CatalogToMakers: a collaborative cataloging platform for electronic components and physical computing projects related to musical creativity

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Abstract. *The Maker Movement is a growing reality in the new industry and academic community. It consists of the Do-It-Yourself (DIY) style-spreading proposal, emphasizing the creation and development of creative thinking. In this context, the democratization of the Internet has meant that non-expert users are capable of developing new hardware technologies. In the music context, the easy access to low-cost equipment and the large number of people sharing knowledge facilitate prototyping and extend the creation of digital musical instruments. However, the places where the information related to the components used in these projects are not centralized nor organized. Therefore, it makes access to this information difficult, slowing down and hindering the flow of creative development. Thus, to reduce this development time and facilitate access to this information, this paper describes the processes for designing the CatalogToMakers tool, a collaborative cataloging platform for electronic components, and physical computing projects focusing on musical creativity. This approach implements several essential functions to facilitate the conception process of hardware development. Finally, an evaluation focused on non-expert users showed promising results.*

1. Introduction

Although it is an ancient activity, cataloging is commonly used today in different areas of knowledge. It aims to carry out two main tasks: the organization of information relating to a specific domain and providing and guaranteeing access to that information [1].

This method has been renewed continuously, especially after the advent of the Internet. The evolution of the web ended up making information increasingly accessible to a large part of the population. However, this constant and rapid dissemination of information ended up causing problems concerning the organization and retrieval of this information, making it difficult for the user to find the desired content of the more efficient way [2].

In order to support this, Information Retrieval (IR) appears as a procedure that searches for information in a specific document based on a set or collection. Currently, this information base can be understood as a repository or digital database [3]. In computing, those responsible for retrieving and displaying this information are the Information Retrieval Systems (SRI), which perform the same process as IR, but in the digital environment, [2].

Given the diverse multidisciplinary areas in which SRIs operate, physical computing also becomes one of them. Physical computing is the process of transforming physical environments and objects through information processing using microcontrollers, actuators, and sensors [4], requiring in some cases the use of other components to support them, such as shields and batteries. Through the design and development of several instruments focused on new ways of sound expression and musical interaction [5].

In this context, the Maker Movement is currently a growing reality in the new industry and the academic community. It consists of the proposal to disseminate the Do-It-Yourself (DIY) approach, emphasizing the creation and development of creative thinking through physical computing and the development of new digital musical instruments [6].

Therefore, we hypothesize that obtaining information can be enhanced. This work aims to propose significant improvements in information retrieval systems related to electronic components and physical computing projects. Our approach is to design a collaborative cataloging tool.

2. Contextualization

The Maker Movement has been gaining proportion through the influence of teachers and enthusiasts who, by inserting the movement's proposal in traditional environments, encourage the creation and evolution of people's critical thinking. This concept is sufficiently disseminated in countries such as the United States and has increased interest in Brazil. In this new wave, the Fab Labs (Fabrication Laboratories) have been providing new aspirations, and philosophies for creating local ideas, managed by a global network based on this movement [7].

In this context, according to [8], Physical Computing is about the union of computing with electronics in the process of creating prototypes of physical objects through the use of microcontrollers, sensors, and actuators, allowing their interaction with human beings, having as main objective the connection of the physical and virtual worlds. In this way, ways of relating the use of computing in the interaction with other technologies are created, thus encouraging the development of solutions that can be used

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in everyday life [8]. An area with the direct influence of physical computing is computer music, through the prototyping and development of new digital musical instruments and many other ways of music interaction and expression using sensors, actuators, microcontrollers, and many others types of electronic components [5].

Technological development with a focus on the process of organizing, searching, and retrieving information begins to gain importance in this environment because of the various difficulties in obtaining relevant information in the face of such large and unstructured spaces on the web [9]. In the context of prototyping in physical computing and computer music, authors [10] reports that there is a deficit in an environment with centralized information regarding the components used in designing new objects of innovation. These factors increase efforts and costs that could be reduced in a more organized scenario, with more specific functions and focused on users' primary needs [10].

