (Figure 12), the web page's dynamics would involve selecting a node in the radial tree layout, triggering the display of information in a window on the left side of the page. As the experts proposed, the structure of multimodal topics associated with each node in this project follows a predefined logic. And facilitate the user's understanding of the connection between topics.

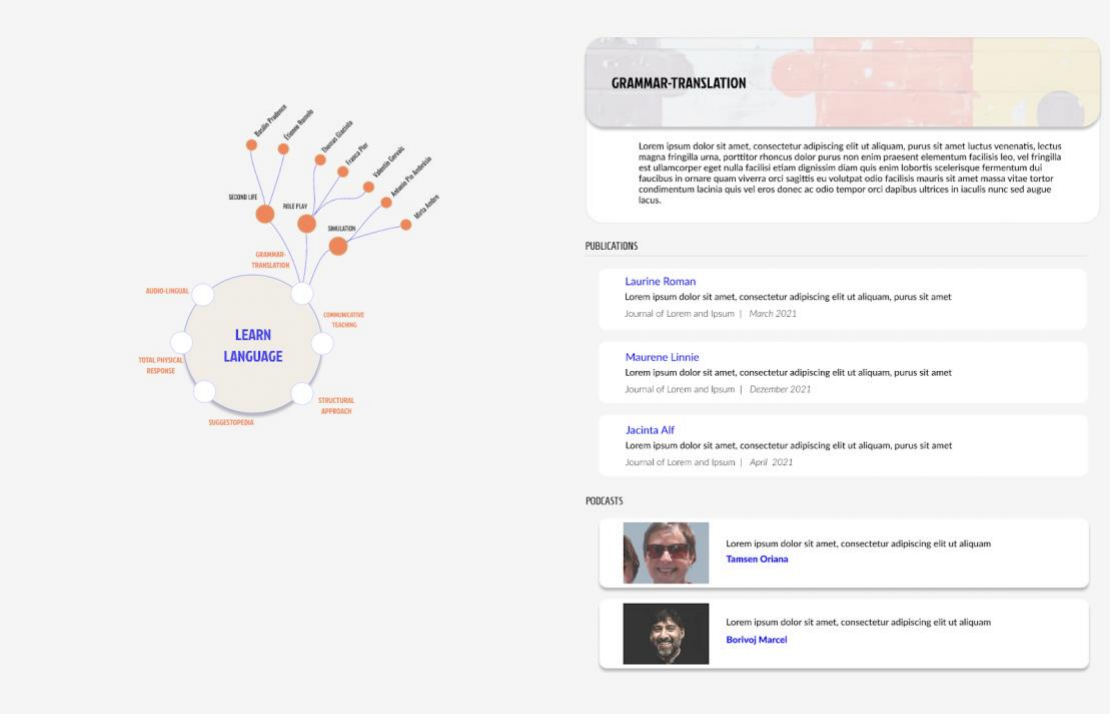
[25] Prototype available on Figma.

Figure 13. Second prototype present a more detailed version of the webpage.



In this second prototype (Figure 13), the main objective was to obtain a deeper understanding of specific requirements. When a user selects or interacts with a node in the view, the name or label associated with that node is dynamically displayed in the central bar of the interface. This feature provides users immediate context and information about the selected node, contributing to a more intuitive and user-friendly experience. I relocated the multimodal content box from the left side to the right side of the interface, improving the overall layout and organization of content.

Figure 14. Final prototype in which all the content related to the node click.



During the prototype evaluation with the team, we perceived that the webpage needed to be more uncluttered. This way, a third prototype[26] was developed, the main change of which resides in the translocation of the node title from the up central position to the right column. Besides that, the colors used on this prototype (Figure 14) are more neutral. To maintain the user focus on specific resources such as the radial tree and the node title on the right column.

4.4. Data Visualization

The process of creating this visualization initially involved a careful library selection phase. Echarts.js[27] was the chosen library for its notable strengths, including high-quality image rendering in SVG format and seamless integration with HTML files.

[26] Prototype available on Figma.
[27] Available on Apache Echarts webpage.

The ECharts, a JavaScript library, was selected because it is a powerful open-source JavaScript visualization tool optimized for web and mobile devices. It offers a wide range of chart types, customizability, and support for interactive elements. ECharts simplifies dynamic data updates, supports geographic and 3D visualizations, and complies with accessibility standards, making it a versatile choice for data visualization.

ECharts is a prominent project under the Apache Foundation that was implemented in JS. It boasts compatibility with major web browsers, cross-platform performance, and a wide range of data visualization options. It supports various graphic combinations and data formats, asynchronous rendering for data block loading, and interactive features like legends, prompts, and animations. This comprehensive toolkit effectively addresses the diverse needs of front-end data visualization.

4.4.1. Radial Tree Layout

Employing the radial tree layout stems from its exceptional ability to organize hierarchical structures, a trait well-documented in prior research. Its visual prowess is particularly effective in delineating the hierarchy of subcategories within overarching classifications, providing clear insights into their relative proportions. Moreover, its integration of interactive elements facilitates an intuitive portrayal of expansion and contraction dynamics (node triggering) and content scalability (zoom in/zoom out).

The radial tree layout can consolidate information about a specific topic within a dedicated node. This layout simplifies the process of identifying pertinent content, especially when exploring for nuanced terms or isolating content within a context.

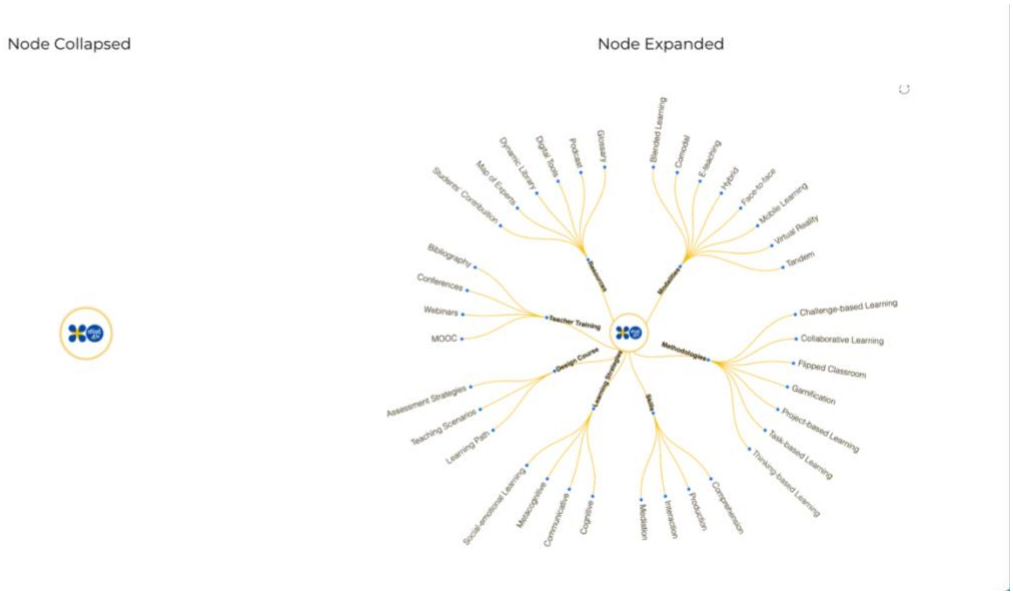
In essence, the radial tree layout provides an overview of a given topic by presenting its primary domains and the associated nodes within each field (Burch et al., 2022). This visual representation streamlines the identification of valuable and relevant information, offering users a quick and efficient means of accessing suitable content.

The DIAL4U project incorporates a dynamic and intuitive data visualization feature, the radial tree layout (Li et al., 2020). This visualization has been positioned on the left side of the webpage to enhance user interactions and facilitate a logical exploration of the data hierarchy.

The radial tree layout within DIAL4U boasts several vital characteristics that drove this placement decision:

- Expand and Collapsible Nature: DIAL4U's data is structured hierarchically, often with numerous nodes. To manage this complexity, the radial tree allows users to expand and collapse subtrees, revealing or concealing data layers. Placing this visualization on the left side of the webpage offers ample space for users to engage with this expand-and-collapse (Figure 15) interaction seamlessly.

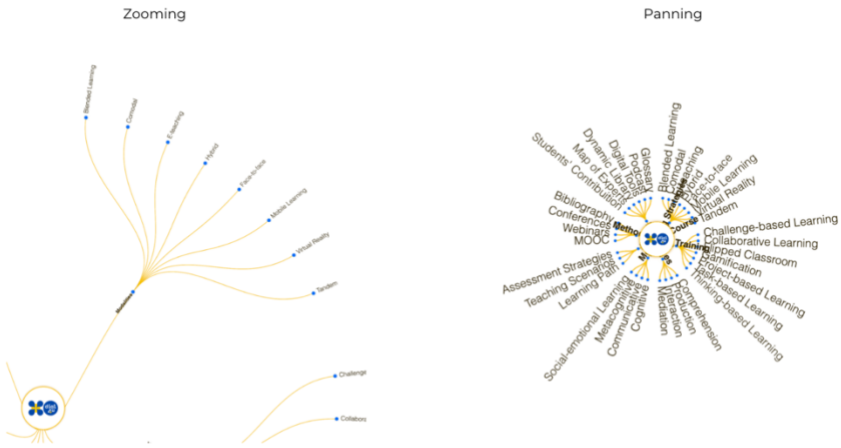
Figure 15. Node Collapsed and Node Expanded Representation



Note. This radial tree compares the screen space usage between the collapsed and expanded tree views.

- Zoom and Pan Capability: The radial tree visualization supports mouse zooming and panning, enabling users to explore intricate radial tree structures effectively (Figure 16). Situating the visualization on the left ensures users have a dedicated space for these interactions without conflicting with other webpage elements, providing a smooth and unobstructed exploration experience.

