DEPARTMENT OF
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Bachelor in Computer Science

INTERACTIVE TOOLS FOR HISTORICAL CONTENT - MAGIC LANTERN

MASTER IN COMPUTER SCIENCE AND ENGINEERING

NOVA University Lisbon
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Abstract

The magic lantern, an ancestor of the projector, played a significant role in educating and entertaining the masses. The slides used by these machines captivated viewers with their ability to bring drawings to life in simple yet compelling ways. The range of the slides was extensive featuring drawings of landscapes, monuments, and illustrations directly connected to presented lectures - for instance, an illustration of the solar system's dynamics, showing the planets moving around the sun. Magic lantern shows also incorporated storytelling elements, with scenes ranging from heartwarming depictions of children building a snowman to humorous animations, such as a mouse daringly entering the mouth of a sleeping man.

This dissertation developed an application that allows its users to design their magic lantern slide. The slide is then animated, bringing the user's creation to life. Additionally, the application aims to immerse the users in the world of magic lanterns by ensuring historical accuracy in the color palettes provided for use and the images available for painting.

The application development focused on creating a user-friendly interface that focused on visual appeal and ease of use. A recursive flood-fill algorithm was implemented to allow users to color complex images, and a color blending feature was added, so that users could mix colors as they would in a traditional painting. The application went through two iterations, upgrading after each round of user feedback, and improving its usability, and increasing user engagement.

The application had a notable impact on the public, it was especially well-received by children, who demonstrated enthusiasm for personalizing their slides and watching them come to life. While the biggest success was with children, adults also found it entertaining, and coupled with the historical context in which this application is going to be presented (as a plus to exhibitions related to Magic Lanterns and their slides) the application has both an educational and entertaining role.

Keywords: Magic Lantern, Slides, Interactive Experience, Computer Graphics

Resumo

A lanterna mágica, um dos antepassados dos projetores que conhecemos hoje em dia, teve um papel significativo tanto na educação como no entertenimento do público. Os slides usados por estes dispositivos cativavam os espetadores devido à sua capacidade de dar vida aos desenhos que continham. A variedade dos slides é extensa, desde paisagens, monumentos e ilustrações diretamente ligadas a lições, como por exemplo, a ilustração da dinâmica do sistema solar, onde se consegue ver os planetas a moverem-se à volta do sol. Os espetáculos das lanternas mágicas também podiam incorporar elementos de narrativa, desde cenas simples e comoventes, como duas crianças a construírem um boneco de neve, até àquelas cujo o objetivo era provocar a gargalhada, como, por exemplo, um rato a entrar na boca de uma pessoa a dormir.

Esta dissertação desenvolve uma aplicação que permite aos seus utilizadores pintar o seu próprio slide. O slide personalizado pelo utilizador é, em seguida, animado, fazendo com que a criação do utilizador ganhe vida. Além disso, a aplicação visa levar os utilizadores para o mundo das lanternas mágicas, e fá-lo ao assegurar a precisão histórica das paletas de cor fornecidas para pintar e das imagens que podem ser escolhidas.

Um importante aspeto no desenvolvimento desta aplicação foi a criação da sua interface. A facilidade de uso e uma aparência visualmente atraente foram pontos importantes que se tiveram em consideração. Um algoritmo de preenchimento recursivo (flood-fill) foi implementado para garantir que, independentemente da complexidade da forma presente nas imagens, esta fosse colorida se o utilizador assim o desejasse. Uma funcionalidade ligada à mistura de cores também foi adicionada, de forma a permitir aos utilizadores misturar cores como o fariam numa pintura tradicional. A aplicação passou por duas iterações e, após cada fase de testes, aperfeiçoamentos e melhorias foram realizados.

A aplicação causou algum impacto no público, tendo sido especialmente eficaz a cativar e reter a atenção das crianças, visto estas terem demonstrado entusiasmo quando, após pintarem o seu slide de lanterna mágica, o viram ganhar vida ao ser animado pela aplicação. Embora o maior sucesso tenha sido com as crianças, os adultos também tiveram uma experiência agradável com a aplicação, e, devido ao context oem que se enquadra (como complemento a exposições relacionadas com Lanternas Mágicas e os seus slides),

reconhecem-lhe tanto um papel educativo como de entretenimento.

Palavras-chave: Lanterna Mágica, Slides, Experiência Interativa, Gráficos de Computação

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Introduction

This chapter presents the context of the project in which this dissertation is integrated, the motivation behind it, the proposed solution, the expected contributions, and the structure that is expected to be found.

1.1 Context

This dissertation is integrated in the *MAGICA project*, a research initiative investigating the historical and cultural impact of the Magic Lantern, an ancestor of the modern projector, focusing on its glass slides and their role in education, society, and the arts from the 17th to the 20th century, with a particular emphasis on Portugal.

The *MAGICA project* [28] grows out of a collaboration between the Research Units VICARTE from the NOVA School of Science and Technology and CESEM from the NOVA School of Social Sciences and Humanities, the University of Salamanca, the Science Museum of the University of Coimbra (MCUC) and the National Museum of Natural History and Science (MUHNAC) of the University of Lisbon. It also counts with the Portuguese Cinematheque - Museum of Cinema and the Museum of the Faculty of Engineering of the University of Porto (FEUP).

The objective of this dissertation project is to create an application specially designed for museums, aiming to provide visitors with an engaging way to explore magic lanterns and the images crafted for projection by these historical devices. The applications will allow users to actively engage with the content by creating their slides and experiencing the unique process of projecting them.

1.2 Motivation and Problem Definition

Museums are vital institutions that serve as the guardians of heritage, by preserving artworks, cultural artifacts, and historical treasures. They also connect the past to educate and warn the people - cruelties that happened in the past should serve as a warning to the present so that they will not repeat in the future [36].

The magic lantern is an early type of image projector, it was used to educate and entertain the masses and as an early form of advertisement. One of the difficulties of preserving this artifact is its slides, as they were made of glass, some were completely hand-painted while others had the outline printed and then were hand-painted. With time not only the slides could break but also the colours ould fade or detach from the support [46].

This instrument was capable of producing a wide range of shows, from creating the illusion of movement to telling stories through a sequence of slides. It could be used to craft narratives, with each slide advancing the plot, or simply to display advertisements or offer glimpses of distant parts of the world. Slides like those used in these shows can be found in figure 1.1.

The importance of interactivity in the modern museum experience arises from the preferences and expectations of modern audiences. Traditional museums, while rich in historical content, often encounter the need for personalized and engaging interactions and therefore it is essential to address this shift in the audience expectations while upholding the authenticity and reliability of the information presented. Taking this into consideration, the motivation behind this dissertation is to infuse digital innovation into the museum setting.

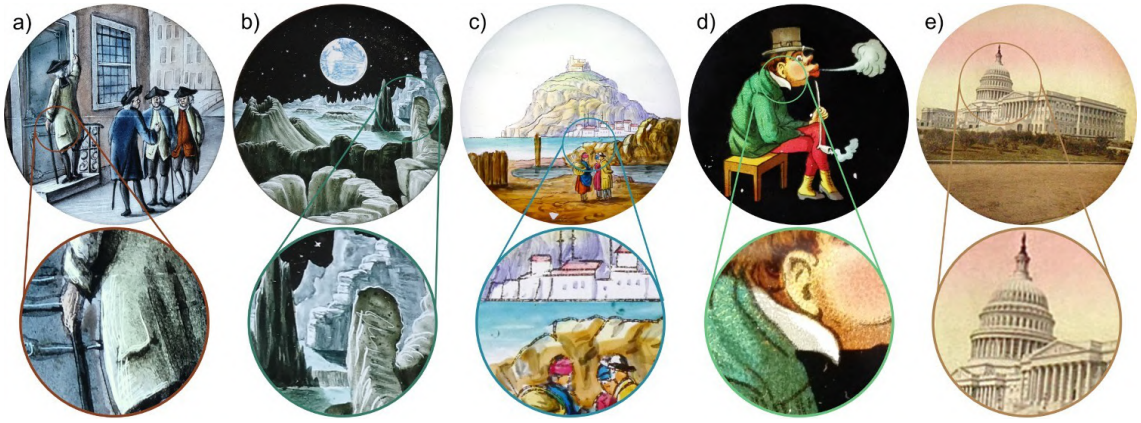


Figure 1.1: Magic Lantern Slides [46]

1.3 Solution

This dissertation presents a web application that enables its users to craft their own customized magic lantern slides by painting pre-defined drawings. These personalized slides are then animated to replicate a typical magic lantern show. While initially tailored for museum exhibitions related to magic lanterns, the application is also accessible online, allowing users to engage with the content beyond a museum setting. Its target audience includes the general public, irrespective of age, offering an accessible and interactive experience for all.

The application offers two primary features. The first focuses on the user's creative process, allowing users to paint and customize their slides according to their preferences. The second animates those creations.

The project combines the transition from static images to animated content. Therefore, part of the challenge was seamlessly integrating these features to make it smooth and visually coherent while replicating the classical magic lantern effect where movement is created through a sequence of images. Various approaches were explored, and the final solution involves the application identifying specific elements of the user's drawing, altering their positions, and transitioning between the original user-created image and its modified version. For example, if the user paints a bird (image A), the application will identify specific parts of the bird, such as wings and the rest of the body, adjust their position, and save the modified version as a new image (image B). The effect of movement is then achieved by altering between images A and B on the screen.

Another challenge was ensuring that users feel like authentic lanternists, painting slides and creating their own stories with them. To achieve this it is essential to create an environment and interactions with it that are believable. This includes the visual design of the application, such as the use of wood frames to replicate the look of traditional magic lantern slides. Additionally, in the museum setting, the application will be displayed on a tablet positioned at an inclined angle, mimicking the way the slides were painted.

Interactions within the web application were designed to be realistic and immersive, allowing users to genuinely engage with the process. For example, users can change color tones or mix colors to create new ones, enhancing the sense of authenticity.

Since this dissertation project is a collaboration with the *MAGICA project* and it is intended to complement the exhibitions by giving it a more interactive side, special attention was given to conservation and historical accuracy. For instance, users can only use colors from predefined palettes that were available at that time, only getting new colors by combining those in the palettes (e.g., yellow and blue to make green). Each slide is limited to a single color palette, reflecting the fact that different regions, such as Italy or France, had different palettes available at their disposal.

Furthermore, the pre-defined images are based on original slides from various collections, including those from the *National Museum of Natural History and Science of the University of Lisbon (MUL-MUHNAC)*, Cinemateca Portuguesa, and the *Science Museum of the University of Coimbra (MCUC)*.

1.4 Contributions

Based on the efforts taken to complete this dissertation, the following contributions resulted are:

- **Dissemination and preservation of Magic Lanterns** - development of an application that allows users to create images resembling those projected by magic lanterns. This

aims to promote awareness of their historical and cultural significance, contributing to the preservation of this heritage.

- **Recreating the painting stage** - the application replicates the traditional painting process used to create magic lantern slides, allowing users to experience it interactively.
- **Evaluation results** - any problem found while developing the project can be used as a base when trying to build something similar. The problems found and their solutions will serve as a template for future works.

1.5 Document Structure

This document is divided in the following chapters:

- **Introduction** - The first chapter presents the topic of this dissertation, the project that will be developed, the motivations behind it and its context.
- **Background** - The second chapter focuses on the areas of work this dissertation falls into. It introduces cultural and digital heritage, magic lanterns and museology- its importance.
- **Related Work** - The third chapter consists of the description of the study of other works related to this one. This includes tools related with learning and creativity such as **I/O Brush** and **Osmo Monster**; Drawing applications such as **Microsoft Paint** and more kid-friendly applications, in this case **Draw and Tell**; Digital interactive artwork including **Sketch Aquarium** and **Sketch Piston - Playing Music**.
- **Design and Implementation** - In the fourth chapter, the solution developed will be presented, covering the hardware, software, and techniques utilized. The main functionalities of the project, as well as the explanation of their implementation, will be given.
- **Evaluation and Results** - This chapter details how the project was evaluated, analyses those results and outlines the improvements that resulted from them.
- **Conclusions and Future Work** - The final chapter presents the conclusions drawn from the development and evaluation of this project, along with some suggestions for future improvements and work.

2

Background

In this chapter, the fundamental concepts to develop this dissertation are presented. The first section describes the meaning of cultural heritage and the digital realm (2.1); the attention turns to the historical significance of magic lanterns, their workings, types of slides used and shows (2.2); Museology is then discussed in the third section emphasizing the role that museums have in the modern world and their evolution from *"Cabinet of Curiosities"* to today's museum (2.3).

2.1 Cultural Heritage

Cultural heritage refers to the collective wealth of elements that define the identity of a society or a region, that were inherited by past generations and preserved for the benefit of present and future ones [8]. It can be divided into tangible and intangible heritage, where the first includes physical parts of the heritage and therefore *tangible*, such as historical sites, artworks, and monuments. While the intangible heritage involves traditions, language, rituals, and folklore. Together they form a reflection of the public in that region or society as well as their memory of the place.

The preservation of cultural heritage is crucial, as not only does it promote the identity of a community, but it also links history to the present and enriches others with different knowledge and inspiration [3]. Therefore there is a need to conserve these cultural treasures and make them accessible to future generations. Conservation practices include the careful maintenance and restoration of physical artifacts for tangible cultural inheritance and documentation and the transmission of oral traditions and performing arts.

Despite its significance, cultural heritage faces a lot of challenges such as climate changes, for example, the acid rains caused by pollution that degrade statues in Europe [48] at a faster rate, urbanization, namely the rise of new buildings that would replace those that had a historical value and conflicts that can endanger its integrity, in particular, the burning of books to suppress and control ideologies can be seen as an act of destruction of culture [22].

Technology offers solutions for the preservation, dissemination, and accessibility of

cultural heritage [15]. Digital tools, virtual reality, and online platforms allow for new experiences while exploring a culture as well as new ways to preserve artifacts. There should be caution however as even with the new range of opportunities that technology makes available ethical considerations and a need for sustainable practices to preserve cultural heritage are essential.

2.1.1 Digital Heritage

Digital heritage, including the preservation and accessibility of cultural artifacts through digital means, changed the way museums interacted with the public and preserved their aspects of cultural heritage [6]. The use of technology for tangible or intangible elements serves as a bridge between cultural heritage and digital evolution, as digitalizing artifacts and showcasing them through interactive digital platforms not only conserves the collections but also extends their accessibility [10] and fosters a deeper connection with different individuals.

Applications tailored for museums play an important role in extending the legacy of digital heritage to the public as well as preserving what is known as intangible cultural heritage more easily [35]. Whether through virtual exhibits, educational games, or augmented reality experiences, these applications transform the visit to the museum into another level that transcends geographic limitations and allows users to explore and interact with cultural artifacts virtually. This digital engagement not only preserves cultural heritage for future generations but also ensures that a global audience can access and appreciate the wealth of human creativity and history.

2.2 Magic Lantern

The Magic Lantern [24] is the precursor to modern-day projection devices and cinema [43], as it started the idea of entertaining or educating the public with projected images that moved in a darkened room.

There is a debate about who the inventor of this machine is, as German Jesuit priest Athanasius Kircher and the renowned physicist Christiaan Huygens are frequently referred to as inventors [46]. The second is the person most recognized for being the inventor as although Kircher described a projection system close to a magic lantern, the former had already demonstrated the illusion of movement created by the glass figures.

In the figure 2.1 there can be seen the functioning of a magic lantern. This machine relies on the manipulation of light and lenses to project images from glass slides onto a surface. For the slides to project the image correctly they need to be introduced in the Magic Lantern upside down, a result of how the light passes through the objective lens (O).

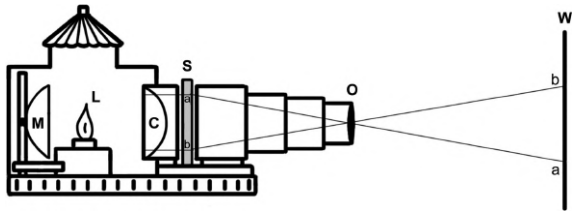


Figure 2.1: Scheme of the working principle of a magic lantern with a concave mirror (M), a light source (L), a condenser lens (C), a glass slide (S) with a transparent image (a-b orientation), an objective lens (O), and a wall (W) with the projected image inverted (b-a orientation). © Drawing by Ângela Santos [46]

The magic lantern evolved from the basic models to more complex ones, with two or three objectives (*biunial* or *triple lanterns*, respectively) and those alterations made more techniques possible such as dissolving effects by juxtaposing complementary images (dissolving views) [46].

2.2.1 Slides

A "magic lantern slide" refers to positive and transparent images captured on glass plates intended for projection using 'magic' (or optical) lantern instruments [46].

In the beginning, the only technique to produce glass slides was by hand painting, with the change of centuries two other techniques were added for their production: printing and photography [11].

The figure 2.2 provides an insight into the process of crafting hand-painted glass slides. Typically, the production of such slides encompasses four primary stages: selecting and preparing the glass support, outlining and painting the image, and framing the slide. There is also the recommendation to do these tasks in dust-free environments and under artificial light, such as gaslight or a paraffin lamp with a green shade so that when the slides are projected the colors reflected are those intended and the quality of the slide aren't compromised [46].

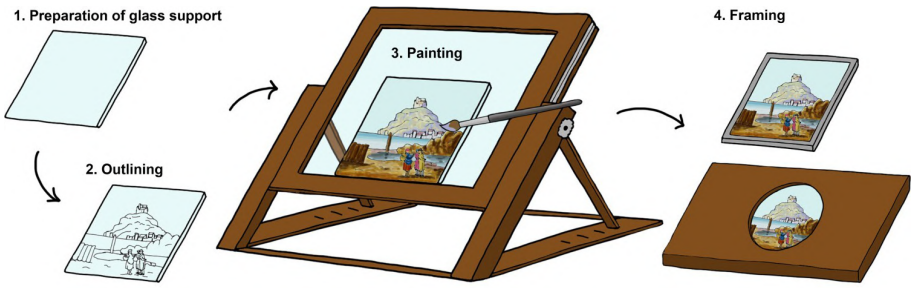


Figure 2.2: Main production stages of hand-painted magic lantern slides: (1) preparation of glass support, (2) outlining, (3) painting, and (4) framing. © Drawings by Ângela Santos [46]

Magic lantern glass slides pose significant conservation challenges, manifesting in issues like fractures, paper frame or handle wear, and scratches on wooden frames and paint layers, these damages frequently stem from improper or excessive handling. The paint layer, being the most delicate, exhibits crack patterns, flaking, and lacunas, likely attributed to binders' deterioration from prolonged exposure to light and high temperatures, as noted by Santos et al [47]. Therefore it is important to find ways to preserve them carefully.

2.2.2 Show

Magic lantern shows were a popular form of entertainment in the 18th and 19th centuries, captivating audiences with the optical illusions and stories that the slides displayed. These spectacles were orchestrated by the *lanternists*, the operators of the device who were in charge of changing the slides, adjusting focus, and adding special effects [4].

Different shows were created using this instrument, and the illusion of moving animated figures could be achieved by projecting magic lantern slides with movement mechanisms that created a sequence of images, as the example shown the figure 2.3. The content of these shows was diverse, as stated above they could go from entertaining an audience to lecturing about historical events or scientific principles, such as the movement of planet Earth or the solar system [4]. Audiences could embark on journeys to other parts of the world by seeing their landscapes projected, a story could be staged such as a myth or a simple tale, advertisements could also be found and optical illusions such as those typically produced by kaleidoscopes [46]. These shows could often have accompanying music, narration, or live performances creating a captivating experience.

Figure 2.3: Hand-painted magic lantern slide with a double slipping movement mechanism produced in 19th-century England (inv. PC3302/021,10 x 17 cm). © Portuguese Cinematheque – Museum of Cinema, Portugal (photographed by Ângela Santos) [45]

While these shows were completely overtaken by the adoption of motion pictures (cinema), they have their charm, as they rely on the artistic sense of the lanterns to weave the information contained in the slides. Magic lantern shows left an important mark on the history of visual entertainment, showcasing a blend of technology and imagination.

2.3 Museology

Museums have an important role in society as arks of cultural heritage, knowledge, and artistic expression. They are a link between the past and the present and offer their visitors the opportunity to explore and engage with aspects of human history and their art. Museums also have the important job of educating the public, as they are expected

to provide curated exhibitions that inform, inspire, and contribute to the enrichment of the visitors and they are spaces that promote dialogue and the understanding of other cultures and practices [17].

Museology or museum studies is the study of museums. It embraces the principles, theories, practices, curation, and management of museums. In summary, museums refer to the physical or virtual institutions that store artifacts and serve as places for community engagement [37, 29] while museology is the field that studies those institutions and guides their practices.

2.3.1 The evolution of museums

In the beginning, museums were private collections from individuals that were accessible to a small circle of people, limiting the dissemination of knowledge and culture, as only the *elite* could access those collections [30]. With the shift in mentality in the Renaissance public museums started to appear, to educate the public [14]. In the 19th century, museums had their golden age, as there was an increase in the number of museums. Until this point in time, museums were just displays of artifacts [49] and their categorization.

Community engagement has become a fundamental aspect of the role of today's museums, a departure from historical perspectives where museums were not traditionally viewed as key contributors to community life. A significant shift occurred in the 1972 UNESCO World Heritage Convention held in Santiago, Chile [19]. This event marked a turning point for the importance of cultural heritage, its protection globally, and the role that museums should play within the communities to which they belong. Even though it acknowledged the pivotal role and necessity of museums to protect cultural heritage it also brought up the need museums have to adapt to changing perspectives and address challenges like repatriation (the act of returning individuals' cultural artifacts, or human remains to their country or community of origin), cultural sensitivity, and inclusivity [58]. Museums need to be more transparent each passing day so that different voices can be heard and their opinions implemented so that there can be a promotion of community engagement and more ethical practices in the conservation of artifacts and their history.

Museums nowadays are expected to be dynamic and inclusive spaces that go beyond traditional exhibition models. Contemporary museums strive to respond to changes in society, embracing technology and new approaches to ensure accessibility, engagement, and cultural sensitivity [30].

2.3.2 Interactive Exhibits

Museums are a major source of public education outside of the schooling system [16], they are also a source of leisure and entertainment, and therefore there is a need to find a way to teach and entertain in the exhibitions of the museums.

With the advancement of technology, museums have created interactive exhibits to become more engaging and inclusive, as visitors are encouraged to explore the exhibits

through a more hands-on approach, while technology such as virtual reality adds a more immersive experience.

Not only is technology a way for museums to transform their experiences it also allows for them to be more accessible and enable the narratives to be more personalized and resonate with diverse audiences [50].

Interactive museums should not be confused with interactive exhibits, while both concepts are interconnected they refer to different sizes and extents of interactive learning experiences, each serving distinct purposes and covering various levels of detail. While the former encompasses an entire institution or facility dedicated to interactive and hands-on experiences, the latter refers to specific sections or displays within museums or other educational spaces that incorporate hands-on and participatory elements.

2.4 Summary

This chapter provides a concise overview of the essential areas of study pertinent to the development of this dissertation. The analysis of this chapter will allow to guide the solution proposal of this application.

Firstly, we explore the connection between cultural heritage and the digital world. The importance of cultural heritage, the connection between its intangible and tangible aspects, how their preservation is important and the problems that they face as well as how the digital world can have an enormous impact on their conservation and in changing the way museums exhibit their artifacts and how they interact with their visitors.

The focus goes on the historical importance of the magic lanterns, an early projection device that laid the foundation for modern projections and the cinema. The workings beyond the contraption and the type of slides that were used to be projected, how they could be divided into hand-painted, printed, and photography. The magic lantern shows were also addressed, as they could have many uses, for instance, to educate or to advertise something, and how they would normally be multi-sensory experiences because the images were accompanied by narration, music, or live performances.

Finally, the section related to museology highlights the importance of museums and their history as well as how interactive exhibitions play an important role in today's society to engage and entertain the public. Understanding museology is crucial for the development of the application in this dissertation, especially considering its intended use in museums. Recognizing that museums are no longer simply listing their artifacts and that they now are dynamic spaces that actively engage with their visitors. This knowledge shapes the foundation of the application highlighting how this application aligns seamlessly with the evolving practices of contemporary museums.

3

Related Work

In this chapter, there will be a focus on works that have concepts or functionalities similar to the ones that are to be developed in this dissertation.

There will be a highlight on some tools related to interactive learning and creativity (section 3.1), followed by drawing applications (section 3.2) and ending with digital interactive artwork (section 3.3).

3.1 Interactive Learning Tools

The integration of interactive learning tools into educational settings has gained attention due to their ability to enhance unser engagement and promote creativity [54]. These tools transform traditional learning into an active, hands-on experience, allowing learners to interact directly with the content. The shift from traditional learning methods to more interactive approaches is increasingly important, since there has been a growing necessity of integrating technology into education to enhance the learning experience [12].

The qualities of interactive tools, particularly the ability to experiment and iterate and to create a dynamic learning environment encourages learners to take risks, make mistakes, experiemnt, explore and grow. For instance, by using digital platforms, learners can refine their skills through trial and error, gaining confidence in their abilities while developing a deeper understanding of the subject matter. This process allows students to engage more actively with the content, fostering creativity and critical thinking as they navigate new challenges and discover innovative solutions.

In this context, two exapmles of interactive learning tools that have shown a significant impact in creative education are the I/O Brush and Osmo Monster. These tools exemplify the potential of interactive technology to engage users in artistic and musical exploration, providing a deeper understanding of creative processes while promoting critical skills such as experimentation, problem-solving, and innovation.

3.1.1 I/O Brush

The **I/O Brush** is an innovative interactive tool designed to combine traditional painting with digital technology, allowing users to create a digital artwork using patterns and colors from the real world.

This tool was developed at the **MIT Media Lab** [1] and resembles a traditional paintbrush the only difference is that this paintbrush is equiped with advanced sensors that capture textures, colors, and even mmotion from the real world, as seen in figure 3.1. The elements that were captured are then transferred to a digital canvas, where users can create unique and dynamic artworks [44].

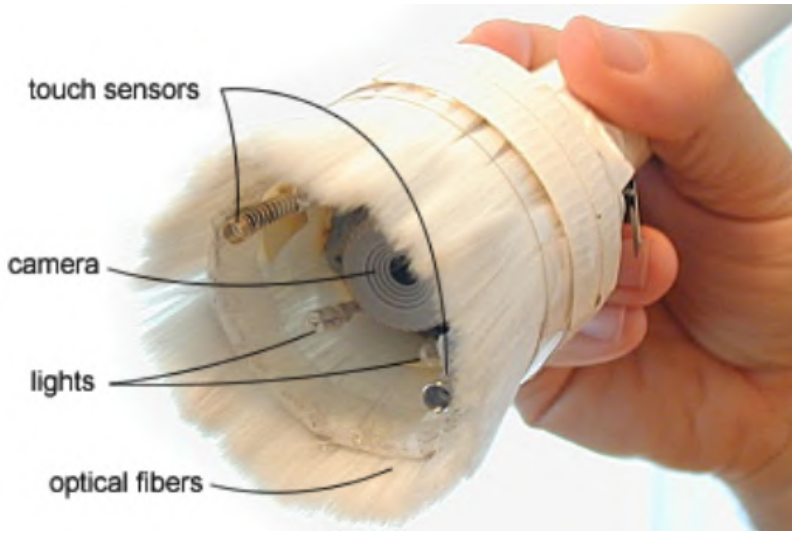


Figure 3.1: The I/O Brush tips [44]

The I/O Brush offers three distinct modes for picking up "ink": Texture, Color, and Movement.

- **Texture** - The brush captures a single snapshot of the brushed surface, creating an image that mimics the surface's appearance.
- **Color** - The most common RGB value of the captured frame is calculated so that the user can apint with a solid color.
- **Movement** - This is the most dynamic mode, as it records 30 consecutive frames of the brushed surface, and drops them in the digital canvas in a continuous loop.continuous loop.

For example, the user could use the brush to capture a blinking eye and use that "ink" to add expressive eyes to elements of their painting [44]. For a practical demonstration of the I/O Brush in action, see the video [2]

[1] MIT Media Lab https://www.media.mit.edu/research/?filter=groups_centers_initiatives Last accessed in December 2024

[2] I/O Brush https://www.youtube.com/watch?v=04v_v1gnyO8&t=0s Last accessed in December 2024

The I/O Brush has proven to be an interesting and fun learning tool, as children engaged with the objects and materials around them to create their painting. Through these exploration process they discussed about design elements and principles, such as color, texture, and movement, allowing them to connect with abstract concepts in a meaningful way [44].

3.1.2 Osmo Monster

Osmo Monster is an interactive educational tool created by **Osmo** [3], a company known for combining physical play with the digital world to create an unique learning experience for children. Their innovative approach has resulted in a range of award-winning products that encourage creativity, problem-solving, and hands-on learning [55].

Osmo Monster is a tool that transforms children's drawings into lively digital animations, and works with the help of the Osmo base and reflector, which are attached to a tablet, as seen in figure 3.2. These components allow the system to "see" and "bring" the drawings made by the children into the digital world.

The tool engages children in a variety of creative activities, from drawing celestial objects to decorating a house. These activities encourage children to think creatively and express themselves.

Figure 3.2: Osmo starter kit

How does it work? Children draw on a physical surface (it can be on the pad of the kit or on a paper), and then the animated character "Mo" (the monster) interacts with the drawings in real-time. For example, if a child draws a rocket ship, *Mo* will "pick it up" and interact with it, as seen in figure 3.3.

