

Smart Makerspace

A Web Platform Implementation

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Abstract—Makerspaces are creative and learning environments, home to activities such as fabrication processes and Do-It-Yourself (DIY) tasks. However, containing equipment that are not commonly seen or handled, these spaces can look rather challenging to novice users. This paper is based on the Smart Makerspace research from Autodesk, which uses a smart workbench for an immersive instructional space for DIY tasks. Having its functionalities in mind and trying to overcome some of its limitations, we approach the concept building an immersive instructional space as a web platform. The platform, introduced to users in a makerspace, had a feedback that reflects its potential between novice and intermediate users, for creating facilitators and encouraging these users.

Keywords—makerspaces, immersive instructional spaces, web platforms

1 Introduction

Nowadays, Makerspaces, along with terms such as Hackerspaces and FabLabs, are a growing phenomenon which academia has already grappled with it from multiple lens and fields [1]. They can be home to a range of activities and be used for fabrication processes and accomplishing Do-It-Yourself (DIY) tasks, also acting as creative spaces and learning environments. Ref. [2] practically defines them as a community workshop where “hackers” share knowledge, expertise and access to tools in order to produce something tangible.

However, these environments can look rather challenging to novice users, since they make available equipment that are not commonly seen or handled, that have not been introduced or made accessible to people yet. These spaces mainly include machinery such as 3D printers, laser cutters, soldering irons, drilling machines, electronics and various raw materials used for making.

Additionally, these spaces are not that commonly available to the public, though the maker movement is a tendency, especially in emerging countries. For that, it is

necessary to think of ways to provide this experience and disseminate these activities, who contribute to develop the creative, collaborative, experiential and participatory sense through the maker experience. In this paper it is describe the process of development of a web platform, trying to fulfill the maker experience previously mentioned, directed to act as an immersive instructional space, willing to encourage new users to maker activities, being an auxiliary agent to provide context and necessary information for the development of maker tasks.

1.1 Motivation and inspiration

For such reasons, researchers from Autodesk have presented an immersive instructional workspace for novice and intermediate makers [3]. Called the Smart Makerspace, the goal is to guide makers through the completion of a DIY task, while providing detailed contextually-relevant assistance, domain knowledge, tool location, usage cues, and safety advice [3].

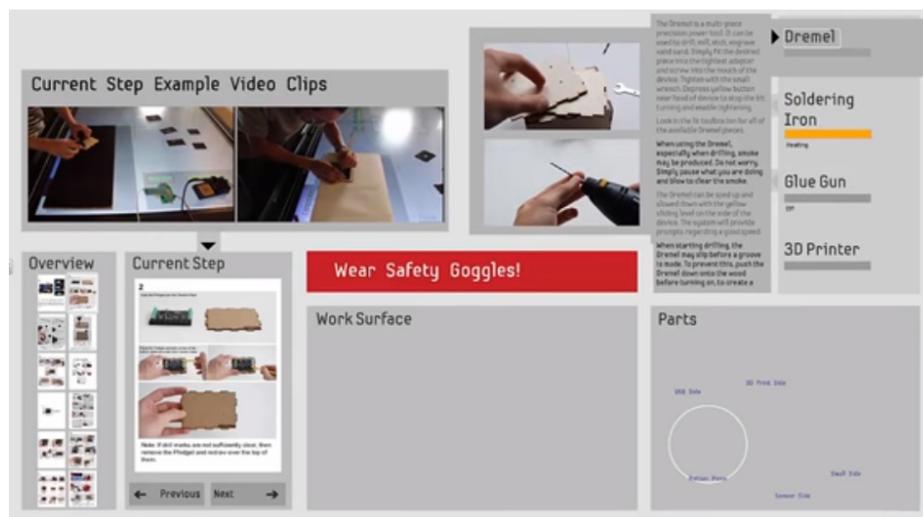


Fig. 1. Underneath screen view of the smart workbench

Technically, the making environment proposed by Ref. [3] is focused around a smart workbench, a toolbox and power-tools such as glue gun, soldering iron, drilling machine and a 3D printer. With all the equipment connected to the augmented workbench, the translucent surface has a screen below that shows information necessary for handling equipment and keeping track of a DIY task, which includes the DIY task manual, an overview of the task, videos of the current step and alerts. At the same workbench, it is also given the space for working, piece tracking and placing power-tools.

