POLITECNICO SETUBAL

Novembro 2023
16 a 18

Atas SIIE23

XXV Simpósio Internacional de Informática Educativa

Atas do XXV Simpósio Internacional de Informática Educativa

FICHA TÉCNICA
Setúbal, Portugal
16, 17 e 18 de novembro de 2023
Instituto Politécnico de Setúbal

Editores
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Título: Atas do XXV Simpósio Internacional de Informática Educativa
Editor e Copyright Instituto Politécnico de Setúbal
Local: Setúbal, Portugal
Website: https://eventos.ese.ips.pt/siie2023/
ISBN: 978-989-35377-2-5
Ano: 2023
Nº de Páginas: 340

PARTICIPATORY DESIGN OF A HIGH-FIDELITY PROTOTYPE OF AN ESSENTIAL LEARNING CURRICULAR TOOL

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Abstract— In the context of the AE.Maps project (IPL/2022/AE.Maps_ESELx) – Essential learnings: mapping to promote curriculum integration – this paper presents the design of a high-fidelity prototype of a tool to support pre-service and in-service teachers, during curricular vertical and horizontal articulation. This tool should make it possible to query a database of Essential learning (EL), using a user-friendly interface. The four-stage double-diamond model was used to guide the participatory design process. In the discovery phase, through task analysis and focus group, involving 51 pre-service and in-service teachers, user needs regarding EL search were gathered. In the exploratory and definition phase, problems were explored and defined, while personas were created. In the development phase, sketches made by different participants were used to develop and explore solutions for a friendly interface. Moreover, during this phase, an Excel medium-fidelity prototype was implemented, and a high-fidelity prototype was iteratively designed in a participatory way.

Keywords—Participatory design, elementary education, database, interface, curricular orientations,

I. INTRODUCTION

Recently, in Portugal, a new curriculum was designed. This process involved, among other measures, the definition of a common set of learning outcomes for every student – the Essential Learning (EL) and implied the effective recognition of schools as a level of curricular decision-making, responsible for the contextualized implementation of the national common core curriculum [1]. In this level of curricular decision-making, teachers are the critical actors [2], [3]. However, recent data indicate that teachers report weaknesses in curriculum management related to the reading, interpretation, and operationalization of EL, regarding links to other levels of education and, above all, between the EL of various subjects [4]. This is an important problem, because according to OECD (2020) [5], "When it is difficult to navigate through the curriculum, teachers are more likely to misunderstand its intent and use it ineffectively" (p.15).

The AE.Maps project (IPL/2022/AE.Maps_ESELx) – Essential learnings: mapping to promote curriculum integration – aims at supporting in-service and pre-service elementary school teachers in the horizontal and vertical curriculum articulation process, namely through the development of a high-fidelity prototype, which will integrate a database for an interactive search and query of the EL documents. This is quite relevant since many recommendations stress the need to demonstrate connections between subjects.

Considering the need to develop a tool to support teachers in the interactive search and query of EL, it is important to remark that the mentioned tool should be useful, evidencing utility and usability, since the quality of the design of computer-based products is related to the utility and usability of such products. Furthermore, any computer-based tool should have a "friendly" interface. More than making easy and transparent the user-tool interactions, an interface should support thinking and the discovery of new patterns in the tool world [6].

The user interface is the set of inputs and outputs controlled by the user and the technological system, composing the interactive activity. It includes the appearance, but also the reified ideas of user-system interaction [7].

In this context, the study presented in this paper aims at the participatory design of a high-fidelity prototype of a useful tool, with a "friendly" and thought-provoking interface, to query a database of Essential learning (EL), during horizontal and vertical curriculum articulation.

The paper starts with this introduction, continues with the presentation theoretical and empirical context, the results, and closes with the conclusion and bibliographic references.

II. THEORETHICAL AND EMPIRICAL CONTEXT

A. Curricular orientations and management in elementary school in Portugal

In Portugal, in the last 25 years, there has been a succession of curricular changes, resulting from the lack of consensus on what is considered to be learned in each historical and social period [1], [8]. Not only have there been frequent changes, but documents with different guidelines, elaborated in different periods, with a lack of coherence between them and sometimes with contradictory rationales, have also coexisted. These inconsistent curricular documents created difficulties, not only in horizontal, but also in vertical articulation.