[3]Osmo https://www.playosmo.com/en-US/ Last accessed in December 2024

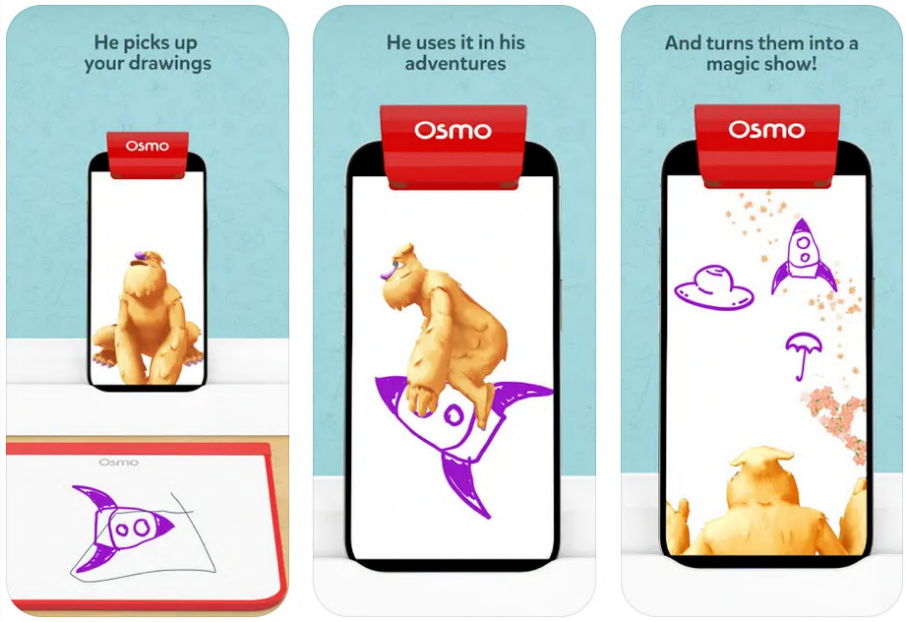


Figure 3.3: Example of an interaction with *Mo*

3.2 Drawing Applications

Drawing has served as a means of expression, allowing humans to convey emotions, share ideas, and communicate information across linguistic barriers, an example of this is the cave and rock paintings created by the caveman, some of those exposed how to hunt an animal in group or represented the animals and rituals present in those times.

There are multiple fields where drawing makes an impact, some are easy to understand, like architecture others have a more subtle influence like medicine [41]. Archeology is a field that often uses detailed drawings to record locations, structures, and artifacts, not only do these drawings serve as a visual record to the archeologists they also aid in the communication between the public and other experts [60].

With the change of the times, and the evolution of technology, drawing stopped being only done on paper, nowadays numerous apps let their users draw on their phones or tablets to express themselves. It is important to notice that different age groups may have different preferences about what a drawing app may offer, talking specifically about children, in [59] it was seen that pencils more colorful appealed to very young children (ages three) while features like zoom or undo where a hit to the children aged twelve.

Drawing can be an essential tool to help visualize and organize ideas, as well as to facilitate the processing of information, especially when applied to children, as highlighted by [5]. Therefore creating applications that integrate drawing with interactive learning can engage users while teaching them valuable concepts, an example of this cn be explored in subsection 3.2.2.

3.2.1 Microsoft Paint

Microsoft Paint [4] is one of the earliest and most widely recognized digital painting tools. It was introduced in 1985 with the release of the first Microsoft Windows [56], in the beginning, it was called *Microsoft Paintbrush*, and it wasn't until Windows 2.0 that the name changed to *Microsoft Paint*, commonly referred to as *MS Paint* [57].

As previously said, this graphics editing program that offers basic tools such as brushes, shapes, and a color palette, enabling its users to create and edit images with ease, was developed by Microsoft [5]. The simplicity of its design allowed it to be accessible to users of different ages and different levels of skill.

This program has undergone several updates through the years, as a means to keep up with the times and still stay relevant even as more advanced digital art tools have become available. Even with all those improvements *Microsoft Paint* was able to keep the key to its success - its simplicity, this can be observed in the figure 3.4 where the image of the same program can be seen, one from 1987 [32] and the other from 2024.

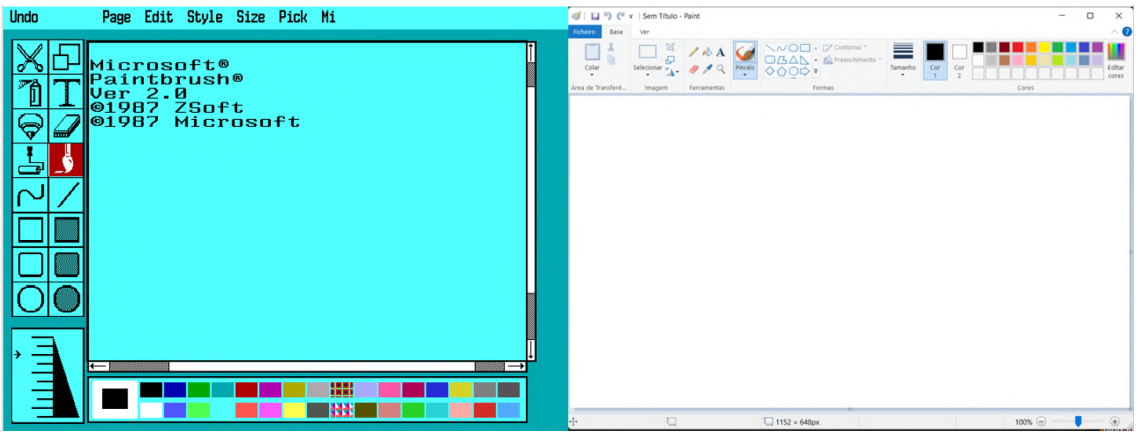


Figure 3.4: The left image is a screenshot of the *Microsoft Paintbrush* 2.0 taken from [32] and the right picture is a screenshot of the *Microsoft Paint*

One of the significant limitations of *Microsoft Paint* is its lack of advanced features that allow for more complex image editing and digital painting, for example, it doesn't support layers. Another limitation is the finite color and brush options that it gives to its users, restraining their creativity.

Despite its limitations, *Microsoft Paint* has remained popular for quick and easy image editing and creation, playing a significant role in the history of digital art tools and in influencing artists [31].

[4]Microsoft Paint https://www.devx.com/terms/microsoft-paint/ Last accessed in August 2024
[5]Microsoft https://www.microsoft.com/en-gb Last accessed in September 2024

3.2.2 Draw and Tell

Draw and Tell [9] is an interactive drawing and coloring application designed for children, it was developed by *Duck Duck Moose* [6], a subsidiary of the nonprofit *Khan Academy* [7].

This application is specifically made for children, as such its interface is simple and intuitive, it has large icons and it is intuitive how to use the features that the application provides, as seen inn figure 3.5 ensuring that the children can use the application independently.

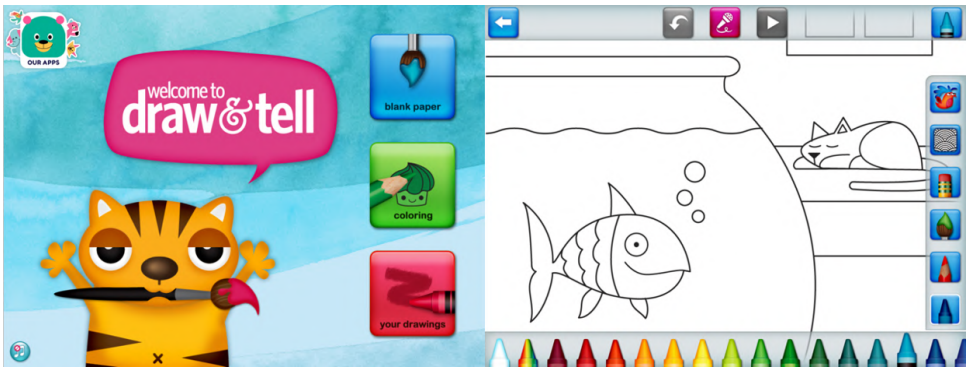


Figure 3.5: Left image is a screenshot of *Draw and Tell*'s home screen and the right image is one of the coloring pages with the features available displayed

Draw and Tell offers three main features that encourage creativity and storytelling. The first is **Draw: Be Creative**, with the painting tools that the application provides as well as a wide array of colors and more than 150 stickers the children can be as creative as they want. Secondly **Tell: Create a Story**, it is possible for the user to tell a story with their drawing while moving the stickers as they talk. And finally **COLOR SHARE: Save a Memory**, the user can also color pages, save and share their colored drawings with records with their friends [9].

3.3 Digital Interactive Artwork

In recent years, the number of artworks that rely on technology has been rising, this rise is a result of the advances that computer technology has accomplished that have made these kinds of tools more accessible and available to artists and creators. The intersection of these two fields - technology and art - has picked the interest of numerous artists and museums. Therefore more and more artists-technologists collaborations are taking place [2].

As art changes, the way works of art are displayed needs to change as well. Cultural institutions have been forced to adapt to the modern world and the expectations and needs of the public. On that account, the culture industry has focused on applications designed with user experience in mind [23].

[6]Duck Duck Moose `https://www.duckduckmoose.com/about/` Last accessed in August 2024
[7]Khan Academy `https://www.khanacademy.org/` Last accessed in August 2024

"Digital interactive artwork", also known as "Interactive digital art", is a genre of artwork where technology plays a crucial part in the creation and presentation of the art. This type of artwork combines the digital part - where technology is used as an integral part of the creative or presentation process and interactive art, which engages the audience in a way that allows the art to be perceived with the impact intended [2].

Understanding the environment in which this dissertation project belongs is essential to effectively navigate the existing knowledge and meaningfully contribute to its field. As this project aims to be utilized within a museum setting, it is important to explore how these institutions use interactive digital installations, such as those exemplified by Sketch Aquarium (3.3.1) and Sketch Piston - Playing Music (3.3.2), are used to engage diverse audiences. These installations demonstrate how combining technology with art can create immersive, interactive, and engaging experiences.

3.3.1 Sketch Aquarium

Sketch Aquarium is an interactive art installation created by teamLab Kids [8], a Japanese art collective that wants to achieve a balance between science, technology, and art. This group has innovated the world of art, as by using a combination of traditional artistic mediums (in this case drawing and painting) and cutting-edge technology it has allowed artwork to transcend static forms. teamLab's ultimate vision is that this type of 21st-century art not only exists independently but also actively involves viewers, enabling them to become an integral part of the artwork [20].

Figure 3.6: Photo from Sketch Aquarium [51]

Sketch Aquarium consists of a digital aquarium that comes to life as the creatures drawn by viewers come to life and interact with each other in a vibrant underwater environment, as seen in figure 3.6.

This project was created so that children can observe the power of their creative imagination, as well as interact with their artwork because they can feed the fish when

[8] teamLab Kids https://futurepark.teamlab.art/en/ Last accessed in January 2024

touching the virtual food bag or touch the fish and see them swim away [20, 51].

How does this art piece work? Each participant is given the chance to color a drawing of a sea creature of their choice, as seen in the left photo in figure 3.7. Once the sea creature is completed, the drawing will be scanned, similar to what is seen in the right photo of figure 3.7, and in a few moments the drawing will come to life and start swimming in the digital aquarium [20, 51].

Figure 3.7: Photos from Sketch Aquarium [51]

There are various installations like Sketch Aquarium in museums throughout the world, and there are other ways to use this technology without it having to be related to aquariums and sea creatures, an example of that is Sketch Flight [9] where instead of marine life the audience draws butterflies, hawk or airplanes and controls them with a tablet or phone after they are scanned.

3.3.2 Sketch Piston - Playing Music

Similar to Sketch Aquarium, Sketch Piston - Playing Music, a creation of teamLab Kids, is an interactive art installation that instead of letting its participants bring life to a sea creature and then interact with it in the aquarium, enables the user to create their own music by following the laws of mechanics.

In figure 3.8 there can be seen two children playing with the exhibition, there can be found lines and stamps, which are what will produce sound when they interact. That sound will vary following the laws of mechanics such as the law of inertia, the law of motion as well as the law of action and reaction, for example, if two stamps collide with one another they will have different sounds - the same applies if the stamps collide with the lines.

How to create music? Select the flowers and stars on the display by touching them, play music by drawing on the screen with a finger - the musical scale played on a line depends on the height where it is drawn, choose from the stamps shown on the display, and place it into the world of the canvas. More than one visitor can be creating music, transforming it into a collaborative and dynamic experience.

[9] Sketch Flight https://www.teamlab.art/pt/ew/sketchflight_asm/artsciencemuseum Last accessed in January 2024

Figure 3.8: Photo from Sketch Piston [52]

3.4 Summary

This chapter references numerous games, projects, and applications that are pertinent to this dissertation project, which merits analysis. They are not only valuable for establishing the contextual background but also for offering potential insights into potential solutions for challenges that may arise.

It was established in section 3.1 through subsection 3.1.1 and subsection 3.1.2 that interactive tools and their ability to merge the experiences in the real world with the digital one, foster creativity and critical thinking, while providing a hands-on experience.

Concerning drawing applications, as seen in section 3.2, in the context of this dissertation, as *Microsoft Paint* and *Draw and Tell* reveal important insights into user interaction and creative possibilities in digital art, the proposed web application seeks to integrate the strengths of these applications to offer a simple and engaging application for its users.

In section 3.3, the digital interactive artworks there discussed emerge as an important element of this dissertation project. This significance is caused by how similar the installations are with the project, they all use the creations of their users to create a dynamic and immersive experience. By letting people create their art, these installations mix personal creativity with technology, just like what this project aims to do, let users paint their slides and then bring their drawings to life by creating a magic lantern show with their creations.

In subsection 3.3.1 and subsection 3.3.2 examples of how art and painting can interact with technology as well as how to make the passing of information something fun, not only for children but also for adults.

4

Design and Implementation

As previously stated in chapter 1, this dissertation focuses on the development of an application designed to enhance exhibitions centered on magic lanterns by offering a more interactive and engaging experience for visitors. The application allows users to immerse themselves in the creative process of crafting their own magic lantern slides, not only entertaining them but also fostering a deeper connection with magic lanterns. This chapter provides an overview of the decisions made concerning the design (4.1) and implementation (4.2) of this project.

Additionally, this chapter also explores the aspects of the application that are not central to the main functionalities but were incorporated to enhance engagement and add an element of fun. For those interested, the most recent version of the web application can be found here [1]

4.1 Design

The application is a web-based platform created to captivate museum visitors by letting them make their own magic lantern slides and experience animations that bring them to life, offering a glimpse into the historical process of magic lantern shows. The application comprises three main pages: the Home page, the slide selection page, and the painting page. Each of these pages is designed to guide users smoothly through the experience.

The design of these pages was centered on making them as intuitive and engaging as possible, to ensure that regardless of the age or skill level of the users they still could effortlessly navigate through the application and have a fun experience during the process. By creating a straightforward interface, the visitors can easily follow the necessary steps to develop their personalized magic slides.

A navigation bar is present at the top of each page, enhancing usability and providing access to key sections of the application. This navigation bar allows users to return to the Home Page, by clicking the image that is in the top left corner of the navigation bar, switch

[1]Mágica- Ciência e Espetáculo https://ridsilva.github.io/LanternaMagica/ Last accessed in December 2024

the display language between Portuguese and English, or access the MAGICA project page [2].

4.1.1 Home Page

The Home Page serves as the entry point to the application, creating the first impression for the users. Upon arriving at this page, users are welcomed by an animation that occupies most of the screen, along with a section at the bottom where the project collaborators are displayed.

The animation features the MAGICA project icon, a white magic lantern, positioned on the left side of the page, as shown in figure 4.1. The lantern appears to project an image of a little man who moves his eyes and has an open book on his hands, the book covering his whole body, only showing his feet. On one of the book's pages is the "Start" button, inviting users to begin their journey.

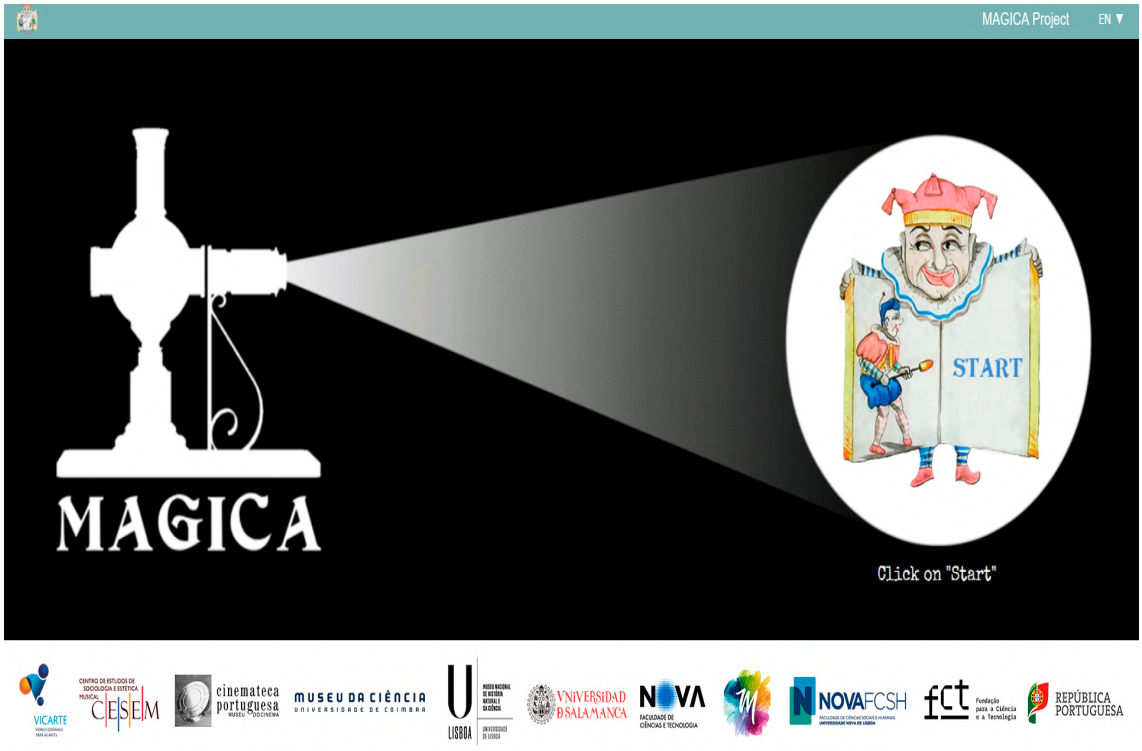


Figure 4.1: Screenshot of the Home Page of the application

Key elements on the Home Page:

- **Start button** - A clear thing that leads users to the second page of the application.
- **Collaborators** - There is a section where the user can see all the collaborators of this project, this section is located at the bottom of the page.

[2]MAGICA project, urlhttps://www.magica-project.com/ Last accessed September

- **Navigation Bar** - A navigation bar at the top of the page allowing users to quickly return to the Home Page, visit the MAGICA project page or change the language displyed on the page.

4.1.2 Slide Selection Page

After clicking on "Start", users are directed to the second page of the application. This page is divided into two parts, as seen in figure 4.2. The left section explains how the user should behave to go to the next page, while the right section is the collection of pre-defined images that the user can choose to paint.

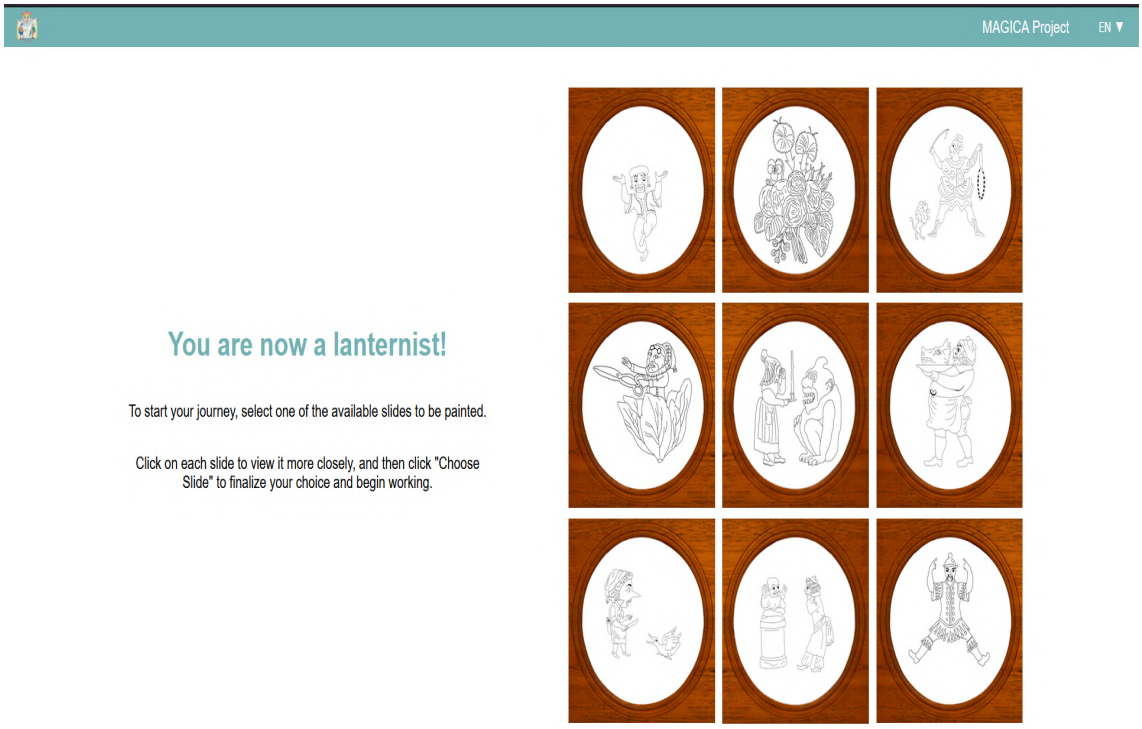


Figure 4.2: Screenshot of the Second Page of the application

These images are inspired by hand-painted slides that were originally used in magic lanterns. The slides that served as models for these images came from three different collections: the National Museum of Natural History and Science (MUHNAC), the Science Museum of the University of Coimbra (MCUC), and the Cinemateca Portuguesa - Cinema Museum. Each collection contributed with three images, making a total of nine images available for users to select from.

All the images are shown upfront, providing users with an overview of what is available. When a user decides to examine an image more closely, they can click on it and a preview of the animation that can be expected can be seen. This interaction is illustrated in figure 4.3, in this particular example, the colors that the user uses to customize the slide will be inverted.

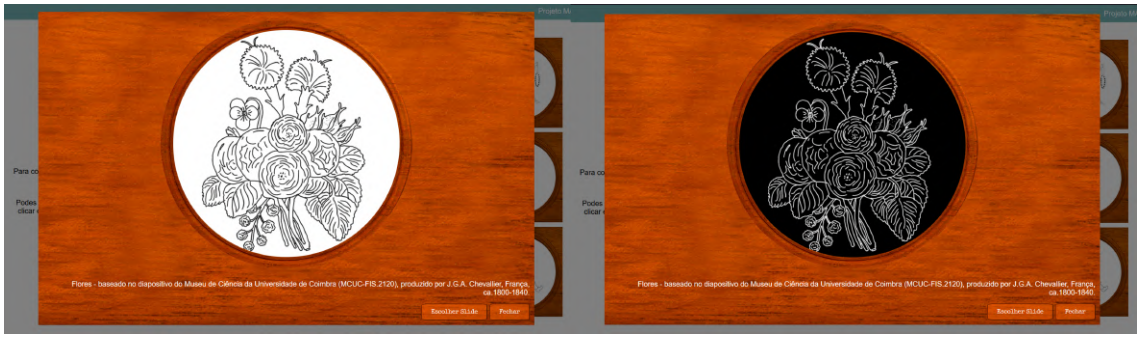


Figure 4.3: Screenshot of selection PopUp of the second slide. On the left is the image that the user can personalize, on the rigth the transformation that will be applied on that image

The design of the second page focuses on accessibility and simplicity:

- **Image Gallery** - A gallery that allows users to see every image that is available to help them make their selection.
- **PopUp for each image** - Users can click on any image to see it in detail, along with a preview of the animation that will occur.
- **Historical Accuracy** - Special care was taken to ensure that the images are as historically accurate as possible.
- **Immersive Experience** - The design of the image collection and the PopUp aims to replicate the framing of magic lantern slides, enhancing the user's sense of immersion.
- **Navigation Bar** - Similar to the Home Page, the navigation bar remains at the top, allowing users to return to the Home Page, change the language of the page, or visit the MAGICA project page at any time.

4.1.3 Painting Page

Once an image is selected, the user is taken to the third page of the application. This is the core interactive component of the application, seeing as it's on this page that the users can modify and customize the image that they selected.

The interface on the third page, as shown in figure 4.4, is designed to be user-friendly, offering a variety of tools, colors, and actions.

To preserve the historical accuracy of the experience, the color palettes provided to the users are those that were used to paint the traditional magic lantern slides, those palettes can be seen in figure 4.4 on the top left corner of the wood surface. Users can only use one palette to paint the image, and if they choose to switch palettes midway through, all progress will be lost, requiring them to start over. This design choice was made to replicate the experience of the craftsmen who originally painted these slides.

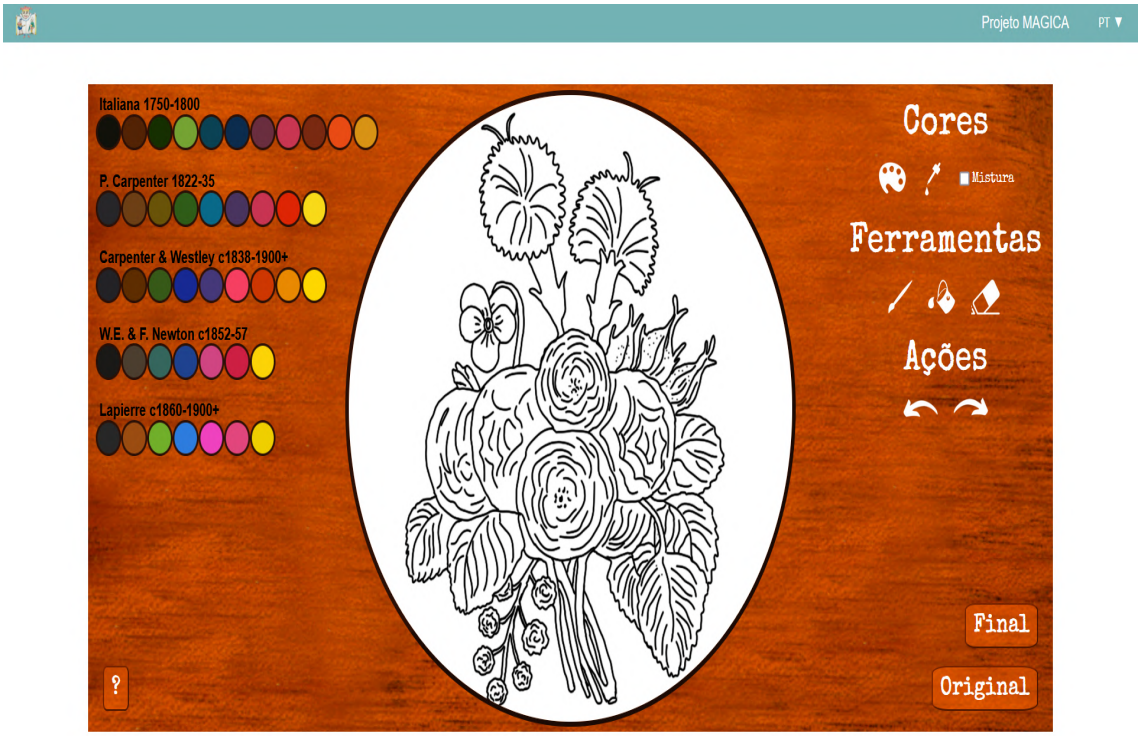


Figure 4.4: Screenshot of the Painting Page with the flower image

Once the image has been customized, the user can click on "Final" to see the animation of the slide that they created. They can also click on "Original" to see the transformation of the slide that the image that the user chose was modeled after or in "?" if they have any doubt about the functionalities of the application, these last two buttons can be clicked at any time.

The third page is designed with both creativity and simplicity in mind:

- **Historical Accuracy** - A selection of historically accurate color palettes are available for the user to choose from and the user can see the transformation of the slide that the image was modeled after.
- **Customization Options** - The user can freely paint the image, encouraging creative exploration.
- **Animation** - After customizing the image the user proceeds to animate it.
- **Navigation Bar** - The navigation bar is still available on the third page of the application and its function has not changed.

4.2 Implementation

To build this system, its environment, elements, and functionalities had to be implemented.

This stage focused on selecting the right technologies, revising and improving the code, and addressing any emerging problems to ensure the final product was accessible, historically accurate, and interesting. Achieving this required careful attention to both the resources, such as the images available for the users to paint and the historically precise color palettes, and the technical aspects, including image manipulation and how animation is handled. The following sections provide an overview of the technologies used and outline the application's development journey.

4.2.1 Technologies

A combination of standard web technologies, including Javascript, HTML and CSS, and several supplementary tools, such as p5.js, Mixbox, and Github Pages, were employed to support this application's functionality and facilitate its deployment.

4.2.1.1 Javascript

Javascript [21] is the programming language that is responsible for the interactive features of this application. As a versatile, high-level language, it is widely used to add interactivity to web pages [39], allowing for real-time updates and responsive user experiences directly within the browsers.

Due to its event-driven architecture, it can handle user actions like key presses, clicks, and scrolling, making it ideal for creating responsive and interactive web applications like the one developed in this dissertation.

Moreover, Javascript has a broad ecosystem that includes numerous libraries and frameworks that expand its capabilities, making it a dominant language in modern web development.

4.2.1.2 HTML and CSS

HTML (HyperText Markup Language) [18] and CSS (Cascading Style Sheets) [7] work together to create the design and layout of the web pages.

HTML is the standard markup language used to structure content on the web by defining elements such as headings, links, and images. It provides the fundamental building blocks that define the layout and content of a webpage. On the other hand, CSS is responsible for the visual presentation of that content, allowing developers to style HTML elements as they want, changing their colors, fonts, spacing, and positioning [40]. Together they are the "bones and skin" of web pages.

4.2.1.3 GitHub Pages

Github Pages is a static site hosting service provided by GitHub that allows developers to publish their web projects directly from a GitHub repository [13]. By linking a Github repository to a Github Pages, developers can quickly deploy changes and updates, have

version control of the website, make it easy to collaborate with others, and revert to previous versions if necessary.

4.2.1.4 p5.js

p5.js is an open-source JavaScript library designed to make creative coding accessible for artists, designers, educators, and beginners [38]. It supports audio-visual, interactive, and experimental works for the web, is accessible in many languages, and has expansive documentation with visual examples.

One of the most valuable aspects of p5.js is its supportive community. Whether the user has experience with the library or is a novice, there is a wealth of resources to benefit from, such as forums, guides, and tutorials. Additionally, the built-in web editor allows users to write, test, and share their code directly from their browser, making it convenient to get started without needing to install any software.