In an attempt to assist in this process, some initiatives in the industry (Mouser.com, Filipeflop.com, Adafruit.com, Seedstudio.io, Labdegaragem.com, and Eletrogate, for example) and in the academy (such as Sci-fi Gesture Catalog and Sensor Wiki)[11][12] try to bring solutions that can help the creative process and improve access to information. However, it is possible to identify some gaps concerning usability, performance, and availability of information that, if filled, can bring good results about the learning of the target audience of these initiatives and the process of investigation and information retrieval of components and projects related to physical computing.

3. Development process

The design techniques used for the development of this project were based on the Design Thinking, developed by [13]. This method explores human-centered design. That is, it first explores the user's needs and then creates the product design. The phases of this process are divided into "inspiration," "implementation," and "evaluation".

These steps can be performed more than once in a circular fashion until a more solid and well-defined result is obtained. After developing these three steps, Design Thinking is structured within three crossed restrictions, they are:

- **Possibility:** it is directly related to what can be done;
- **Viability:** what can be practiced with the success of the project, and;
- **Desirability:** what the public wants or wants to see from the project.

Working based on these constraints, the designer begins to focus his efforts on highlighted problems and a structured project. This project is already started based on the specific problem and its probable solutions, using the identified objectives to solve them, based on the focus on the user.

For this work, the inspiration phase was carried out through the collection of pieces of information derived from the personal experiences of designers. The designers are part of the research group [blind review], in which several projects focused on Interaction Design have been developed, with the main focus on digital musical instruments. In the design stage, what was identified in the inspiration phase became solutions so that, in future phases, they could be improved. In this context, the methodology used was the same as that performed by [4] (Figure 1), where the author adapts the process proposed by Resnick [14], called Creative Thinking Spiral, which makes analogies to the children's learning flow in kindergarten, showing that they learn from the repetition of a cycle of activities.

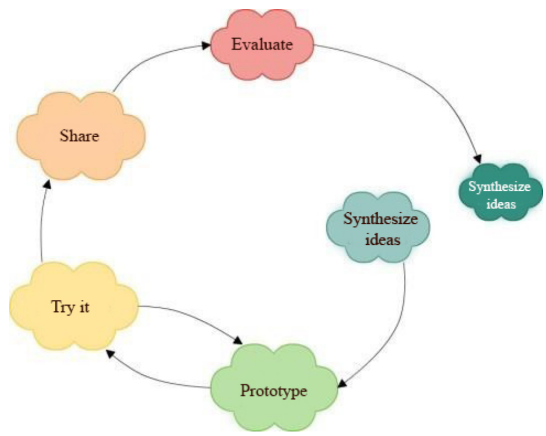

Figure 1: Spiral iterative process for the design phase

According to [4], using the spiral flow, the design stage developed for this approach is performed at least twice during the process, making it possible to improve the developed ideas. Thus, the main steps are described below:

- **Synthesize the ideas:** stage of organization of the collected data and summary of the key ideas;
- **Create prototypes:** step to create non-functional prototypes;
- **Try it:** stage where the low-fidelity prototype is executed with cycles for refinement;
- **Share:** test stage of the prototype with potential users;
- **Evaluate:** stage where the user's information is registered and the prototype is evaluated, if necessary, to start another phase of synthesis of ideas.

This entire process was developed based on the Maker audience, enthusiasts, and experts in physical and computer music, interaction design, and the development of connected objects using IoT.

Thus, after analyzing the methods and tools found in the literature, the ideas for the initial prototypes design phase were based on the most widespread methods of organizing and visualizing information in the last five years. This made it possible to build prototypes based on standards that were already widespread in academia and industry, focusing away from potential user's feedback on technical issues and bringing them more into the functional modes of the platform. The first low-fidelity prototype was developed in the form of a drawing using storyboards (Figure 2). The screens were designed according to their sequence of execution, with each frame representative of the screen having a brief description of its functionalities.