Another related work is done at Harvard University, where it was created the Guerilla Makerspace, an initiative that experiments with a space-less makerspace. The

method experimented was to bring making to people instead of bringing people to a space. “We show up at unexpected places with a plastic bucket full of things to make with, two laptops, and a handful of MaKey MaKeys, and we go from there” [4]. In this case, it relates and encourages the creation of a web platform immersive instructional space as the users use their laptops for the whole making process, which could be used and adapted to instruct according to the components and tasks provided in the experiment, for example.

1.2 Our approach

The work presented here is inspired and based on the same concept, but bringing a different implementation. In this case, the idea has been approached by using, instead of a workbench, a web platform that runs in the user’s laptop for accompanying the maker tasks. It also goes around some issues identified in the previous implementation, related to having the need of separate power-tools and a workbench for each user, which does not correspond to reality on makerspaces.

In this model implementation of a Smart Makerspace, the challenge is to create a web platform that can correspond to an immersive instructional space, inspired and based on the features presented by Autodesk [3]. Also, it is aimed to build a system that has a lower cost for implementing in makerspaces, easy to access, and enabling equipment to be shared with multiple users at the makerspace, due to some equipment are not feasible to be dedicated to only one user.

Furthermore, it is designed after demands presented by the instutional makerspace, willing to diminish staff intervention in the making tasks, which gets overloaded hence its users are frequently in need of help and assessment, but also willing to provide higher autonomy for its users. In the next chapter, these concerns will be discussed in more detail as well as this work’s approach for it.

2 Conceptual solutions

The solution is based and inspired on the Smart Makerspace concept proposed by Ref. [3], but with a different implementation. Facing similar difficulties for novice and intermediate users, as well as thinking of its own demands previously mentioned for the instutional makerspace, the Smart Makerspace concept is approached by the development of a web platform.

One of the reasons of building a web platform comes justified by most of the makerspace users work using their laptops, even though some simple maker tasks can be done without the use of a computer. Indeed, approaching maker activities with a workbench can also work for some tasks, but considering that plenty of tasks make use of electronics and some require heavy processing, it could limit the possibility of performing activities such as programming using IDEs or using specific computer tools such as 3D modeling along the steps.

Building the Smart Makerspace as a web platform also allows that the tools and equipment do not have to be specially linked to one workbench, which is very limit-

ing and does not correspond to reality of what is experienced on makerspaces. Normally, this equipment would have to be shared with numerous users during a day and with simultaneous requests, needless to say the physical space and available budget to allocate such individual workbenches and equipment.

2.1 Web application basis

In a nutshell, the web platform works as the user, at first, fills in a small form page for then then being redirected right away to a page for choosing a maker task of desire. After choosing a task to work on, the tutorial page (Instructable, for example) comes along with a sidebar where the user can find information needed whenever necessary, such as guidance information and instructions for 3D printing or other equipment.

More specifically, it is implemented as a sidebar helper alongside the tutorial steps, making it possible for the user to show it or hide it with a toggle button whenever necessary. This way, it can be shown when help or assistance is needed, but at the same time it does not get in the way of the user if the same has enough confidence to follow up the work. In addition, the sidebar buttons trigger modal boxes that appear in the page for further information and actions.

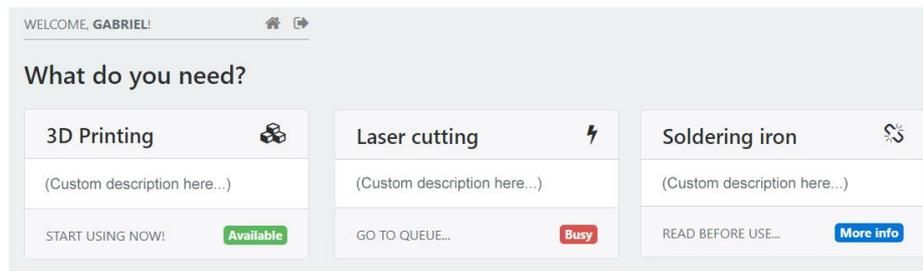


Fig. 2. Toggleable sidebar helper (items horizontally listed in this figure for space matters)

Regarding the matter of having specially connected equipment to only one workbench, it will work out through a queueing system implemented in the platform, making it possible for the equipment to be shared with other users. The users will be able to join the queues through the sidebar helper, where they can select the equipment they need to use and can also upload files (a 3D model, for example) to it. At the same location, it is possible access further information regarding how to use, security and warnings.