4.2.1.5 Mixbox

Mixbox is a Javascript library that specializes in paint-like color mixing [33]. It provides tools for smooth color transitions, blending colors, and adjusting color properties such as brightness, contrast, and saturation.

This library is useful for applications that require color interactions, as it ensures that color mixing behaves similarly to how pigments mix in real life, rather than relying on basic digital color algorithms. This creates a more authentic experience for users engaged in creative tasks, like digital painting or color customization.

4.2.2 Resources

A variety of resources were required to develop this application, some were custom-made while others externally sourced. Custom-made resources include the images to embellish the application, the images users can paint, and the masks and outlines necessary for facilitating seamless transformations. Additionally, GIFs were created to show a preview of the transformations applied to these images, alongside with GIFs illustrating the original transformations of the magic lantern slides.

On the other hand, externally sourced resources encompassed icons, logos, and base images that were later modified in Photoshop, all acquired with strict adherence to copyright regulations.

The icons, for example, were obtained from Canva and resized to fit the overall design. Most of these icons were simple and intuitive: the eraser icon was used for erasing what the user painted, the bucket for filling, the palette for selecting colors, etc. Meanwhile, the decorative elements, such as the wooden frames used to display the slides, were created by applying Photoshop to pre-existing images of the actual frames. Similarly, the GIF on the home page was also developed using Photoshop, where four different images were

produced, two in Portuguese and two in English. In each language, one version featured the character's eyes looking to the left, while the other had the eyes looking to the right, an example of these images can be seen in figure 4.5 and 4.6.

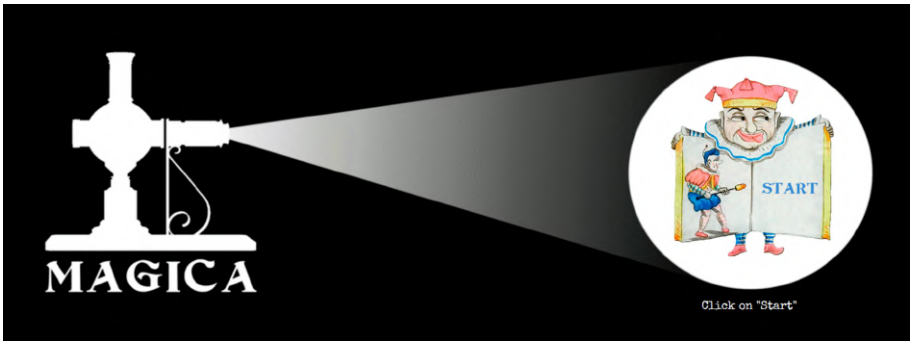


Figure 4.5: Home page image (English version) – character's eyes looking to the right

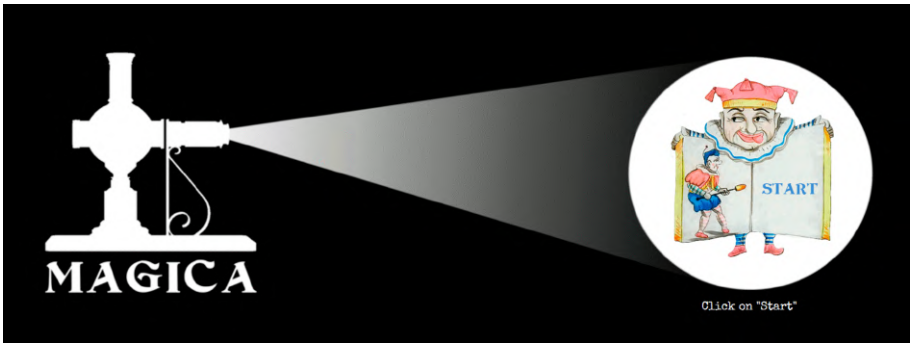


Figure 4.6: Home page image (English version) – character's eyes looking to the left

A very important part of this application is the set of images that users can paint, which can be found in the appendix A. These images, as already stated, are based on nine slides sourced from three different collections: the National Museum of Natural History and Science (MUHNAC), the Science Museum of the University of Coimbra (MCUC), and the Cinemateca Portuguesa - Ciname Museum. The slides were selected from the animations that they provide, such as disappearing elements, color changes, or movements of body parts.

Some of the images available for the users to paint were modified to allow seamless transformations. Since the goal of the application is for users to paint an image that will then suffer a transformation it is essential that these images include all necessary elements to facilitate a smooth and coherent transition.

For example, in one magic lantern slide, a genie is initially shown holding its head in his hands, in the next moment, the genie's head is separated from his body and its hands are no longer near its face, as seen in the figure 4.7.

(a) Initial frame (b) Final frame

Figure 4.7: Illustration of the transformation sequence of the genie from the original magic lantern slide

For this transformation to be possible, the image that the users paint omits the genie's hands grabbing the head, ensuring that when the transformation is applied, only the head moves without taking the hands with it, as illustrated in figure 4.8.

Figure 4.8: Image created for the user to paint

These careful adaptations were crucial for achieving a smooth and visually coherent transformation. By removing elements and changing elements that would interfere with the intended animation effect, the application ensures that the transition between images is similar to the magic lantern slides while still making and maintaining engaging animated sequences.

Lastly, the color palettes used in the application represent another important resource. Thanks to the contributions of the MAGICA project members, who provided both the names of the palettes available at the time and verified the accuracy of the colors, users have access to a historically authentic painting experience.

4.2.3 Development Process

The development process of this application followed an iterative approach, allowing for step-by-step construction, continuous testing, and ongoing refinements throughout each phase.

At the start, brainstorming sessions were crucial for defining the core features of the application. The goal was to create a user-friendly design that delivered a unique and captivating experience. This early stage established a clear direction for the subsequent development.

Once the core ideas were established, the prototype was built to bring those concepts to life. This prototype was essential for testing the feasibility of the design choices and identifying areas that needed improvement. It provided a tangible application version, enabling valuable evaluations and user feedback.

The process then moved into a phase of rigorous testing and refinement. Multiple tests were conducted to evaluate the application's functionality, while user feedback was gathered and analyzed. Adjustments were made based on this feedback, allowing for the resolution of issues and the enhancement and creation of some features.

Finally, the development process concluded with a final iteration. This iteration ensured that the application met its objectives in terms of functionality, usability, and user engagement, delivering a polished and effective final product.

4.2.3.1 Initial Planning

The initial planning phase was the foundation of the application, as it was decided in this phase the core features and constraints. The main goal was to create an application where users could paint on images resembling magic lantern slides, which would then be animated to simulate the shows that those slides created. This concept aimed to combine interactivity with historical content.

The features established during this phase were: users needed to be able to paint on the digital canvas, and the painted images should be animated. To refine these features, several brainstorming sessions were conducted, including discussions with members of the MAGICA project. In those discussions, the point was made for the application to try to closely replicate the appearance and experience of hand-painted magic lantern slides, while still allowing for user flexibility. Therefore, a requirement was set for the color palettes to be historically accurate.

Additionally MAGICA project set requirements to ensure that the application sticked closely to the historical context. Since the application was going to replicate the painting process of magic lantern slides, a key decision was to limit the user to using only one palette per image. If the user chose a different palette mid-painting, the image would be cleared of color, and the user would have to start from the beggining. This decision was made to mirror the conditions faced by the original painters, who did not have access to different palettes and could not switch between them while painting.

Another design choice was to ensure that the transformations applied to the slides that the users created closely replicated the transformations used in the shows produced by the original slides, on which the images available for users to paint were based. For example, if a magic lantern slide featured an image of a tree, and the application offered the same image for the user to paint. If, in the original show, the tree appeared and disappeared as part of the performance, the applicaton would try to replicate that effect. If it wasn't possible to exactly reproduce the transformation,the application would generate the closest possible effect to the original.

Research was conducted to identify appropriate color palettes, leading to the creation of initial palette designs based on historical data. Five manufacturers were identified: three from Great Britain—P. Carpenter (c. 1822-35), Carpenter & Westley (c. 1838-1900+), and W.E. & F. Newton (c. 1852-57)—one from France, Lapierre (c. 1860-1900+), and one from Italy, whose details remain unknown (c. 1750-1800). An example of a traditional palette and the newly created palette can be found in figure 4.9.

(a) Traditional color palette from Lapierre (b) Newly created color palette

Figure 4.9: Comparison between Traditional and Newly Created Color Palette

Additionally, five images that the users could choose from to paint were created, each representing a different type of transformation. These images can be found in B. These images served as simple drafts to facilitate the testing of various animations and assess the application's capability to achieve those transformations. For example, in the image depicted in figure 4.10, the intended animation involved a man opening and closing his mouth, with a mouse appearing only when his mouth was open.

However, including the mouse in the image the user would paint posed a challenge: if the mouse were to disappear and reappear, it would create gaps in the image, resulting in white spaces when the mouse was not visible. Similarly, attempting to animate the man's jaw closing would lead to parts of the image vanishing during the transition, this case is illustrated in figure 4.11, where the red area disappears. Since the goal was to closely replicate the transformations of the original magic lantern slide, these issues rendered the image unsuitable for animation.

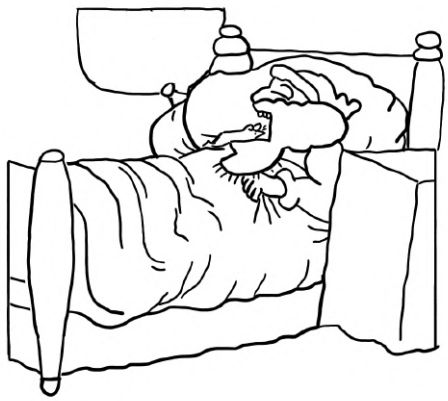
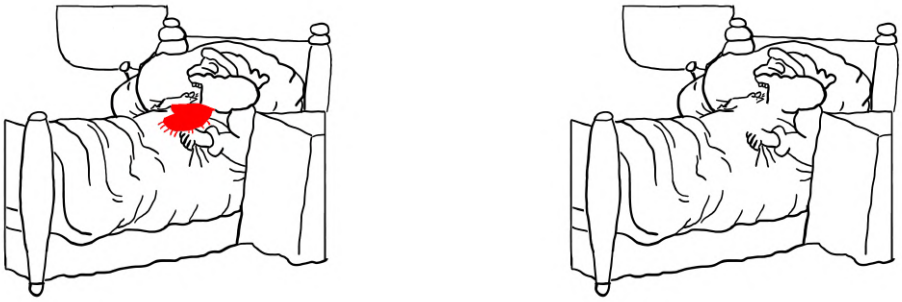


Figure 4.10: Draft image of the Sleeping man and the mouse



(a) The image with the red area visible (b) The same scene with the red area removed

Figure 4.11: Illustration of the animation challenge

The development of the basic functionalities of the application, particularly the implementation of the fill tool, posed a challenge. While the drawing and erasing functionalities were simple to implement because of the use of the p5.js library, the fill tool required more exploration.

Two approaches were considered for implementing the fill tool: masks and the flood fill algorithm. The first involved the use of masks to control which areas of the image would be filled while the other made use of the algorithm.

The mask approach involved creating a separate "mask" layer where the mask would control if the fill tool can apply color in the digital image. In this method, white or transparent areas of the mask represent regions that can be filled with color, while black areas block the color from spreading.

For this method to work, the mask needs to match perfectly with the image, pixel-by-pixel. While this approach offers precision, especially when dealing with complex shapes because the mask ensures that the color doesn't go beyond the intended boundaries, it comes with several challenges.

One is that it's time-consuming. Each image requires separate masks for each distinct region, as illustrated in figure 4.12, where different colors represent the different masks

needed for a single image, in total sixteen colors were used. Managing and maintaining these masks is also labor-intensive.

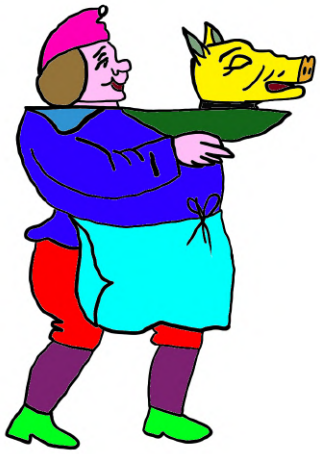


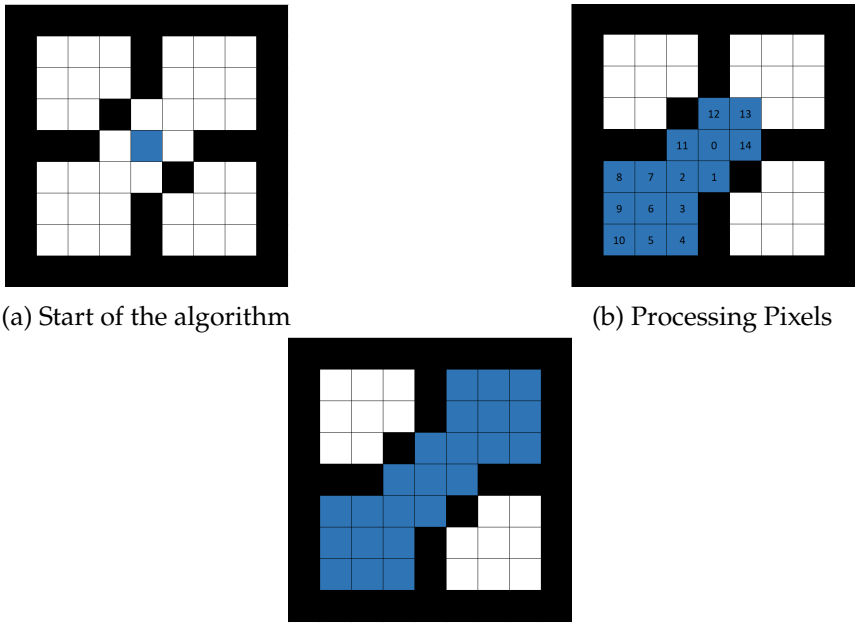
Figure 4.12: Illustration of the color-coded masks required for a single image, with each color representing a distinct region of the image.

Another issue is that when the user attempts to fill an area along the boundary of two different masked zones, for example clicking on the line of the image, it can result in unintended outcomes, such as incomplete fills or color spilling into the wrong areas.

Performance is also a concern, seeing as each mask is essentially its own image file and an individual image needs multiple masks, the number of files needed to be stored, loaded, and managed increases. When a user accesses the web application, they have to download all the mask files along with the main images and all other images needed for the application, which can severely slow down performance. Plus, GitHub Pages isn't designed to handle large amounts of data efficiently.

While the mask method is precise, is too complex and demanding to be practical for this project.

The alternative approach considered was the flood fill algorithm, with the recursive method being chosen because of its simplicity and ease of implementation. The recursive flood fill starts at a specific pixel and spreads out to fill all neighboring pixels of the same color by calling itself repeatedly, as illustrated in figure 4.13.



(a) Start of the algorithm

(b) Processing Pixels

(c) Final result

Figure 4.13: Illustration of the recursive flood fill with 4 directions

While a scanline flood fill could potentially improve performance for larger fill areas, the improvement it offers isn't significant, so the recursive flood fill algorithm is sufficient.

The simplicity and clarity of the recursive flood fill algorithm allowed for quicker implementation and easier maintenance without sacrificing functionality.

Overall, while the recursive method may have its challenges, it is very suitable for the project.

The images and palettes developed during the draft phase of this project are documented in appendix B.

4.2.3.2 The Prototype

After the core ideas were established and a draft of the application was developed, the next step of the iteration was creating a prototype. The prototype played an important role in refining the design and structure, as well as testing the application's functionalities. It provided a working version that enabled user testing and feedback.

During the prototype stage, an important focus was on the design of the application's interface. A meeting with a designer helped shape the visual direction of the application, offering clear insights into crafting the user experience. Figure 4.14 illustrates one of those mockups.

The meeting with the designer was very valuable, as it highlighted overlooked aspects of the interface. For example, instead of placing the pencil size option in a separate location, it was suggested that it should only appear when the pencil or eraser icon is selected, as illustrated in figure 4.14.

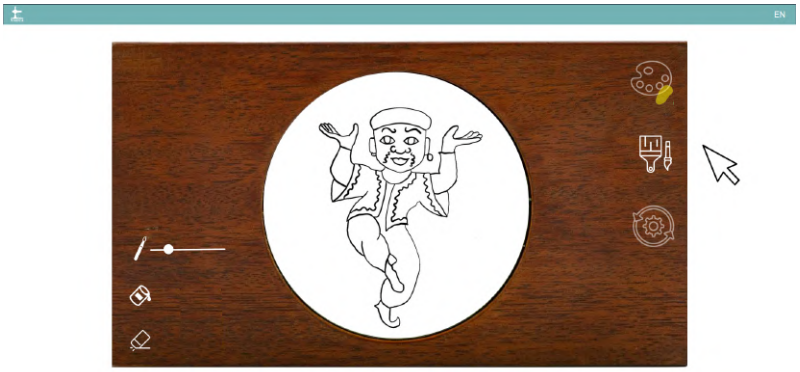
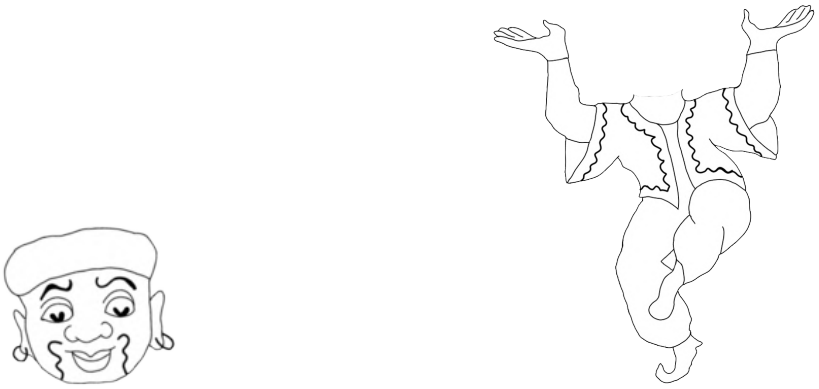


Figure 4.14: Design Mockup of the application when the Tools are selected

Another focus during this phase was selecting the magic lantern slides that would serve as the basis for the images available to the users to choose from in the application. It was decided to base the images on three slides from three different collections, with two collections sourced from museums collaborating with the MAGICA project for their magic lantern exhibitions. However, by the end of the prototype phase, not all images had their transformations implemented and thus could not be animated, as the preparation for those images was still in progress.

For the application to function correctly, each image requires three elements: the image that the users paint, an outline-only version of the previous image to ensure that even if the user painted over the lines, those would be restored, and specific masks for transformations to save the user's creation and transform it. Figure 4.15 illustrates the masks needed for the Genie.



(a) Mask of the head (b) Mask of the body

Figure 4.15: Masks needed for the Genie to be animated

The MAGICA project team proposed in a meeting that the application should allow its users to mix colors, seeing as many tones found in traditional magic lantern slides were achieved through the mixing of colors of the painter's palette. Adding this element to the application would enhance user immersion and provide a bigger range of color options

for creativity.

Color mixing became a challenge during the development of the application, primarily due to the differences between how colors blend in the real world versus how they are represented and mixed digitally. In the real world, colors follow the subtractive color mixing theory of pigments, where each pigment absorbs specific wavelengths of light and reflects others [34]. This means that when blue and yellow are mixed, for example, the result is green because the pigments absorb all other wavelengths and only reflect the ones that combine to form the green color [34]. This natural interaction is difficult to replicate in a digital environment.

Initially, the application implemented the RGB color model, which is based on the additive color mixing theory. Additive color mixing involves combining different colors of light, more specifically red (R), green (G), and blue (B), to produce new colors [1]. When all three colors are combined at full intensity, they create white light. However, this approach proved unsuccessful in simulating pigment mixing. For example, mixing yellow and blue in the RGB model did not produce green but instead resulted in a dull grey, which showed the limitations of additive mixing in this context.

Later, the CMYK (Cyan, Magenta, Yellow, Black) color model was explored, as it follows subtractive color mixing [1], as it follows how pigments behave in the real world. The process involved switching from RGB to CMYK for mixing and then converting back to RGB. And, while CMYK allowed the application to become closer to mimicking how pigments blend in the real world, the results were still unsatisfactorily. The colors produced in the application lacked the vivacity needed for a realistic painting experience. The mixed colors appeared muted and lifeless, undermining the goal of providing users with a realistic and engaging color palette.

Eventually, the search for an effective method to blend colors in the application while still maintaining the vibrancy and brightness expected led to the discovery of the Mixbox library. This library offers a more accurate simulation of pigment mixing, capturing the nuances of how physical colors combine [53]. It uses the Kubelka-Munk (K-M) theory, that predicts hoe pigments absorb and scatter light.

Instead of simply blending RGB colors, Mixbox decomposes each of those colors into a mix of primary pigments, like Titanium White and Hansa Yellow. Once those pigments are belnded, the result is converted back to RGB format [53]. By using this library, the application was able to produce richer, more dynamic colors, closely mimicking the depth and liveliness of real-world pigment blending.

Finally, the prototype underwent preliminary testing with 10 participants to identify areas for improvement and validate design decisions and is documented in 5.1.

4.2.3.3 Final Version

The development of the application reached its final version following a comprehensive testing phase, where the preliminary, during which the preliminary tests were conducted.

This process pointed out specific areas that needed improvement based on user feedback from the prototype [3]. Some of those improvements included the addition of the undo and redo actions, which significantly enhanced user experience.

To implement these functionalities, a *MyStack* class was created. This class is used to manage the undo and redo actions efficiently. It has two main stacks: one for storing the previous actions (the *undo stack*) and another to save the actions that are undone (*the redo stack*), as seen in figure 4.16.

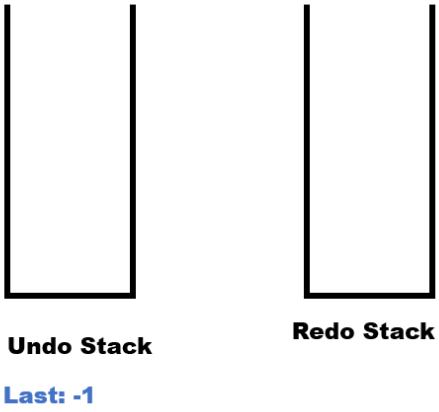
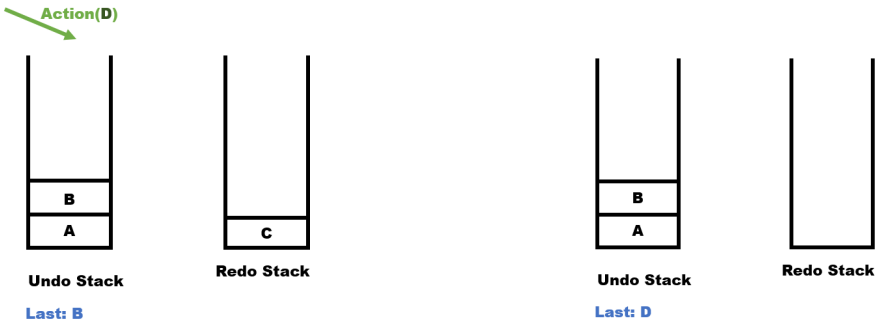


Figure 4.16: Initial state of the MyStack class with empty undo and redo stacks

The *action(value)* function records each user input by pushing the current state onto the *undo stack*, ensuring that it is possible to revert to prior stages if needed, the action is painting the canvas. Whenever a new action is performed, any previous redo options are cleared to reflect the latest change, as shown in figure 4.17.



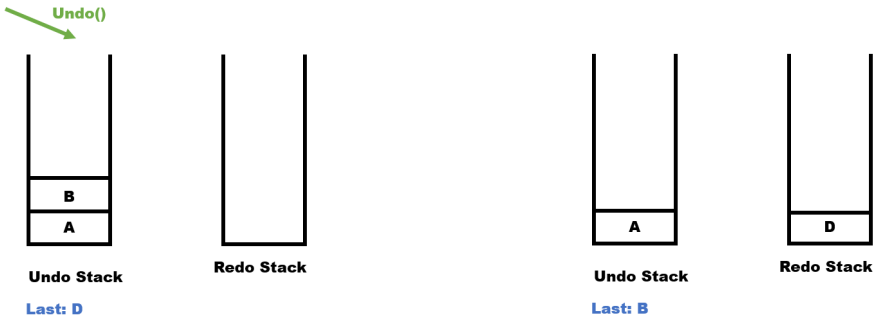
(a) State of the stacks before action(D) (b) State of the stacks after action(D)

Figure 4.17: Illustrates the before and after of action(D) is performed

The undo() and redo() functions allow users to navigate back and forth between their actions, more specifically, between their painting versions, providing flexibility and control over their creative process. In cases where the undo stack reaches its maximum size, the

[3]The feedback can be found in 5.1.2.1

oldest entry is removed to maintain performance. An example of how the undo() function works can be seen in figure 4.18, which is composed of two images: one depicting the state before the undo action 4.18a, and the other showing the state after 4.18b. If the redo() function were to be applied to the result shown in figure 4.18b, it would return the application to the state represented in the second image of figure 4.18.



(a) State of the stacks before undo() (b) State of the stacks after undo()

Figure 4.18: Illustrates the stacks before and after undo() is performed

Special attention was given to the images to ensure that their transformations closely mirrored those of the original magic lantern slides where they were based. However, there are two images in the application that deviate from this approach: the general and the flowers.

The transformation of the general involved only the legs moving, as seen in image 4.19, which when tried to be replicated in the application resulted in an awkward transformation that did not align with the intended realism, and therefore a new transformation was devised, allowing both arms and legs to be separated from the body. This transformation can be viewed in appendix A.

(a) First Frame (b) Second Frame

Figure 4.19: Movement of the slide that the general was based on

For the flowers, the effect wanted was a gradual transition from white to the colors painted by the user. However, as the creation of a unique algorithm for each flower was not

feasible, because of the complexity involved in managing each flower and the colors that each had, another approach was taken: making the flowers slowly appear and disappear. Unfortunately, this transformation lacked the desired beauty and enticement. As a result, the transformation that is applied to the flowers is the invertion of all its colors.

The resources used in the final version of the application, including the color palletes, the images that can be selected and their transformations can be found in appendix A.

After incorporating these modifications, this version was tested on two separate occasions: first, at *NOVA School of Science and Technology* with 11 participants, and later during the *Noite Europeia dos Investigadores (NEI)* with 20 attendees. Between these two testing phases, the application underwent further adjustments, which, along with the detailed results and the evaluation method are discussed in 5.2.

5

Evaluation and Results

This chapter outlines the tests used to evaluate this dissertation project and the results obtained from these evaluations.

The development of the application followed an iterative approach, consisting of two phases. In the first phase, most functionalities were implemented, and in the second phase the errors found in the initial phase were corrected and additional functionalities were added. After each iteration, user testing was conducted to evaluate the system and identify areas to improve.

5.1 Preliminary User Tests

In this initial user tests, participants were presented with a prototype of the application that was still in develpoment. Each participant was given a specific scenario to follow to see how they navigated through the application while performing their given tasks. The study included five different scenarios designed to test various functionalities and use cases:

- **Scenario 1** - Select the slide called " The Elf and the cabbage", choose the italian palette and paint a part of the elf with any color.
- **Scenario 2** - Navigate to the MAGICA project Home page and then go back to the application being tested. Change the language of the Home page of the application, go to the second page, change the language again, select any slide and when in the painting page change the language one last time.
- **Scenario 3** - Select the slide called "The pig's head", paint the apron in the drawing and animate it.
- **Scenario 4** - Select any slide, use the brush to paint a part of the drawing, use the eraser to erase a small portion of what was painted and finally use the bucket to fill the space erased with another color.

- **Scenario 5** - In the second page, view three different slides and select one of them to paint. In the painting page click on the button that shows the original slide from which the chosen slide was based on, finally find the button that gives extra information or support and click on it.

For this test, participants interacted with the prototype on a computer rather than a tablet.

5.1.1 Participants and Evaluation Method

In this study, two types of participants were identified: those who had some knowledge about the application and its capabilities, and those with no prior knowledge of the application. The number of participants in each group was balanced, with five individuals in each category, and care was taken to ensure that each scenario was only tested once per group. Of the 10 participants, 3 were members of the *MAGICA* project, 2 were students from *NOVA School of Science and Technology* and the remaining 5 belonged to *Vicarte*.

Since the main objective of these preliminary tests was to observe how participants interacted with the application, and the final goal was to use the application in a museum with a broader audience, the participant's age and gender were not considered relevant factors in this evaluation.

The system was evaluated through a combination of direct observation and user feedback. Participants were asked to complete their given scenario, followed by a five-minute free exploration of the painting and animation features of the application. Next, they answered a questionnaire to judge the layout and design of each page, how certain elements should be displayed, and their understanding of the icons, buttons, and their functionalities. For example, one question related to the second page asked for their opinion on how the collection of images should be presented.

After the user finished the questionnaire, a small informal interview followed, in which participants were asked about the application's color-mixing capabilities, the animation of their created image, and any areas that could be improved.

5.1.2 Results

The results of the questionnaire can be found in appendix C. Feedback from the user observations and interviews is presented in 5.1.2.1, while the modifications made in response to the questionnaire are documented in 5.1.2.2.

5.1.2.1 Observation and Interview Results

Based on the user tests, it was determined that several corrections were necessary, and additional functionalities were needed. These conclusions were mostly drawn from observing how the participants interacted with the application, as well as the result of the interview.

Certain issues were identified by most participants. One key area of improvement was to change the mouse cursor to a "clickable" pointer when hovering over interactive elements. This change was necessary to make clear what elements could be interacted with.

Additionally, users expressed annoyance at not being able to close the pop-up on the second page by clicking outside the said pop-up, they had to click on the button "Close" to close the pop-up. Another common suggestion was to increase the size of the "?" button to enhance its visibility.

Furthermore, participants recommended adding "redo" and "undo" functionalities to the painting page to offer more control and flexibility over the painting process. There was also the suggestion to prevent users from painting until they have selected a palette.

In addition to these shared concerns, a few specific issues were raised that were also adopted. For example, a user was confused by the need to click on "Start" on the Home page to proceed to the next page, therefore the caption "Click on Start" was added to ensure that this kind of confusion wouldn't happen again. Another user pointed out that the design of the language button was not intuitive, as it wasn't obvious that it could be used to change the language of the page, and as seen in figure 5.1 the button was updated to improve clarity.