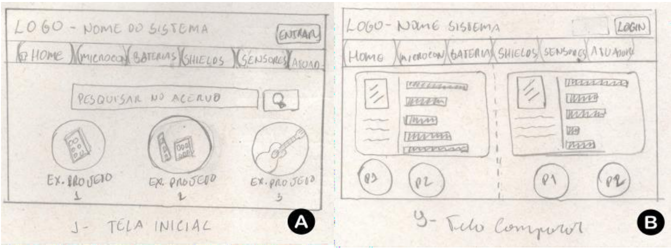

Figure 2: Example of screens from prototype 1 (A - Initial screen, B - Comparison screen between components).

Four potential users evaluated this first version, all experts in the field of computing or interaction design. Among these evaluations, questions were raised regarding new features and changes in the visual structure of some screens of the prototype. In this context, the information obtained was structured and synthesized to be inserted in the next version of the prototype.

After the ideation stage of the first prototype, the screens of version two were built, already enabling online access and navigation and identification of the flow between the screens. Figure 3 shows some of the screens created for the second prototype.

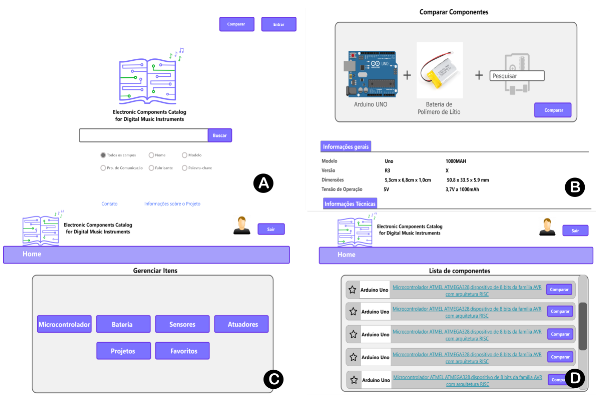

Figure 3: Some screens of prototype 2 (A - Initial screen, B - Comparison screen, C - Component management screen, D- Favorite screen)

The evaluation of the second prototype was carried out with a greater series of steps and with a more significant number of people (14). This time, two different profiles of evaluators were used, the specialists (also used in prototype 1) and potential technical users of the platform. The specialists work in computer science or interaction design, but who are not necessarily potential users, analyzing more the technical and visual part of the platform. On the other hand, the potential technical users are classified here as the people who continually use and need information regarding electronic components and or related projects. Because they have this daily contact, they better understand the needs that a project of this type could supply.

Figure 4 demonstrates how the steps were carried out to evaluate this second prototype to understand better how this interaction with all the evaluators was carried out.

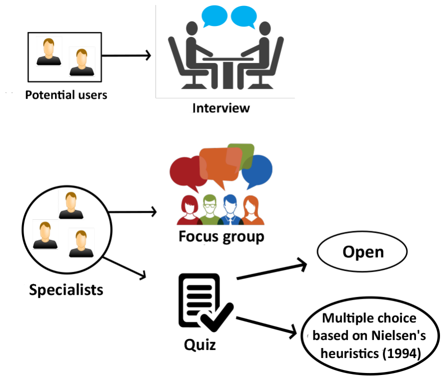

Figure 4: Mockup evaluation process (prototype 2)

The first assessment was made through a questionnaire applied to specialists, divided into multiple-choice questions, and an open field for recording possible suggestions for improvement. The multiple-choice questions were about usability and how information visualization happens on the platform, all of which were based on the Heuristics defined by [15], one of the best accepted and propagated heuristic evaluation methodologies in the literature for evaluating Human-Computer interaction.

4. CatalogToMakers

Based on the principles found in this study, mainly those that touch the methods used in the cataloging and organization of the information found through Literature Review, the CatalogToMakers was developed. The system appears as a tool to streamline the process of creating physical computing projects, whether related to musical computing, connected cities, smart homes, or similar, providing a collaborative cataloging tool, where the user can have centralized access to information in different ways, taking advantage of different features.