Additionally, for every equipment that has a dedicated computer for running the control software, the same will have access to a page with all the information regarding that equipment. In this page, it is possible to visualise the queue, finish the current user allowing space for the next on queue as well as download the files uploaded from the users' laptops.

3 Overall web application

You In this chapter we will focus on the overall web application, the pages it is composed of, how the implemented features appear and how the user interacts with it. First, we will introduce the workflow of the application and how pages interact with each other. Later, we will explain in detail the features that each page contains.

3.1 Welcome page

For every user that enters the web application, it is mandatory to start a session before working, since every action that is taken by the user is identified and related to its session. Therefore, the first page is the Start Session page, where the user fills in some personal and student data. It requires a first and last name, a student number and the institution of studies.

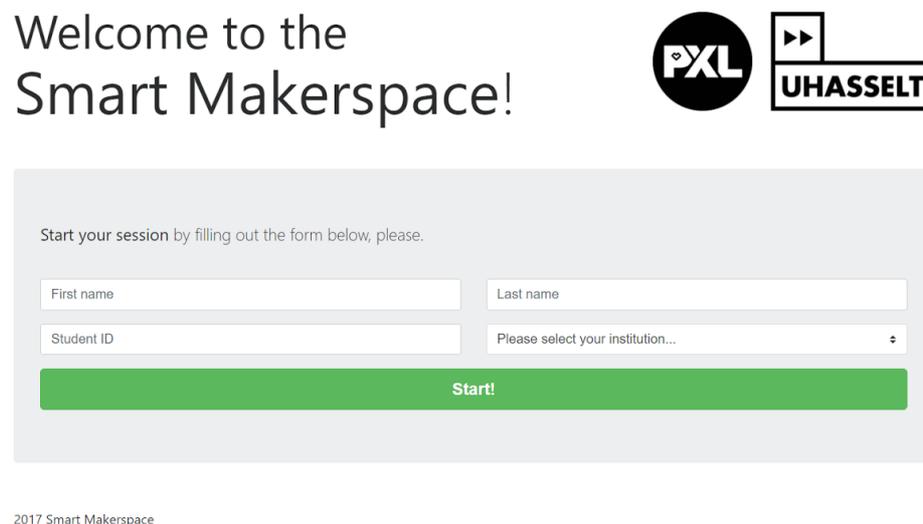


Fig. 3. Start Session page

3.2 DIY websites and FabMoments page

After filling in the data and starting the session, the user is redirected to the second page, where it is possible to choose a DIY website to choose a project and start working. The second page has mainly two sections, the first one is where the user has DIY websites available to choose from and, secondly, the FabMoments section, where users' previously projects can be published so that others can see its results and get inspired by.

Welcome, Gabriel!

You can choose a DIY website to start now or go through some FabMoments.

My fabMoments

Finish session

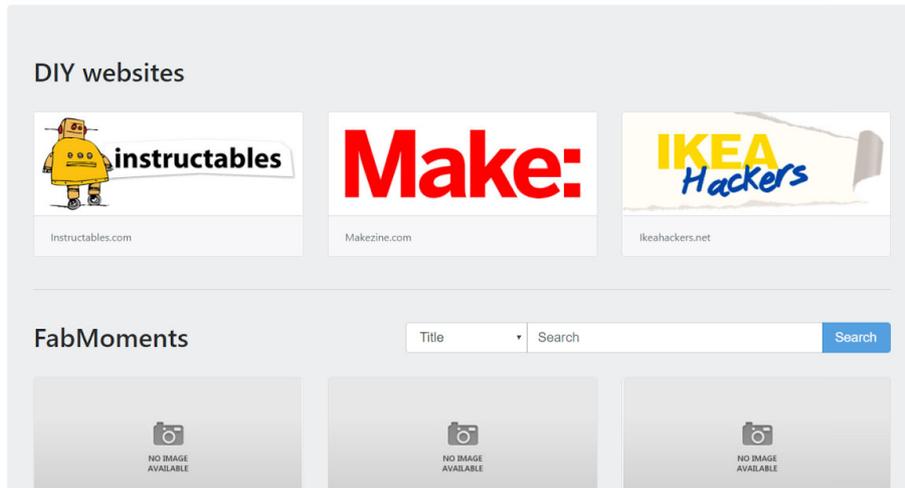


Fig. 4. DIY websites and FabMoments page

The FabMoments is link to a parallel project that is included to the platform. It figures as a section in this page where it is possible to view projects recently done by makers, who after finishing a project at the makerspace have the option to post it on the platform. By clicking on the button at the upper right corner, they are able to view their own FabMoments, edit and create. It supports search for other users' projects and has a pagination for browsing.