In 2015, a new government, with a different understanding of what curriculum policy should be, began a process of curricular changes. Firstly, a Students' Profile by the End of Compulsory Schooling (SP) [9] was defined (Order No. 64787/2017, of 26 June). The SP is a document that describes the vision, principles, values, and skills that students, upon completing compulsory schooling, must have developed and that are fundamental for building a culture and a country that is humanistic, scientific, and artistic. Secondly, schools were given some autonomy to meet their specific needs (e.g. pedagogical differentiation, new disciplines, interdisciplinary

and project work) and curricular flexibility (Decree-Law n.º 55/2018, of July 6th and Ordinance n.º 181/2019, of June 11th). Finally, with the aim of solving the extensive curricular overload, new reference curricular documents called Essential Learning (EL) were prepared. EL are the result of a careful selection of a common set of knowledge to be acquired, as well as skills and attitudes to be developed by all students, in each subject area or discipline (Decree-Law No. 55/2018, of July 6). The development of these documents began in 2016, through an invitation made by the Ministry of Education (ME) to teachers' associations, scientific societies and programs' authors [10].

This process culminated in the publication of Dispatch n.º 6605-A/2021, of July 6, which determined that the EL, in convergence with the SP, should become the basic reference for decisions associated with flexibility and curriculum management by schools and teachers, revoking all previous curricular programs and goals. Due to an in-depth analysis of failure in the mathematics subject (Order n.º 12530/2018, of December 28, amended by Order n.º 7269/2019, of August 16), a curricular review of the EL for this subject was carried out (Dispatch n.º 8209/2021, of December 15). Thus, currently, we have a long-desired situation in terms of curricular reference, without the proliferation of documents from different eras and with different logics.

Recently, an evaluation of the implementation of EL was carried out [4] through a questionnaire to teachers at national level, interviews with teachers, parents, and students and also the analysis of curriculum planning. This study concluded that most of the surveyed teachers consider that the EL are better adapted to the needs of the students than the previous curriculum documents, allowing greater flexibility in the management of the curriculum, namely in processes of pedagogical differentiation. However, some teachers consider that the language used in the EL creates difficulties, reducing its use. Most teachers still evidence difficulties, namely "in recognizing the contribution of each subject to achieve the SP, in identifying knowledge, skills and attitudes that must be developed by all students, in understanding the suggested examples of strategic teaching actions" [4, p.11].

B. *Participatory design of a useful tool*

This research uses techniques of the participatory design method to design a useful tool, with a friendly user interface to support teachers in curriculum vertical and horizontal articulation, through the query of a database of EL. Participatory design (PD) is the design of computer-based products with final users as full participants [11].

The quality of the design of computer-based products is related to the utility and usability of such products. In other words, a computer-based system/product is useful when it shows usability and utility.

Utility is related to the functionality of the system/product, to whether the system/product performs the functions you need. According to [12], utility refers to whether the system provides the features needed by the user.

Furthermore, usability is related to easiness of the use of a system/product by the user and to how pleasurable that use is. Reference [12] defines usability relating it to how easy and pleasant is the user experience, making explicit five quality components of usability: Learnability; Efficiency; Memorability; Error minimization; and Satisfaction.

In this way, this research aims at developing a high-fidelity prototype of a tool to support teachers in the interactive search and query of EL, assuring its usefulness, through the investment in its utility and usability.

III. METHODOLOGY

The double diamond model [13] was used to guide the participatory design process. This model divides the design thinking process into 4 stages: discovery, where problems are explored, user needs gathered and ideas generated (divergent thinking); definition, where problems are defined and refined (convergent thinking); development, where solutions are created and explored (divergent thinking); and delivery, where the solution is tested and evaluated (convergent thinking). The first divergence-convergence process aims at designing the right thing, while the second aims at designing the thing right. The study presented in this paper is focused on the first three phases.