Figure 5.1: Comparison of the language button design before (left)and after (right) user testing

Through the interviews, it became clear that the method for triggering the animation needed improvement, as users sometimes exited the painting page without animating their drawings. As a result, a new button labeled "Final" was added above the existing "Original" button. This "Final" button allows users to initiate the animation of their drawing, and it will be replaced by the "Exit" button once clicked, making sure that the image is animated before the users can leave.

All these insights led to adjustments that aimed to enhance overall user experience and functionality.

5.1.2.2 Modifications made from Questionnaire Results

The modifications resulting from the questionnaire were mostly focused on aesthetic improvements. While the overall design and layout of the application received positive feedback, several minor adjustments were made on the majority vote. These changes included maintaining a grid layout for the image collection on the second page of the

application and changing the design of the painting page to have both icons and titles in white.

One notable exception was the aesthetic of the buttons. The questionnaire revealed that the participants had a preference for buttons that resembled traditional clickable elements rather than text-based options. Further discussions indicated that the initial blue-green color of the button was not well-received. Many participants suggested changing the color to brown or black, therefore the buttons of the application were updated from blue-green to wood tones, as seen in figure 5.2.

Figure 5.2: Comparison of the button design before (left)and after (right) the questionnaire

5.2 Final User Tests

In the final user tests, the final state of the application, which was described in 4.2.3.3, was evaluated. In the user tests, participants were first introduced to the application and its functionalities. They then were asked to choose one of the available images for selection. Once the image was selected, they engaged with the painting tools to personalize the image chosen. After finishing their painting, users then animate their artwork.

For this test, participants interacted with the application on a tablet utilizing a stylus [1].

5.2.1 Participants and Evaluation Method

A total of 31 volunteers participated in this study. Of these 31 participants, 11 were students and faculty members of *NOVA School of Science and Technology*, and 20 were attendees from *Noite Europeia dos Investigadores (NEI)*, an annual event, that brings the public and researchers together to showcase scientific work [2]. None of the participants from the previous user tests were involved in the final user tests.

As in the first user tests, the evaluation of the system was made through passive observation of the user utilizing the application, and the realization of questionnaires and an informal interview. Each user answers to two questionnaires: the User Experience Questionnaire (UEQ) [3], which measures both traditional usability principles and user experience principles, and the Post-Study System Usability Questionnaire (PSSUQ) [25].

[1]stylus https://www.dictionary.com/browse/stylus Last accessed in September 2024
[2]NEI https://noitedosinvestigadores.org/programas-locais/programa-lisboa-2024/ Last accessed September 2024
[3]User experience Questionaire https://www.ueq-online.org/ Last accessed in September 2024

Unlike the UEQ, which already has tests available in multiple languages, the PSSUQ does not have as many options. However, a seamless translation from English to European Portuguese was identified [42] and used. Both questionnaires can be found in appendix D.

Following the questionnaires, participants took part in an informal interview to share their experiences with the application. They were asked about the functionalities of the application and the challenges they encountered. This feedback complemented the results that the questionnaires provided, offering a better understanding of user satisfaction and potential areas for improvement.

For the children participating from NEI, 10 in total, a different approach was taken. Instead of completing formal questionnaires like the adults, the children and how they interacted with the application were observed, and some notes were taken.

The entire duration of the user test, including filling out the questionnaires and answering the questions of the interview, took approximately 10 to 15 minutes per participant. And, despite the more informal evaluation, no child took more than 10 minutes painting an image.

5.2.2 Results

The questionnaire results are in appendix D. The evaluation of these results will be conducted in two distinct groups.

The initial user tests were performed with participants from *NOVA School of Science and Technology*, whose feedback played a crucial role in refining the application for the subsequent testing at the *Noite Europeia dos Investigadores (NEI)*. Therefore, the results from the different groups will be analyzed separately to understand the impact of the modifications made based on the first group's input.

In this study, the Post-Study System Usability Questionnaire (PSSUQ) was administered using a 7-point Likert scale, where 1 indicated "Strongly Disagree" and 7 indicated "Strongly Agree." A higher score reflects greater satisfaction. Additionally, in the User Experience Questionnaire (UEQ), the question related to the application's security was removed, as it was irrelevant.

5.2.2.1 First Group

The interface of the Painting Page of the application changed from the first group to the second group, where the participants in the first group had the interface shown in figure 5.3.

The results of the Post-Study System Usability Questionaire (PSSUQ) indicated that users had an overall positive experience with the application. The questionnaire evaluated three categories: System Usefulness (SysUse), which focuses on how effective the application enables users to complete their tasks (in this case painting an image and then seeing it get animated); Information Quality (InfoQual), which measures the clarity, accuracy,

Figure 5.3: Painting Page shown to the first group

and helpfulness of the information provided by the application; and Interface Quality (IntQual), which reflects the ease of use and aesthetic appeal of the interface design.

The average overall usability score was 5.8, reflecting a high level of user satisfaction. In the System Usefulness category, a score of 5.9 was recorded, indicating that the users felt the application was largely successful in helping them achieve their goals efficiently. For Information Quality and Interface Quality, the scores were 5.6 and 5.9 respectively, highlighting that the application was helpful, intuitive, and easy to navigate.

The average results of the User Experience Questionnaire (UEQ) provide a clear picture of how users perceive the application, having an overall positive opinion of it, as seen in figure 5.4. Overall the application scored well in all categories, performing particularly well in categories such as Attractiveness, Perspicuity, and Dependability, highlighting its ease of use, visual appeal, and reliability.

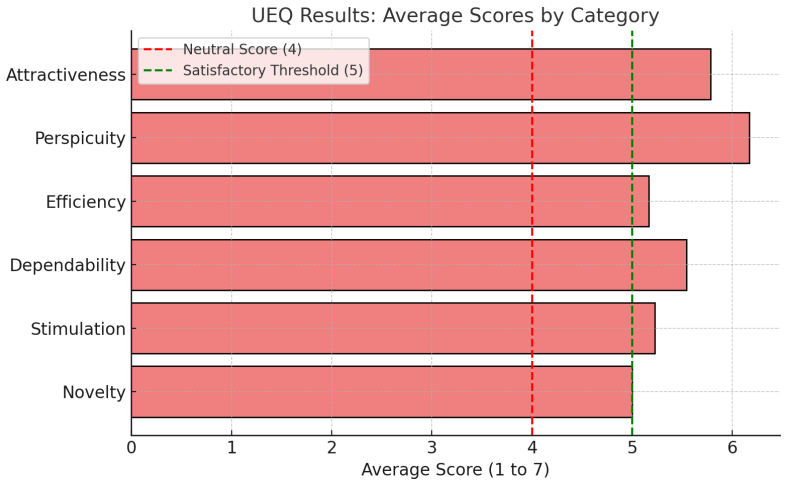


Figure 5.4: Results of the UEQ questionnaire of the first group by category

As shown in figure 5.5, most of the questions received an average score above 5.

Several strengths emerged, particularly regarding the application's ease of learning and visual appeal. However, figure 5.5 which breaks down the results question by question, reveals some weaknesses. In particular, in relation with the Fast-Low dimension, which received the lowest score of 4.50. The scores related to creativity and innovation also indicate that this category requires significant attention.

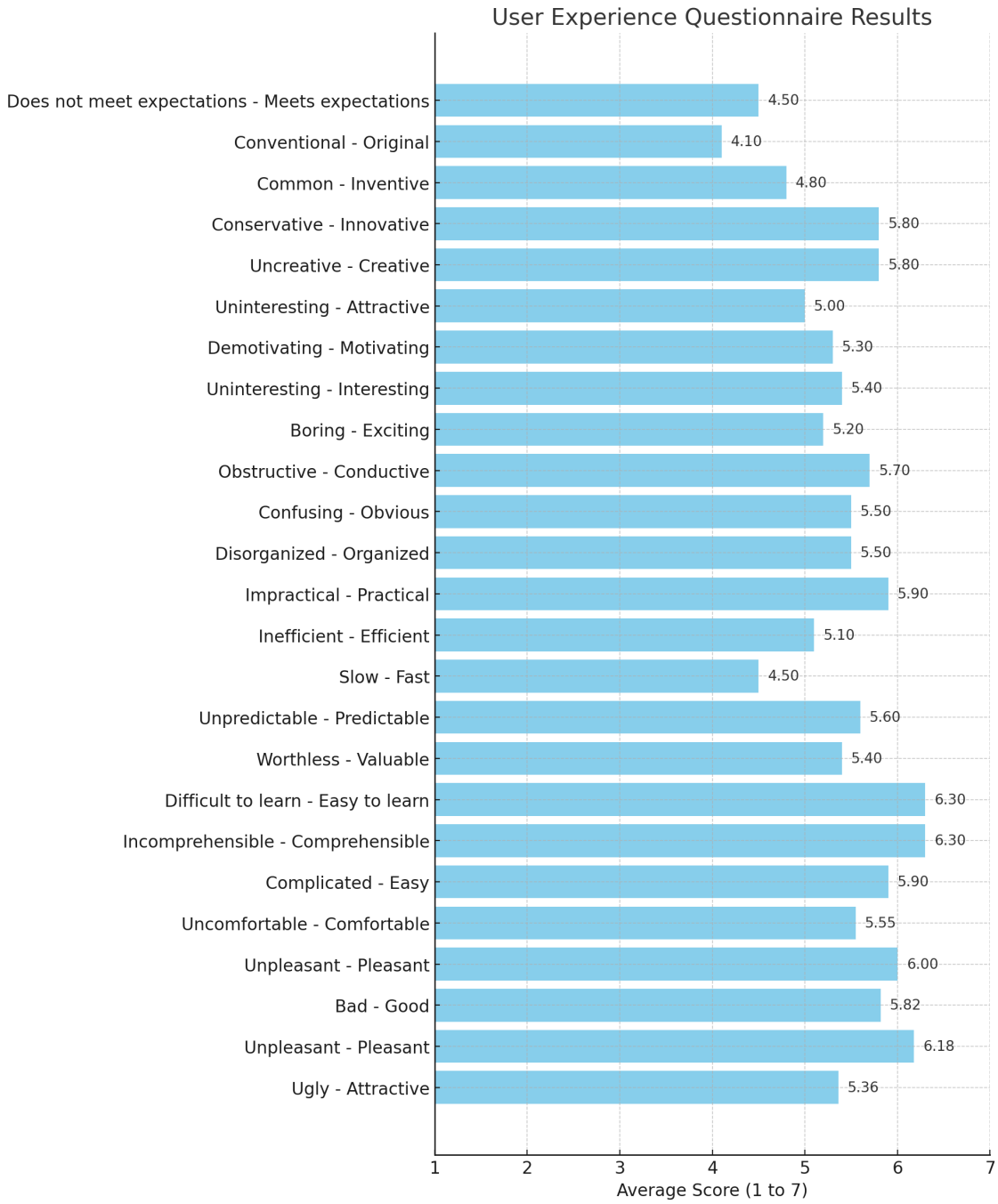


Figure 5.5: Results of the UEQ questionnaire of the first group

During the interviews, many users expressed familiarity with drawing applications, which led them to perceive the application as lacking in innovation and interest. This

perception aligns with the results of the UEQ tests, where the lowest scores were related to Originality and Invention, further highlighting users' expectations for more novel and inventive features. The only participant who found the application innovative had prior knowledge of magic lanterns and found the idea of the application - painting her magic lantern slide, very novel, especially after she saw her painting move.

To address the performance concerns identified in the evaluation, a timer was added to the flood fill algorithm. This adjustment ensures that if the network conditions are poor and performance is less than optimal, the flood fill process will terminate rather than leave the users stuck in a loading state. Changes were also made in to the Color Options feature, introducing a checkbox labeled *Mix*. This change was implemented in response to the feedback given, seeing as many participants found the previous mixing functionality confusing. The new checkbox allows users to choose whether to mix colors or simply replace one color with another.

5.2.2.2 Second Group

The updated Painting page interface, revised based on feedback from the first group of users, was presented to the second group and is shown in figure 5.6.

Figure 5.6: Painting Page shown to the second group

The results of the Post-Study System Usability Questionaire (PSSUQ) for the second group indicated an even stronger user satisfaction with the updated interface, as the average overall usability score for the second group was 6.3, 0.5 higher than in the first group. Similarly, the System Usefulness score improved to 6.3, up from 5.9; the Information Quality score increased to 6.1, compared to 5.6 in the first group; and the Interface Quality score rose to 6.4, an increase from 5.9.

About the User Experience Questionnaire (UEQ), various improvements were seen in all categories, as seen in figure 5.7.

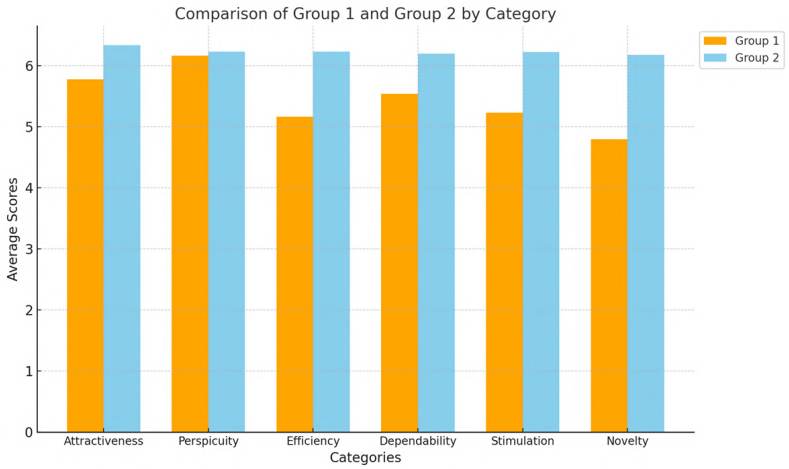


Figure 5.7: UEQ comparison by category

In relation to more concrete aspects of the user experience, figure 5.8 foccuses on the comparison of individual questions between the two groups, . The Fast-Slow dimension saw notable improvement. Similarly, the application's overall value was rated higher by the second group, suggesting that the context of magic lanterns enhanced the user experience and made the application more engaging.

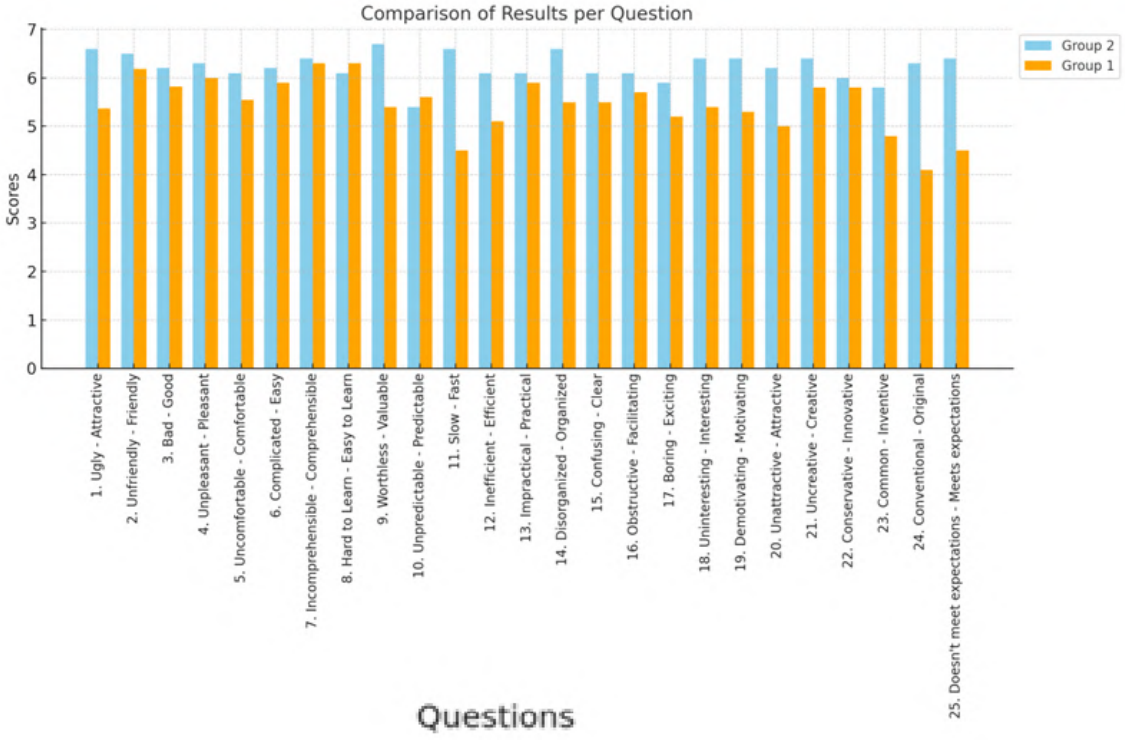


Figure 5.8: UEQ comparison

However, there were two dimensions where the second group's scores were lower than those of the first. The Predictable-Unpredictable received a lower score, but during the interviews, some participants mentioned that while the animation of their painting

was unexpected, it was seen as a positive aspect of the application. The Easy to Learn - Difficult to Learn dimension also scored lower, with participants noting that the icon used for lightening colors caused some confusion, as it resembled a color picker and not all functionalities of the application are intuitive and obvious, such as checking the *Mix* box to be able to blend colors. To address this, participants suggested adding a brief introductory guide to explain the features more clearly and if possible to change the icon similar to a color picker.

The application appeared to have more appeal with children than with adults, as half of the participants in the NEI were children, rangingfrom 6 to 9 years of age. Many children painted and animated multiple images, with one child completing and seeing the animation of four images.

6

Conclusions and Future Work

This chapter presents the conclusions from the work developed in this dissertation project and describes several directions and ideas for improving the solution in the future.

6.1 Conclusions

This work resulted in the creation of an interactive web application based on hand-painted magic lantern slides, with a focus on recreating the process of creating them and their animations. The application allows users to paint on predefined images, that were based on traditional magic lantern slides, which then transform, creating an engaging and interesting experience.

The system was developed to introduce users to magic lantern slides while providing an immersive and entertaining experience. Users can paint images on a digital canvas, with historically accurate color palettes, and watch their creations transform in ways that resemble the original animations found in magic lantern shows. This allows users to experience the creative process from the conception of the slides to their animation.

The development of this project encountered and solved several challenges. One of the initial issues was implementing the fill tool, as it wasn't as straightforward as the drawing and erasing functionalities. A mask-based approach was explored and because of its limitations, the flood-fill algorithm was adopted.

The other issue found in the beginning was ensuring the integration of the images the user could select and the predefined transformations that came with each one. To address this images were adapted to omit or discard certain elements to ensure that transformations like body part movements or appearance and disappearance of certain elements were seamless.

The last challenge was related to mixing color in the application. As the application was going for a historically accurate approach it was important to ensure that color blending followed the principles of color theory as they occur in reality. After finding problems with the RGB model, the HSV color model was also explored and after experimentation and research, the Mixbox Javascript library was the most suitable solution.

From the feedback given by users during the first user tests, the usability of the painting tools and the effectiveness of the transformations were evaluated. Overall users enjoyed the application and found it engaging, particularly in relation to the transformations, as they were showered with compliments. However, users suggested enhancements for the fill tool and adding options for undoing and redoing actions.

An iterative approach was adopted in the design and development of the application, containing two main iterations. After each iteration, user tests were performed to assess usability and engagement. The first user tests were crucial in shaping the final design of the application. User feedback improved the overall experience, focusing specifically on the drawing functionality.

The user tests showed positive results, as the users enjoyed the application. While some technical challenges were identified, particularly related to page loading speed and functionality of the fill tool for painting the background of the canvas, these issues were within what was expected for this web application.

It can be concluded that the use of the chosen framework (such as p5.js for drawing functionality) was an appropriate choice, having allowed for the easy implementation of all required functionalities.

In summary, the goals of this dissertation were met, and all contributions in section 1.4 were achieved. Despite this, there remains room for further enhancement, particularly in refining the drawing tools and expanding the collection of images and transformations.

6.2 Future Work

Although the application has been successfully developed, there are still some functionalities that could be further refined or even added. Besides that, future iterations could introduce new techniques to enhance the user experience. There is still plenty of room to make the app even better, such as boosting performance and adding more ways for users to customize their painting and the animation that results from it.

One significant improvement would be to expand the collection of images that the user can select to paint. Currently, the application is limited in image selection due to storage and loading constraints on GitHub Pages. To address this problem, creating a dedicated database for the application to store and manage the images could be a solution. Alternatively, transitioning to a dedicated server or cloud storage could improve image loading times and overall performance.

In addition to expanding the image library, expanding the customization options available in the application could greatly enrich the experience of the users. For instance, introducing paint brushes that replicate painting methods, such as watercolor, would allow users to experiment with diverse styles. Also, providing users with the ability to manipulate the animations that are a result of their art, by allowing them to control the speed of the transition between frames or/and giving them the power to incorporate

sound elements into the animation would further immerse them into the world of magic lanterns.

As the application grows, the images that can be handled by it could also become more intricate and complex, and therefore a need to upgrade the fill algorithm used for painting will arise. While the recursive flood fill method is adequate for simpler designs, the scanline flood fill algorithm will need to be implemented to improve the performance and accuracy of the fill tool, particularly for images with detailed backgrounds, such as slides depicting a ship caught in a storm or vibrant landscapes. By adopting a more advanced filling technique, the application can provide users with a smoother painting experience and allow the addition of more detailed slides for users to paint.

Furthermore, improving the animation capabilities of the application could provide a richer user experience. Currently, the animations that the application can produce are limited to the transition between two different frames, but for the application to have more than that number of frames special care needs to be taken and research needs to be done. This feature could open the door for more complex storytelling like the slides that tell the story of Cinderella or other fairy tales [27].

Finally, incorporating a designated area within the application for color mixing would be interesting. This feature would allow users to experiment with different color combinations before applying them to their paintings, promoting a more interactive and immersive creative process. This addition would not only make the application more realistic but also allow users to explore and refine their color choices.

At some point in the future, the application could also be transformed into an educational resource. By integrating historical context and information about the slides that served as inspiration for the images and the palettes, users could learn while they paint. This could be accomplished by creating pop-ups, or a dedicated educational section within the application.

Furthermore, the application could also offer more than one path of action for the user to choose from. Instead of leading the users immediately to select an image for painting, the application could have a page where the users could choose between two different experiences. The first is what the application already does, it allows users to create their own magic lantern slide and then see it come to life through animation. The second experience would immerse the users in the historical context of magic lantern shows, allowing them to experience the role of a magic lantern operator. In this scenario, users would encounter a collection of pre-defined slides that were already painted. Upon selecting a slide, the application would display it within a virtual magic lantern and project it. Users would then interact with the digital lantern, touching the control mechanism that would trigger the transformations of the slide, and therefore recreating the experience of manipulating a traditional magic lantern.

Lastly, the application is planned to be showcased in two exhibitions scheduled for 2025 at the National Museum of Natural History and Science (MUHNAC) and the Science Museum of the University of Coimbra (MCUC). In preparation for these events, ongoing

updates and refinements will be made to ensure that the application aligns with the requirements of each exhibition.

Bibliography

[1] G. A. Agoston. *Color theory and its application in art and design*. Vol. 19. Springer, 2013 (cit. on p. 35).

[2] S. U. Ahmed. "Interaction and interactivity: in the context of digital interactive art installation". In: *Human-Computer Interaction. Interaction in Context: 20th International Conference, HCI International 2018, Las Vegas, NV, USA, July 15–20, 2018, Proceedings, Part II 20*. Springer. 2018, pp. 241–257 (cit. on pp. 16, 17).

[3] J. Blake. "Taking a human rights approach to cultural heritage protection". In: *Heritage & Society* 4.2 (2011), pp. 199–238 (cit. on p. 5).

[4] J. BROOKER. "A Grand Gothic Magic Lantern Entertainment". In: *Manchester Memoirs* (2019) (cit. on p. 8).

[5] M. L. Brooks. *Drawing to learn*. Springer, 2017 (cit. on p. 14).

[6] *Concept of Digital Heritage*. https://en.unesco.org/themes/information-preservation/digital-heritage/concept-digital-heritage. Accessed: 2024-01-17 (cit. on p. 6).

[7] *CSS Documentation*. https://developer.mozilla.org/en-US/docs/Web/CSS. Accessed: 2024-09-05 (cit. on p. 25).

[8] *Cultural Heritage definition*. https://culture.ec.europa.eu/cultural-heritage. Accessed: 2024-01-27 (cit. on p. 5).

[9] *Draw and Tell*. https://www.duckduckmoose.com/educational-iphone-itouch-apps-for-kids/draw-and-tell/. Accessed: 2024-08-22 (cit. on p. 16).

[10] M. Economou. "Heritage in the digital age". In: *A companion to heritage studies* (2015), pp. 215–228 (cit. on p. 6).

[11] F. J. Frutos Esteban et al. "From Luminous Pictures to Transparent Photographs: The Evolution of Techniques for Making Magic Lantern Slides". In: (2013) (cit. on p. 7).

[12] J. P. Gee. "What video games have to teach us about learning and literacy". In: *Computers in entertainment (CIE)* 1.1 (2003), pp. 20–20 (cit. on p. 11).

[13] *GitHub Pages Documentation*. https://docs.github.com/en/pages/getting-started-with-github-pages/about-github-pages. Accessed: 2024-09-07 (cit. on p. 25).

[14] B. Günay. "Museum concept from past to present and importance of museums as centers of art education". In: *Procedia-Social and Behavioral Sciences* 55 (2012), pp. 1250–1258 (cit. on p. 9).

[15] L. K. Harrison. "A roadmap to applied digital heritage: introduction to the special issue on Digital Heritage Technologies, Applications and Impacts". In: *Studies in Digital Heritage* 3.1 (2019), pp. 40–45 (cit. on p. 6).

[16] N. Haywood and P. Cairns. "Engagement with an interactive museum exhibit". In: *People and computers XIX—The bigger picture: Proceedings of HCI 2005*. Springer. 2006, pp. 113–129 (cit. on p. 9).

[17] E. Hooper-Greenhill. *The educational role of the museum*. Psychology Press, 1999 (cit. on p. 9).

[18] *HTML Documentation*. https://developer.mozilla.org/en-US/docs/Web/HTML. Accessed: 2024-09-05 (cit. on p. 25).

[19] I. ICOM. "Round Table Santiago do Chile ICOM, 1972". In: *Cadernos de Sociomuseologia* 38 (2010) (cit. on p. 9).

[20] *Introducing Sketch Aquarium*. https://thinkplaycreate.org/blog/introducing-sketch-aquarium/. Accessed: 2024-01-18 (cit. on pp. 17, 18).

[21] *Javascript Documentation*. https://developer.mozilla.org/en-US/docs/Web/JavaScript. Accessed: 2024-09-05 (cit. on p. 25).

[22] C. Kaczvinsky. "Burning Books and Bricks: a Brief History of Cultural Destruction". In: *Sigma Iota Rho Journal of International Relations* (2016) (cit. on p. 5).

[23] G. Karayılanoğlu and B. C. Arabacıoğlu. "Digital interactive experiences in contemporary art museums". In: *Turkish Online Journal of Design Art and Communication* 10.4 (2020), pp. 423–440 (cit. on p. 16).

[24] Laterna Magica. *Magic Lantern Collection*. https://www.laternamagica.co/magic-lantern-collection/. Last accessed: September, 2024 (cit. on p. 6).

[25] J. R. Lewis. "Psychometric evaluation of the post-study system usability questionnaire: The PSSUQ". In: *Proceedings of the human factors society annual meeting*. Vol. 36. 16. Sage Publications Sage CA: Los Angeles, CA. 1992, pp. 1259–1260 (cit. on p. 42).

[26] J. M. Lourenço. *The NOVAthesis LaTeX Template User's Manual*. NOVA University Lisbon. 2021. URL: https://github.com/joaomlourenco/novathesis/raw/main/template.pdf (cit. on p. i).

[27] Luikerwaal. *Virtual Museum - Other fairy Tales*. Accessed: 2024-09-24. n.d. URL: https://www.luikerwaal.com/newframe_uk.htm?/inh_thema_uk.htm (cit. on p. 51).

[28] *MAGICA Project*. https://www.magica-project.com/home. Accessed: 2023-12-20 (cit. on p. 1).

[29] F. Mairesse. "The definition of the museum: History and issues". In: *Museum International* 71.1-2 (2019), pp. 152–159 (cit. on p. 9).

[30] K. McLean. "Museum exhibitions and the dynamics of dialogue". In: *Daedalus* 128.3 (1999), pp. 83–107 (cit. on p. 9).

[31] "Microsoft Paint's Influence on Artists Is Bigger Than You Migth Think". In: *Artsy* (). URL: https://www.artsy.net/article/artsy-editorial-microsoft-paints-influence-artists-bigger (visited on 2024-08-22) (cit. on p. 15).

[32] *Microsoft Paintbrush*. https://winworldpc.com/product/microsoft-paintbrush/20. Accessed: 2024-08-22 (cit. on p. 15).

[33] *Mixbox*. https://scrtwpns.com/mixbox/. Accessed: 2024-09-07 (cit. on p. 26).

[34] P. Mollica. *Color Theory: An essential guide to color-from basic principles to practical applications*. Vol. 53. Walter Foster, 2013 (cit. on p. 35).

[35] M. Mortara et al. "Learning cultural heritage by serious games". In: *Journal of Cultural Heritage* 15.3 (2014), pp. 318–325 (cit. on p. 6).

[36] *Museum definition*. https://developer.mozilla.org/en-US/docs/Web/JavaScript. Accessed: 2024-01-27 (cit. on p. 1).

[37] *Museums*. https://en.unesco.org/themes/museums. Accessed: 2024-01-17 (cit. on p. 9).

[38] *P5js*. https://p5js.org/. Accessed: 2024-09-06 (cit. on p. 26).

[39] O. J. du Preez. *JavaScript for Gurus: Use JavaScript programming features, techniques and modules to solve everyday problems*. BPB Publications, 2020 (cit. on p. 25).

[40] A. Ranjan, A. Sinha, and R. Battewad. *JavaScript for modern web development: building a web application using HTML, CSS, and JavaScript*. BPB Publications, 2020 (cit. on p. 25).