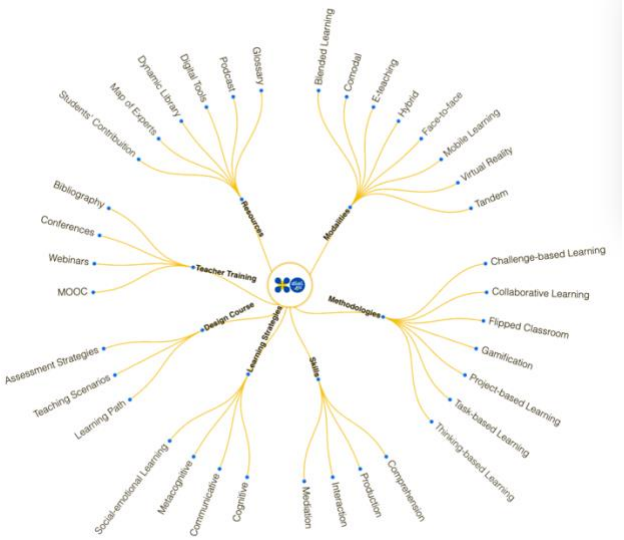
Figure 16. Zoom and Pan Capability



Note. Comparison of the zoom and pan capability of the radial tree layout.

- Initial Tree Depth: Radial trees typically feature multiple layers or levels, with the root node as the initial layer (depth 0), followed by successive layers. By positioning the visualization on the left, DIAL4U aligns with the user's expectation that data exploration starts from the left and extends to the right as they delve deeper into the tree, following a clockwise direction. This logical arrangement aids users in intuitively navigating through the data hierarchy.

Figure 17. Initial Tree Depth



Note. The initial radial tree configuration.

- Mitigating Label Overlaps: The visualization design interaction aimed to maintain the readability of labels associated with nodes. Labels are organized horizontally and sequentially to prevent overlaps (Figure 18). The visualization on the left guarantees that labels can be arranged without obstruction, allowing users to easily access and comprehend the information presented. However, overlaps are still observed, especially when zooming out (Figure 19).

Figure 18. Radial Tree Labels

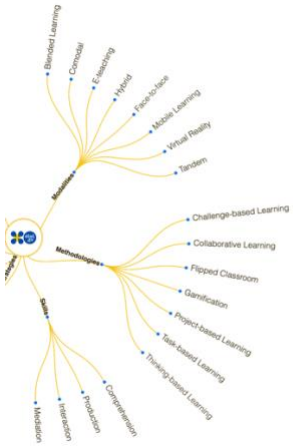
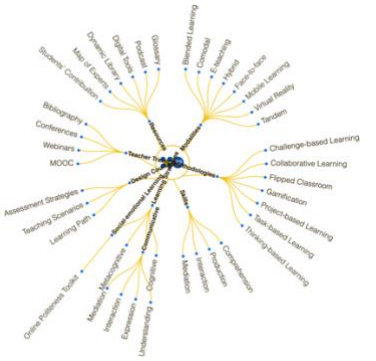
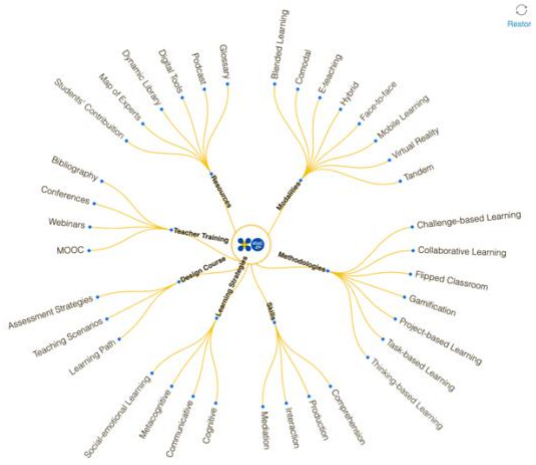


Figure 19. Radial Tree Labels Overlap



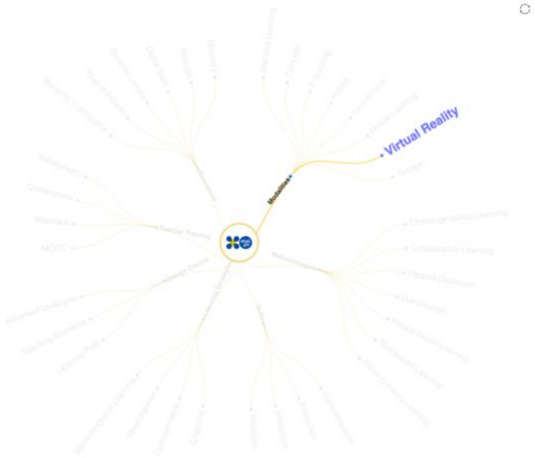
- Restore: a tooltip has been added to the top-right corner of the data visualization (Figure 20). This tooltip triggers the option to return to the initial tree, making it easier for users to navigate back to the starting point.

Figure 20. Restore the tooltip tree layout.



- Path Tracking: When the mouse hovers over a node, its appearance changes (Figure 21), making highlighting or tracking the node's hierarchical path easier. This is particularly useful for monitoring specific nodes (Burch et al., 2022).

Figure 21. Viewing the path of the selected node in the layout



These are the most relevant interaction techniques used during the layout creation process. They cover different aspects of the layout.

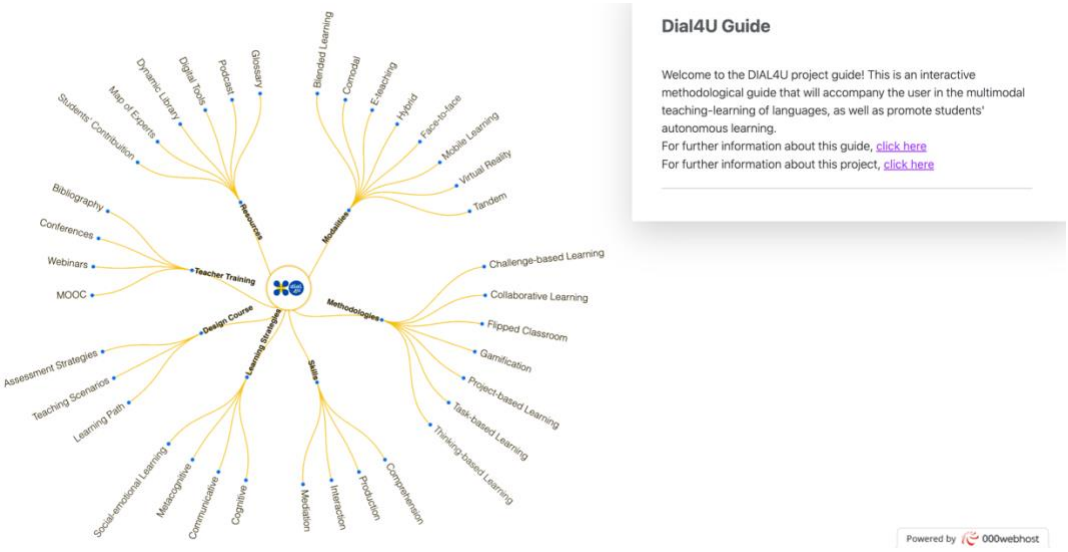
4.4.2. Interactive Design

The DIAL4U view strongly emphasizes the data structure within the radial tree format. However, it's important to note that as the radial tree expands, data visualization becomes

increasingly challenging once the expansion of the tree is associated with a higher probability of overlapping (De Luca et al., 2019).

Two key interaction features, zoom functionality, and the radial tree function, were implemented to address this limitation inherent in radial tree layouts. On the homepage, users can initially view the root and two additional levels of the tree (Figure 22). Users can click on specific nodes for more detailed information to delve deeper into the content.

Figure 22. Tree initial view on the home page



Additionally, to enhance user experience and offer customization, an interactive option that allows users to toggle the display of labels on or off was integrated into the glossary visualization. This feature provides a more straightforward mode, enabling users to tailor their viewing preferences.

4.4.3. Color Design

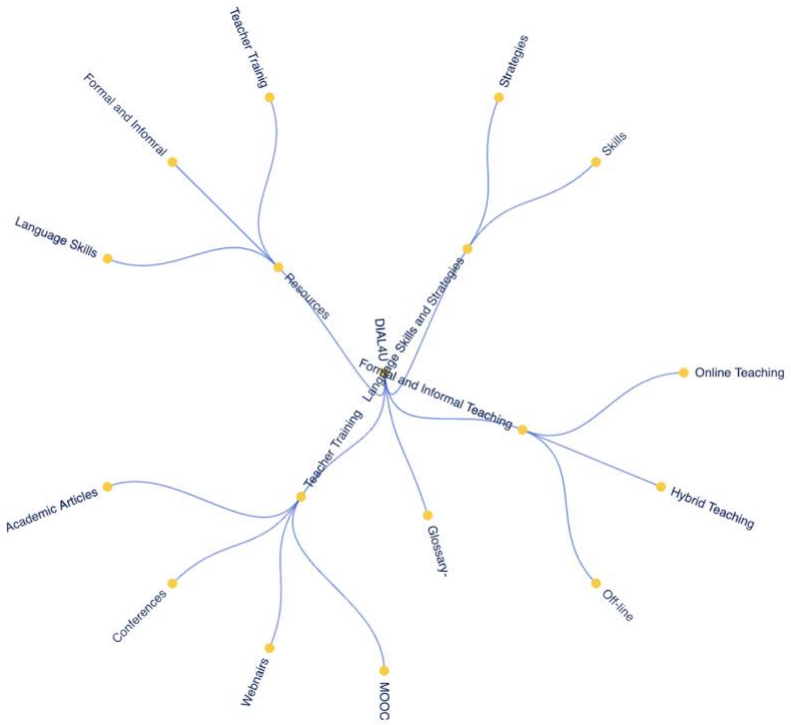
The color design for this visualization drew inspiration from the DIAL4U logo's color palette (Figure 23), predominantly featuring hex colors #1B459F and #F7CE46. Two primary considerations influenced the color selection: the lines and the nodes.

Figure 23. DIAL4U logo and hexadecimal color palette extracted from the logo.

When addressing the lines, the paramount concern was navigation. The contrast between the thin lines and the white background initially posed a challenge in meeting contrast standards. To resolve this, we opted to introduce a darker shadow color to the lines to improve the overall contrast and enhance navigation.

As for the node color, I chose a shade closely aligned with the logo color but with heightened vibrancy (HEX #006AF5). This color successfully passed contrast tests on the Adobe color tool, ensuring user comfort and readability within the visualization.

Figure 24. Radial tree prototype featured a radial tree layout with blue lines and yellow nodes.