C. *Discovery Phase*

During the first phase, and to get insight in the (future) teachers' perceptions and needs, different research methods were used. We conducted a task analysis (TA) with 27 students enrolled in the last year of the Bachelor in Basic Education and with 7 future teachers enrolled in the last year of a 2-year master's program in a Portuguese School of Education (4 in the master in Teaching the 1st Cycle of Basic Education and Mathematics and Natural Sciences in the 2nd Cycle of Basic Education, and 3 in the Master in Teaching the 1st Cycle of Basic Education and Portuguese Language and Portuguese History and Geography in the 2nd Cycle of Basic Education). In the task analysis future students were asked to perform different types of curriculum articulation and, to do that, they had to search in the EL documents with different goals. Students were also asked to think aloud, while performing the curriculum articulation. Thinking aloud is a method that elicits verbal reports of thinking and can be combined with other qualitative methods [14].

We also conducted focus groups (FG) with 17 teachers and with 7 future teachers. Of the 17 teachers, 1 is a special education teacher, 8 teach in the 1st Cycle of Basic Education (CBE) and 8 in the 2nd CBE (5 taught Mathematics and Natural Sciences and 2 Portuguese and History and Geography). The aim of the focus group sessions was to gather data about: (1) how participants evaluate the actual page where EL are made available, (2) which functions they believe would help them to increase vertical and horizontal curriculum articulation.

D. *Second phase*

During the second phase, the data from the task analysis and focus group were transcribed and analyzed using a general inductive analysis [15]. Based on research, and through problem definition methods, the problem was redefined. Moreover, 6 students (3 man and 3 women) enrolled in the first year of the bachelor's in visual arts and Technology, also analyzed data collected during the first phase and developed personas.

E. *Third phase*

During the third phase and for the creation and exploration of solutions, in a quick and inexpensive way, we used sketches to co-design, in a free and divergent way. Sketches are used in initial "early divergent stages of the design process" [16]. Sketches are not technically prototypes, but they are very

important in creating and exploring multiple initial ideas, since they are fast to create, cheap and disposable [16].

First, a medium technology prototype [11], built in Excel by the authors, was used with the pre-service teachers, enrolled in the last year of the Bachelor in Basic Education, to test the database functionalities (queries), making explicit the possible involved variables in common didactic planning tasks. After a familiarization with the data and variables future teachers were asked to sketch the initial menus of the tool to query EL.

IV. RESULTS

F. *Discovery phase*

A.1.Task Analysis

When faced with the need to solve tasks that involved consulting the EL, the participants adopted different strategies.

The first difference concerns the way in which they accessed the EL: some groups consulted the EL stored on their own computer while others googled the expression "essential learning" and opened the page of the Directorate-General for Education (Direção-Geral da Educação) of the Portuguese Ministry of Education.

The existence, on the personal computer, of a folder with the EL for the different years of education levels is, according to one participant, a consequence of the need to access the EL, even in the absence of internet access.

The second difference is related to the strategy used to search inside the documents. Four groups, all comprising undergraduate students, proceeded to read the entire content of the EL. The other four groups (2 bachelor's groups and 2 Master's groups) searched for a word or an expression, using the find tool in the PDF. As for the words/expressions used, different attempts were made, depending on the answers obtained. For example, in a task that aimed to verify if in grade 4 students should learn the circle area, the following steps were carried out: i) using the PDF Find tool, the student wrote the expression "circle area"; ii) as there were no results, she searched again, but only for the word "area"; iii) in face of several results («circles of fractions»; «blocks of circles of fractions»), the student mentioned that it was necessary to «distinguish circle from circumference» and wrote «circumference» in the Find tool of the PDF.

During the task analysis, students made different comments that denote not only the relevance and frequency of this type of task, but also the low efficiency associated with the chosen strategy:

P3- Yes… Trial and error.