[41] L. Reynolds et al. "Patients' drawings illustrate psychological and functional status in heart failure". In: *Journal of psychosomatic research* 63.5 (2007), pp. 525–532 (cit. on p. 14).

[42] A. F. Rosa et al. "European Portuguese validation of the post-study system usability questionnaire (PSSUQ)". In: *2015 10th Iberian Conference on Information Systems and Technologies (CISTI)*. IEEE. 2015, pp. 1–5 (cit. on p. 43).

[43] D. W. Rossell. "Double Think: The Cinema and Magic Lantern Culture". In: (1998) (cit. on p. 6).

[44] K. Ryokai, S. Marti, and H. Ishii. "I/O brush: drawing with everyday objects as ink". In: *Proceedings of the SIGCHI conference on Human factors in computing systems*. 2004, pp. 303–310 (cit. on pp. 12, 13).

[45] A. Santos, V. Otero, and M. Vilarigues. "The colour of moving images: A documentary study of Winsor & Newton 19th-century watercolours used to paint glass slides for magic lanterns". In: *Proceedings of the 8th Symposium of the ICOM-CC Working Group Art Technological Source Research, Cologne, Germany*. 2019, pp. 26–27 (cit. on p. 8).

[46] Â. Santos, V. Otero, and M. Vilarigues. "Production of Hand-painted Magic Lantern Glass Slides: A Literature Review". In: *Studies in Conservation* (2023), pp. 1–15 (cit. on pp. 2, 6–8).

[47] Â. Santos et al. "Defining the first preventive conservation guidelines for hand-painted magic lantern glass slides". In: *Conservar Património* 37 (2021) (cit. on p. 8).

[48] E. Sesana et al. "Climate change impacts on cultural heritage: A literature review". In: *Wiley Interdisciplinary Reviews: Climate Change* 12.4 (2021), e710 (cit. on p. 5).

[49] J. E. Simmons. "History of museums". In: *Encyclopedia of Library and Information Science* (2010), pp. 2096–2106 (cit. on p. 9).

[50] N. Simon. *The participatory museum*. Museum 2.0, 2010 (cit. on p. 10).

[51] *Sketch Aquarium*. https://futurepark.teamlab.art/en/playinstallations/sketch_aquarium/. Accessed: 2024-01-18 (cit. on pp. 17, 18).

[52] *Sketch Piston - Playing Music*. https://www.teamlab.art/pt/ew/asm_playingmusic/artsciencemuseum/. Accessed: 2024-01-18 (cit. on p. 19).

[53] Š. Sochorová and O. Jamriška. "Practical pigment mixing for digital painting". In: *ACM Transactions on Graphics (TOG)* 40.6 (2021), pp. 1–11 (cit. on p. 35).

[54] "Supporting Student Engagement With Technology". In: *edutopia* (2023-06-05). URL: https://www.edutopia.org/article/using-technology-support-student-engagement/?utm_source=chatgpt.com (visited on 2024-12-27) (cit. on p. 11).

[55] M. SZYMANSKI and R. CASTILLO. "Osmo: Toy or Learning System? Identifying a Road to Success". In: (2021) (cit. on p. 13).

[56] "The Evolution of MS Paint: From Classic to Modern Version". In: *Ask* (2023-11-28). URL: https://www.ask.com/news/evolution-ms-paint-classic-modern-version (visited on 2024-08-21) (cit. on p. 15).

[57] "The Legacy of MS Paint: A Retrospective". In: *Medium* (). URL: https://medium.com/@aurel_code/history-of-microsoft-paint-1985-2017-an-lgr-retrospective-d5e690d1a525 (visited on 2024-08-22) (cit. on p. 15).

[58] P. H. Welsh. "Repatriation and cultural preservation: potent objects, potent pasts". In: *U. Mich. JL Reform* 25 (1991), p. 837 (cit. on p. 9).

[59] S. Yadav, P. Chakraborty, and P. Mittal. "Designing drawing apps for children: Artistic and technological factors". In: *International Journal of Human–Computer Interaction* 38.2 (2022), pp. 103–117 (cit. on p. 14).

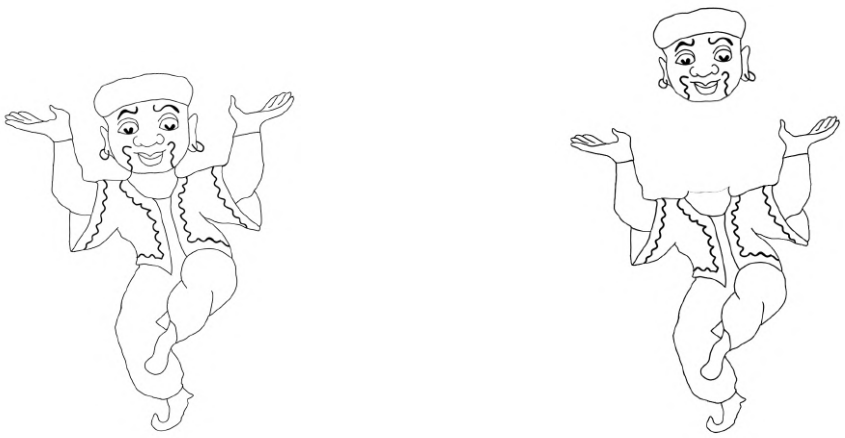
[60] J. Zhang, Z. Liu, and S. Liu. "Computer simulation of archaeological drawings". In: *Journal of Cultural Heritage* 37 (2019), pp. 181–191 (cit. on p. 14).

A

Final Version Resources

A.1 Paintable Images and their transformations

A.1.1 Genie



(a) Initial frame (b) Final frame

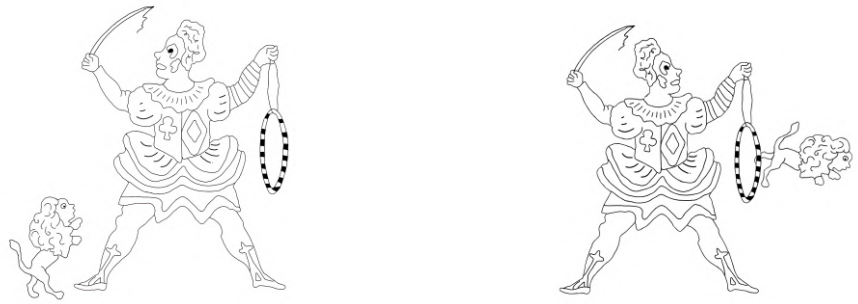
Figure A.1: Illustration of the transformation sequence of the Genie from the paintable image

A.1.2 Flowers

(a) Initial frame (b) Final frame

Figure A.2: Illustration of the transformation sequence of the Flowers from the paintable image

A.1.3 Circus



(a) Initial frame (b) Final frame

Figure A.3: Illustration of the transformation sequence of the Circus from the paintable image

A.1.4 The Elf and the cabbage

(a) Initial frame (b) Final frame

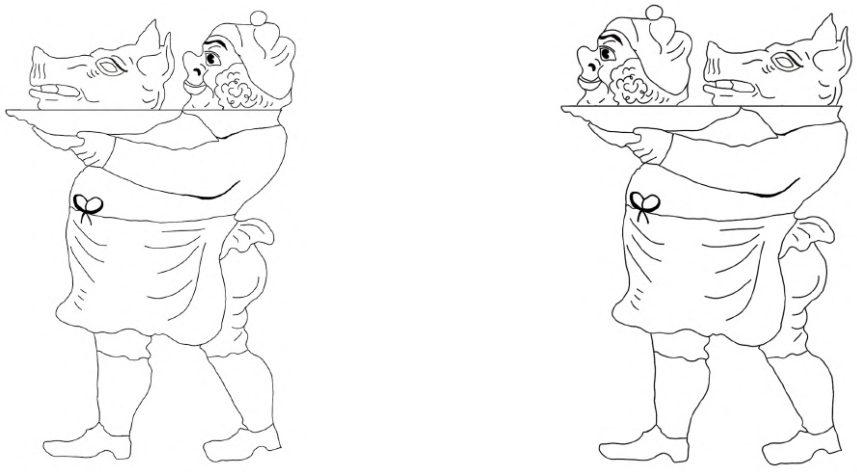
Figure A.4: Illustration of the transformation sequence of the The Elf and the cabbage from the paintable image

A.1.5 Monster

(a) Initial frame (b) Final frame

Figure A.5: Illustration of the transformation sequence of the The Monster from the paintable image

A.1.6 The pig's head



(a) Initial frame (b) Final frame

Figure A.6: Illustration of the transformation sequence of the The The pig's head from the paintable image

A.1.7 The goose

(a) Initial frame

(b) Final frame

Figure A.7: Illustration of the transformation sequence of the The The goose from the paintable image

A.1.8 The statue

(a) Initial frame

(b) Final frame

Figure A.8: Illustration of the transformation sequence of the The The statue from the paintable image

A.1.9 The general

(a) Initial frame

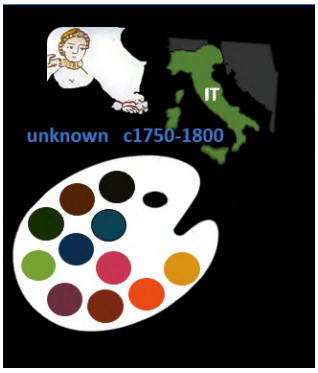
(b) Final frame

Figure A.9: Illustration of the transformation sequence of the The The general from the paintable image

A.2 Palettes

A.2.1 Unkown c1750-1800

(a) Previous color palette



(b) Current color palette

Figure A.10: Comparison between the previous and current color palette

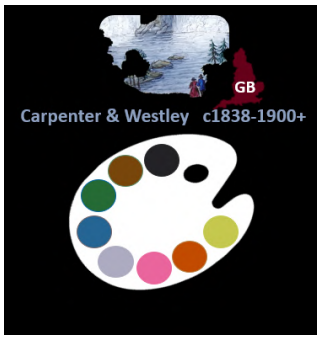
A.2.2 P. Carpenter c1822-35

(a) Previous color palette

(b) Current color palette

Figure A.11: Comparison between the previous and current color palette

A.2.3 Carpenter & Westley c1838-1900+

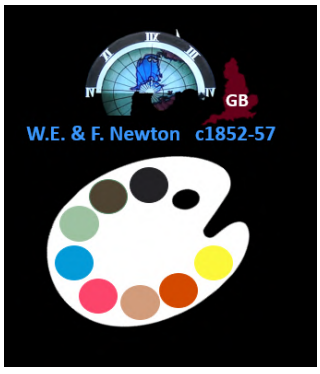


(a) Previous color palette

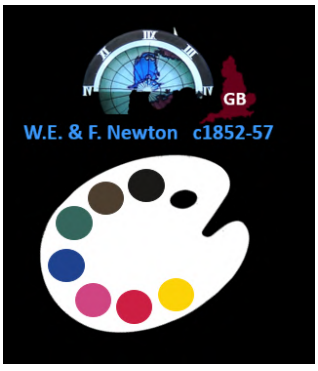
(b) Current color palette

Figure A.12: Comparison between the previous and current color palette

A.2.4 W.E. & F. Newton c1852-57



(a) Previous color palette



(b) Current color palette

Figure A.13: Comparison between the previous and current color palette

A.2.5 Lapierre c1860-1900+

(a) Previous color palette

(b) Current color palette

Figure A.14: Comparison between the previous and current color palette

B

Draft Phase Resources

B.1 Images

B.1.1 Genie

Figure B.1: Draft of the Genie

B.1.2 Circus

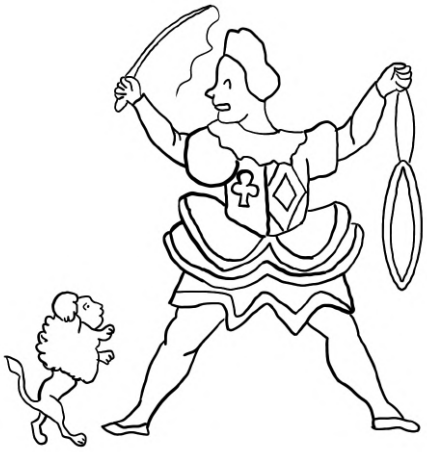


Figure B.2: Draft of the Circus

B.1.3 The Pig's Head

Figure B.3: Draft of the Pig's Head

B.1.4 Sleeping man

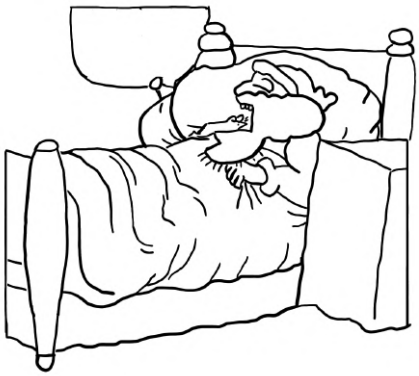


Figure B.4: Draft of the Sleeping man

B.1.5 The elf and the cabbage

Figure B.5: Draft of the elf and the cabbage

B.2 Palettes

B.2.1 Unkown c1750-1800

(a) Traditional color palette

(b) Newly created color palette

Figure B.6: Comparison between Traditional and Newly Created Color Palette

B.2.2 P. Carpenter c1822-35

(a) Traditional color palette

(b) Newly created color palette

Figure B.7: Comparison between Traditional and Newly Created Color Palette

B.2.3 Carpenter & Westley c1838-1900+

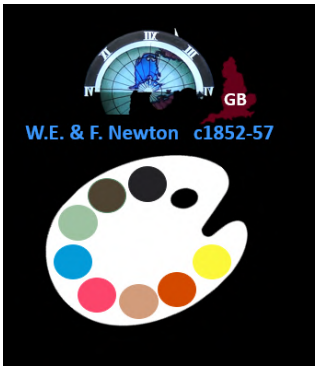
(a) Traditional color palette

(b) Newly created color palette

Figure B.8: Comparison between Traditional and Newly Created Color Palette

B.2.4 W.E. & F. Newton c1852-57

(a) Traditional color palette



(b) Newly created color palette

Figure B.9: Comparison between Traditional and Newly Created Color Palette

B.2.5 Lapierre c1860-1900+

(a) Traditional color palette

(b) Newly created color palette

Figure B.10: Comparison between Traditional and Newly Created Color Palette

C

Questionnaire Results of Preliminary Tests

C.1 How would you classify the layout and design of the home page?

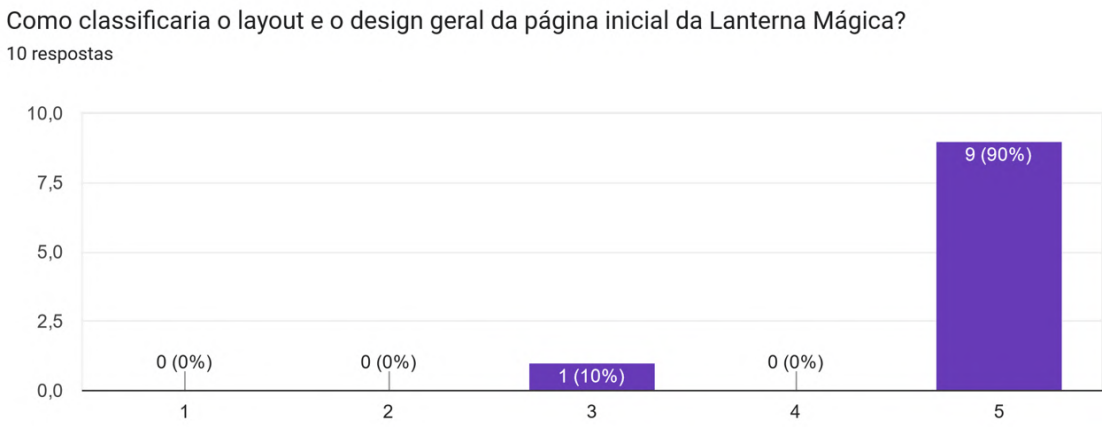


Figure C.1: Results of the first question: 1 = Very Bad, 5 = Excellent

C.2 Is it easy to understand how to navigate to the next page?

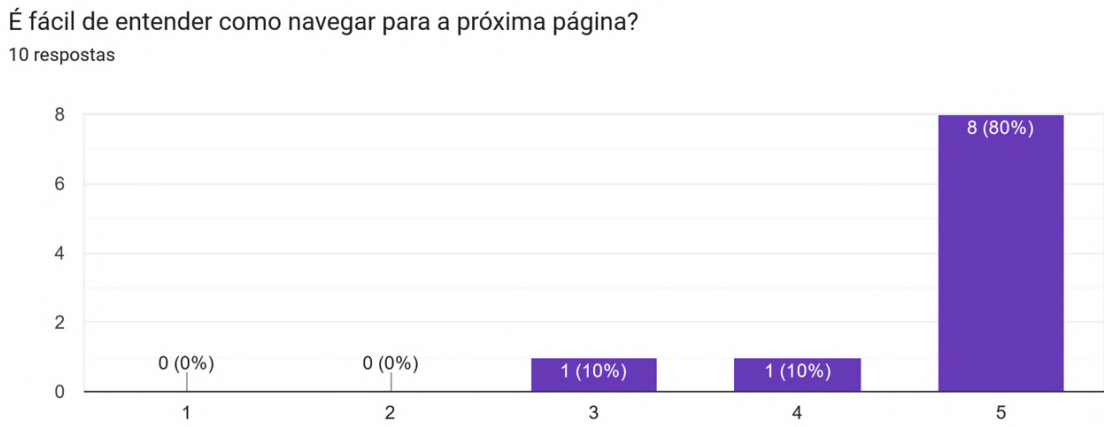


Figure C.2: Results of the second question: 1 = Strongly Disagree, 5 = Strongly Agree

C.3 How would you classify the layout and design of the second page of the application?

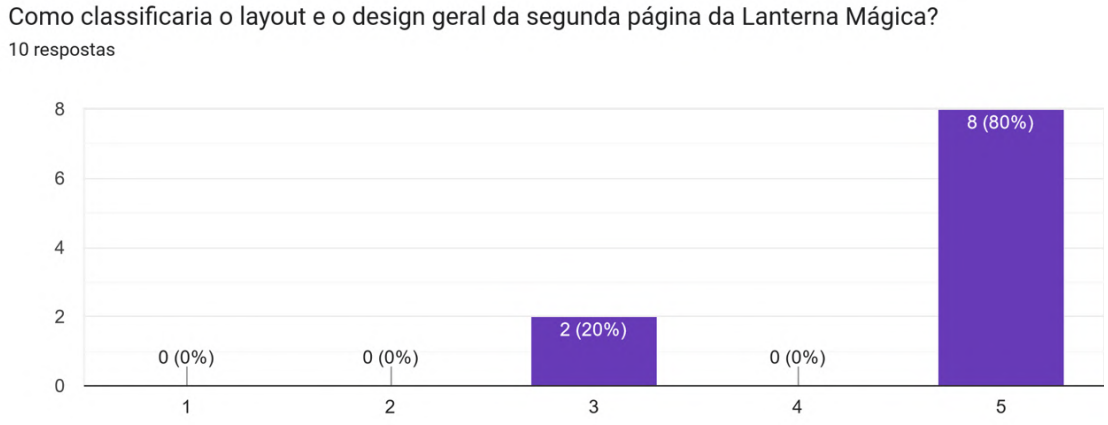


Figure C.3: Results of the third question: 1 = Very Bad, 5 = Excellent

C.4 Is the text on the second page enough?

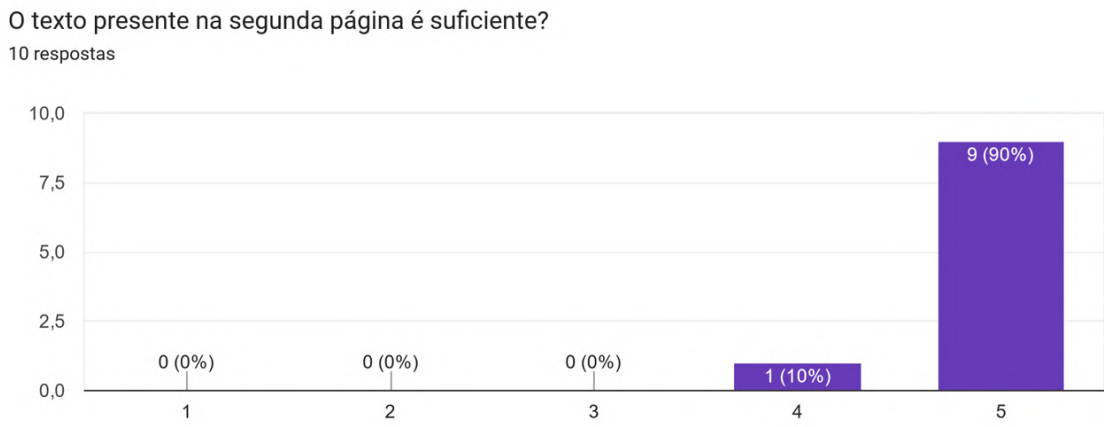


Figure C.4: Results of the fourth question: 1 = Strongly Disagree, 5 = Strongly Agree

C.5 Which of the available slide viewing options is the most appropriate?

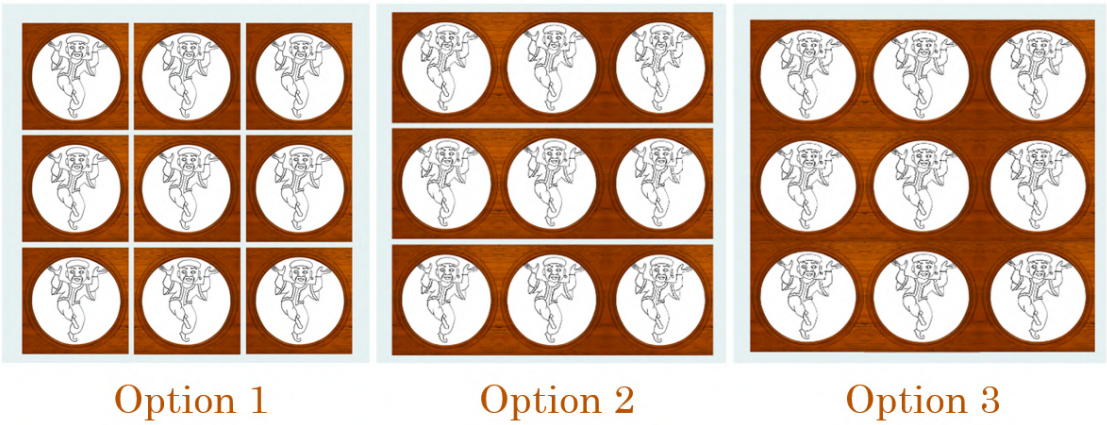


Figure C.5: Options that the user could choose

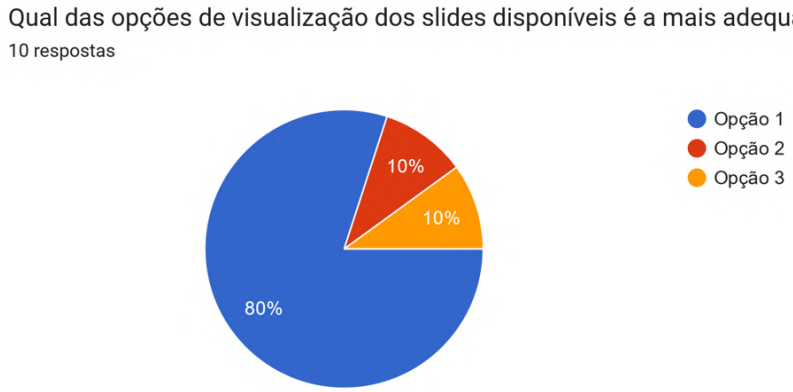


Figure C.6: Results of the fifth question

C.6 In relation to the visualization of the slides with greater detail, what type of buttons are the most appropriate?

Figure C.7: Options that the user could choose

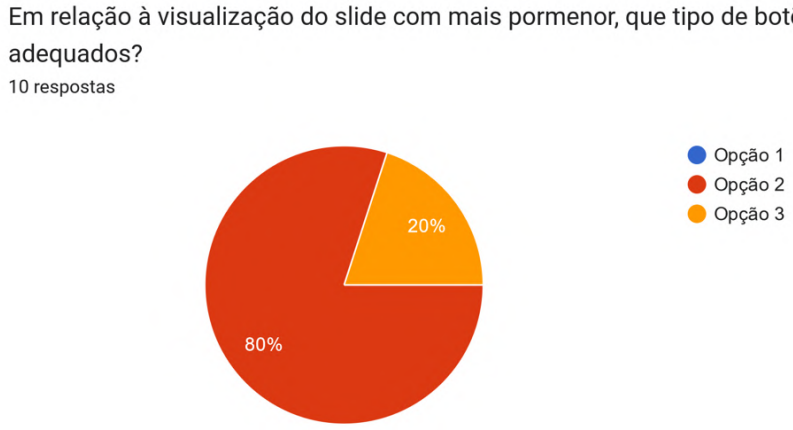


Figure C.8: Results of the sixth question

C.7 Is it easy to navigate between slides?

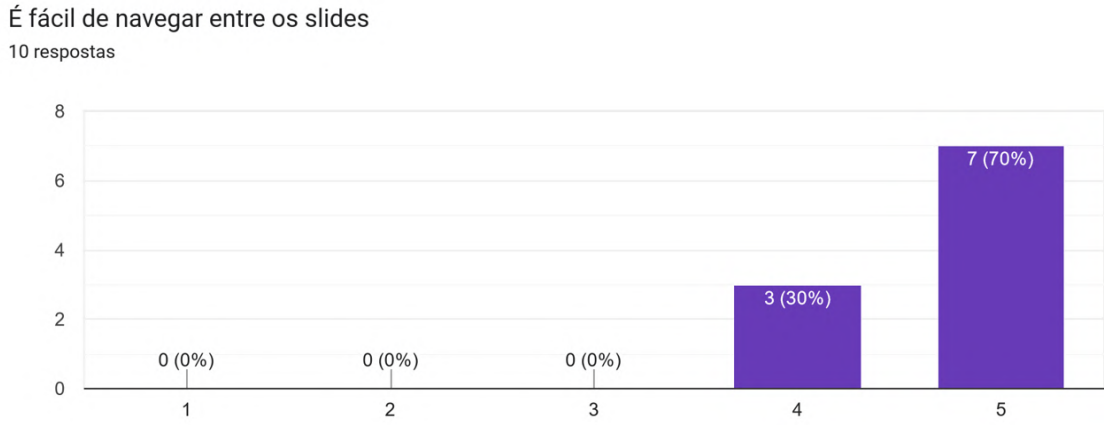


Figure C.9: Results of the seventh question: 1 = Strongly Disagree, 5 = Strongly Agree

C.8 How would you classify the layout and design of the painting page of the application?

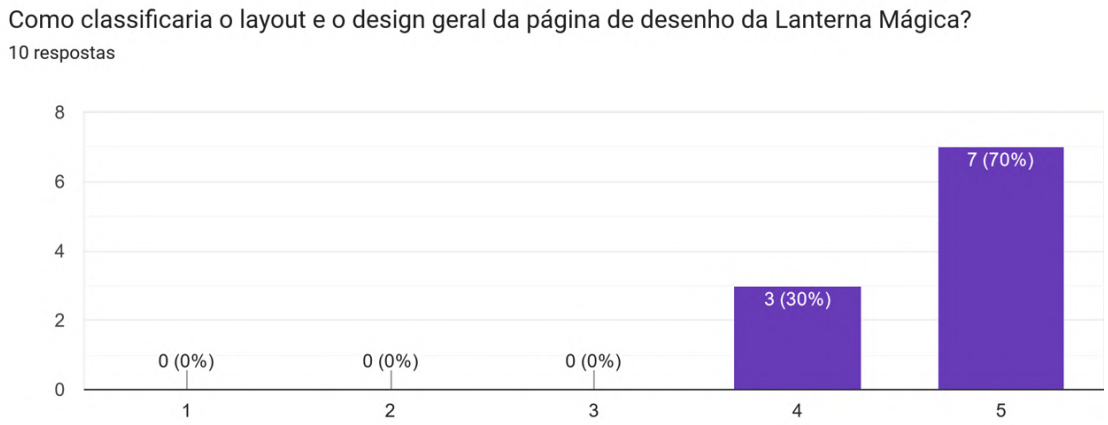


Figure C.10: Results of the eigth question: 1 = Very Bad, 5 = Excellent

C.9 Wich of the layouts do you prefer?

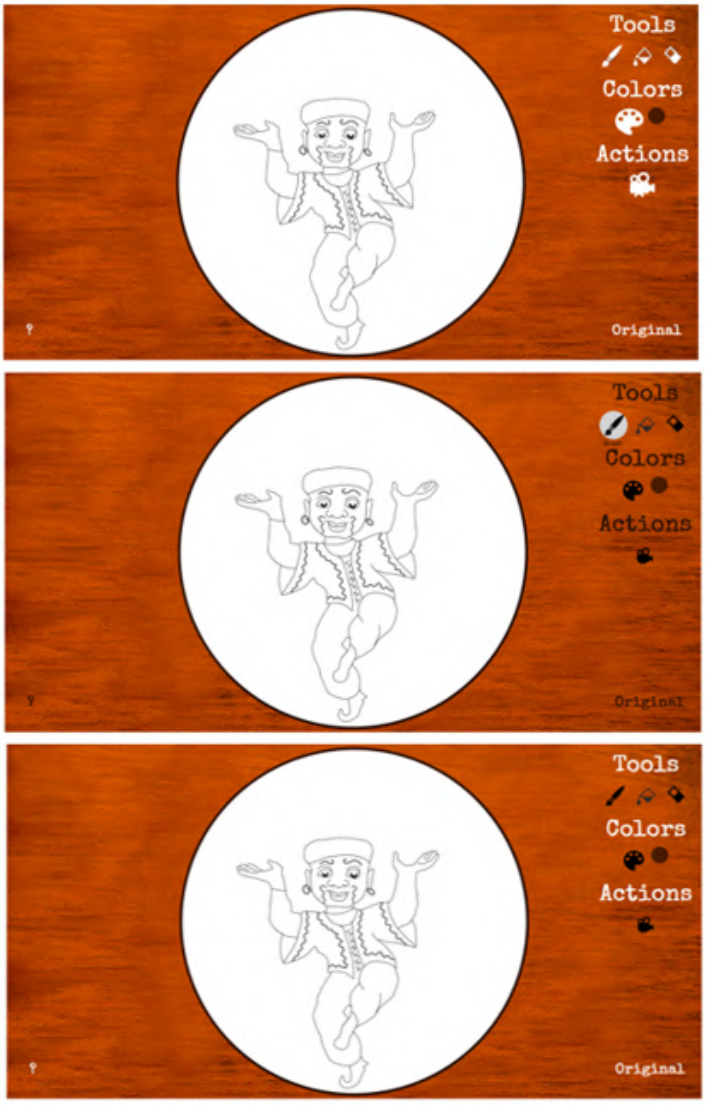


Figure C.11: Options that the user could choose from

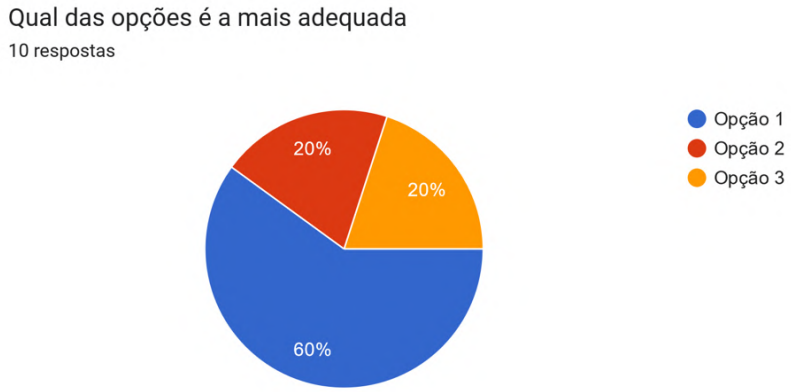


Figure C.12: Results of the ninth question

C.10 Regarding the Tools, I understand what each option does (for example, that the eraser erases and the brush paints).