3.3 Tutorial page and helper

By choosing any of the DIY websites given in the application, the user is then redirected to the respective website where it is possible to freely navigate the website and choose any task to work on. The Smart Makerspace comes in with a sidebar helper that has a toggle (hide/show) button, so the user can continue the steps without it getting on the way.

The sidebar helper shows a list of the most commonly used equipment in DIY tasks, which in this case are 3D printer, laser cutter, soldering iron, drilling machine and glue gun. Moreover, by using a queuing system, it also shows its status whether it is available for use or busy at the moment, when another user is currently using it.

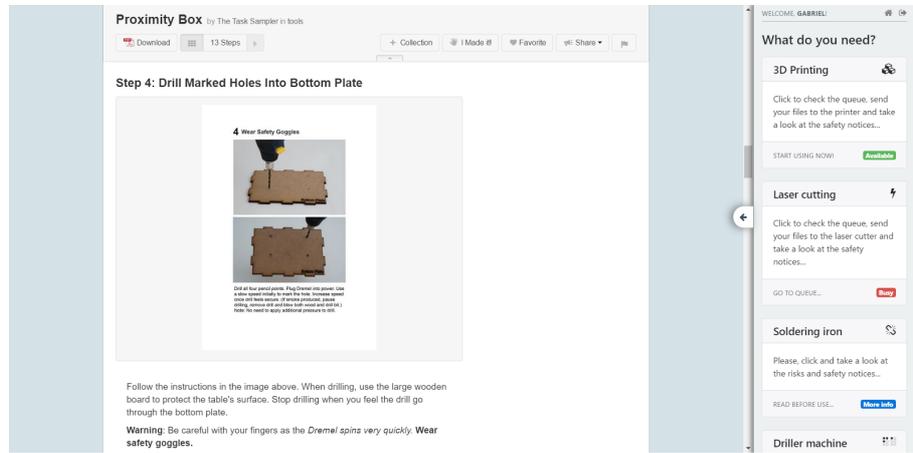


Fig. 5. "Proximity Box" Instructable and sidebar helper

3.4 Equipment modal windows

For every equipment listed in the sidebar helper, clicking on it will result on opening a specialised modal¹ for the equipment which contains its specific information. This information regards to the queueing system, file uploading system and technical information for the equipment, concerning as well security notices and usage instructions.

For using some of the equipment, it is necessary to enter a queue. By opening the modal, it is possible to find all the users in the queue who are willing to use an equipment, where you can as well enter the queue or leave it, in case. Another feature is the file uploading system, where you can send files from the laptop to the respective equipment computer, when applicable, such as 3D models or vector files that are input to the equipment software.

However, it is not pertinent that for every equipment there is queueing and file uploading system implemented. In fact, some machinery need a dedicated computer in order to work, such as a 3D printer or laser cutter, for example, which both need a computer in for running the software that controls it. Therefore, this equipment will get a queueing and file uploading system, once both of them work with specialised software, both need input files and are highly requested.

¹ A modal is a floating window that appears in focus, centered in the foreground, always on top. Example in Figure 4.

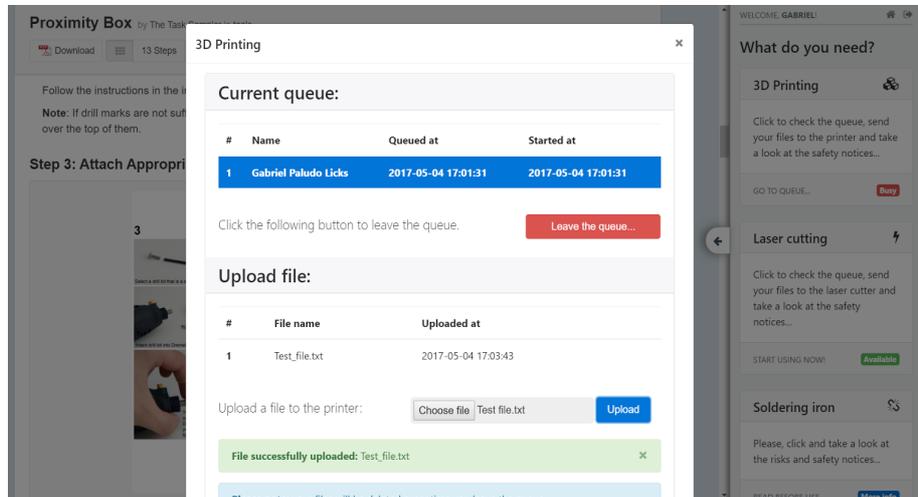


Fig. 6. 3D printer modal opened with queueing and file uploading

3.5 Equipment pages

For the equipment that uses a dedicated computer to work, those will have a dedicated page that will be open in the computer. This page works as a complement to the modals, giving extra functionality to the queueing and file uploading system. Nevertheless, it also shows all the proper information regarding how to use the equipment and security measures for a smooth operation.