P2- And this happens often. We want to find a content and we must open all the 1st Cycle EL to find out in which year that content is in. We have an idea, for example «in the 3rd or 4th», but we must open both documents to compare (Master students, TA1)

A.2.Focus Group

During the focus groups participants pointed positive and negative aspects to the way EL are made available. It is also important to mention that some teachers revealed that they had never reflected on how the EL are organized and made available: "I never thought about whether this could have another organization" (P2, FG6); "That's what I was going to say, I had never thought about it" (P4, FG4).

A.2.1. Positive aspects

Most participants indicated that it is very easy to access the portal of the Directorate-General for Education, where the EL are available. According to one future teacher: "I immediately search on the Internet for «essential learning in the first cycle» and this table immediately appears. I think it's easy, in my opinion. (E1, Master student, FG1) (Fig.1).

The positive assessment regarding the accessibility of the webpage is the reason why one teacher, that initially choose to print the EL, change her practice:

> When they came out in this format, I printed them (…) I worked a lot on paper, but after that I began to realize that it took a lot of time (…) So I started to consult more here [on the site]. (...) It is accessible, it is something that is accessible, at any time, by anyone, at any time. (P3, FG7).

The fact that the documents can be downloaded very easily is also another positive aspect. As one teacher says: "From the point of view of downloading the PDFs and storing them on our computers, it is good" (P2, FG5).

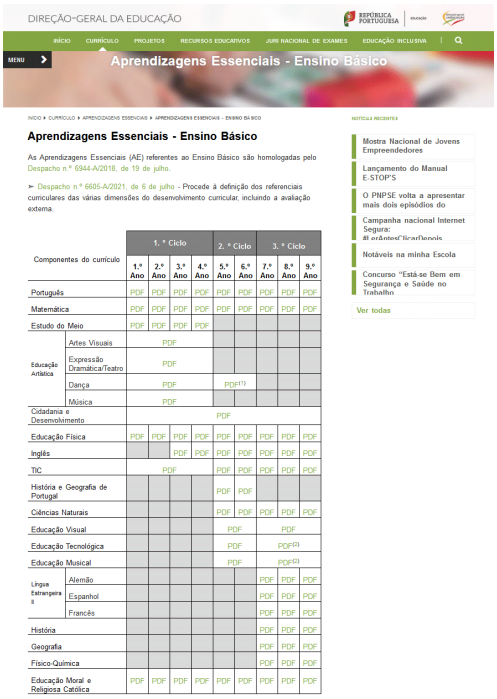

Fig. 1. Webpage of Directorate-General for Education with the EL.

The existence of a double-entry table, crossing the year and the curriculum component, was valued by some participants, as it allows the user to have a holistic view of the curriculum. This appreciation was more audible among future teachers than among teachers, which may be a consequence of the different levels of knowledge that these participants have about the curriculum and its organization.

P2- And I think this [webpage] is super functional. You see the year; you see the discipline, and everything is there (P2, master student, FG1)

Yes, yes. I also think so. I think it has a very clean and very objective vision and even for those who are starting to use

this document, we can immediately understand that the Environmental Studies only exists in the 1st Cycle and does not continue (P3, master student, FG2)

A.2.2. Negative aspects

In all focus groups, criticisms emerged. However, in some cases, these evaluations only appeared after specific questions about the impact of the site's organization on the vertical and horizontal articulation.

Some teachers highlighted, as a less positive aspect, the graphical component. For example, for a teacher "This page is very uncomfortable. Graphically, it's horrible. It makes no sense" (P2, FG5). Future teachers also highlighted this aspect; yet they didn't value it too much:

P3- It's not pretty, but it doesn't have to be.

P1- But it doesn't have to be, exactly.

P2- It must be functional.

P3- Yes, it must be functional, it must be practical. (FG1)

The way information is fragmented, having one document per year and per subject, was a criticism made by many participants, especially by teachers. The difference between having access to and being able to navigate and compare is quite evident in the following excerpt:

P2: This page does not help us at all, neither within the discipline itself nor within the cycle.

P1: That is, it gives us access to the document, but in terms of exploration we must explore it alone and understand, interpret. (FG6)

One teacher even established a causal relationship between the experienced articulation difficulties and the way the page is organized. According to her: "perhaps our difficulty came from that page since everything is so divided. Things are not integrated" (P2, FG6).