The platform allows the user to search, register, modify and delete components and compare components of the same category to understand more about which could be more suitable for a particular need. In addition, each component has related projects, with which the user can better understand the first steps of use, seeing in practice experiences developed by other designers. These related projects can also be registered by the tool's users, making possible a greater exchange of experiences among its users.

The great advantage of the tool concerning those already existing in the academy and the market is precisely the combination of several different functions. Each project can be evaluated and receive comments on its general context. Working together allows a better user experience on a single platform.

Because it is a catalog, retrieving information must be quick and easy. For this, the user has three text search modes and a visual search mode. The textual search is done by item name, project name, and keyword, the latter being used for both projects and items. The keyword search field becomes important because it is the user who defines them (based on the principles related to Folksnomy), so the search can be done using non-technical terms registered by users, making it easier to find the item or desired project.

On the other hand, the visual search part is made through demonstrative icons of each category, that is, microcontrollers, sensors, shields, actuators, batteries, and projects. All of them will have a quick access button on the home screen, which means that even if the user does not know exactly what he wants to search for, he has access to the catalog items in general, exploring each item by the desired category. Figure 5 represents the flow of user interaction with the platform's search function. Potential users range from novice maker to the most technical and experienced.

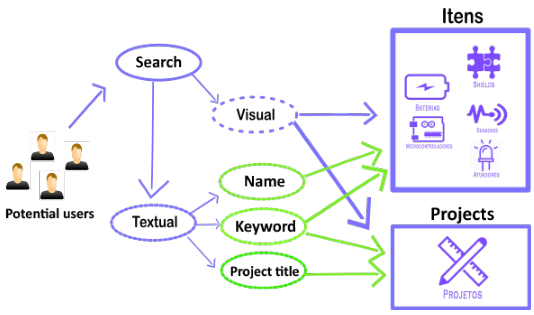

Figure 5: User interaction with the search function

These searches return a list with all the items or projects containing the text of their title or keywords, some sequence related to the characters typed. The initial screen of the application is shown in Figure 6.

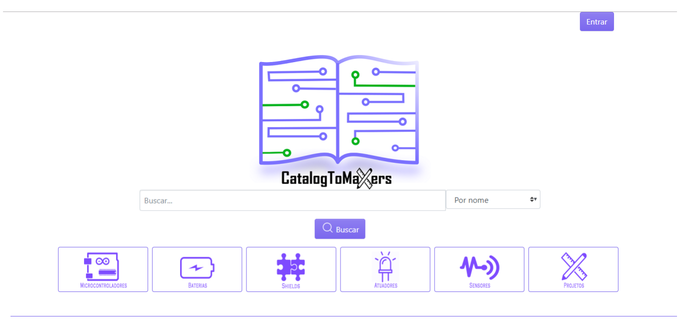

Figure 6: Platform initial screen

The display of items related to visual search is done in card format, where each item or project appears with the highlight of its characteristic image and a brief description of its functions, in addition to a button that links to the page related to it, Figure 7 shows an example of the listing of some items in the "Shields" category.

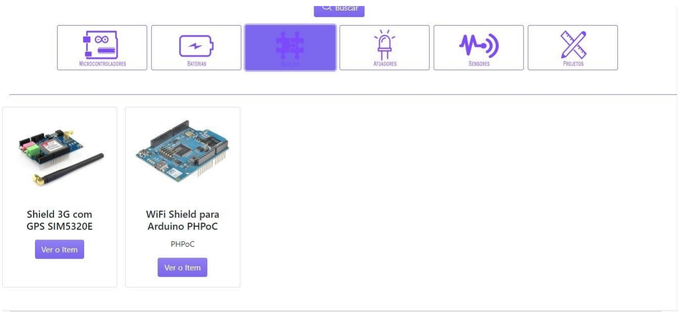

Figure 7: List of shields in the visual search

The result of the textual search is redirected to another page, where the components and projects are displayed in a list format. Each listed component has a favorites button (if the user wants to store that component in a list of his favorite items), a button with the link to view the component's information, containing its name, its average price and keywords referring to it, and another to perform a possible comparison with a component of its same category.