Concerning the queue, it will show the current queue for that specific equipment, where it will allow users when finished working on the equipment to allocate the next user on the queue to start. For the file uploading system, it will list all of the files that different users have sent, where each of them has a button to download it to the computer and then work on it with the equipment software.

In the next chapter, we will describe in detail all the features presented here, regarding its implementation and a more technical point of view. The different tools used during the project will also be pointed out next.

3D Printer

The screenshot displays a web interface for a 3D printer. It is divided into two main sections: 'Current queue:' and 'Files uploaded:'. The 'Current queue:' section contains a table with columns for '#', 'Name', 'Queued at', and 'Started at'. A single entry is shown: '# 1', 'Gabriel Paludo Licks', '2017-05-04 17:01:31', and '2017-05-04 17:01:31'. Below the table is a text prompt 'Please, finish your session after you are done.' and a blue button labeled 'Next user'. The 'Files uploaded:' section contains a table with columns for '#', 'User name', 'File name', 'Uploaded at', and 'Download'. A single entry is shown: '# 1', 'Gabriel Paludo Licks', 'Test_file.txt', '2017-05-04 17:03:43', and a download icon. At the bottom of the interface, there is a blue header bar with the text 'Leapfrog dual extruder Creatr HS'.

Fig. 7. Specialised page for the 3D printer with queue and file list

4 Features and implementation

In this chapter we will detail the tools used for implementing the web application, which covers the frameworks used, programming languages, softwares and IDEs necessary to build and run the application. Furthermore, we will introduce the specific features of the application, which consists on the logics used for implementing each of them along with the role they have in the application.

4.1 Implementing tools used

The implementation of the web platform consisted of two development stages. The first one is the front-end development, which relates to the user interface, the pages' flow and the triggers for user interaction. The second part was responsible for the back-end of the application, which consisted on the programming and logics of the application features, database and server interactions.

After describing the two development stages, we will cover other fundamental aspects for the application to be ran, such as the database and server as well as other tools used along the project.

Front-end development. In this first stage of the development, the main goal was to build a consistent user interface aiming ease of use and a proper look and feel. For that, basic languages used for constructing a web page such as HTML (HyperText Markup Language), CSS (Cascading Style Sheet) and JS (JavaScript) were used.

Initially, the languages used were pure HTML and CSS for structuring and styling the page. However, the Bootstrap² framework has been used for further styling and element positioning, which comes with built-in alignment classes and elements that are automatically styled when using the respective classes.

Back-end development. The second stage of the development was responsible for the back-end of the application, which was developed following the Model-View-Controller³ (MVC) architecture. The main language used for this stage was PHP⁴ (Hypertext Preprocessor), a general-purpose scripting language that is especially suited for web development and can be embedded into HTML.

However, nowadays there is a range of frameworks with built-in features that help developers to save time and reuse code. Therefore, this application has been developed over the CodeIgniter⁵ PHP framework, which is lightweight and has good support for implementing some of the basic features of the application. In addition, the jQuery library has also been used mainly for making AJAX⁶ calls in some pages for dynamically refresh the content.

Database, server and other tools. For database, this project has used the MariaDB 10.1, which is open source and uses MySQL commands. Even though, some operations were made using phpMyAdmin⁷, a free tool intended to handle the administration of MySQL over the web.

The web server used is Apache 2.4 HTTP Server, free and open source as well. And finally, tools such as the NetBeans IDE 8.2 and Sublime Text 3 were used for coding and handling files during the project.

4.2 Specific functionalities

In this section we will describe some of the particular functionalities that figure the platform. They represent some of the conceptual ideas behind the challenge of implementing the workbench functionalities to a web platform, adding a queueing system for equipment that enables sharing and organising equipment information regarding how to use, instructions and warnings.

² Bootstrap is an HTML, CSS, and JS front-end framework for building responsive projects on the web. Official webpage at <http://getbootstrap.com/>.