A.2.3. User needs and suggestions

Following some criticisms, the participants began to identify needs that were not fulfilled with the current interface, and that will imply greater interactivity.

The need to establish and visualize curricular articulations, both vertically and horizontally, was one of the most mentioned. Nevertheless, reflections were different according to each type of articulation.

The vertical articulation was more discussed among teachers than among future teachers. This analysis is closely associated with knowing that curriculum follows a spiral pattern, which encourages reinforcement of previously learned concepts, and the conviction that having roadmaps illustrating those progressions would support instructional planning. As one teacher says, to ensure deep learning, it is not sufficient to know only the curriculum being taught in her grade; there is a need to understand what the students learned before, and what they will need learn after:

I would like to get a sense of what the students worked on in previous years. And if it's a spiral, I think it's important to understand what was worked in the 1st, 2nd, 3rd and 4th grade. And I felt this need this year, in the 5th grade, to look back, for example, to what they had been working on, regarding statistical knowledge and rational numbers. (P3, FG4)

Not only do the teachers verbalize this need, but they also recognize the need for resources with these roadmaps, because the preparation of these progressions by teachers is difficult and time-consuming:

In one of the sessions of the in-service training of the Mathematics EL, the trainer asked us to make a roadmap regarding the decimals, fractions, and percentages, from the 1st to the 9th year. And it was very difficult (...) a terrible difficulty (...) This vertical analysis would really make perfect sense here (P2, FG4)

To operationalize the visualization of the vertical articulation, different hypotheses emerged. Some teachers mentioned the possibility of doing it based on the domains/organizers: "putting on the same grid, for example, in terms of Portuguese, «orality», «oral production», «oral comprehension», and putting the four years side by side (...) it would be easier to read" (P2, GF7). Other teachers and future teachers considered that it would be important to see how the contents/concepts evolved over the years.

As for the graphical solution, the construction of comparative tables was the most invoked suggestion. The suggestions both seem to refer to static tables, which could be consulted according to an existing list, but also to interactive tables, made as a result of requests made by the user ("For example, we could search for a concept and understand the progression it has over the years").

Although the table was the more invoked format, one teacher highlights the importance of having different graphical solutions (like a frieze, a spiral) and the possibility to choose the one each teacher prefers, because "we teachers, we are not all the same" (P4, FG4).

Other articulations were also discussed. For example, for some teachers it would be nice to improve the connection between the SP and the EL. According to one participant: "Clicking on a button for this competence, «interpersonal relationship», it would appear, the EL that develops this competence, so that the teacher can better focus or prepare the work throughout the year. (P13MCNCI).

In order to provide greater interactivity, the participants mentioned different functionalities, such as a search box, filters (for year, area, cycle) and hyperlinks. The search box was mentioned by both teachers and future teachers.

P1- you write a keyword, and it will open a series of pages that contain that keyword (...) I put «astrology», hit Enter, and it said astrology detected on the following pages: 1st Cycle, EL of grade 2, for example. And we easily went and found the document.

The hyperlinks were mentioned as a possible solution to the need to explain some concepts and ideas in more detail: "there is a word that is underlined (...) that take us to other documents, or even in the document itself leads us to another explanation that is further down, or elsewhere in the document" (P3, FG1). According to a teacher, it is astonishing

"how today, being so easy to build interactive internet pages, how is it possible that the EL is not presented with links, with "linked" words (P2, FG6).

G. Definition

Data collected through task analysis and focus groups, during the discovery phase, helped us build a clear picture of the problem. First, we found confirmation that (future) teachers often face challenges while searching the EL. Second, we found evidence that the webpage where the EL are made available is at least, in part, responsible for those challenges.

Based on research, the problem was redefined. Teachers need to visualize learning progressions and the articulations between subjects to be able to promote more meaningful learning, but EL are organized by year/cycle and by subject and searching EL this way is difficult and time-consuming.

Moreover, the following "how might we" questions were formulated: how might we make the process of searching EL easier, so teachers can see connections between subjects? How might we make learning progressions evident, so that teachers feel more confident in their teaching choices?