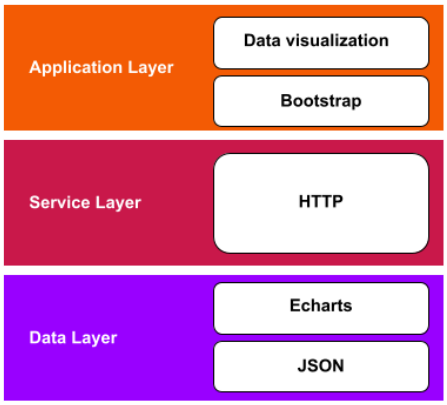
During the development process, a preliminary experiment was conducted using a radial tree layout with blue lines and yellow nodes (Figure 24). However, this initial color scheme proved unsatisfactory regarding visual appreciation and overall aesthetics. When I presented this prototype to the team members, some pointed out that visualizing the lines, as they were skinny, took a lot of work. So, one of the requirements was that the radial lines of the trees should be thicker.

4.5. Front-End Development

4.1.2. System Architecture Design

The system's architecture (Figure 25) is structured into three distinct layers: the application layer, the service layer, and the data layer.

Figure 25. Website Architecture



Note. Qualifications of the data layers, services, and applications used on the webpage architecture.

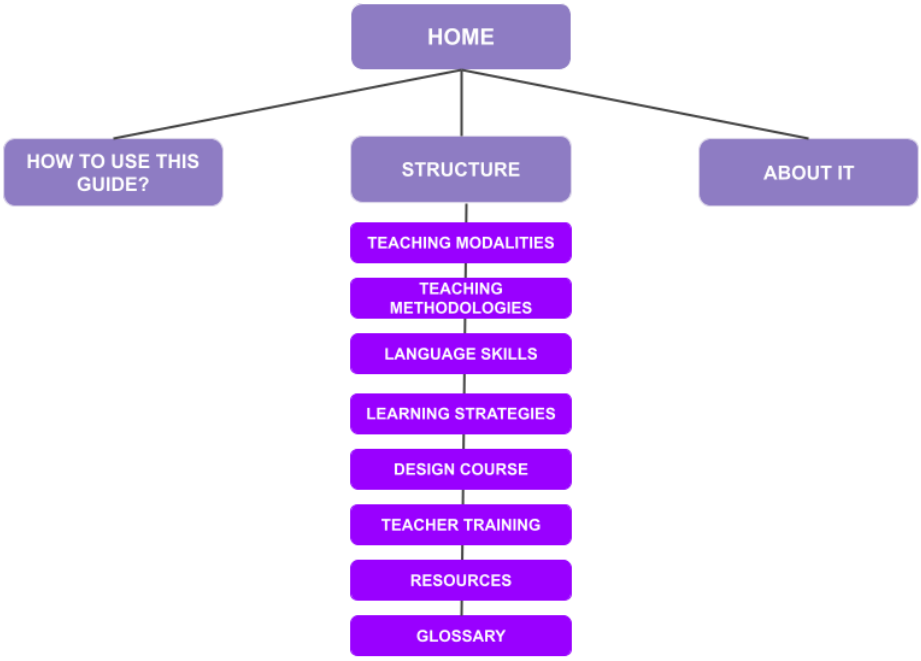
Within the data layer, a comprehensive database stores the intricate content of DIAL4U, employing JSON for storage. Moving up to the service layer, this accommodates critical components like the web page framework and essential data services upon which the platform depends. It facilitates the transmission of requests, data transfer, data retrieval from the JSON, and storage of information and API interface files, all orchestrated via the HTTP interface. Complementing this architecture, the front-end framework leverages BOOTSTRAP 3[28] for seamless integration and enhanced user experience.

4.1.3. Website Architecture

The website architecture (Figure 26) is thoughtfully designed to provide users with a seamless and informative experience. The home page serves as the initial point of entry for users. Here, users will find the main content related to the DIAL4U project, presented through a dynamic visualization. The page also offers quick access to essential resources.

[28] Bootstrap simplifies front-end web development with CSS templates for mobile-first, responsive design elements, such as typography, forms, and buttons.

Figure 26. Webpages Architecture



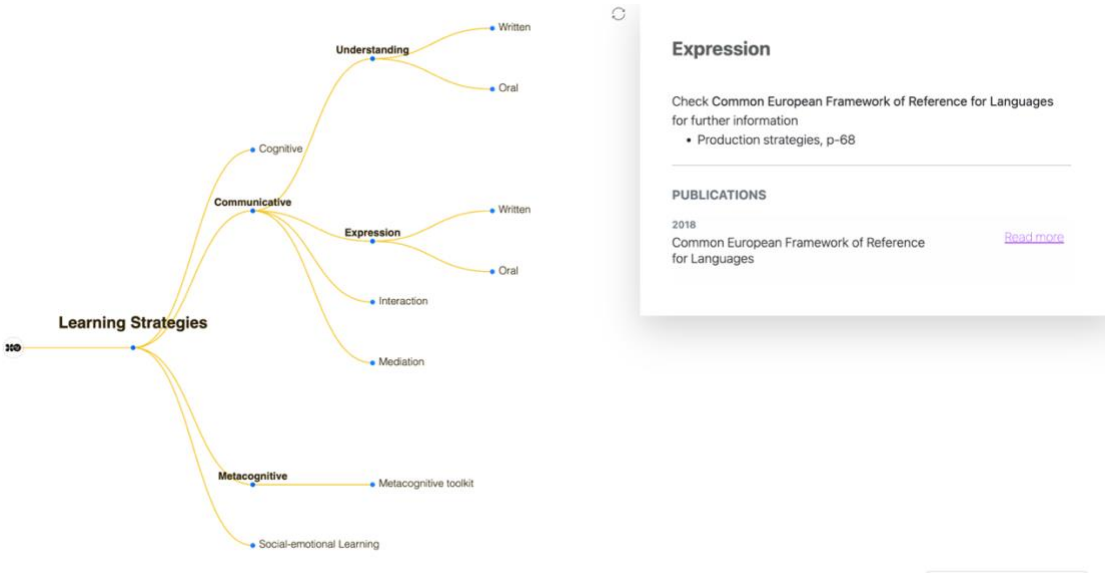
The section How to Use This Guide instructs users on navigating and utilizing the resource. It provides step-by-step instructions for various user goals, such as understanding the interface's contents or planning language lessons using digital technologies.

The "About It" page outlines the project's context and purpose objectives. It clarifies that DIAL4U aims to assist foreign language teachers in promoting autonomous lifelong learning among their students using technology.

In the "Structure" section, users can explore a vertical tree visualization that represents the content of the interface. This vertical tree layout (Figure 27) offers a more detailed and organized view of the content structure. Each page within the Structure menu corresponds to one branch of the first level of the radial tree layout. This means that the content of each page mirrors the information presented in the radial tree layout, allowing users to access the same content

through both visualizations. This dual representation ensures that users can choose the navigation style that best suits their preferences and needs.

Figure 27. Vertical tree layout



Note. Image from the interface on the webpage Learning Strategies.

The vertical tree layout provides an advantage by avoiding overlapping branches or labels in the radial tree layout. This layout ensures users can navigate the interface without visual clutter, enhancing their overall experience. Each branch and label are neatly organized, making it easier for users to access the desired content and understand the layout structure comprehensively.

4.1.4. User Interface

The Document Object Model (DOM) plays a pivotal role in the interface functionality, enabling it to dynamically update and incorporate new information without necessitating a full-page refresh. Essentially, the DOM serves as a programming interface for web documents. Through the DOM, programs can interact with and manipulate a web page's structure, style, and content. This interaction is primarily facilitated by scripting languages like JavaScript. Whether a web page is viewed in a browser window or examined as HTML source code, the DOM offers a consistent interface for making alterations.

The DOM is constructed using various APIs that complement one another. The core DOM defines the fundamental entities and objects within a document. Additional APIs for handling HTML documents or the SVG API for managing SVG documents extend the DOM's capabilities to cater to specific document types.

JavaScript was chosen as a fundamental resource for this project due to its integral role in facilitating interactivity through the Document Object Model (DOM). The DOM is the backbone for handling and generating dynamic content within web applications, making JavaScript an indispensable technology for achieving the defined project requirements. Enabling real-time updates, interactive features, and the ability to respond to user actions without requiring page reload. This synergy between JavaScript and the DOM empowers the interface with the interactivity needed to provide a user-friendly and dynamic experience.

The connection of JS, HTML, and JSON allows for the creation of HTML and CSS blocks that correspond to the specific node where the user action is triggered. This dynamic behavior lies in the binary options within the JSON structure. When JavaScript processes the JSON data and returns a value of 1 for a particular node, it signifies that the corresponding content related to that topic in the JSON should be used to generate an HTML block.

In practical terms, when a user interacts with the radial tree and clicks on a node, it has an attribute of 1 in the "have_" variable of the JSON structure (Figure 28). HTML and CSS blocks will be generated dynamically, with content coming directly from JSON. This process ensures no need for page reloads or manual navigation to deliver a responsive experience.

Figure 28. Function handles the DOM elements as the users click on the radial tree map

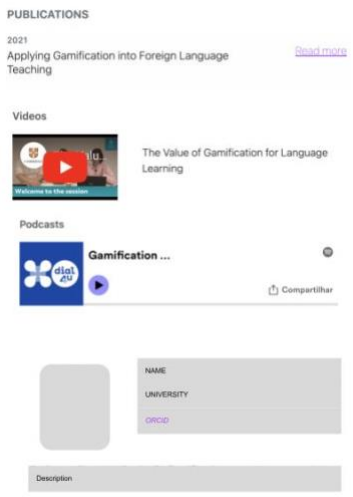
```
myChart.on('click', function (params, myChart) {

        //PERFIL
        if(`${params.data.have_profile}`=="1"){…
          } else{};
        //IMAGEM
        if (`${params.data.have_img}` == "1") {…
          } else{};
        //PUBLICAÇÃO
        if (`${params.data.have_pub}` == "1") {…
          }else{};
        //PODCAST
        if (`${params.data.have_pod}` == "1") {…
          } else{};
        //VIDEO
        if (`${params.data.have_video}` == "1") {…
 } else{};
});
```

Note. Image from the JavaScript function to handle with the user click.