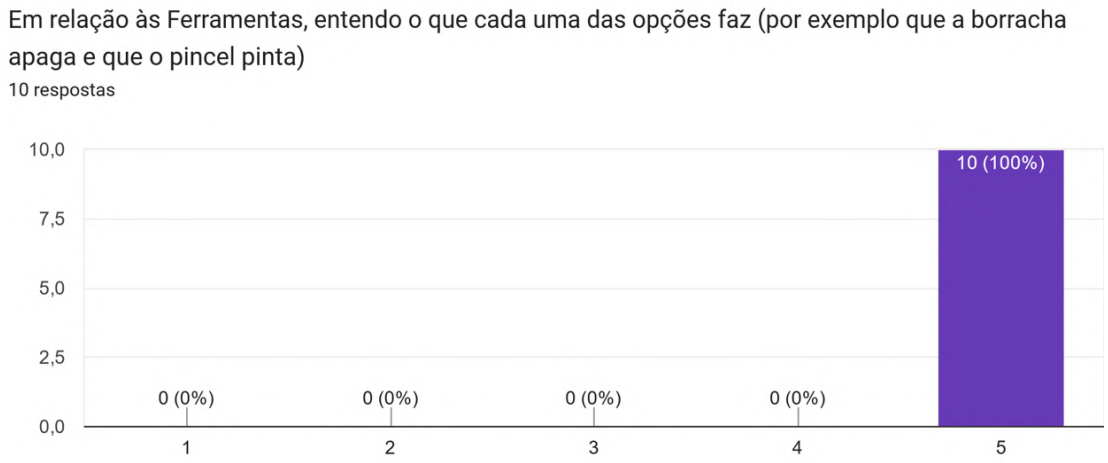


Figure C.13: Results of the tenth question: 1 = Strongly Disagree, 5 = Strongly Agree

C.11 Regarding the Colors, I understand that the palette is used to choose the colors that will be used for drawing.

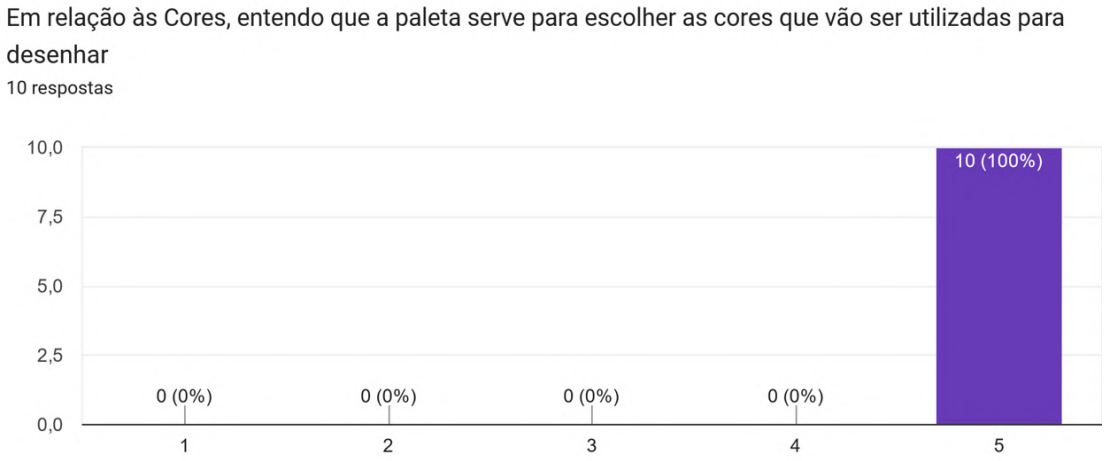


Figure C.14: Results of the eleventh question: 1 = Strongly Disagree, 5 = Strongly Agree

C.12 Is it intuitive that clicking on the camera will animate the drawing?

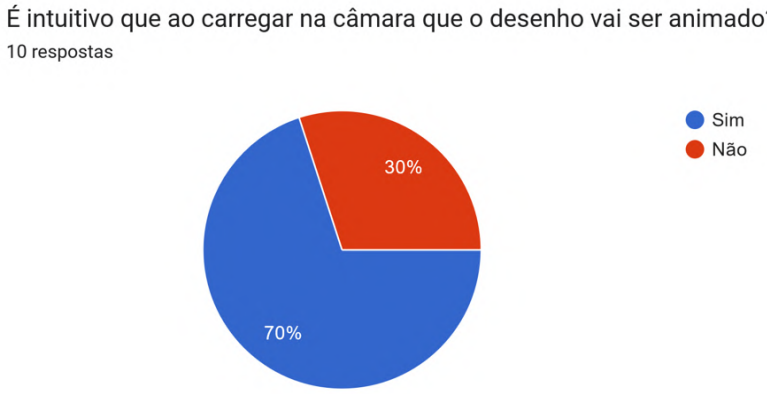


Figure C.15: Results of the twelfth question. Blue represents ***yes***, while red represents ***no***.

C.13 In relation to the 'Original' button, is it preferable to display a GIF that demonstrates the transformation of the original slide or just an image of the original slide?

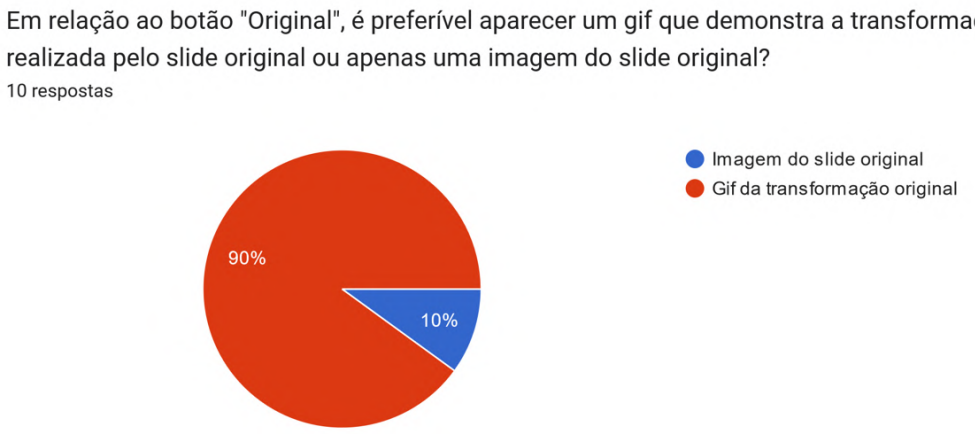


Figure C.16: Results of the thirteenth question. The blue represents the ***image***, while the red represents the ***GIF***

C.14 Do I understand what the button "?" represents?

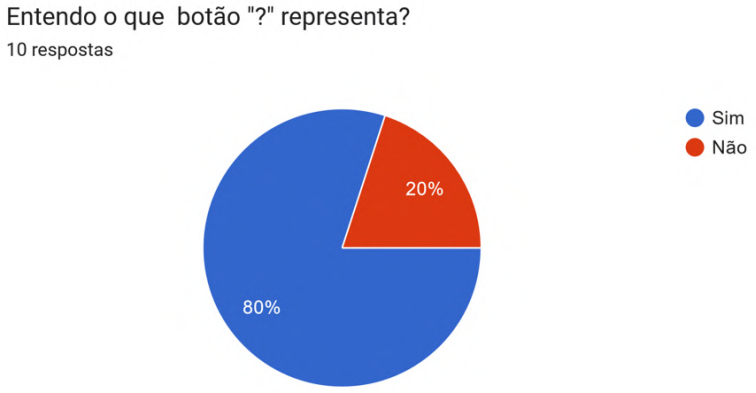


Figure C.17: Results of the fourteenth question. The blue represents ***yes*** while the red represents ***no***.

D

UEQ and PSSUQ questionnaires

D.1 PSSUQ - Question and Results

This Post-Study System Usability Questionnaire (PSSUQ) used a 7-point Likert scale, where 1 indicates "Strongly Disagree" and 7 indicates "Strongly Agree.".

D.1.1 Overall I am satisfied for how easy it is to use this system

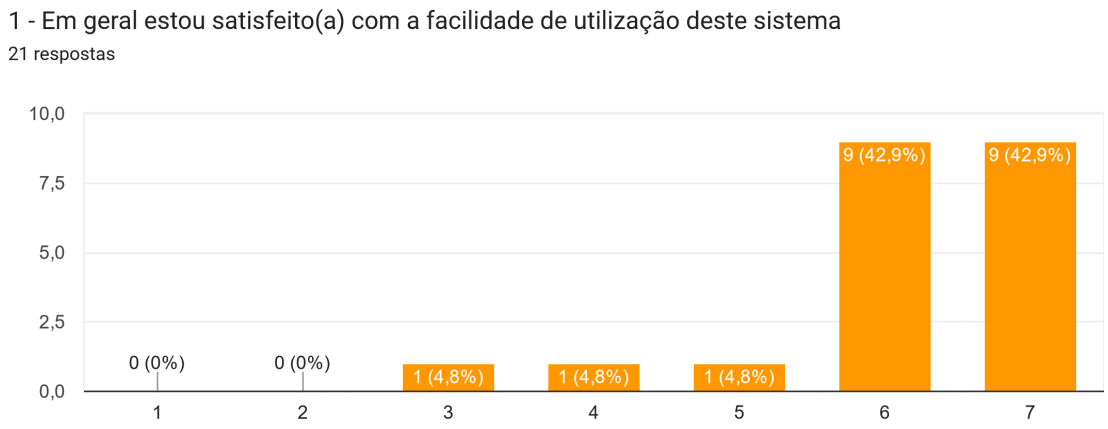


Figure D.1: Total results of the first question

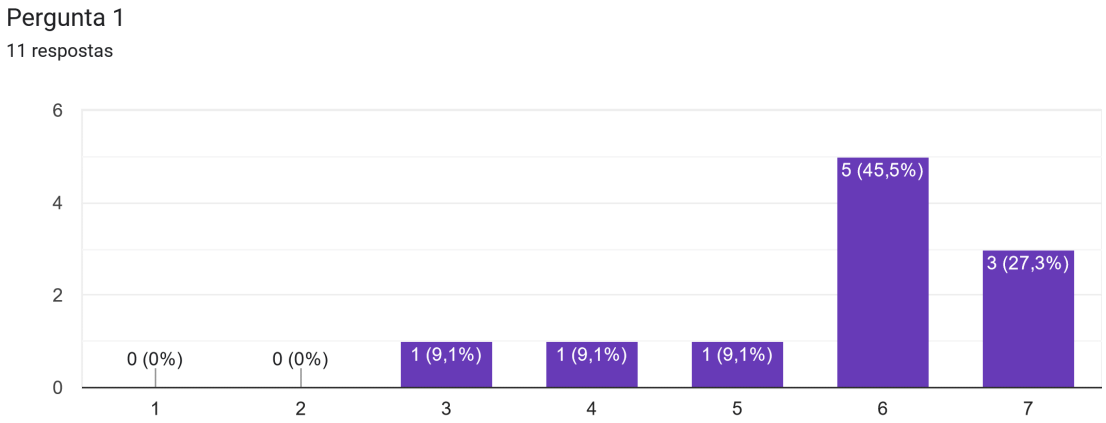


Figure D.2: Results of the first group in relation to the first question

D.1.2 It was simple to use this application

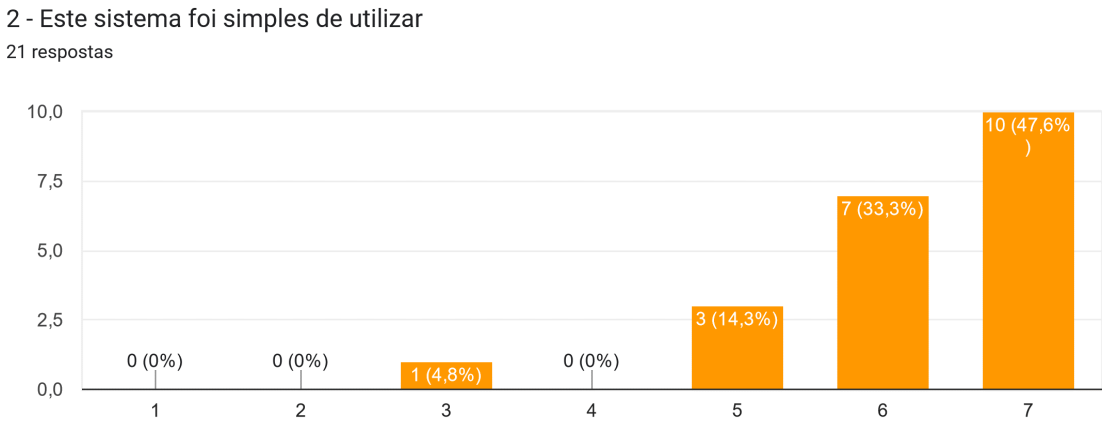


Figure D.3: Total results of the second question

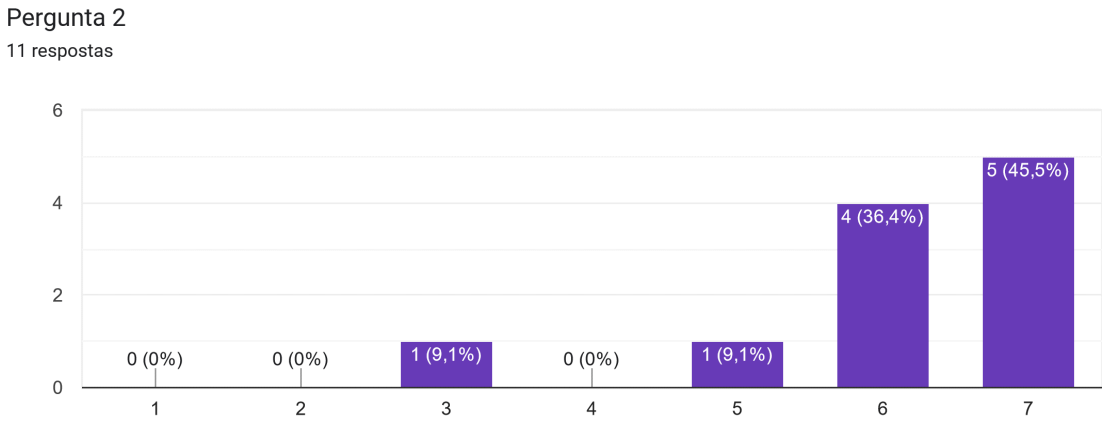


Figure D.4: Results of the first group in relation to the second question

D.1.3 I could effectively complete the tasks and scenarios using this system

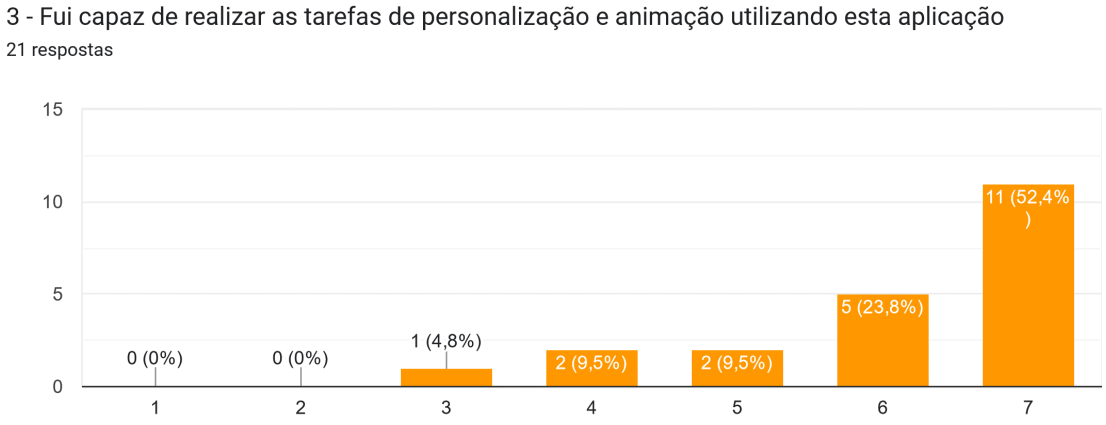


Figure D.5: Total results of the third question

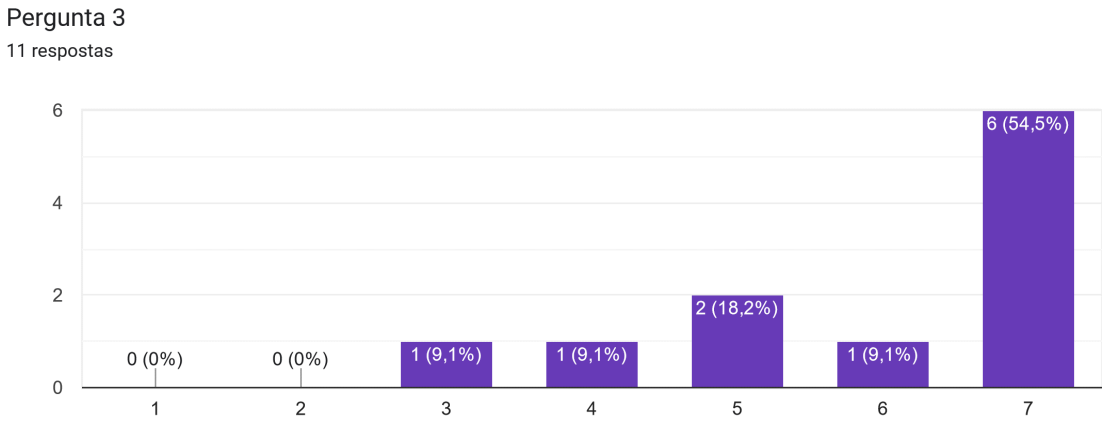


Figure D.6: Results of the first group in relation to the third question

D.1.4 I was able to complete the painting and animation tasks quickly for this application

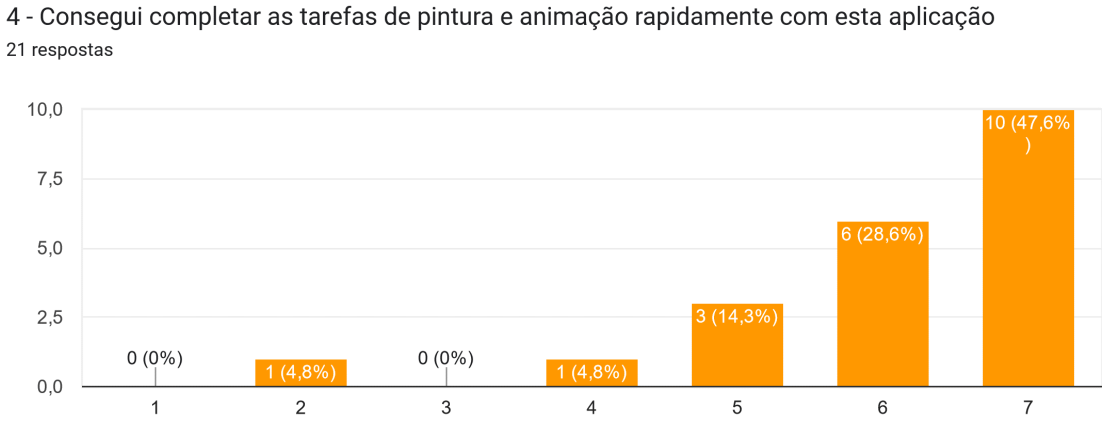


Figure D.7: Total results of the fourth question

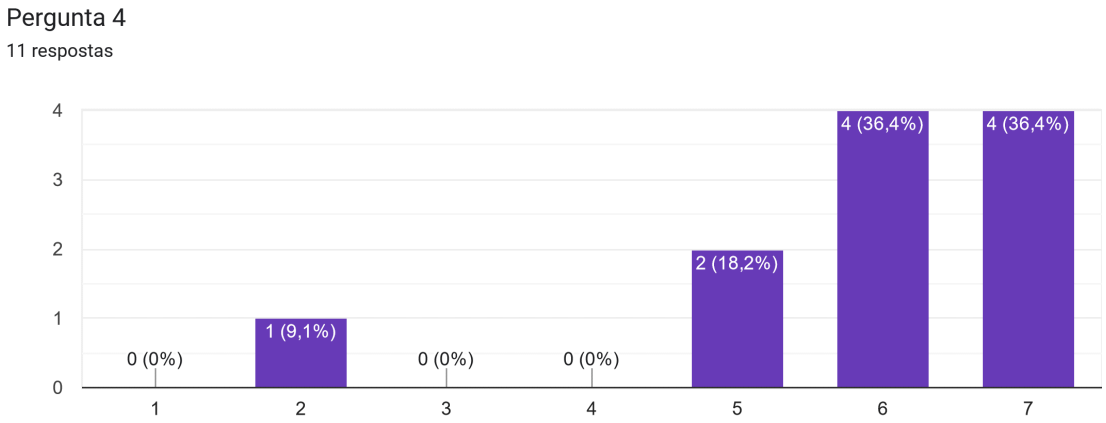


Figure D.8: Results of the first group in relation to the fourth question

D.1.5 I was able to efficiently complete the painting and animation tasks for this application