Figure 8 shows the component list screen after searching for the term "Arduino" in the search field name. This screen also has a quick search bar and a Home button, which takes the user to the home screen. Some buttons are displayed differently for users logged in to the system and for users not logged in at this point, and several others. Unregistered users do not have access to the favorites area or the item management screen.

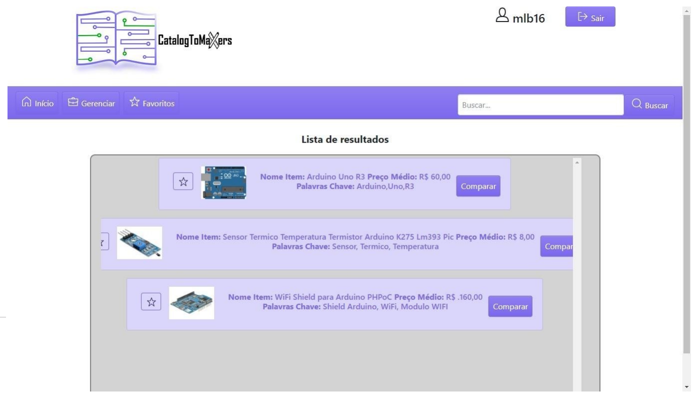

Figure 8: List of text search components

As seen above, one of the buttons that accompany the items is that of "compare." It is useful when the user wants to understand more about the technical possibilities of each component so that he can solve a specific problem, such as understanding which component consumes less battery or which wireless technology of a particular component is more suitable for some project.

In summary, the main functions of the application involve research of components and projects already registered (both in textual and visual pruning), comparison between components of the same category, management of components and projects, favorite function, and a field for comments and evaluations of the users of the application for each project.

The entire development of the platform was based on the principles of Information Retrieval and the best cataloging practices currently reported in the literature, such as Folksonomy, Information Visualization (VI) principles, and some indexing methods. Regarding the implementation, technologies such as PHP5, CSS3, HTML5, Bootstrap 4, JavaScript, Ajax, and MySql were used as a database. All of this, structured in an MVC design pattern.

5. Implementation

The structure used in developing the final prototype for this project was based on the principles of Information Retrieval (IR) to provide the user with quick access to the catalog content. According to [2], IR is directly linked to the forms of representation, storage, search, and retrieval of information in information systems. This process mainly provides better communication between the user and what is indexed in the application.

Several versions of diagrams explore the information retrieval process, each one being developed based on the type of need for informational representation. Silva [2] demonstrates one of these diagram models (Figure 9) developed based on several studies of information representation models already carried out in the literature.

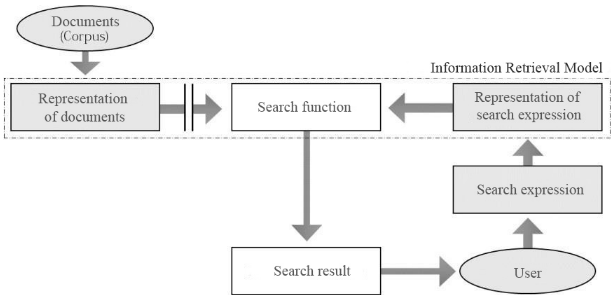

Figure 9: Representation of the information retrieval process

The CatalogToMakers was implemented to provide the best possible assistance to these steps used in the retrieval of information. That is why the phase of creating and evaluating low-fidelity prototypes was so important, serving to create a final prototype that was planned and focused on the user's needs.