The content blocks (Figure 29) correspond to each content type, ensuring that users can easily access various resources within the resource. Although this process efficiently generates content blocks, the structure of node and description names is designed differently. These elements are fully integrated into the Document Object Model (DOM) and manipulated directly in JS and HTML code, allowing for optimized performance.

Figure 29. Block basic structure on HTML.

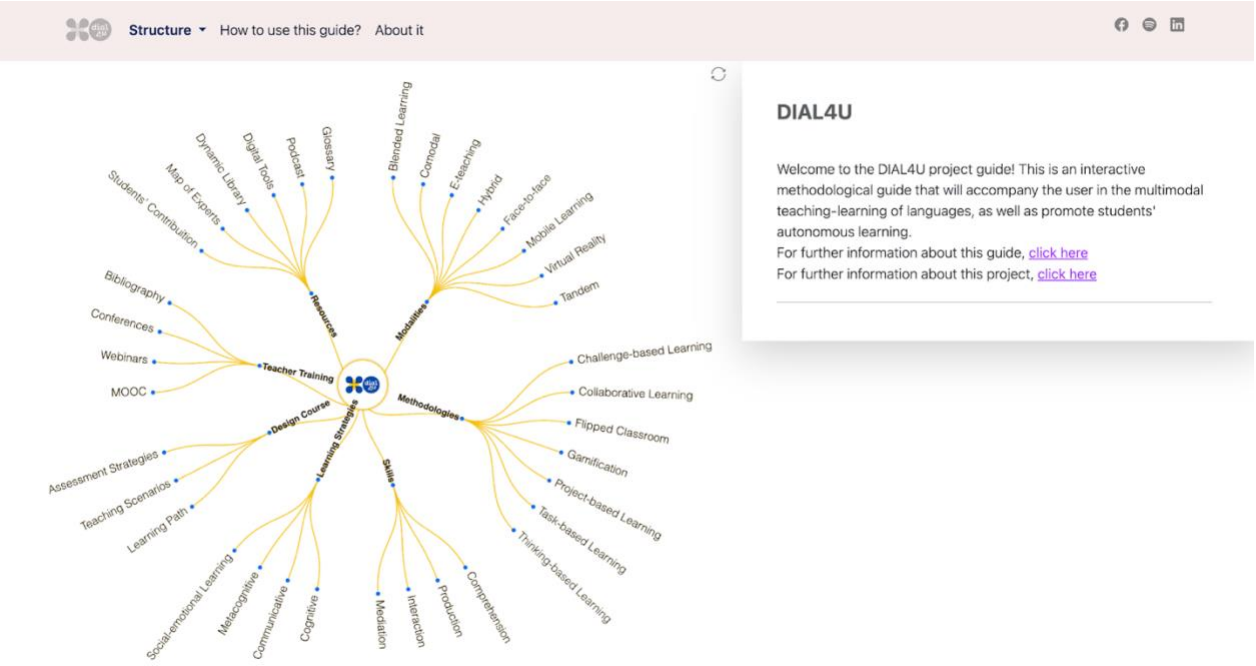


Note. Image from the content block wireframe in HTML

This project's final homepage (Figure 30) comprises two primary components: a dynamic data visualization on the left side and an information panel on the right. At the top of the page, a menu provides convenient access to three key sections: "Structure," "How to Use this Guide?" and "About It."

Upon entering the homepage, users are immediately presented with essential project information in the right-side panel. This section is a gateway to the "How to Use this Guide?" page, where users can find comprehensive guidance on navigating the resource effectively. Additionally, users can access an external page hosted by Lille University, which offers valuable insights and supplementary resources related to the project's overarching goals.

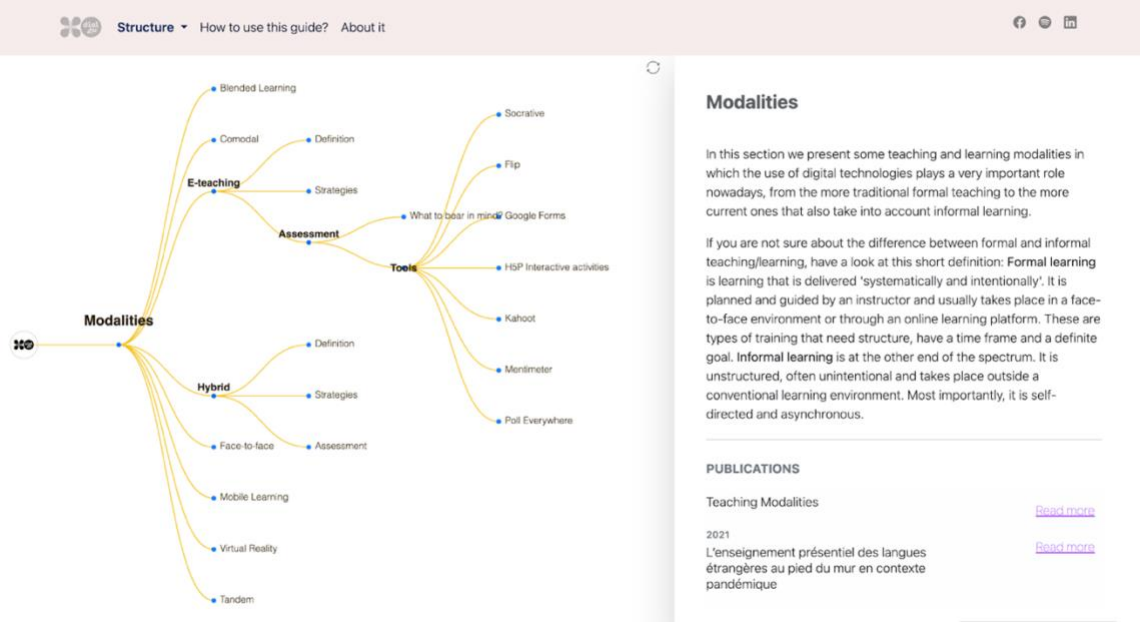
Figure 30. Final DIAL4U Home Page



As previously discussed, users can explore the data visualization using radial or vertical tree layouts, which have advantages and cater to diverse user preferences. The Figure 30 illustration showcases the finalized homepage layout, featuring a specific tree branch in intricate detail. This design choice ensures that users can seamlessly delve into the content they seek,

whether related to language teaching methodologies, digital tools, or other pertinent topics covered in the resource.

Figure 31. Vertical tree layout webpage



After implementing the InfoVis (Figure 31) on the completed, the next phase is the workshop, which will serve as a data source for future improvements.

5. Workshop

The workshop was part of the Learning Teaching Training Activity (LTTA), an event organized by the DIAL4U project. It took place at the Jaume I University in Spain from 12 to 14 December 2022. A key objective of the LTTA was to evaluate the products the project's partners developed.

In this particular event, a specific focus was placed on language teachers; each participating university was tasked with bringing five language teachers to the event to ensure a diverse group of educators with varying backgrounds and experiences.

The LTTA provided an ideal setting for the user's initial contact with the product, as the product presented here was designed with this target audience in mind. This event served as an opportunity to gather feedback from educators who could benefit from the project's resources.

The following section will delve into the detailed process of creating and conducting the workshop during the LTTA event, outlining this phase's methodology, objectives, and outcomes in evaluating the product.

5.1. Materials

The materials used in the workshop comprised three questionnaires. The first (Appendix A) was administered at two different times. Previously, the first questionnaire was applied to the workshop, aiming to provide information about the training and profile of the participating teachers. The second questionnaire was used after completing the tasks set out in the second questionnaire (Appendix B). These two forms were available online, and participants accessed them through the event's webpage using Google Forms. A third questionnaire (Appendix C) was delivered to the participants to provide suggestions and report errors and was distributed in printed format.

To participate in the workshop, participants must have their computers and headphones, as they are needed to listen to the podcasts and not disturb the others in the room.

5.2. Procedure

During this workshop, our objectives were as follows:

1. To gather foreign language teachers to utilize the interface.
2. To identify points of friction that participants encountered concerning the content and/or the design of the visualization.
3. To foster discussions regarding content, the design, and potential problems.

The workshop took place in a previously designated room at Universitat Jaume I on the second day of the LTTA event and lasted 90 minutes. The initial 15 minutes were dedicated to presenting the workshop's objectives and administering the first questionnaire. Subsequently, the following 60 minutes allowed participants to complete tasks, after which they filled out the final questionnaire. Once all attendees had completed their tasks and forms, the remaining 15 minutes were allocated for a discussion focused on participants' feedback and impressions regarding the interface. The first phase was conducted by the Uminho team, and the second phase of the workshop was led by the Universitat Jaume I team[29].

This timeframe allowed ample time for participants to explore the InfoVis, perform assigned tasks (Appendix B), and provide comprehensive feedback. Ensure that participants have sufficient time to engage with the visualization, allowing for a thorough understanding of its functionalities and features. The workshop proceeded as follows:

1. The Uminho team presented the manual and its application within the first 10 minutes.
2. Attendees were given a 5 to 10-minute window to investigate the interface independently.

[29] Universitat Jaume I team.

3. The assignments (Appendix B) were distributed, with 60 minutes allocated for their fulfillment.
4. Fifteen minutes were designated for participants to complete a survey (Appendix A). If participants detect any errors, problems, or malfunctions, they must be noted in Appendix C.
5. The last 15 minutes were set aside for a conversation and feedback session led by the Jaume team to exchange viewpoints and gather insights from the audience.

5.3. Preparation

Before the workshop commenced, participants were contacted via email and requested a computer and headphones. This preliminary communication was essential to ensure participants could interact individually with elements, such as podcasts and videos, during the workshop section.

5.4. Persona

Creating a persona was a tool to approximate the project to the idealized final user. The creation of a persona can be approached through various methods based on the necessity of the research. A persona represents user types by creating a fictional person (Salimen et al., 2020). The creation process may draw from user studies, designer assumptions, experiences, and creative possibilities. Some researchers argue that a persona based on a single individual may not be essential. In contrast, others warn against combining characteristics from multiple individuals, which could create noise in the data (Bowen et al., 2020).

Design processes don't strictly follow a linear path. The goal-directed design approach may involve conducting user research, creating personas, and using them to drive design scenarios (Salminen et al., 2020). However, according to the research design process, a persona doesn't necessarily have to be introduced during the first research phase. The persona can be introduced at various stages of the design process and may evolve throughout the investigative process.