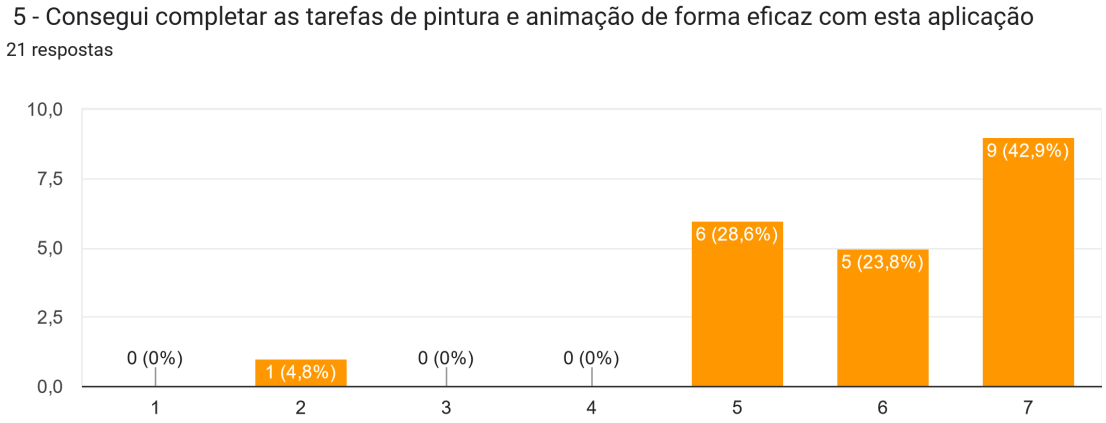


Figure D.9: Total results of the fifth question

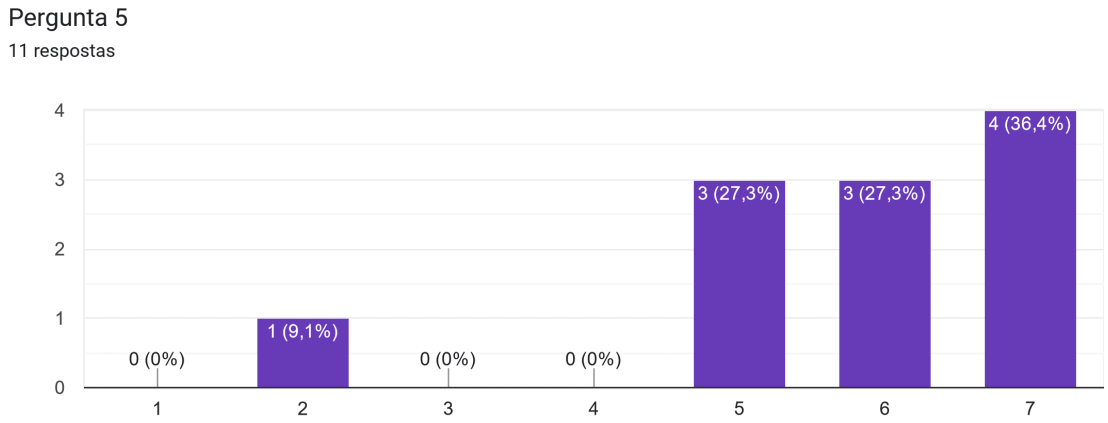


Figure D.10: Results of the first group in relation to the fifth question

D.1.6 I felt comfortable using this application

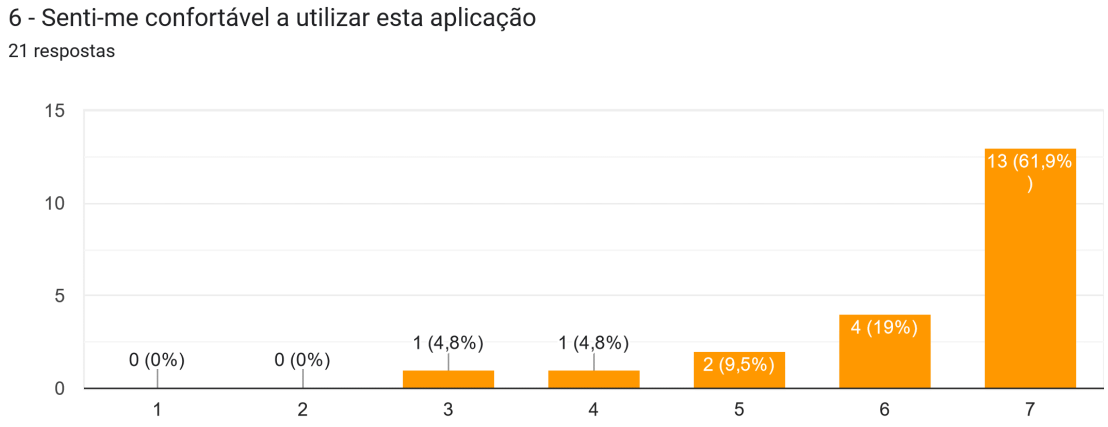


Figure D.11: Total results of the sixth question

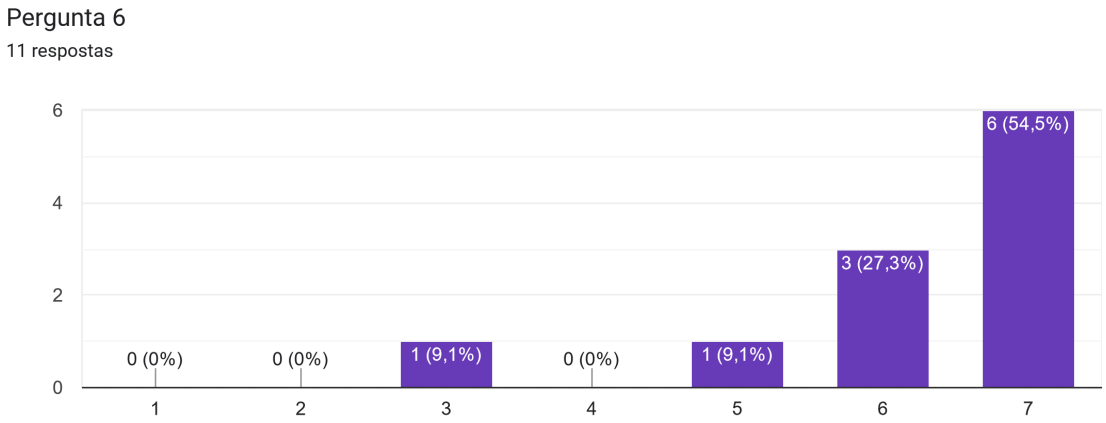


Figure D.12: Results of the first group in relation to the sixth question

D.1.7 It was easy to learn how to use this application

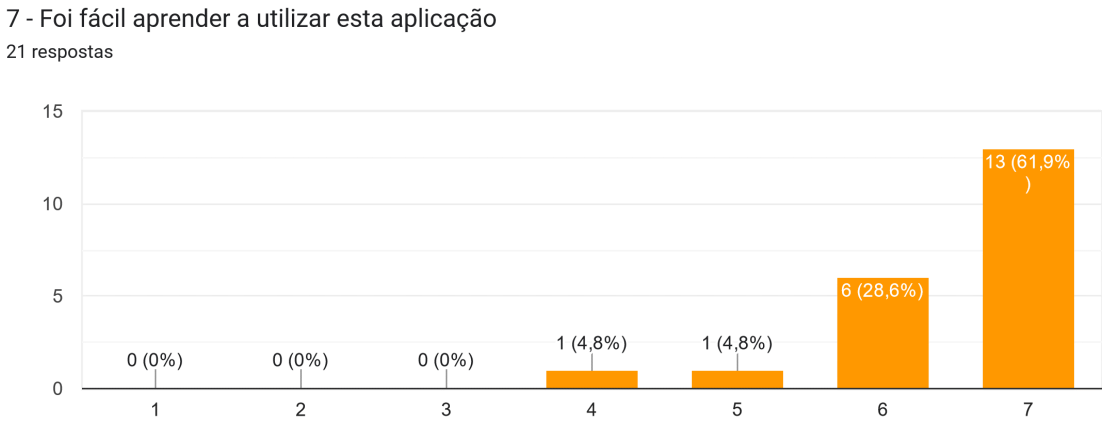


Figure D.13: Total results of the seventh question

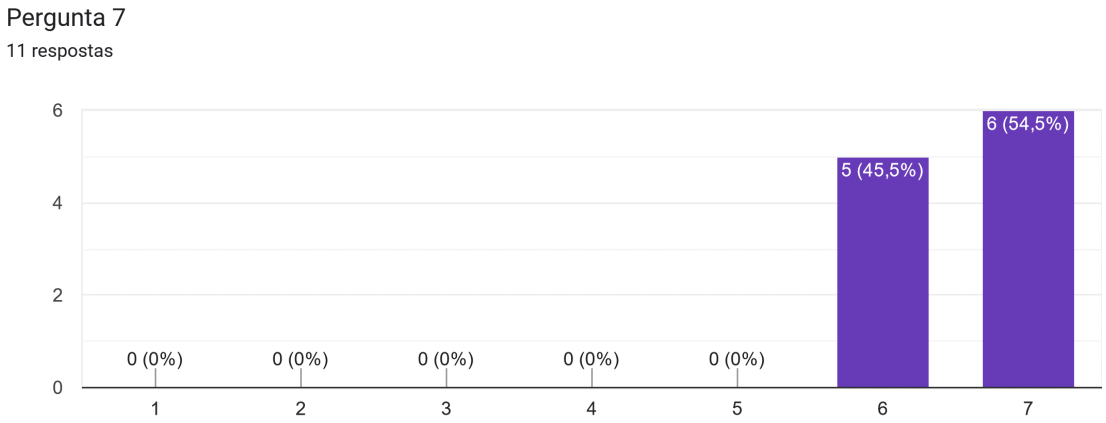


Figure D.14: Results of the first group in relation to the seventh question

D.1.8 I believe I could become productive quickly using this application

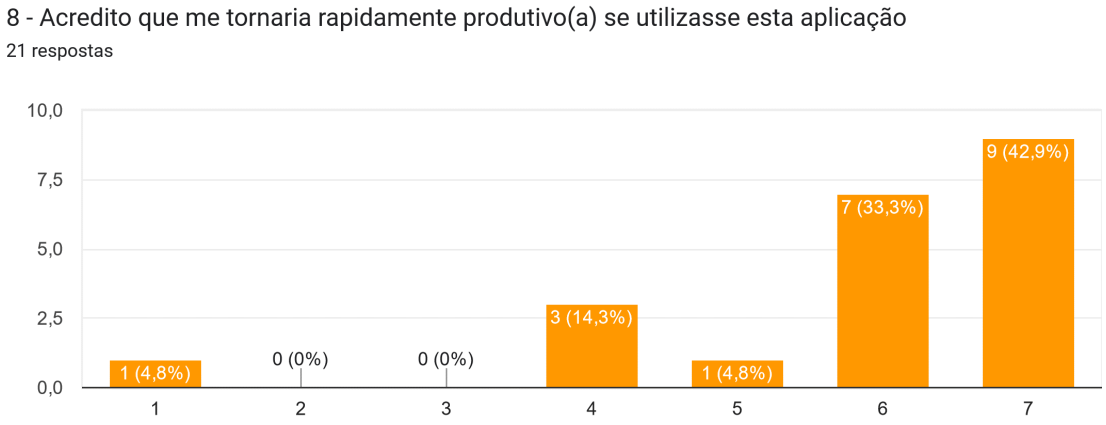


Figure D.15: Total results of the eighth question

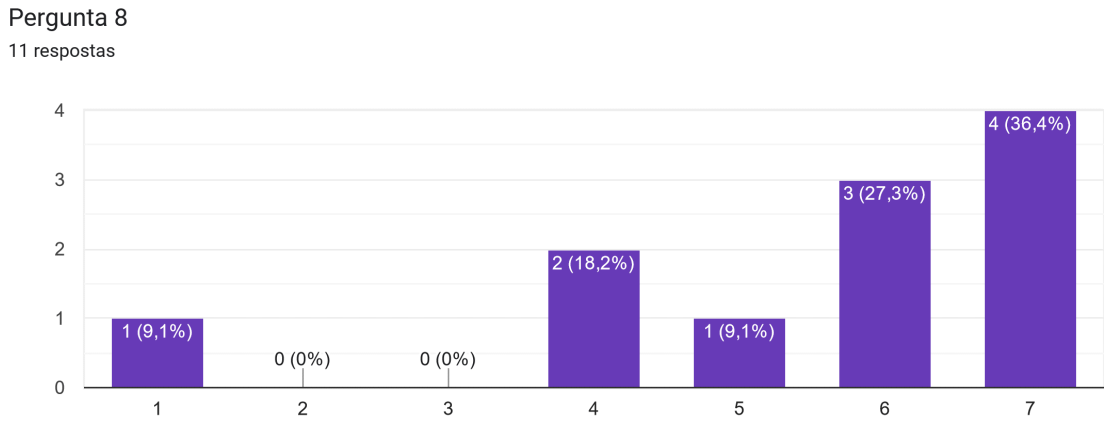


Figure D.16: Results of the first group in relation to the eighth question

D.1.9 The application gave me error messages that clearly told me how to fix the problems

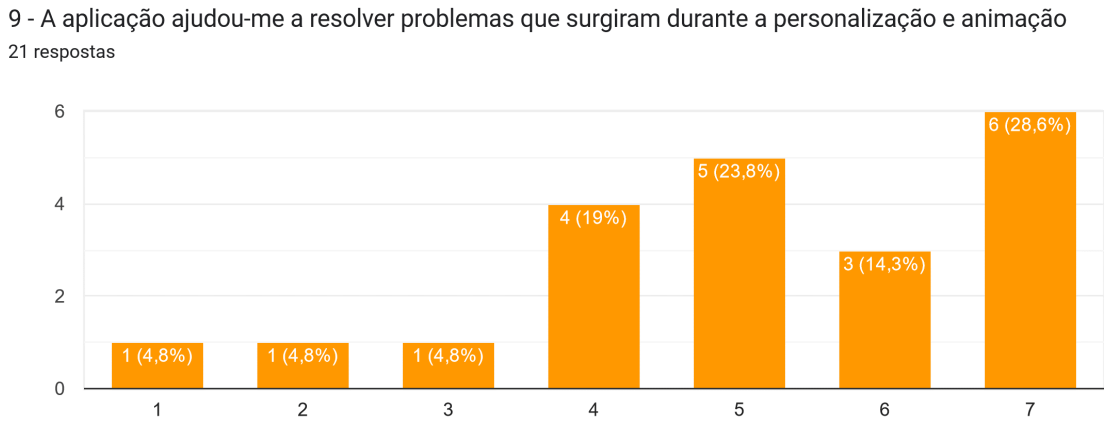


Figure D.17: Total results of the nineth question

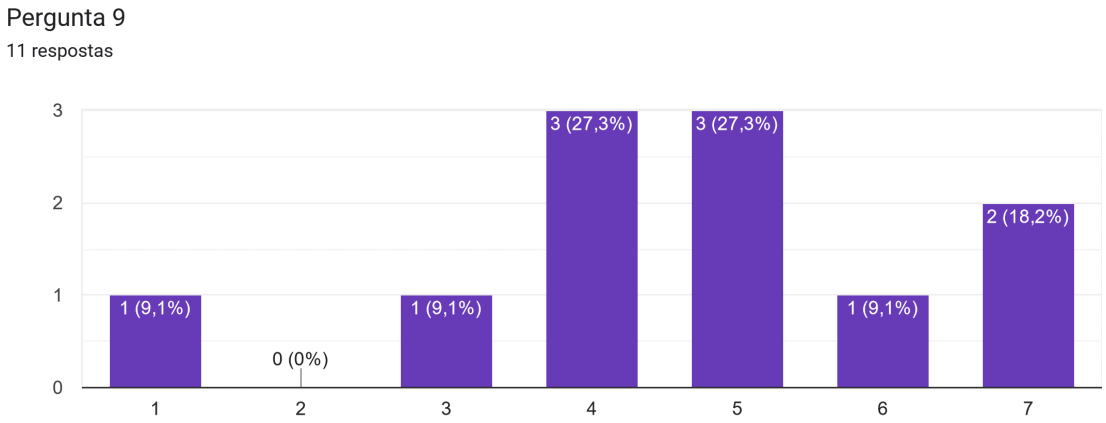


Figure D.18: Results of the first group in relation to the nineth question

D.1.10 Whenever I made a mistake using the application I could recover quickly and easily

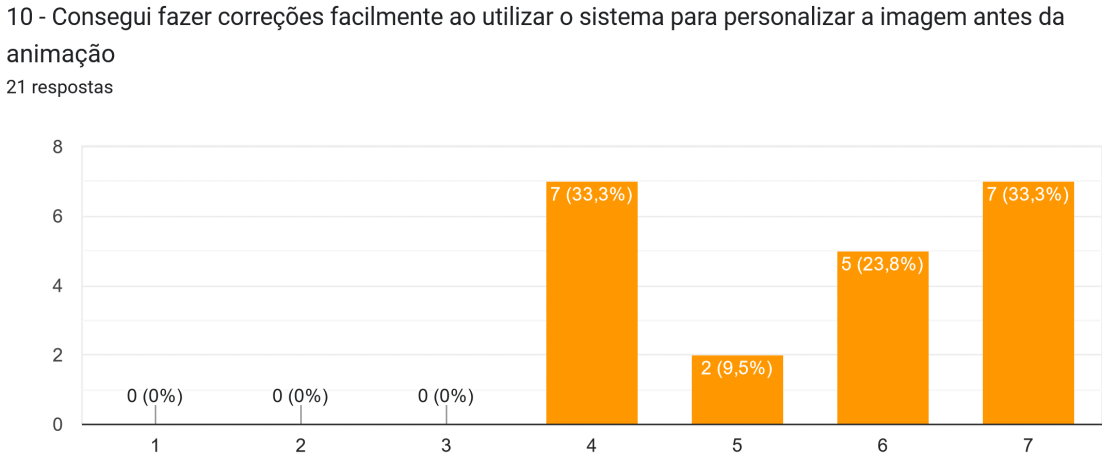


Figure D.19: Total results of the tenth question

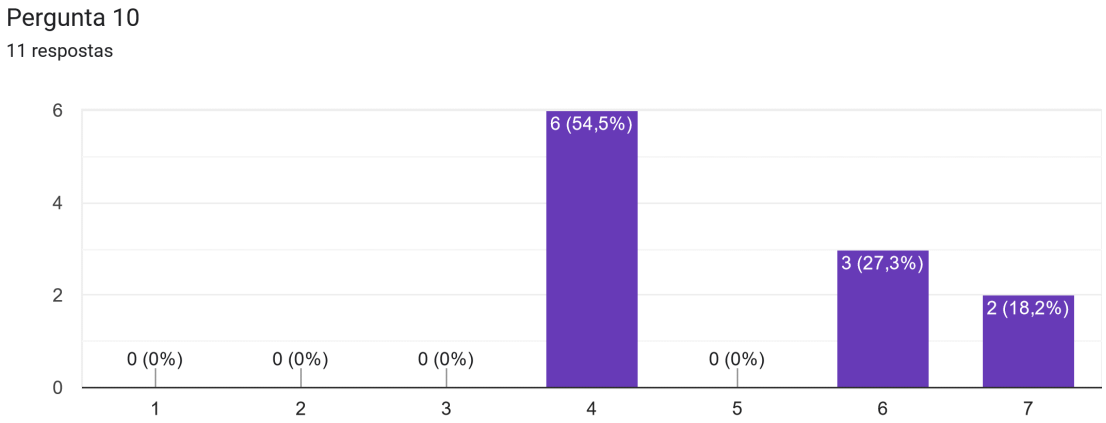


Figure D.20: Results of the first group in relation to the tenth question

D.1.11 The information provided by the application (alerts, pop-ups, etc) was clear

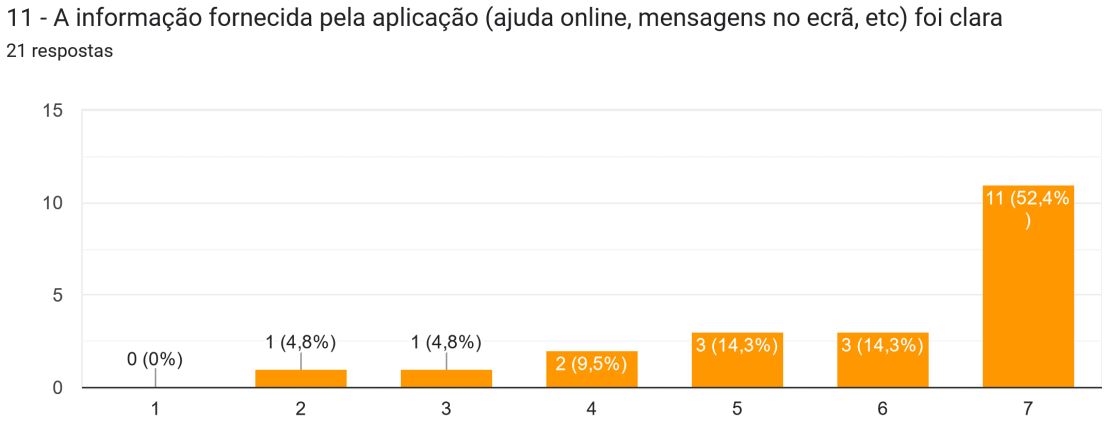


Figure D.21: Total results of the eleventh question

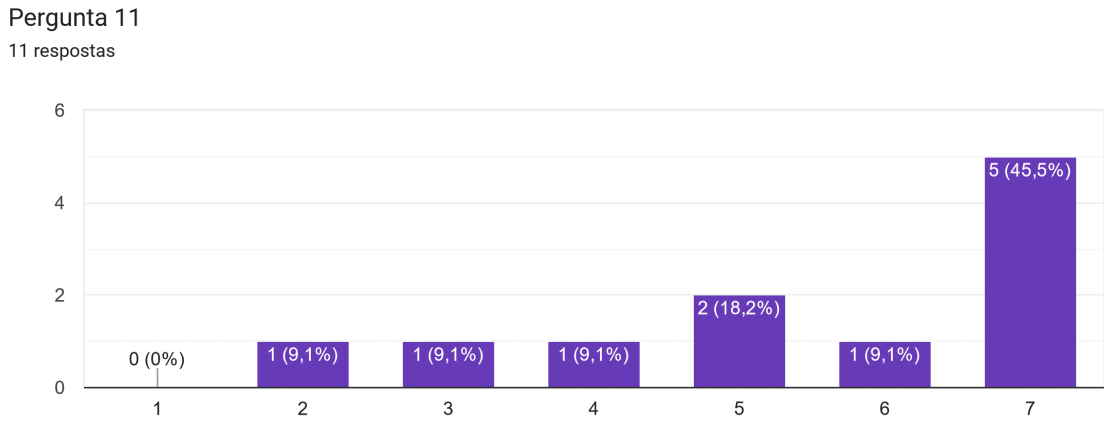


Figure D.22: Results of the first group in relation to the eleventh question

D.1.12 It was easy to find the information I needed

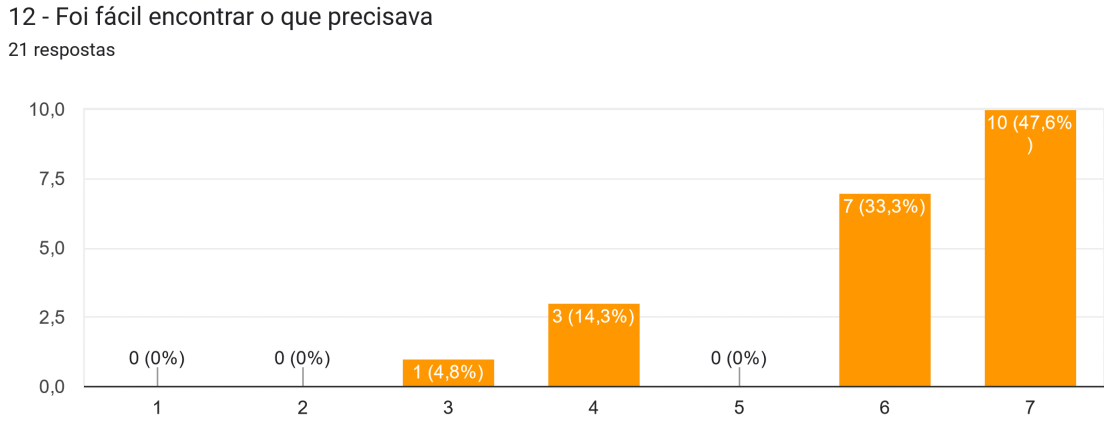


Figure D.23: Total results of the twelfth question

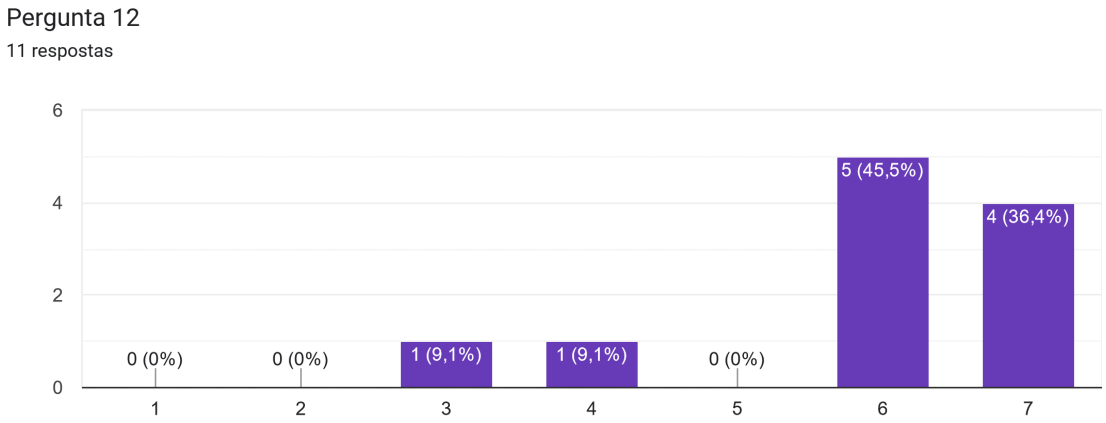


Figure D.24: Results of the first group in relation to the twelfth question

D.1.13 The information provided by the application was easy to understand

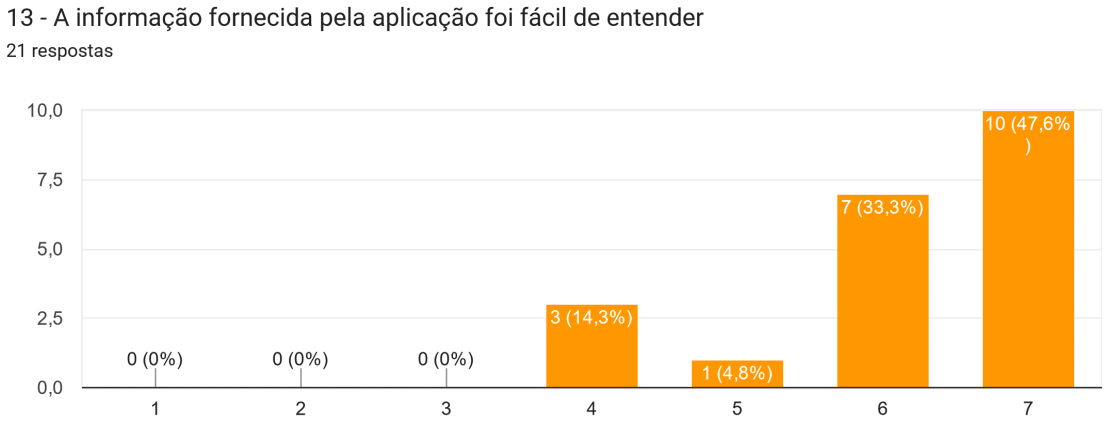


Figure D.25: Total results of the thirteenth question

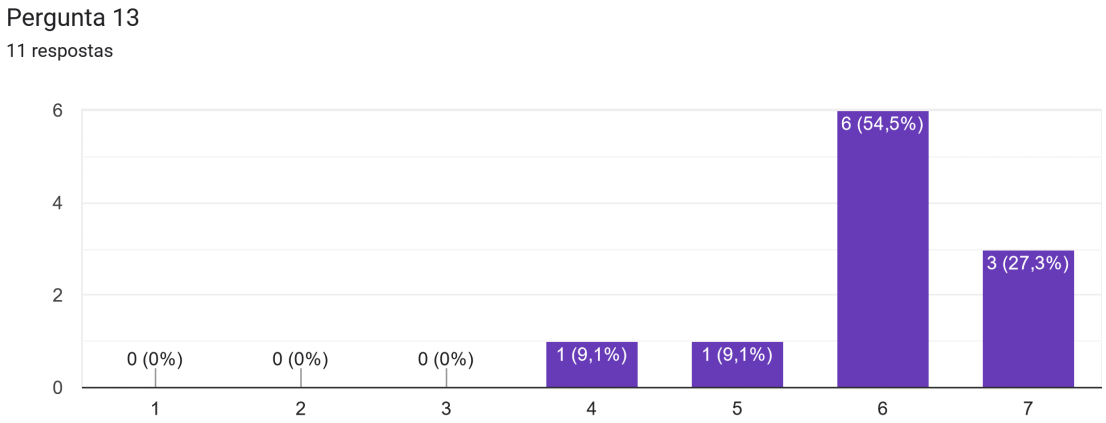


Figure D.26: Results of the first group in relation to the thirteenth question

D.1.14 The information was effective in completing the painting and animation tasks