As the system is a collaborative platform, that is, several people can insert and edit the catalog information as well as in a Wiki. The users also become catalog indexers since they will perform the process of representing the catalog document using its own terms. The platform also allows the insertion of Tags (keywords) to facilitate the information retrieval process further. Figure 10 demonstrates in a simplified way how the user indexes the information process, as well as how he has access to information from the catalog components.

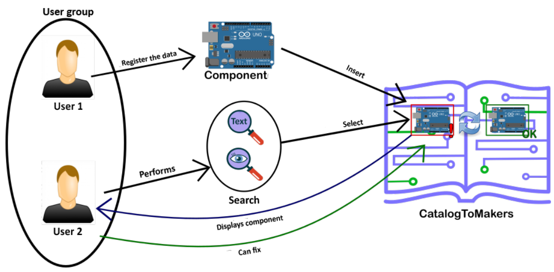

Figure 10: Catalog information retrieval and indexing process

In this example, user 1 performs the registration of information related to a specific component, where he himself chooses which terms best identify the element being registered. However, in this situation, one or more information is being registered incorrectly, going unnoticed by the indexing user who registered it. Then, user 2 performs a search for the same component and, through the search result, checks for incorrect information. At this point, the user edits the incorrect information and leaves the catalog updated again, and this modification can also be done to add new terms to the component, expanding the expressiveness of the element's representation.

6. Data Collection and Evaluation

The evaluation phase of the tool was divided into two stages. In the first, a face-to-face comparative analysis took place, and in the second, a usability analysis was carried out with a set of different potential users of the platform. In summary, this process was partitioned as follows:

- **Face-to-face comparative analysis:** in this process, the evaluators were invited to perform a series of tasks using the CatalogToMakers tool and Filipeflop e-commerce. The objective of this step was to analyze the user's reactions and the information retrieval process, as well as the time they were able to perform the tasks using both systems.
- **Usability analysis:** in this step, users were asked to use the platform (CatalogToMakers only) in an exploratory way, without a specific script, only with suggestions of where they could start. After that, the System Usability Scale [16] and an open questionnaire were applied to understand how the interactive process between the system and the end-user is being established.

6.1. Face-to-face comparative analysis

This stage of the analysis had the participation of 11 users, with the objective of understanding and comparing in practice the process of retrieving information from the CatalogToMakers tool and the Filipeflop website. It was done by executing a series of 10 Activities (5 the same for each system) by a group of users with different profiles and experiences, where each of these activities aimed to explore different functions in common to both systems.

All evaluations were filmed with the consent of the evaluators, with a view to identifying the time that each performed the activities on the platforms and trying to find moments of difficulties and inconsistencies in the execution of tasks for operational or even visual reasons. In this context, participants should say whether or not they were able to perform a certain task within the flow of each application. At the end of the activities of both systems, the evaluators recorded their reports and suggestions regarding the experience they had with the platforms.

In carrying out all activities, CatalogToMakers demonstrated greater efficiency in the information retrieval process in relation to the Filipeflop site, being successfully executed by a more significant number of evaluators in all proposed tasks. The general list of the number of activities performed by the evaluators on each platform is seen in the graph in Figure 11.

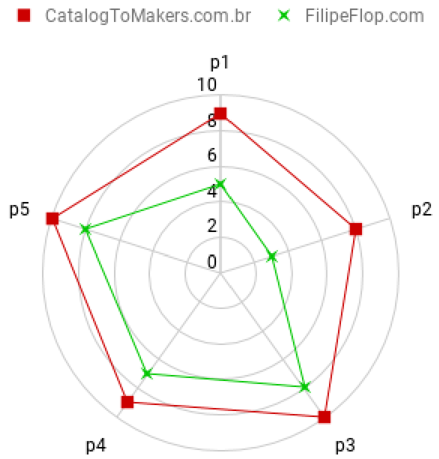

Figure 11: List of number of steps (P) performed by the evaluators for each platform

In addition, to analyze the agility in the access to information and the usability of the tools by the users, the time taken by each one to perform the five tasks proposed by the study on each platform was mapped. CatalogToMakers had its activities carried out in less time in 6 evaluations than 5 of the Filipeflop site. The relation of the time used by each participant in the execution of the tasks is shown below in Figure 12, where the evaluators were listed from A1 to A11 to better represent them.