In this project, a persona was developed incrementally, with a preliminary version created before the interface development. By the study's conclusion, the persona will be refined. The persona's characteristics and motivations will become evident as the research progresses.

The initial persona for this project is an experienced language educator working in Europe who has traditionally operated in physical teaching environments. During the COVID-19 pandemic, this female-identifying educator seeks innovative tools and resources to navigate the evolving language teaching landscape. Although her technological skills may be B1, she can quickly adapt to different digital contexts. The pandemic was challenging; she had to look for online teaching methodologies, activities, and tools. Despite knowing the names of some tools, she never used them frequently. Therefore, she has searched online for resources to speed up her digital classes. Although she is aware of new technologies and tools and their potential, these tools must enrich her teaching methods and ensure effective student engagement. Her primary needs revolve around discovering effective solutions to optimize language teaching in digital environments. Because she is not used to teaching in a digital environment very often, she is a professional who actively seeks to follow advances in language teaching to remain current.

5.5. Task-based Activity

The workshop encompassed two distinct phases: an initial phase of unrestricted exploration and a subsequent phase of task-based evaluation. This section presents these phases.

In the first phase, participants were encouraged to explore the DIAL4U interface for five minutes freely. The primary aim of this phase was to familiarize users with the interface’s overall structure and content, including its vital component, the radial tree visualization. Participants were free to navigate through various sections and subsections at their own pace, enabling them to explore different aspects of the interface as they saw fit. The interface was named "guide" during the workshop to improve communication and avoid misunderstandings.

Following this five-minute exploration, users were invited to respond to two specific questions on the questionnaire:

1. Regarding the first 5 minutes, when you have been surfing the guide freely, what is the first content that you have consulted?
2. What surfing criteria have you followed? (e.g., random, motivated by professional interest, terms that caught your attention, hierarchical order, etc.)

These questions aim to understand users' initial interactions with the guide, uncover any challenges they encountered, and discover how they overcame these challenges.

The second phase involved task-oriented exploration, with participants receiving specific assignments to complete within the interface. These tasks were designed to evaluate the participant's ability to gauge their ability to locate information efficiently. Participants were encouraged to complete as many tasks as possible within the 60-minute timeframe, and they were informed that if they faced difficulties or couldn't finish a task, they should provide feedback detailing the challenges they encountered.

The list of tasks that participants were tasked with during the second phase of the workshop is presented below. The tasks included identifying a specific node on the tree and pinpointing a leaf within a node. Such activities explore the ability to click on a node and search for a piece of information at the end of this node. Additionally, participants had to find information relevant to their teaching practice or of interest to them, listen to an episode of the project's podcast on Spotify, and explore the glossary.

1. Identify in the guide the teaching modality that best applies to your professional context, or you are interested in.
2. Choose the teaching methodology that you would like to put into practice.
3. Choose the linguistic competences you would like to work on.
4. Choose a strategy that could adapt to / fit into the modality, methodology and competences you have chosen and a digital tool you could use.
5. Find in the guide a podcast related to flipped classrooms and collaborative tools.
6. Check the podcast list on Spotify and if you like the topics, follow us!
7. One of your students has problems following your online classes. Find useful information and resources in the guide that can help you solve the problem.

8. Find a training course that could be of your interest.
9. Surf the dynamic library and find a paper or article of any field of your interest.
10. Use the glossary and select a term you do not know.
11. Think about one of your courses and try to find material from the guide that would help your students to reinforce the content taught in class.

After each task, participants were required to report whether they completed it (yes or no) and offer insights into the specific information they sought during the task. This feedback mechanism allowed us to comprehensively evaluate users' navigational efficiency within the guide and identify any challenges or issues they encountered during the process.

Integrating unrestricted exploration with task-based activities to assess InfoVis thoroughly aids language teachers in accessing pertinent information and resources for their professional development. Upon concluding the workshop session, participants were encouraged to share their valuable feedback through a structured questionnaire. This questionnaire aimed to collect insights regarding their experiences while interacting with the DIAL4U interface and assess their overall satisfaction with the workshop. The questionnaire consisted of the following questions:

1. How many suggested tasks have you accomplished?
2. In general, have you found the information you were searching for easily? [*Yes* | *No* | *Sometimes*]
3. If your answer to the previous question was no or sometimes, can you specify the task or content you were searching for?
4. Do the names on the tags or labels clearly identify the content? [*Yes* | *No* | *Sometimes*]
5. If your answer to the previous question was no or sometimes, can you specify the tags?
6. How would you describe the content of the guide? (Please choose as many adjectives as you need) [*relevant* | *useful* | *useless* | *too general* | *too specific* | *sufficient* | *insufficient]*
7. Surfing the guide has been:

a. *easy: very | moderately | slightly | not at all*
b. *clear: very | moderately | slightly | not at all*
c. *intuitive: very | moderately | slightly | not at a*ll

8. In general, I found this guide:

a. *useful: very | moderately | slightly | not at all*
b. *intuitive: very | moderately | slightly | not at all*
c. *user friendly: very | moderately | slightly | not at all*
d. *legible (word size): very | moderately | slightly | not at all*
e. *interactive: very | moderately | slightly | not at all*
f. *innovative: very | moderately | slightly | not at all*

9. What did you like the most about the guide?

10. What would you improve in the guide?

11. What's your level of satisfaction with this workshop?

a. *Not satisfied at all 1 2 3 4 5 Very satisfied*

12. What's your level of satisfaction regarding the material used at this workshop?

a. *Not satisfied at all 1 2 3 4 5 Very satisfied*

13. Please provide any additional comments about the workshop, the guide, or any other information not included in the questionnaire that you would like to highlight.

The post-task questionnaires were a crucial component of the evaluation process, enabling us to gain deeper insights into the user experience and gather valuable feedback for potential improvements.

5.6. Task Analysis

During the initial phase of the workshop, participants were invited to explore the interface freely before embarking on specific tasks. The findings from this phase reveal the use behavior of a user who will discover the interface before no initial contact with it.

The task evaluation process involves a comprehensive examination of data visualization analysis tasks, some pertinent to this workshop. The primary objective of these tasks is to

establish a shared vocabulary that fosters a more profound understanding of the analytical process (Zeng & Battle, 2023). While Amar et al. (2005) proposed ten tasks, it's worth noting that some do not directly apply to this specific context. Still, the relevant tasks are aligned with qualitative data related to the DIAL4U visualization.

Table 3. Selection of Task Taxonomy related to the DIAL4U project.

Task	Description	Pro Forma Abstract
Retrieve Value	Identify specific attributes associated with a given set of data case	What are the values of attributes {X, Y, Z, ...} in the data cases {A, B, C, ...}?
Filter	Find data points satisfying the specified conditions	Which data cases satisfy conditions {A, B, C...}?
Cluster	Detect clusters of similar attribute values	Which data cases in a set S of data cases are similar in value for attributes {X, Y, Z, …}?
Correlate	Determine/estimate the correlation within the specified attributes	What is the correlation between attributes X and Y over a given set S of data cases?

Note. Zeng & Battle, 2023; Amar et al., 2005.

These tasks collectively offer structured data, serving as a tool for data analysis within the workshop context. The task analysis related to which activity is available in Table 4.

Table 4. Task Taxonomy

Task	Task Taxonomy
1. Identify in the guide the teaching modality that best applies to your professional context or you are interested in.	Retrieve Value
2. Choose the teaching methodology that you would like to put into practice.	Filter
3. Choose the linguistic competences you would like to work on.	Correlate
4. Choose a strategy that could adapt to / fit into the modality, methodology and competences	Correlate and Filter

	you have chosen and a digital tool you could use	
5.	Find in the guide a podcast related to flipped classrooms and collaborative tools.	Filter
6.	Check the podcast list on Spotify and if you like the topics, follow us!	Retrieve Value
7.	One of your students has problems following your online classes. Find useful information and resources in the guide that can help you solve the problem.	Filter and Retrieve value
8.	Find a training course that could be of your interest.	Filter and Retrieve Value
9.	Surf the dynamic library and find a paper or article of any field of your interest.	Retrieve Value
10.	Use the glossary and select a term you do not know.	Retrieve Value
11.	Think about one of your courses and try to find material from the guide that would help your students to reinforce the content taught in class.	Filter and Retrieve value

Note. Created by the author based on Zeng &Battle, 2023

These elaborated tasks offer a structured approach to the analysis process, cultivating a deeper understanding of participants' responses and engagement with each task's objectives. Identifying these analysis tasks promotes an emphasis on analytical measures in information visualization systems as a common language for discussing system capabilities (Zeng & Battle, 2023).

5.6.1. Data Pre-processing

Throughout the data pre-processing phase, a few measures were taken to maintain data consistency while addressing any inconsistencies introduced during data collection. The normalization process and the handling sections contributed to the uniformity and reliability of the dataset used for analysis. By ensuring data uniformity and consistency, we aimed to enhance the accuracy and reliability of our findings and insights.

- Data Cleaning: Upon collecting the workshop data, a data-cleaning process was initiated to address any inconsistencies or errors. This involved reviewing responses for completeness and accuracy. Data entries with missing values or clear inaccuracies were corrected from the analysis to maintain data integrity.
- Data Normalization: A significant aspect of data pre-processing was normalizing responses to open-ended questions. I applied a normalization procedure to the answers to maintain uniformity and ease of analysis. Specifically, responses were normalized to capitalize the first word, with subsequent words in lowercase. This normalization approach enhances the consistency of textual data and facilitates subsequent analysis.
- Handling Comma-Separated and Hyphens: In cases where responses involved listing multiple sections of the InfoVis, we accounted for the presence of commas as separators. Each unit mentioned within a response, separated by a comma or hyphen, was treated as a distinct entity for analysis purposes. This approach ensures that the analysis effectively captures the granularity of feedback related to different sections of the InfoVis.