The information collected also helped to create personas. These personas were created during one course of the bachelor's in visual arts and Technology - user-centered design course. Three subgroups of users were created, expressing the needs, desires, and behaviors of specific groups: one pre-service teacher, more concern with searching the EL for academic tasks, especially to easily find the main contents for each year in each subject and to select possible topics for curricular projects; one in-service primary teacher, responsible for teaching all subjects, more concern with searching EL from different years, in an easy and rapid way, mainly because she has a mixed-grade class; one in-service teacher, teaching Natural Science in grade 5 and 6, more concerned with integration of curricular contents from different subjects within grade 5 and grade 6 and also with what students are supposed to learn in Science during the 1st Cycle to improve teaching coherence.

H. Development

The pre-service teachers, in the last year of the Bachelor in Basic Education, and who were familiarized, through the Excel medium technology prototype, with variables related to common didactic planning tasks, were asked to sketch the initial menus of the tool to query EL. The obtained sketches were diverse, with different numbers of search variables, types of menus (drop-down or fixed menus, top or side bar menus, all-screen menus…), and types of results (goals, activities, resources…). Nevertheless, in all the sketches, the designed interface was easy to use (simple menus), clean (sufficient space, consistent elements, and visual language), and had a set of common variables (Fig. 2).

Global interface metaphors were created in two of the sketches. One sketch used an EL train metaphor, in which the menus were integrated in the carriages, and another one used a living room metaphor, in which the menus were integrated in paintings, thematic books, bibelots, and storage boxes (Fig. 3).

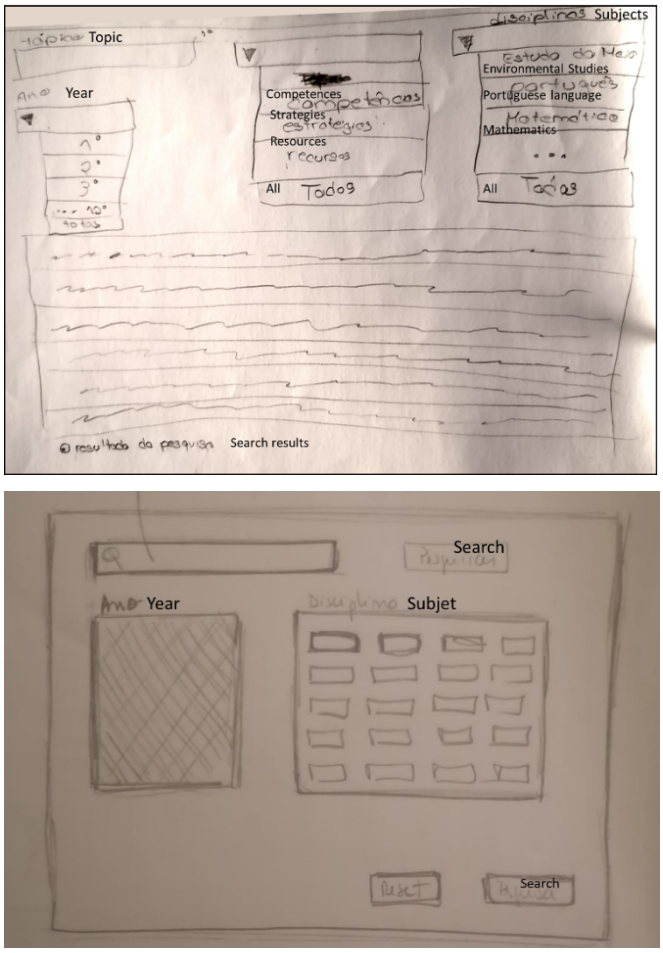

Fig. 2. Examples of sketches with a search box and different filters.