³ Model view controller (MVC) is a design pattern for writing software three fundamental parts: the model represents the data; the view displays the model data and sends user actions; and the controller provides model data to the view, and interprets user actions such as button clicks. Source: <http://www.tomdalling.com/blog/software-design/model-view-controller-explained/>.

⁴ Official webpage at <http://php.net/>.

⁵ CodeIgniter is a PHP framework with MVC design pattern built for developers who need a simple and elegant toolkit to create full-featured web applications. Official webpage at <https://www.codeigniter.com/>.

⁶ jQuery is a feature-rich JavaScript library that makes HTML document traversal and manipulation, event handling, animation, and Ajax much simpler with an easy-to-use API that works across a multitude of browsers. Official website at <https://jquery.com/>.

⁷ Frequently used operations (managing databases, tables, columns, relations, indexes, users, permissions, etc) can be performed via the user interface, while you still have the ability to directly execute any SQL statement. Official webpage at <https://www.phpmyadmin.net/>.

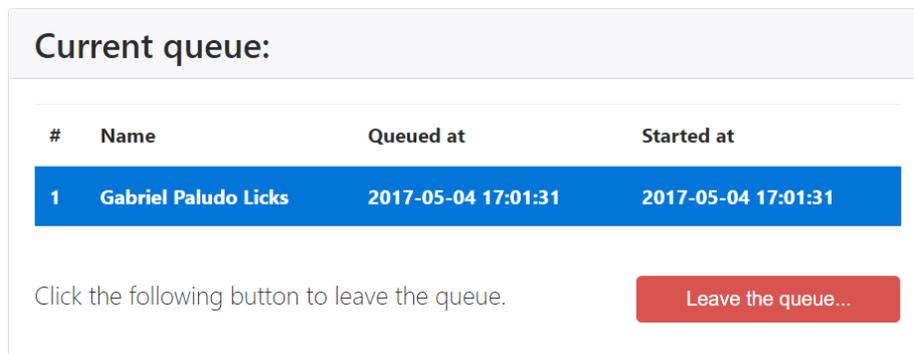
Toggle hide/show button and sidebar. The sidebar helper is where the maker can find the listing of commonly used equipment and access further information for each of them. By clicking over any equipment, the respective modal will open for further features and information.

Also, the sidebar can be shown or hidden by a toggle button on the right side of the page. This is meant to allow the user to choose whether he wants to follow up the task with it or not, giving freedom if one is confident enough to follow up without any assistance. platform.

Queuing system. By opening a modal, it is possible to view the current queue for some equipment, where all users who are willing to use it are listed. Or, there could be none as well, meaning that the queue is empty and ready for the first user (available status).

For entering the queue, it is just necessary to click a button and wait until you get your turn. At the same place, if the user is already in the queue, the button becomes an option to leave the queue, in case no longer necessary.

In every equipment page, the queue will be shown as it appears in the modals, which comes with a button that allows the current user to finish its session and leave space for the next on the queue.



The screenshot shows a modal titled "Current queue:". Inside, there is a table with the following data:

| # | Name | Queued at | Started at |
|---|----------------------|---------------------|---------------------|
| 1 | Gabriel Paludo Licks | 2017-05-04 17:01:31 | 2017-05-04 17:01:31 |

Below the table, there is a text prompt: "Click the following button to leave the queue." and a red button labeled "Leave the queue..."

Fig. 8. Example of queue in a modal

File uploading system. The file uploading feature has been implemented for making the user's life easier while reducing while reducing the traffic of flash disks running around the makerspace. When the user gets its turn for using an equipment, he can go directly to the computer and easily access the previously sent files. The files can be uploaded directly from the equipment modal, and then accessed in the equipment page.

Upload file:

| # | File name | Uploaded at |
|---|---------------|---------------------|
| 1 | Test_file.txt | 2017-05-05 14:30:59 |

Upload a file to the printer: Test file.txt

File successfully uploaded: Test_file.txt ✕

Please note: your files will be deleted every time you leave the queue.
Maximum file size: 100 megabytes.

Fig. 9. Example of a file uploading form in a modal

This system also works along with the queue, since every time a user leaves the queue, either by itself before even using the printer or by having finished his session at the equipment, all the files uploaded from the user will be deleted from the server. Mainly for two reasons: first, for not overloading the list of files at the equipment page and creating a visual pollution for the user with a huge number of files; and second, not to maintain old and unused files in the server, as well as freeing up disk space.