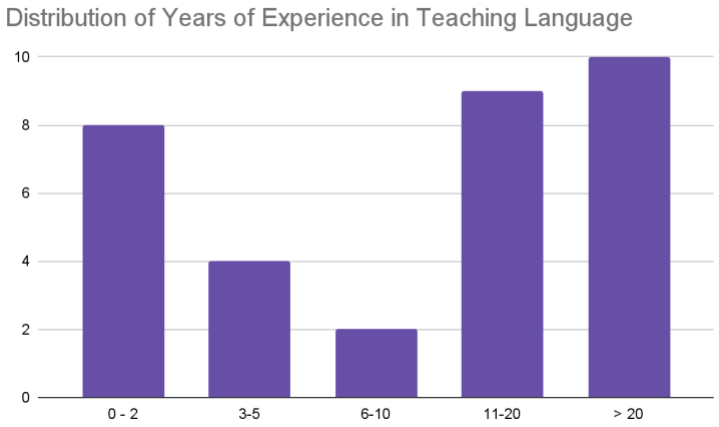
5.6.2. Participants Profile

Understanding the user profiles is essential for interpreting their interactions and feedback effectively. So, two main pieces of information were gathered: the experience in teaching and the self-perception of digital competence.

The workshop was attended by 33 (n=33) foreign language teachers from various partner universities, including Malmö Universitet, Mykolo Romerio Universitetas, Stiftung Europa-Universitat Viadrina Frankfurt, Universidade Do Minho, Universitat Jaume I de Castellon, Universitatea Babeş-Bolyai, Université de Lille, and Uniwersytet Wroclawski invited. Most of the participants have more than 20 years of experience in teaching foreign languages. The next most relevant group is made up of teachers who have between 11 and 20 years of experience teaching languages.

Most users who participated in the workshop had extensive experience in foreign language teaching, with more than 11 years of experience in the field. Participants (*n=33*) self-assessed their digital competence, revealing various technological comfort levels.

Figure 32. Graph Distribution of Years of Experience in Teaching Language



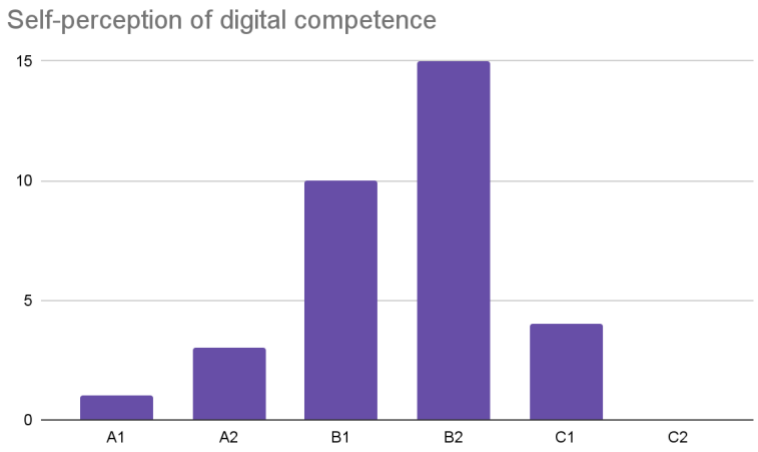
Most users classified themselves within the B1 or B2 levels of digital competence, indicating mean degrees of familiarity and confidence in using digital technologies for professional purposes.

As the scale of digital competence perception beneath (Punie & Redcke, 2017):

- A1-Newcomer: Participants at this level are aware of digital technologies' potential but may require guidance and encouragement to apply them to their professional practice.
- A2-Explorer: Users in this category recognize the potential of digital technologies and express a desire to explore them to enhance their professional practice, albeit with the need for support.
- B1-Integrator: Participants at this level experiment with digital technologies across various contexts and purposes, integrating them into many aspects of their professional practices.
- B2-Expert: Educators at this level use a wide range of digital technologies with confidence, creativity, and a critical perspective to enhance their professional activities.

- C1-Leader: Users with a C1 level have a diverse repertoire of digital strategies and can select the most appropriate ones for specific situations. They engage in continuous reflection and further development of their practices.
- C2-Pioneer: Educators classified as C2-level demonstrate a willingness to experiment with highly innovative and complex digital technologies. They may also be involved in developing new pedagogical approaches.

Figure 33. Self-perception of digital competence.

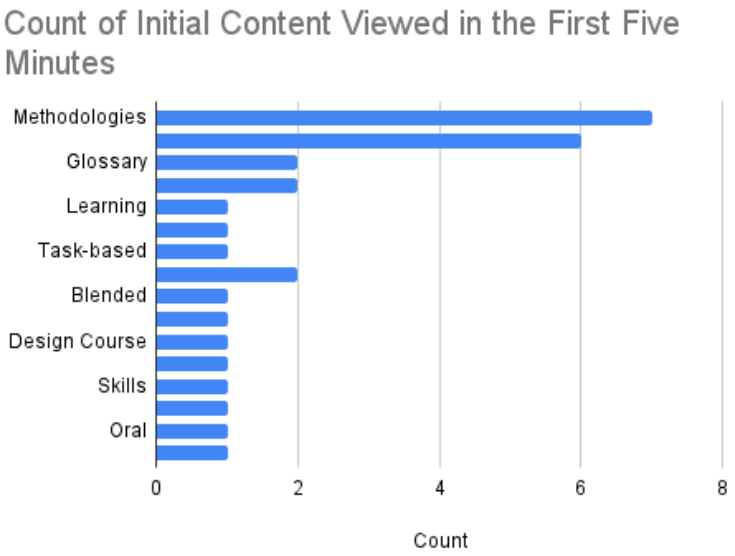


Using this information makes it possible to begin delineating who the persona is. The persona is B2-Expert: Educators at this level use a wide range of digital technologies with confidence, creativity, and a critical perspective to enhance their professional activities. Who have more than ten years of experience in language teaching, being an experienced teacher with a vast background of tools to learn, and having experienced the transformation of the education landscape in the last 20 years (UNESCO, 2020; Sato & Lowen, 2022; UNESCO 2023).

5.6.3. Tasks Analysis

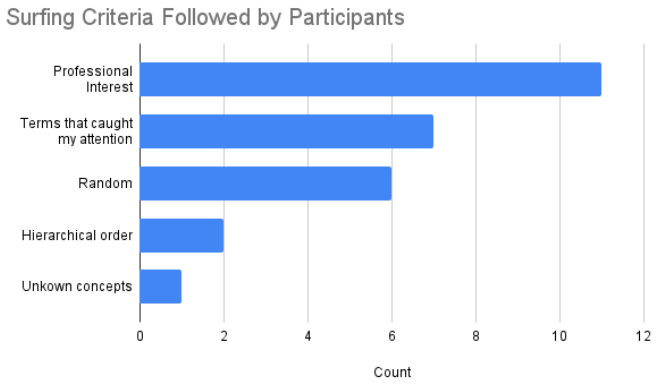
Data analysis indicates that, during the first 5 minutes of interaction with the guide (Figure 34), users predominantly navigated through the "Methodologies" branch. This was followed by an exploration of the "Modalities" section, "Glossary," and "Resources."

Figure 34. Count of Initial Content Viewed in the First Five Minutes



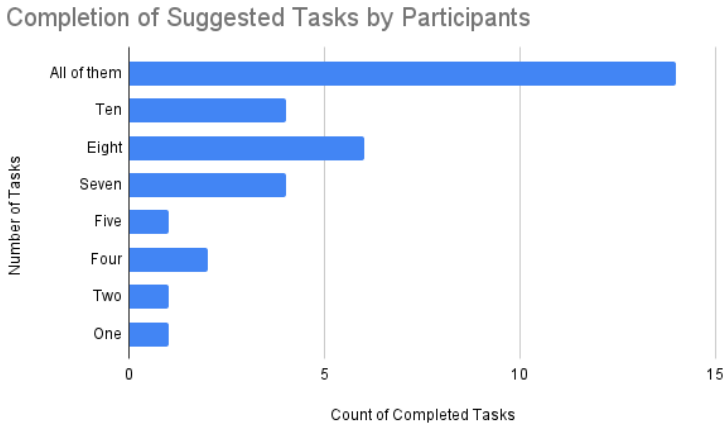
Users employed a range of criteria to guide their navigation (Figure 35). Foremost among these criteria was their professional interest, serving as the primary driver behind their choices. Users also noted that terms that piqued their curiosity at directing their exploration. Some users followed the structured hierarchical order of the guide, while others opted for a random approach, adding an element of unpredictability to their interactions.

Figure 35. Surfing Criteria Followed by Participants



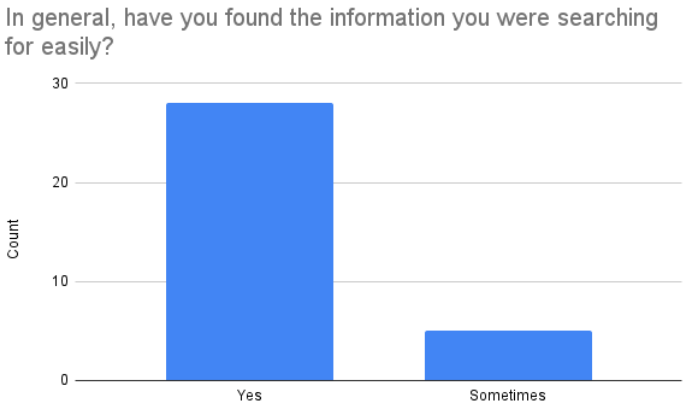
In the second phase, which involved completing specific tasks, most users accomplished all eleven tasks (Figure 36) or a significant portion.

Figure 36. Graph Completion of Suggested Tasks by Participants



When evaluating users' ability to find information, none of the participants reported being unable to locate the information they were looking for (Figure 37). However, five users acknowledged occasional difficulties in this regard. These challenges were primarily associated with identifying specific tag names within the radial tree.

Figure 37. Graph with the result for the question: In general, have you found the information you were searching for easily?

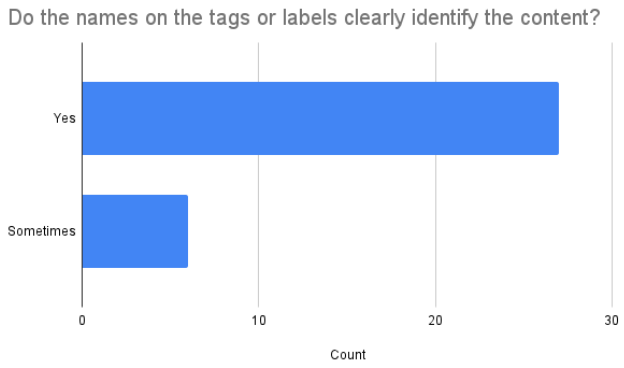


One common issue cited by users was the font size and label overlapping, making it challenging to distinguish node names, such as "Digital Tools." A user mentioned the repeated need to visit the "How to Use this Guide?" page to reorient themself. Nonetheless, it's important to emphasize these difficulties stemmed from two distinct bases: the visualization layout and interface design. Issues were also noted, particularly when zooming in and out, which impacted

the legibility of labels. Some users recommended changing the font size as a potential solution to enhance clarity and user-friendliness.