For a better understanding of the difference between the times taken to perform the tasks in each application, a general average was also made between the times of all evaluators. In this survey, the differences in the execution period taken by the evaluators during their interactions with each application are more evident. This difference is reported in the graph in Figure 13.

The time that users take to perform the activities is directly linked to the information retrieval process. The sooner the user has the desired information, the more satisfied he will be. Applying it to creating a prototype, for example, ends up reducing the effort to find specific components for the project. It is also understood that this process can be improved, as there are still some inconsisten-

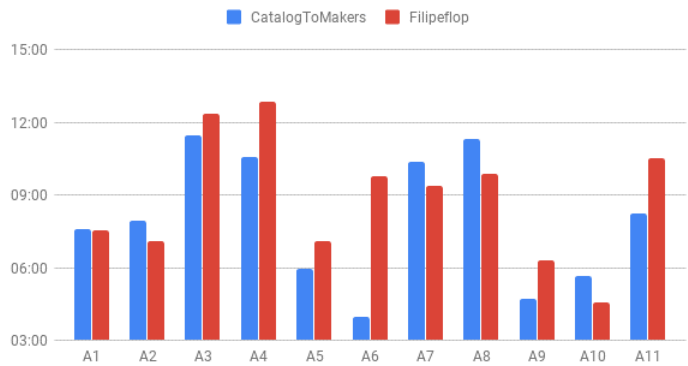

Figure 12: Time of execution of activities by each evaluator (A) on the CatalogToMakers and FilipeFlop platforms (Source: own author)

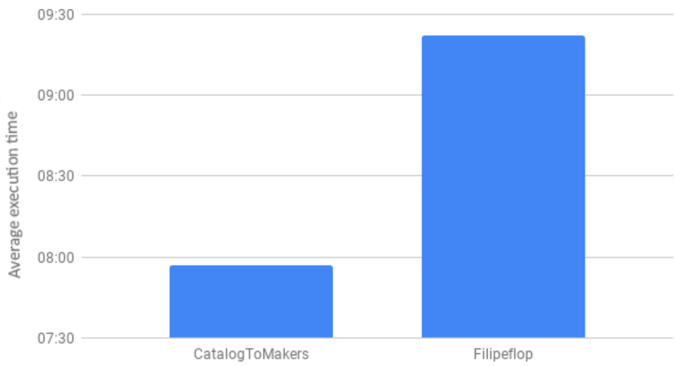

Figure 13: Average time of activities performed by the evaluators for the two applications

cies in the application that have been identified and can be improved in future iterations, further improving the time used to obtain this information.

7. Usability analysis

This stage of the evaluation process had the participation of 21 users, with the main objective of identifying information regarding the tool's usability process, as well as identifying opinions regarding the information retrieval process. The recruited users received instructions on how they could use the tool, and after exploration they were asked to answer a questionnaire, which was divided into three parts: User profile, System Usability Scale (SUS) [16] and Opinion survey, where the latter was divided into 5 open questions, which sought suggestions regarding the context of use of the tool, similar projects, profile of future users and negative and positive points of the same.

For this phase of the evaluation, 21 participants of different profiles were recruited, all Brazilian and with varying levels of knowledge. The affiliations were quite different, with components of graduate and undergraduate courses from different universities and technology institutes in the state of Pernambuco, where they are listed from P1 to P21 for a better organization of citations. Regarding the level of instruction of users on physical computing, the group remained well balanced, with similar percentages for each point, with the exception of level 1 (on a scale of 1 to 5) that had no members. Thus, 19% of the answers were from users who considered themselves with little knowledge about physical computing, choosing option number 2. Users with moderate knowledge, marked option 3, which corresponded to 28.6% of the total evaluators. Also with 28.6%, it was the users who considered themselves with a good level of knowledge about the area, choosing option number 4. And finally, with 23.8% it was the evaluators who marked option number 5, reporting having a lot of knowledge about the study area. This percentage relationship is reported in the graph shown in Figure 14.