Instructions and usage warnings. For every equipment listed in the sidebar, it is provided the respective instructions necessary on how to use the equipment, along with usage and security warnings for dealing with the equipment. The institutional makerspace provides the user with individual protection equipment, which are instructed as well.

Special equipment pages. Every equipment with a dedicated computer, in this case the 3D printer and the laser cutter, will have access to a page that contains the queue and the files sent by the user from the laptop. In these pages, the queue is shown as well as a button for releasing space to the next user and also a list of files sent by every user where every file has a button to download it. An example of this pages is shown in Chapter 3, Figure 5.

5 Feedback and discussion

For an evaluation of the platform, it was elaborated a feedback form to be answered by random users at the institutional makerspace, in the period of May/2017. They have been given an introduction to the project, and then the chance to use the

platform as they would, free to explore. Then, we will be discussing some characteristics between this model of Smart Makerspace and the one presented by Autodesk.

5.1 Feedback results

The web application has been uploaded in a local server at the institutional makerspace, and therefore was introduced to the users who had the interest on the potential of the idea and to collaborate by giving feedback. This is intended for having a primary quantitative evaluation of the work and analyse the acceptance of the features provided, as well as getting suggestions for improvements and new features, nevertheless. For this matter, after being given an introduction and experimenting the features of the platform, the users were asked to answer a feedback form.

The questions that the form contains, that later will be shown in detail, are based on the parameters evaluated by the Autodesk study. Initially, the first questions are to verify the expertise that the user already has, how familiarised and experienced the user already is on DIY tasks and fabrication equipment. Next, the second objective of the form aims to verify how useful each of the platform main features are, rating on a 5-point Likert scale (1 = strongly disagree until 5 = strongly agree). Lastly, also answering in a Likert scale, the overall helpfulness of the platform, look and feel, ease of use and other questions concerning the platform as a whole.

Quantitative results. The students whom the platform was presented had an average age of 22, whom area of studies is Informatics and also Architecture, in a total of 10 students. In level of experience, 30% of them considered themselves Beginners, 60% Intermediate and 10% Experienced; 80% said that enjoy working on DIY tasks; and 90% do use online tutorials for making; having 60% of them already used websites such as Instructables⁸, Makezine⁹ or IKEA Hackers¹⁰.

Later, in the questionnaire, the users were asked on how experienced they were with some specific equipment, commonly used on makerspaces (results are an average of the answers in a 5-point Likert scale):

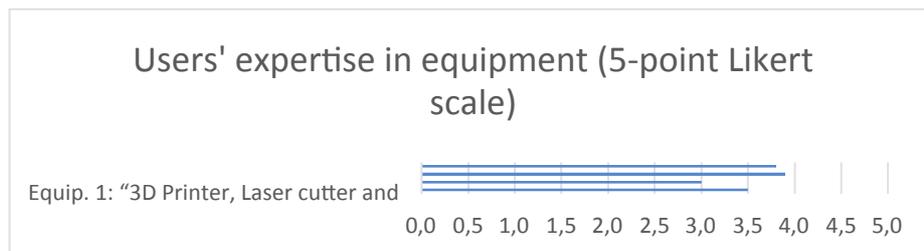


Fig. 10. Chart of users' expertise in equipment

⁸ Access at: <http://www.instructables.com/>.

⁹ Access at: <http://makezine.com/>.

¹⁰ Access at: <http://www.ikeahackers.net/>.

It is possible to see in Fig. 10 chart that most of the interviewed users declare not being that experienced with more complex equipment such as 3D printer and laser cutter, in comparison to other more common hand tools. In a reality which these spaces and equipment are not that common, it is reinforced the need of new methods for appropriating this kind of tool and technology, creating ways for making it more feasible to the public. This is related to the platform’s goal, to encourage and make it easier to approach this kind of equipment, providing the information needed to move forward in tasks, contributing for the users to have the “maker experience”.

Furthermore, the tool they claimed being less experienced was the soldering iron. This tool is mostly related to electronics and robotics tasks, which today is a very specific type of activity between the public, but likely encouraged when making use of the platform’s immersive space.