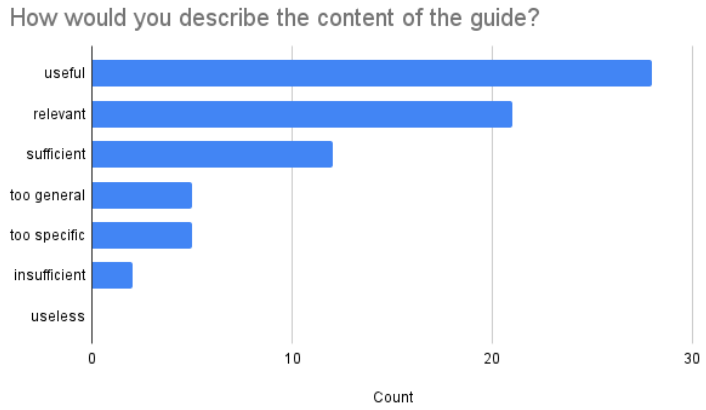
Regarding the clarity of the label node nomenclature (Figure 38), some users expressed uncertainty about whether the description and multimodal content within a node corresponded to the label name. This vagueness led to concerns about the nature of the content and whether it was more suitable for students or intended for teachers.

Figure 38. Graph Do the names on the tags or labels clearly identify the content?



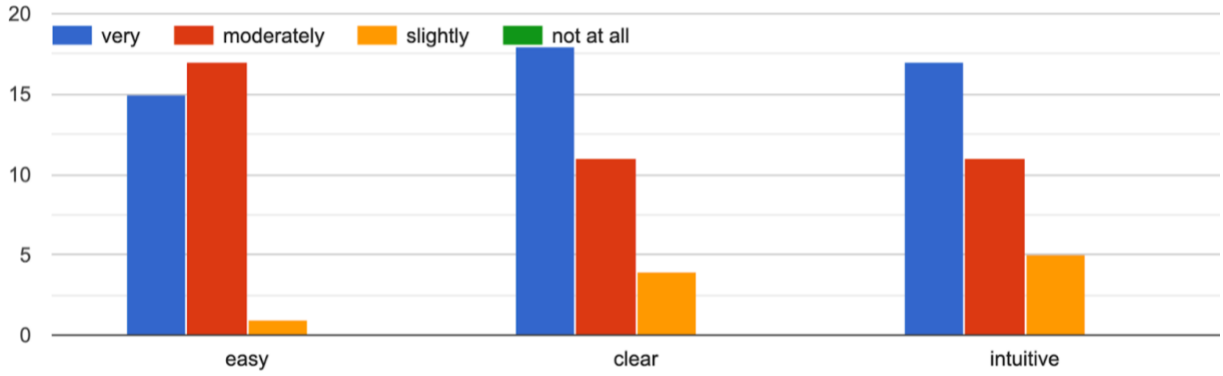
The user's evaluation of the interface content revealed diverse perspectives. Most users described the interface (Figure 39) as "useful," "relevant," and "sufficient.". Conversely, one user characterized the resource as "interesting, practical, and multimodal," while another considered it more suitable for recreational exploration than language teaching and research.

Figure 39. Graphic How would you describe the content of the guide?



Users expressed overall satisfaction with the multimodal content and the diverse resources available. They particularly appreciated the podcasts, highlighting their potential to support autonomous learning. Feedback on the layout and design was uniformly positive (Figure 40), with users finding it clear, intuitive, and efficient.

Figure 40. Graph Surfing the guide experience classification.



Users provided valuable insights into enhancing the interface. Their suggestions included more examples, additional content (particularly videos and more English-language resources), increased web page font size, addressing label overlapping issues, incorporating a search bar, and ensuring accessibility across various devices, including iPads.

5.6.4. Refined Persona

The refined persona embodies an experienced language educator based in Europe with over 11 years of teaching experience. She has in-depth knowledge of language teaching, pedagogical techniques, and student engagement. Her teaching experience goes beyond traditional physical classroom environments. This educator identifies as a woman and defines her technological level as B2. Demonstrating high self-confidence, she is an expert in a wide range of digital technologies. Her technological proficiency has increased during the COVID-19 pandemic. Her professional interest fuels her primary motivation for consulting this interface. She seeks content that directly reinforces her language teaching methodologies and elevates her students' learning experiences.

6. Final Considerations

The projects presented in the Related Work chapter played a fundamental role in defining the vision and design of the interface. Although there are some common points, DIAL4U differentiates itself by its approach to hierarchical structuring of information and by the proposal that invited the community to participate in the creation of resources—incorporating a radial tree layout aimed to enhance the discovery of knowledge by users, complemented by interactive elements strategically integrated into the interface, particularly in data visualization. These design choices were carefully implemented to facilitate access to knowledge for the target audience: foreign language educators.

The workshop conducted as a part of this study has provided invaluable insights into the DIAL4U resource. The findings have shed light on critical aspects of the interface, leading to improvements that aim to enhance the overall user experience. One of the key takeaways was the recognition that the content needed further refinement. The involvement of the University Jaume I team played a pivotal role in this enhancement process. Reviewing and complementing the content ensures alignment with language teaching and learning objectives. The collaborative effort resulted in a more robust and pedagogical resource.

User feedback highlighted specific interface-related issues, particularly concerning font size and label clarity. Responding to these concerns, the font size was increased, making it easier for users to read and navigate the content. Furthermore, label clarity within the radial tree layout received attention, offering users a more seamless and comprehensible experience.

6.1. Content Enhancement

Based on the workshop feedback, a few areas needed content improvement. To address this, language teachers who are integral to the project revised and augmented the content within the interface. This revision process resulted in enriched and more informative content that aligns with users' needs and expectations.

The glossary was also enhanced with more terms. Recognizing users' diverse linguistic backgrounds, it expanded to include English, Portuguese, and French translations. This expansion not only broadens the resource's accessibility but also caters to a broader audience.

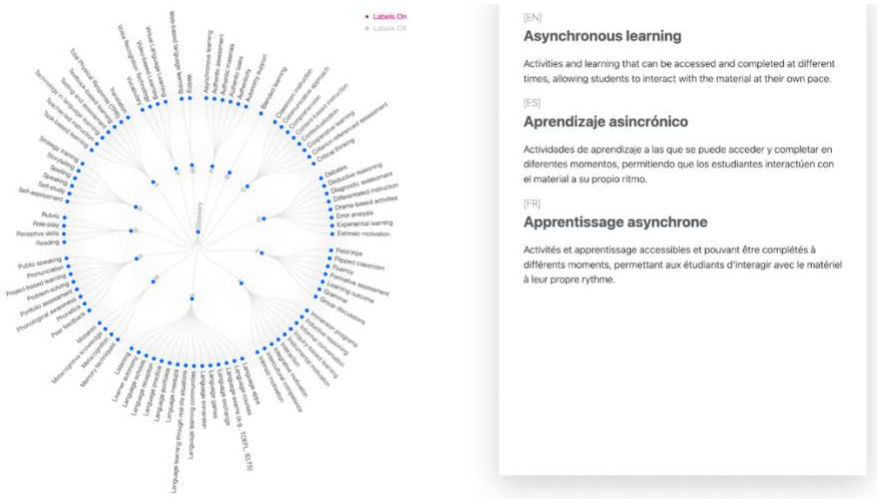
The LTTA2 event at Universitatea Babeş-Bolyai introduced an opportunity to enhance the content. Students from the DIAL4U partner universities were invited to test the deliverables of the intellectual outputs. They had the chance to contribute to the project content from the students' perspective on foreign language learning. These students were invited to record podcasts sharing descriptions of foreign language learning activities or personal practices that significantly improved their language skills. Furthermore, they contributed to creating informative infographics related to the learning process. These contributions are now accessible in the radial tree under the "Student contribution" node.

6.2. Enhanced User Experience

The layout underwent review based on user feedback. Notable changes include increasing font size to enhance readability, especially in the radial tree layout. The labels within the radial tree layout were also improved to provide greater clarity to users.

To provide a more engaging and intuitive experience, as users hover over a node, the font size increases, the text becomes bold, and the color changes, drawing their attention to specific nodes. Additionally, the path to the root node is highlighted, creating a visual hierarchy that aids navigation and comprehension.

Figure 41. Glossary Visualization with the option Labels On and Labels Off



Note. The glossary interface with the radial tree layout and the tooltips allows the users to see or not see the labels.

In response to user preferences for different viewing options, the interface offers a more straightforward approach for the glossary radial tree visualization (Figure 41). Users can view only the leaves' labels, simplifying the visualization while maintaining its informative value. Additionally, the vertical visualization was enhanced with a larger font size to ensure an optimal user experience.

6.3. Impact

The impact and reach of the DIAL4U project have been substantial, and it has been updated frequently. In October 2023, five more podcast episodes were released. The podcast series garnered an audience of 194 users from around the globe, including Portugal, Spain, Romania, France, the United States, Lebanon, Colombia, and Brazil. This diversity of countries and users from different linguistic and cultural backgrounds aligns seamlessly with the project's core objectives. It underscores the project's capacity to transcend geographical boundaries and cater to a global audience interested in foreign language education.

The DIAL4U homepage was integrated with a visitor counter after the LTTA2. This resource allowed us to gauge the reach and engagement of our resources. Since its implementation, the page has recorded 828 visits. In addition, the glossary hosted on Notion has been accessed 110 times. The DIAL4U Library, a repository of academic publications, caught interest with 98

visits. These statistics underscore the project's impact and demonstrate its capacity to engage a diverse and geographically dispersed user base, although it is being born as a European project.