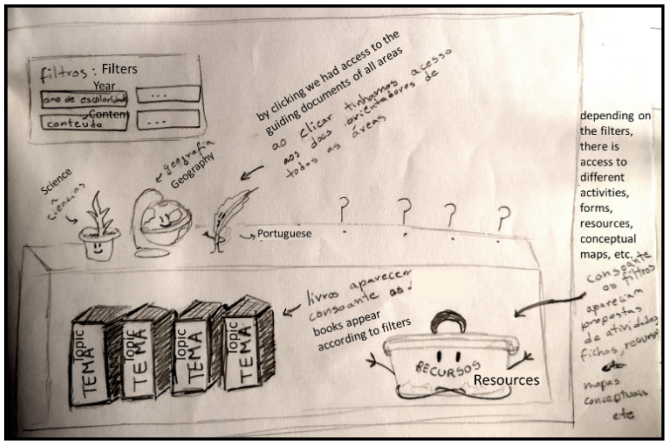

Fig. 3. Example of a sketch, using a global and specific metaphors.

The developed sketches supported the definition of a sketch of the high-fidelity prototype's interface (fig. 4). The most frequent variables in the sketches were selected and the layout was designed to allow different levels of research.

In the high-fidelity prototype's interface, the user should start by selecting the year(s)/level(s) of scholarity. Following this first selection, the correspondent subjects are presented to be selected by the user. The correspondent Domains are, then, presented, and can also be selected by the user.

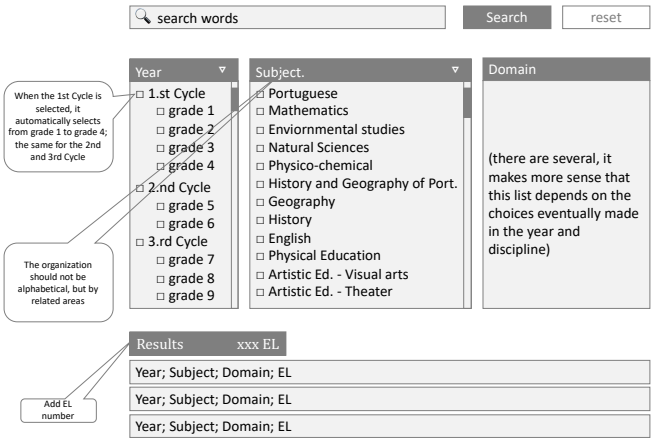

Fig. 4. High-fidelity prototype's interface.

V. CONCLUSION

The study presented in this paper designed a high-fidelity prototype of a tool (EL tool), to support pre-service and in-service teachers during curriculum vertical and horizontal articulation, making possible the querying of an EL database. The high-fidelity prototype is being implemented.

The "AEMaps Project" made use of a set of techniques of Participatory Design, from sketches to task analysis, and to a medium fidelity prototype, to validate the team ideas, learn stories with the users, co-construct artifacts, and test the implementation of selected functionalities.

The set of focus groups developed with pre-service and in-service teachers allowed stories-collecting to inform the future tool/prototype functionalities, through the contribution to the knowledge and understanding of product utility (Muller & Druin, 2012). These results informed the creation of the Excel medium-fidelity EL prototype.

Besides, the task analysis, performed using the thinking aloud method, also contributed to validating the Excel medium-fidelity EL prototype, which made explicit the variables, and their relations, needed in planning curricular activities.

To co-design of the interface of the high-fidelity EL prototype included the production of sketches by future users. Those sketches were created after the familiarization with the Excel medium-fidelity EL prototype variables. This way, regarding usability, the created sketches validated some of the previous ideas of the research team and elicit new ideas to the design of the high-fidelity prototype interface.

The Excel medium-fidelity EL prototype, together with the designed interface of the high-fidelity EL prototype, are the basis of the ongoing implementation of this final prototype, which will be tested in the near future. The final prototype will be assessed through qualitative in-person usability testing with pre-service and in-service teachers. The main idea is to collect data about how participants use the interface while performing specific tasks and listen for feedback.

Concluding, the participatory design described in this document was developed successfully, not only in what concerns the goal of designing a high-fidelity EL prototype, but also in the involvement and engagement of participant future users in their own learning contexts.

ACKNOWLEDGMENT

This work was supported by the Instituto Politécnico de Lisboa [IPL/2022/AE.Maps_ESELx].

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