Regarding the platform’s specific features, the users also answered the following questions (5-point Likert scale):

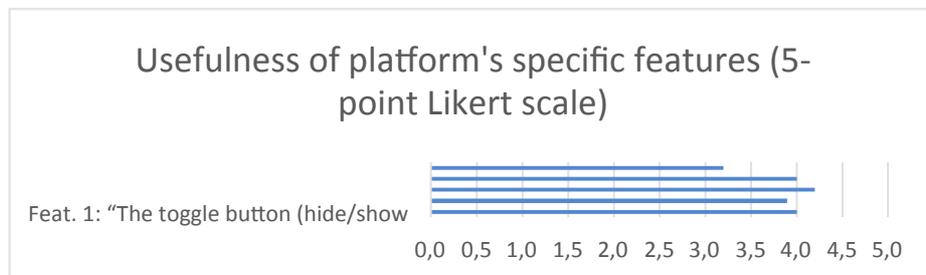


Fig. 11. Chart of usefulness of platform’s specific features

The highest rated feature of the platform was the queueing system, implemented to distribute the access for some equipment between the users. The Smart Makerspace model from Ref. [3] has a limitation of one user only per workbench, limiting the access to the 3D printer only for the current workbench user. The queueing system and the web platform model will allow the users to share the equipment, which goes according some fundamental concepts of the maker movement: sharing and collaborating resources.

And finally, concerning the web platform as a whole, the following questions were made (5-point Likert scale):



Fig. 12. Chart of platform’s likeliness and satisfaction

With the initial ideas of creating an immersive instructional space, it was mandatory to have a platform with ease of use and a good interaction with the user. Based on the feedback numbers in Fig. 12 chart, we verified that we could attend this goal and make a friendly environment.

5.2 Discussion

Approaching the idea of Smart Makerspace as a web application has its benefits, since it allows higher flexibility for incrementing features and adding equipment as needed. On the other hand, the workbench has a rather more immersive experience, since the whole environment is focused to one user. Therefore, both models come out with their own pros and cons.

A characteristic of the Autodesk [3] model is that it has a much higher accuracy on information such as the equipment actual state, where sensors were physically installed on each of the equipment kept track by the workbench. Installing these sensors, such as temperature, light and movement, for example, allows a broader range of possibilities to keep track of each of the equipment in a detailed fashion.

However, this demands special modifications on each of the equipment at the makerspace, plus the communication between microcontrollers and the web application. This is not feasible for expanding the idea between makerspaces and implementing as a web application allows countless equipment to be added - not the case for this initial work - but something to take in consideration when thinking of scalability.

As mentioned in the early chapters, a web application is as well more likely to users as their tasks are normally accompanied using a laptop, being more correspondent to the habitual routine in makerspaces and users' habits. Other features such as the file uploading are to attend demands by the makerspace itself, aiming to avoid running flash disks all around, as well as giving information in advance for users on how to use equipment, making it less likely the need of asking for personal assistance from the staff.

6 Final considerations

This work has, initially, started as a challenge to create a tool that corresponded to the objectives of the Smart Makerspace concept proposed by Autodesk, but aiming to come up with alternatives that could work around some of the issues identified at it, as discussed in the introduction. Our feedback results at the makerspace reflect the potential of this tool between novice and intermediate users, which is satisfying for the objective of creating facilitators and tools that encourage these users to become more familiar with maker activities and equipment.

Having built a web platform is also a facilitator for future implementations in a wide fashion that the web provides. The decision for not using sensors neither receiving direct signals from the equipment was taken in order to reinforce the scalability of the system, both for adding more equipment to keep track and also for simplifying the establishing the idea on other makerspaces.

An interesting future possibility is that, as a web application, makes possible for growing in the meaning of expanding on other makerspaces and creating a network for communication between makerspaces. This could result in benefits such as, for example, being aware of equipment available in others could be useful when one needs the other, as well as visualising different projects that are made, both for inspiring and growing community with all the information shared between these spaces.

As a result of this expansions, an administration dashboard for controlling the content of the application is also a very likely improvement, allowing an administrator to insert new equipment to the Smart Makerspace and managing content according to its needs. Some of the possibilities would be creating multiple queues, inserting more alerts (dynamic or not) regarding security notices, editing any kind of information and adding specialised content that fits better to each makerspace.

The Smart Makerspace as a web application allows much higher flexibility and scalability, as well as being a solution intended for sharing equipment between the user and not having specialised equipment for each session. In contrast, the workbench model does provide more accuracy on its information and delivers more integrated information focusing on the user. However, this is possible to be attained as a web application as well, which remains as a situation for future implementation ideas. Nevertheless, this is a solution that can also be applied in other makerspaces due to its scalability and, with future implementations, has a growing potential for connecting these spaces.

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