The work developed at DIAL4U has resulted in two papers being published at the ArtsIT Interactivity & Game Creation conference in two different editions of the conference. The most recent article, "Enhancing Scientific Communication Through Information Visualisation: A Proposal for a Multimodal Platform" (in press), will be presented in November 2023 at the conference in Brazil[30]. At the Portuguese[31] event, the paper "Designing a Multilingual, Multimodal, and Collaborative Platform of Resources for Higher Education" (Azevedo et al., 2023) was presented. Both papers are dedicated to aspects related to the interface development discussed in this article.

In addition, this research has contributed to the field of scientific communication (Araújo & Pereira, 2022), where data visualizations have been used in projects such as "Lidera" (Alves, 2023), which focuses on women in business and the "Nano Tool" prototype developed by the International Iberian Nanotechnology Laboratory (Silva, 2023).

6.4. Future Work

The adjustments I made while working on the DIAL4U interface characterized significant progress, but more advanced user research techniques could yield more profound insights into user behaviors and interactions. User feedback could evaluate and improve the platform's usability, and this feedback could be used to add new features and functionality that could improve the overall performance of the platform. Also, in the future, data visualization can be explored using more advanced libraries and interactive visualizations to help users explore and analyze data in more detail.

[30] EAI ArtsIT 2023 - 12th EAI International Conference: ArtsIT, Interactivity & Game Creation
[31] EAI ArtsIT 2022 - 11th EAI International Conference: ArtsIT, Interactivity & Game Creation

It is essential to mention that the interface developed here became the webpage integration of all project resources into a single interface, making the interface the portal to all components done on the DIAL4U project due to the smooth characteristic.

The DIAL4U done on this work has a high potential for replicability in different scientific fields. However, some challenges must be addressed to ensure it, as has been done in various aspects of NATO Knowledge Hub and Lang2science. For example, the JSON file should be replaced with an interface allowing users to add information easily. Regardless, inputting data into a JSON file can be an obstacle for some users. Therefore, creating an intuitive interface for data input associated with a database capable of effectively managing large amounts of data is paramount to future replicability projects that give the users autonomy to create their own data visualization and content, focusing on science communication.

This work stood dedicated to building the DIAL4U interface; the platform still has room for improvement in usability, functionality, and data visualization capabilities. However, it has already shown great potential to become a tool for language educators and, in the future, for other academic areas.

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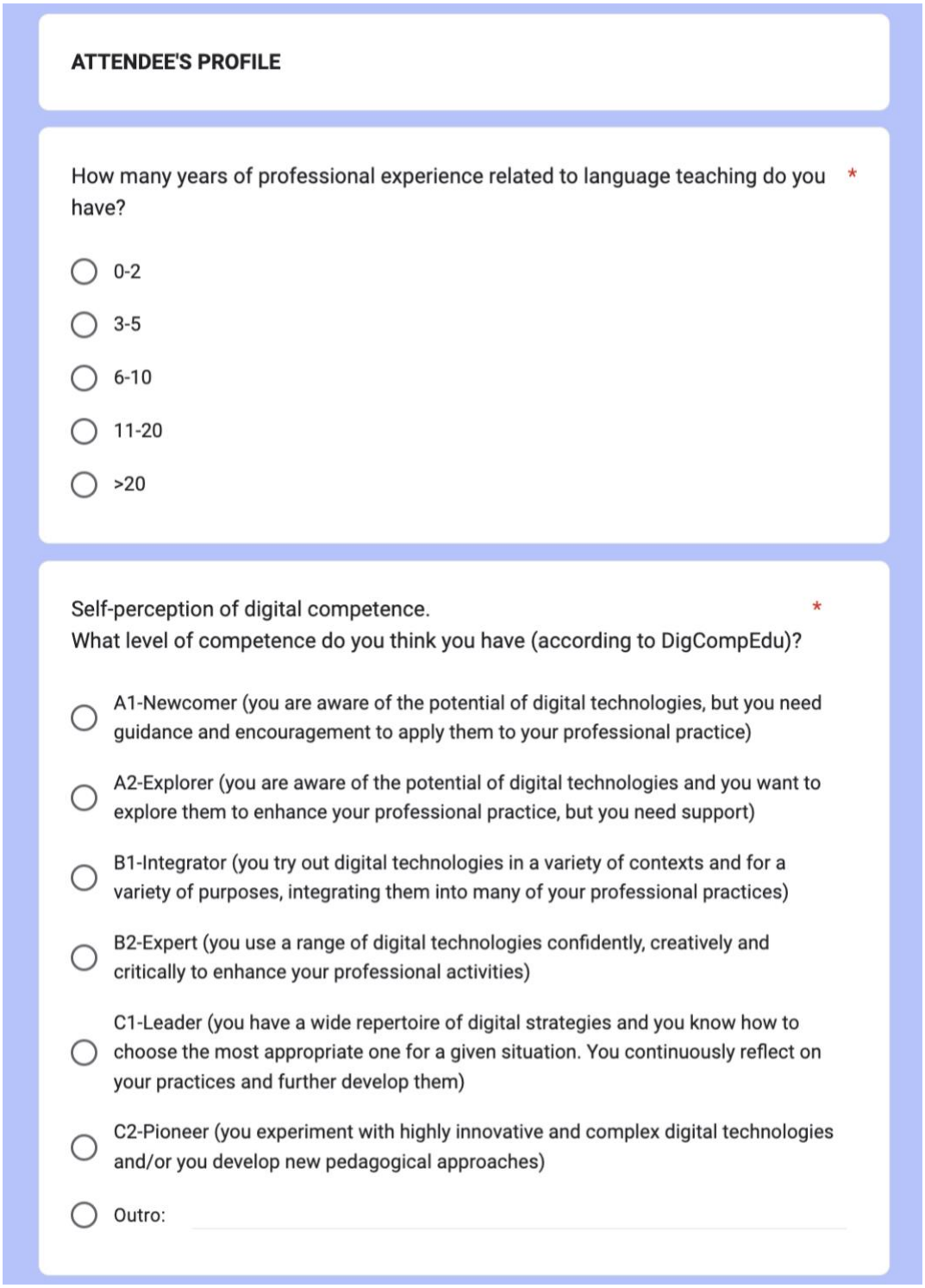
Appendix

Appendix A – Survey Instrument



ATTENDEE'S PROFILE

How many years of professional experience related to language teaching do you have? *

- ◯ 0-2
- ◯ 3-5
- ◯ 6-10
- ◯ 11-20
- ◯ >20

Self-perception of digital competence. *
What level of competence do you think you have (according to DigCompEdu)?

- ◯ A1-Newcomer (you are aware of the potential of digital technologies, but you need guidance and encouragement to apply them to your professional practice)
- ◯ A2-Explorer (you are aware of the potential of digital technologies and you want to explore them to enhance your professional practice, but you need support)
- ◯ B1-Integrator (you try out digital technologies in a variety of contexts and for a variety of purposes, integrating them into many of your professional practices)
- ◯ B2-Expert (you use a range of digital technologies confidently, creatively and critically to enhance your professional activities)
- ◯ C1-Leader (you have a wide repertoire of digital strategies and you know how to choose the most appropriate one for a given situation. You continuously reflect on your practices and further develop them)
- ◯ C2-Pioneer (you experiment with highly innovative and complex digital technologies and/or you develop new pedagogical approaches)
- ◯ Outro: _____

PHASE I: BEFORE THE TASKS

1. Regarding the first 5 minutes, when you have been surfing the guide freely, what is the first content that you have consulted? *

Sua resposta

2. What surfing criteria have you followed? (e.g. random, motivated by professional interest, terms that caught your attention, hierarchical order, etc.) *

Sua resposta

PHASE II: REGARDING THE TASKS

3. How many suggested tasks have you accomplished? *

Escolher

Esta pergunta é obrigatória

4. In general, have you found the information you were searching for easily? *

- Yes
- No
- Sometimes

5. If your answer to the previous question was **no** or **sometimes**, can you specify the task or content you were searching for?

Sua resposta

6. Do the names on the tags or labels clearly identify the content? *

- Yes
- No
- Sometimes

7. If your answer to the previous question was **no** or **sometimes**, can you specify the tags?

Sua resposta

8. How would you describe the content of the guide? (Please choose as many adjectives as you need) *

- [ ] relevant
- [ ] useful
- [ ] useless
- [ ] too general
- [ ] too specific
- [ ] sufficient
- [ ] insufficient
- [ ] Outro:

9. Surfing the guide has been: *

	very	moderately	slightly	not at all
easy	○	○	○	○
clear	○	○	○	○
intuitive	○	○	○	○

Appendix B – Workshop Tasks

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IO3 - WORKSHOP TASKS			
The following tasks will allow you to surf the guide with a specific goal in mind and will provide you with a more in depth knowledge of the information you can find in it. We would like you to do as many tasks as you can, but if you couldn't do any of them just let us know why.			
	Done?		What information did you search for?
1. Identify in the guide the **teaching modality** that best applies to your professional context or you are interested in.	YES	NO	
2. Choose the **teaching methodology** that you would like to put into practice.	YES	NO	
3. Choose the **linguistic competences** you would like to work on.	YES	NO	
4. Choose a **strategy** that could adapt to / fit into the modality, methodology and competences you have chosen and **a digital tool** you could use.	YES	NO	

5. Find in the guide a podcast related to **flipped classrooms** and **collaborative tools**.	YES	NO	
6. Check the **podcast list on Spotify** and if you like the topics, follow us!	YES	NO	
7. One of your students has **problems following your online classes**. Find useful information and resources in the guide that can help you solve the problem.	YES	NO	
8. Find a **training course** that could be of your interest.	YES	NO	
9. Surf the **dynamic library** and find a paper or article of any field of your interest.	YES	NO	
10. Use the **glossary** and select a term you do not know.	YES	NO	
11. Think about one of your courses and try to **find material** from the guide that would help your students to reinforce the content taught in class.	YES	NO	

Appendix C – Errors

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LTTA1 - 12TH to 14TH December 2022 - UJI (Spain) IO3 - Guide's improvement	
Please, help us fix the errors in the guide. We would appreciate it if you could note down in a few words any errors, glitches or problems you come across while surfing it. **Thank you!**	
Where is the problem? (Route)	**What is the problem?**
E.g. Methodologies / Collaborative Learning	*E.g. The link to the first paper is broken*