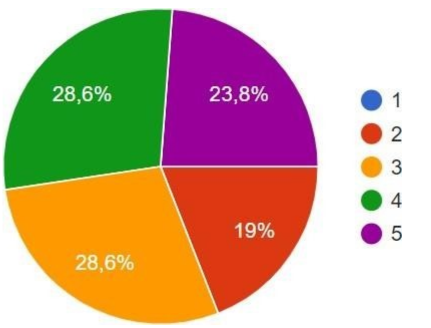

Figure 14: Level of knowledge of users about physical computing

After the process of identifying the characteristics of the evaluators, the SUS questionnaire and a set of 5 open questions were applied, in order to collect information about the context of use of the tool, possible user profiles for the application, related projects and the positive and negative points of the application.

The result of this application obtained a set of information that was analyzed and, in the end, the general SUS score was calculated based on what was defined by [?]. This information is detailed in Table 1.

Table 1: Result of applying the SUS questionnaire

Eval.	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
A1	5	1	5	1	4	1	4	1	4	1
A2	3	3	4	1	2	2	4	4	4	1
A3	5	2	4	3	5	1	5	1	4	3
A4	3	2	4	1	2	4	4	1	2	1
A5	3	2	3	1	3	4	5	1	5	1
A6	2	4	4	1	4	3	4	1	4	1
A7	5	2	4	1	4	2	4	1	4	2
A8	4	1	3	1	3	1	4	1	4	1
A9	4	1	5	1	4	2	5	1	5	1
A10	2	4	2	4	3	3	2	1	2	1
A11	3	4	5	2	4	2	5	1	4	2
A12	5	1	5	1	5	1	2	1	4	1
A13	5	2	3	4	4	2	4	2	4	1
A14	3	2	4	1	4	2	4	1	4	3
A15	4	4	5	1	5	1	5	1	4	2
A16	1	4	4	2	2	5	2	2	2	4
A17	4	1	5	1	3	4	3	1	5	1
A18	3	2	4	4	3	2	4	1	3	1
A19	5	1	5	1	5	1	5	1	5	4
A20	2	3	4	1	3	3	5	2	3	1
A21	5	1	5	1	5	1	5	1	4	1

Mean	3,61	2,23	4,14	1,61	3,66	2,23	4,04	1,28	3,80	1,61	**Result (P1+P2+...P10) 2.5**
(I) M-1 (P) 5-M	2,61	2,76	3,14	3,38	2,66	2,76	3,04	3,71	2,80	3,38	**75,71**

In the application of SUS, according to [17], the average score identified for web interfaces is 68.2. In this sense, the SUS score calculated for the CatalogToMakers based on the recorded evaluations, was higher than the average described in the study, resulting in a final score of **75.71**.

8. Conclusions and Future Works

More broadly, the tool was successful in all evaluation criteria and, in particular, for less technical users (non-specialists). The main contribution of this investigation was the development of a solution for the information retrieval and organization process, enabling a more efficient search for components and projects used in physical and musical computing, having as a differential, in relation to the already existing platforms, the union of several important functionalities on a single platform and the use of essential techniques of design, computing and research information retrieval to promote a single experience to users.

For the development of future works, several recommendations obtained in the final validation process can be applied. Suggestions such as improvements in the interface, portability and the insertion of gamification to encourage the addition of information by employees, were considered of great importance to improve the project. In this way, CatalogToMakers seeks to promote integration between enthusiasts, makers and more technical professionals, in view of the growth of this type of audience and the new demands inherent to society and industry in relation to these technologies.

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