Figure D.27: Total results of the fourteenth question

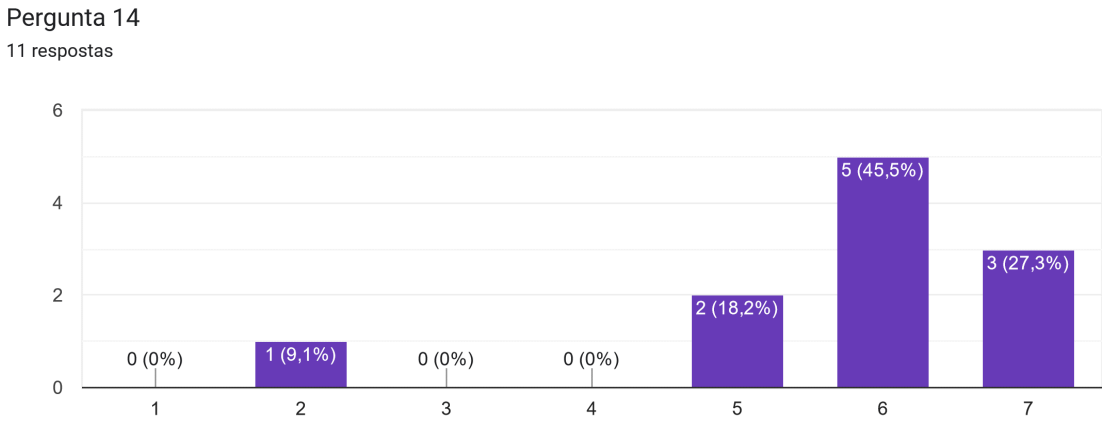


Figure D.28: Results of the first group in relation to the fourteenth question

D.1.15 The organization of the information in the application was clear

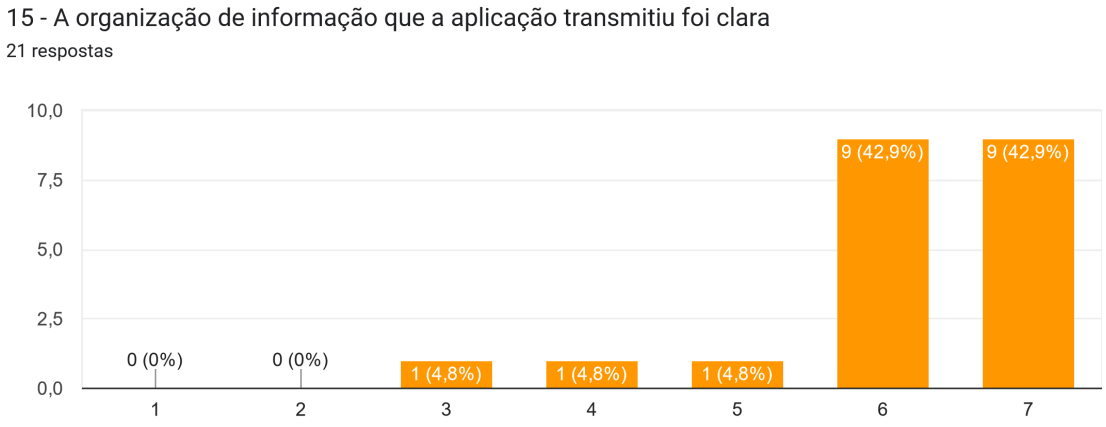


Figure D.29: Total results of the fiftheenth question

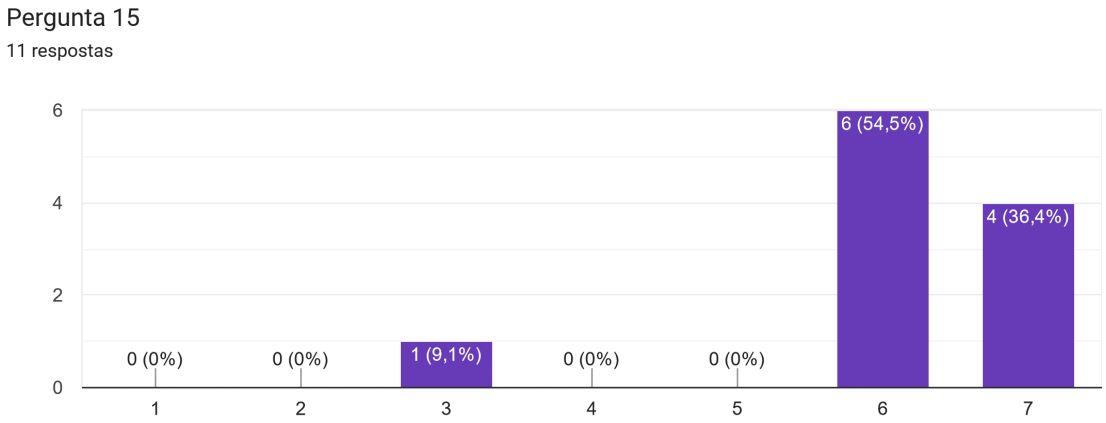


Figure D.30: Results of the first group in relation to the fiftheenth question

D.1.16 The interface of the application was pleasent

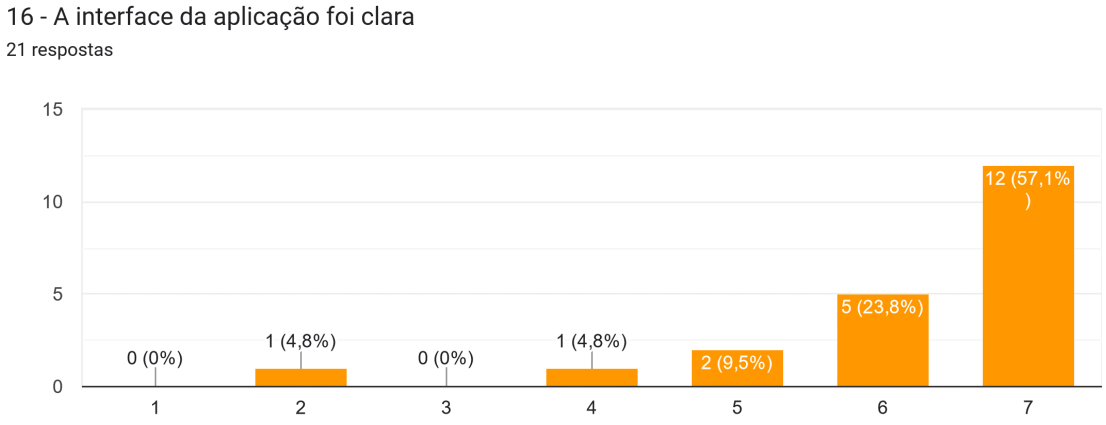


Figure D.31: Total results of the sixteenth question

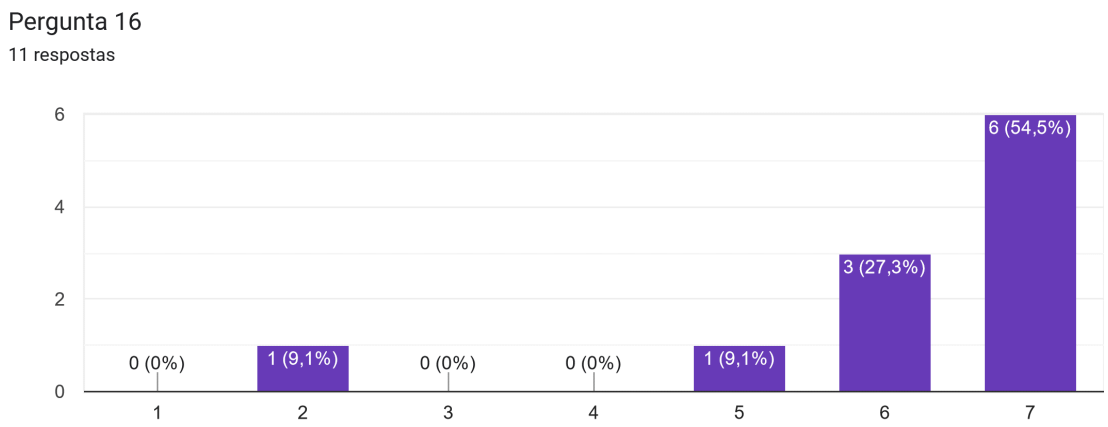


Figure D.32: Results of the first group in relation to the sixteenth question

D.1.17 I liked using the interface of the application

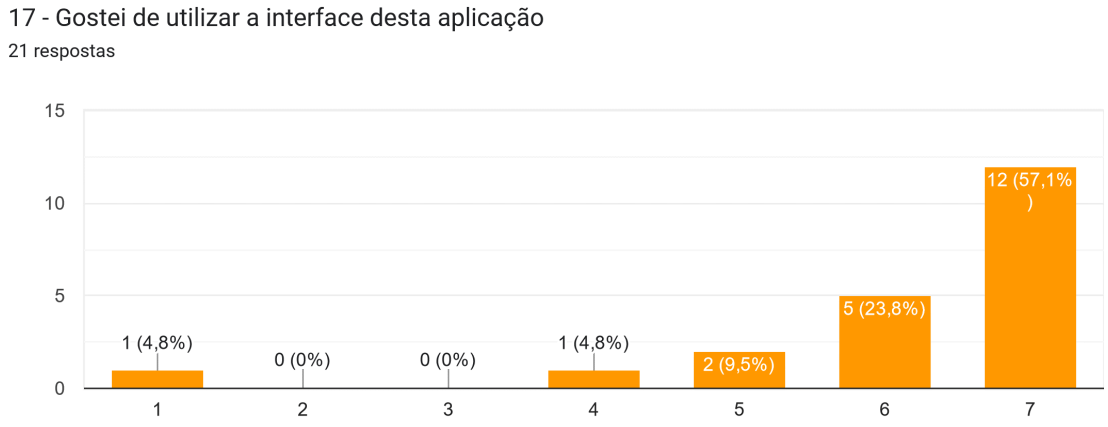


Figure D.33: Total results of the seventeenth question

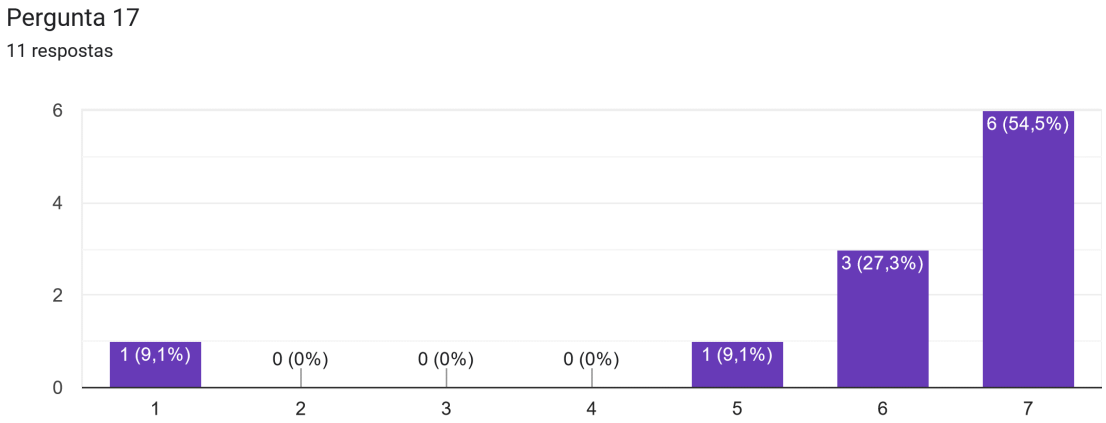


Figure D.34: Results of the first group in relation to the seventeenth question

D.1.18 The application has all the features that I expected

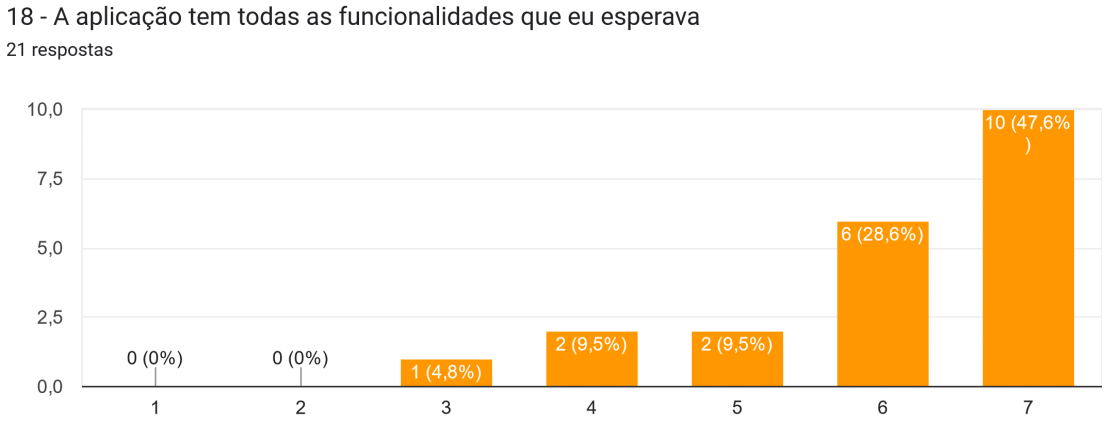


Figure D.35: Total results of the eighteenth question

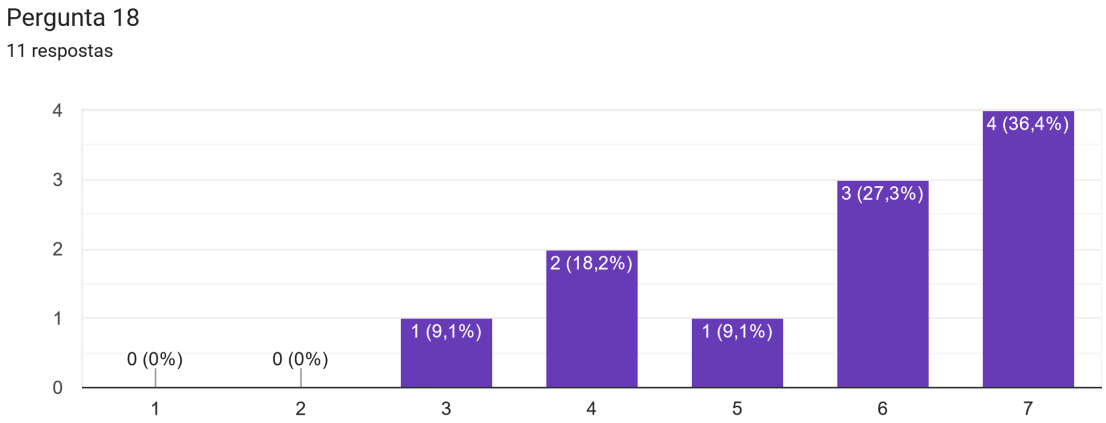


Figure D.36: Results of the first group in relation to the eighteenth question

D.1.19 Overall, I am satisfied with this application

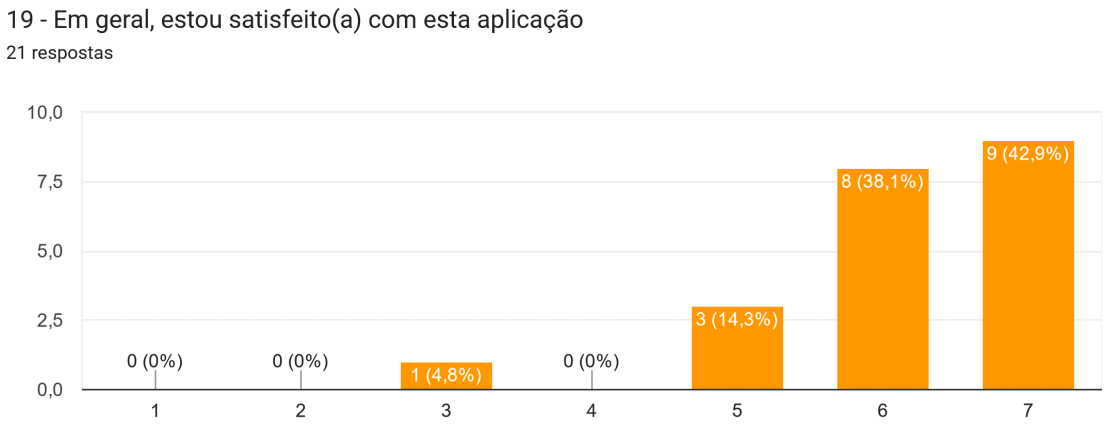


Figure D.37: Total results of the nineteenth question

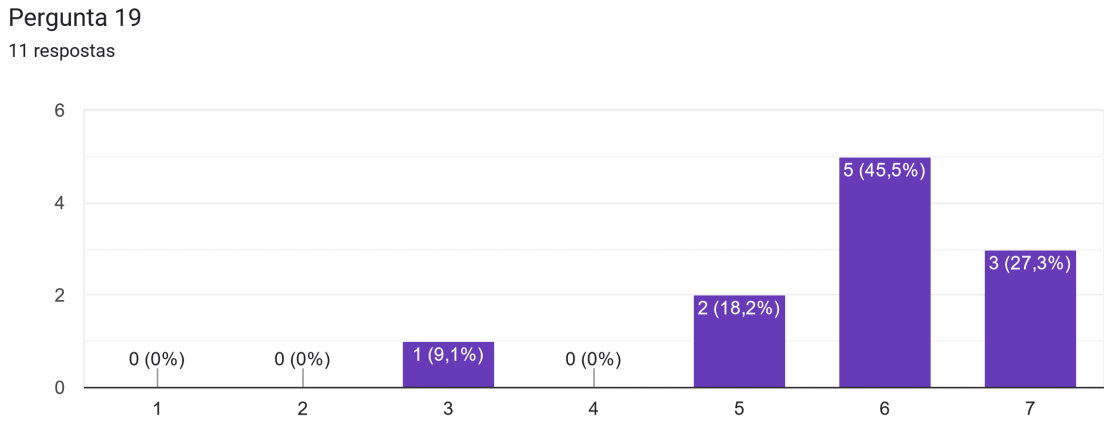


Figure D.38: Results of the first group in relation to the nineteenth question

D.2 UEQ - Questions and Results

This User Experience Questionnaire (UEQ) used a 7-point Likert scale to assess user experience. Each item consisted of opposing adjective pairs, including: Ugly-Attractive, Unfriendly-Friendly, Bad-Good, Unpleasant-Pleasant, Uncomfortable-Comfortable, Complicated-Easy, Incomprehensible-Comprehensible, Difficult to Learn-Easy to Learn, Worthless-Valuable, Unpredictable-Predictable, Slow-Fast, Inefficient-Efficient, Impractical-Practical, Disorganized-Organized, Confusing-Clear, Obstructive-Supportive, Boring-Exciting, Uninteresting-Interesting, Demotivating-Motivating, Unattractive-Attractive, Uncreative-Creative, Conservative-Innovative, Common-Inventive, Conventional-Original, and Does not meet expectations-Meets expectations.

D.2.1 Ugly-Attractive

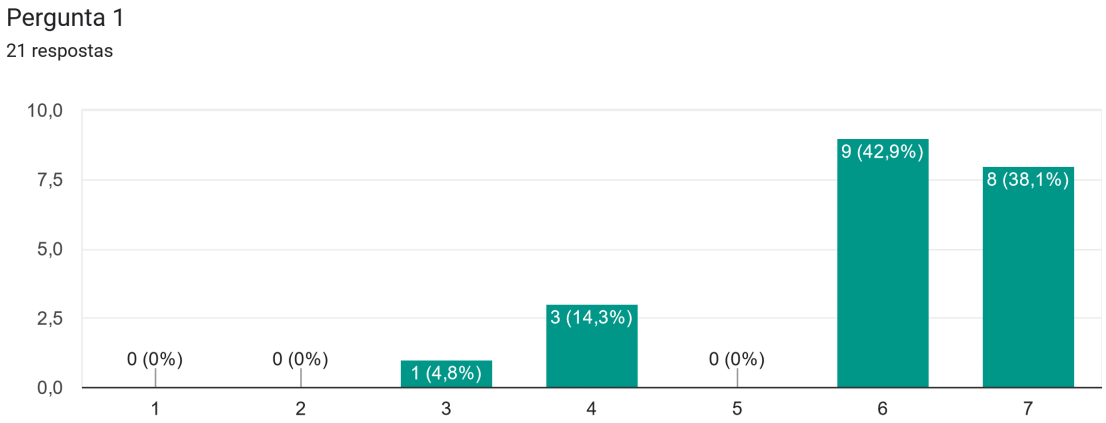


Figure D.39: Total results of the first question

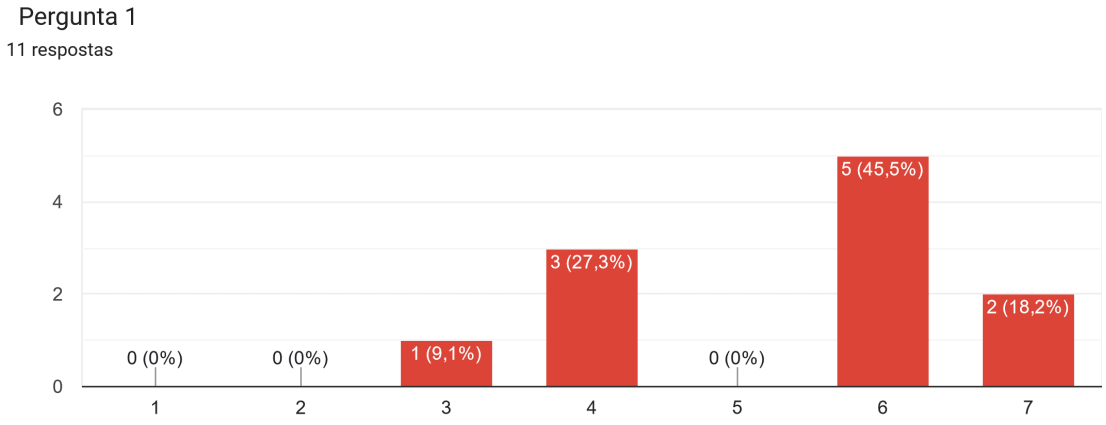


Figure D.40: Results of the first group in relation to the first question

D.2.2 Unfriendly-Friendly

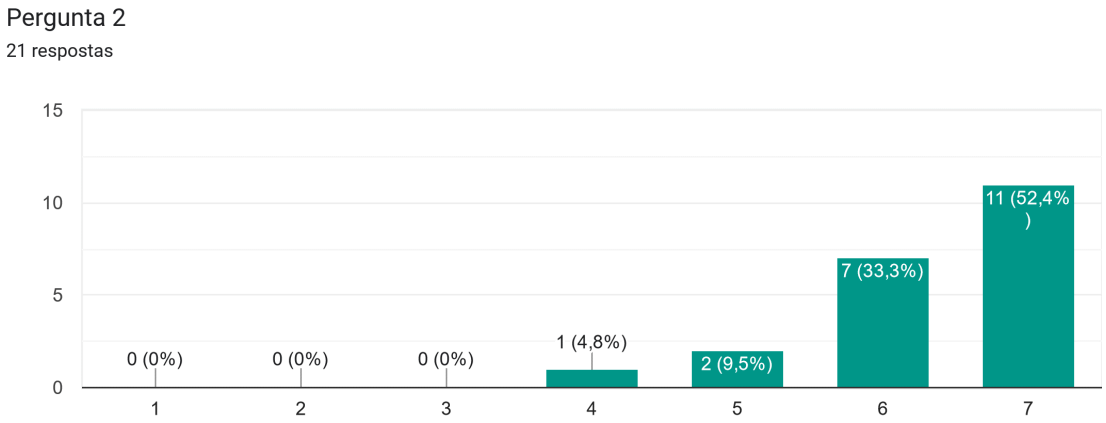


Figure D.41: Total results of the second question

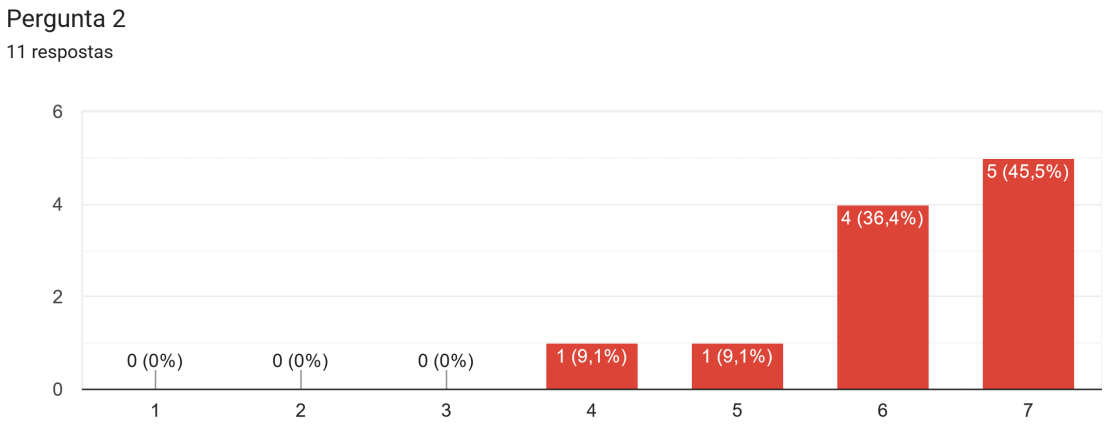


Figure D.42: Results of the first group in relation to the second question

D.2.3 Bad-Good

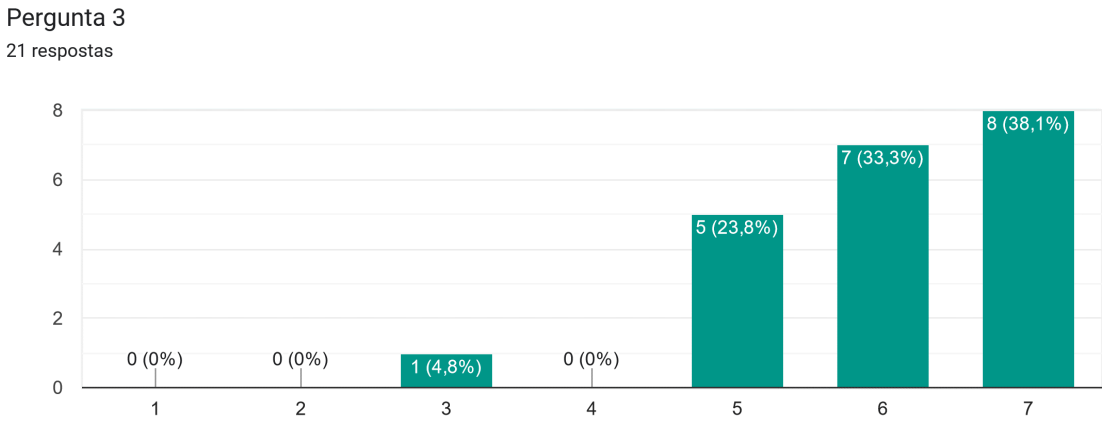


Figure D.43: Total results of the third question

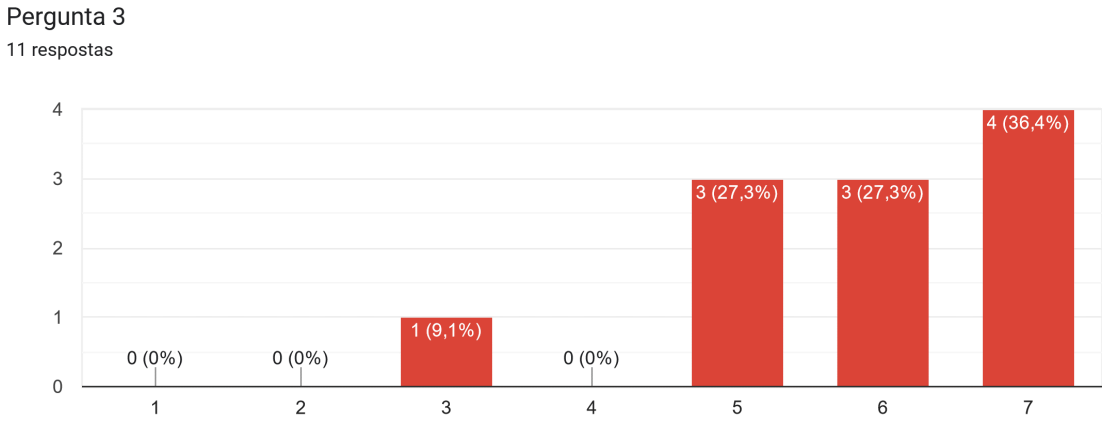


Figure D.44: Results of the first group in relation to the third question

D.2.4 Unpleasant-Pleasant

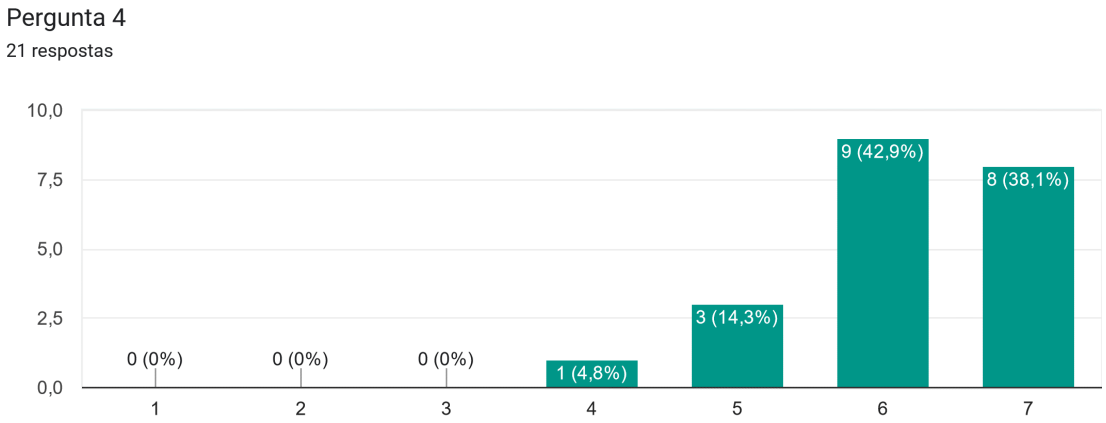


Figure D.45: Total results of the fourth question

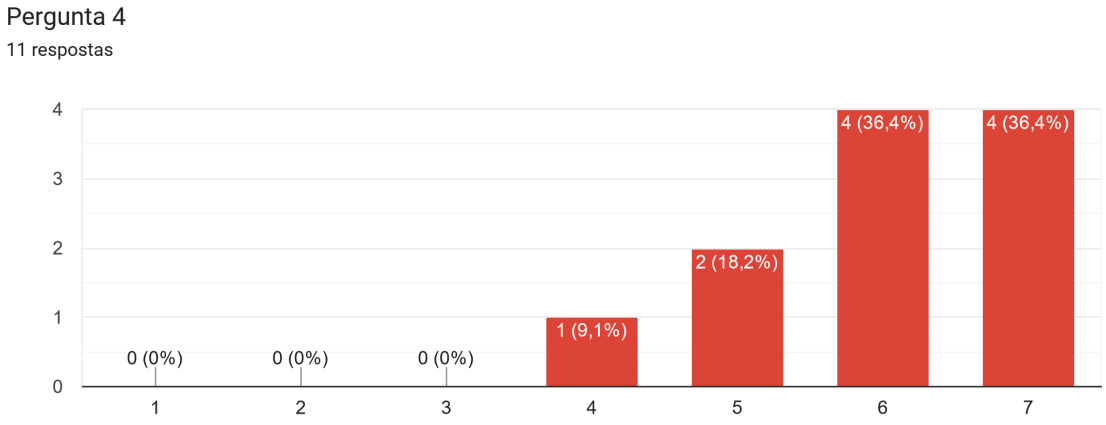


Figure D.46: Results of the first group in relation to the fourth question

D.2.5 Uncomfortable-Comfortable

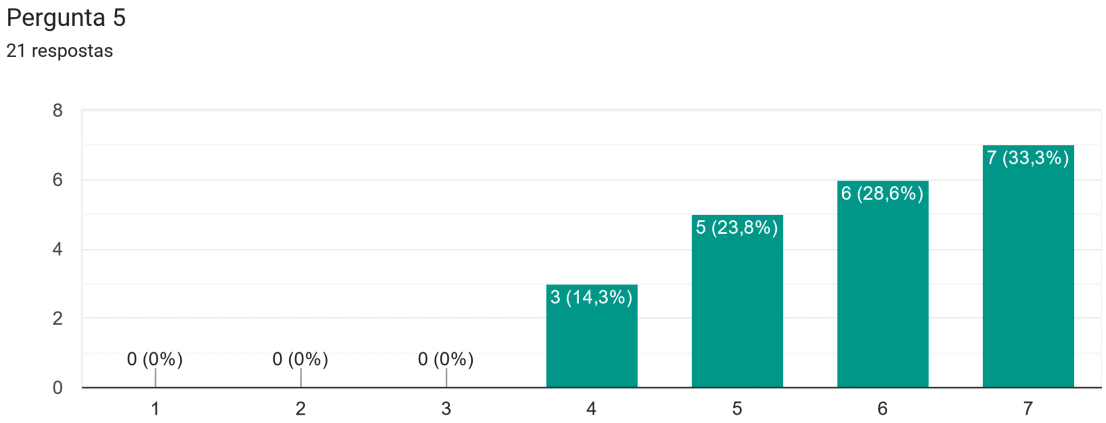


Figure D.47: Total results of the fifth question

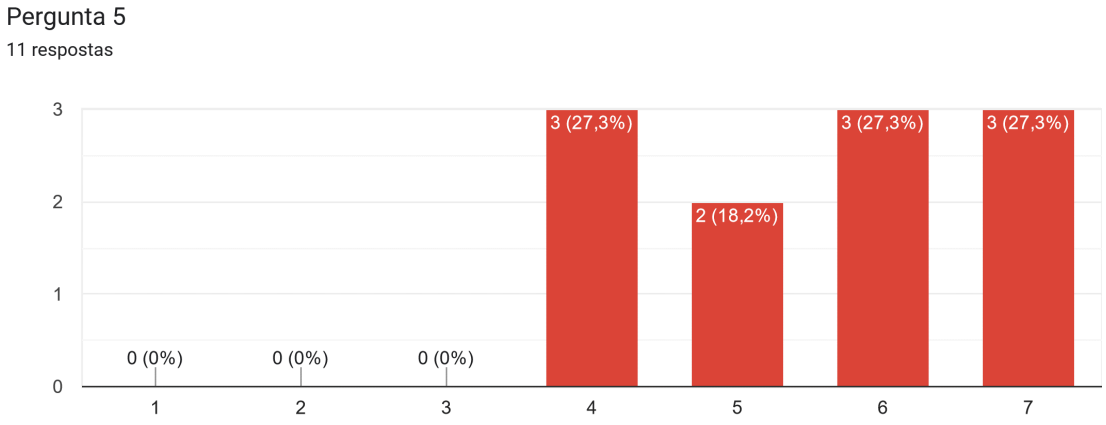


Figure D.48: Results of the first group in relation to the fifth question

D.2.6 Complicated-Easy

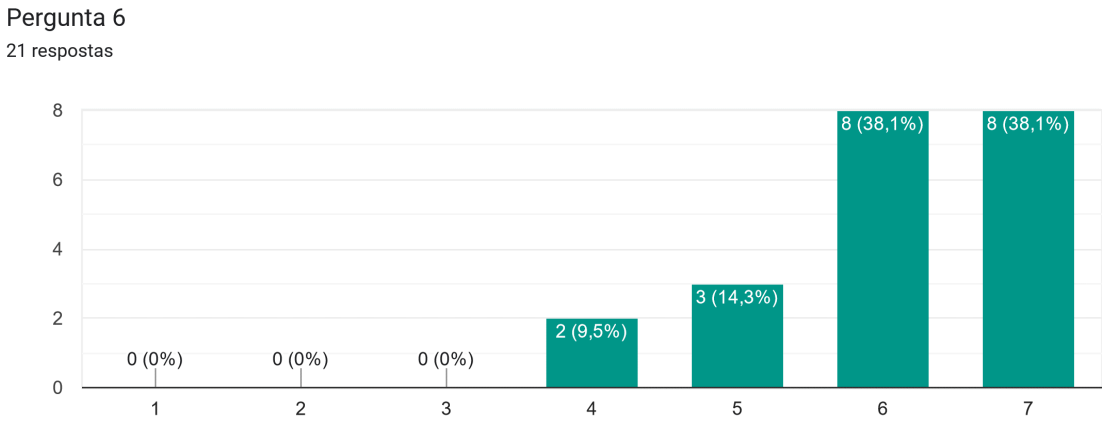


Figure D.49: Total results of the sixth question

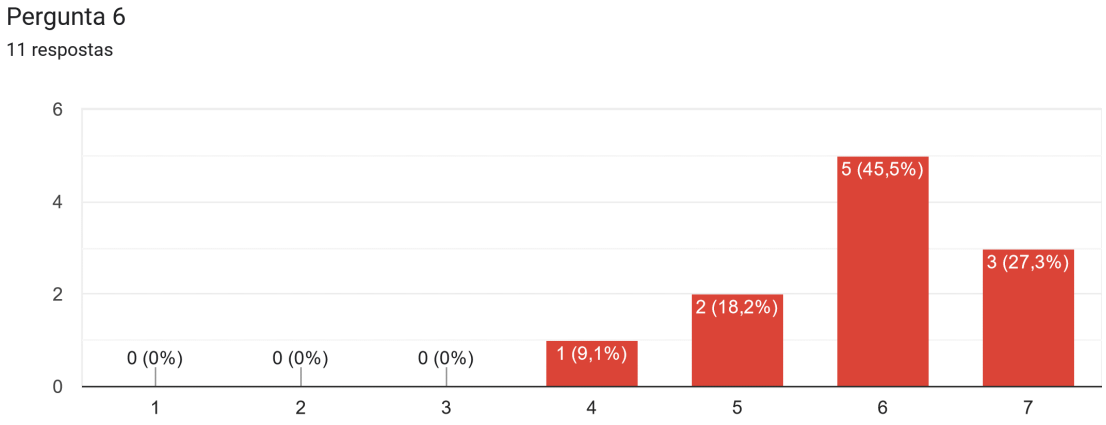


Figure D.50: Results of the first group in relation to the sixth question

D.2.7 Incomprehensible-Comprehensible

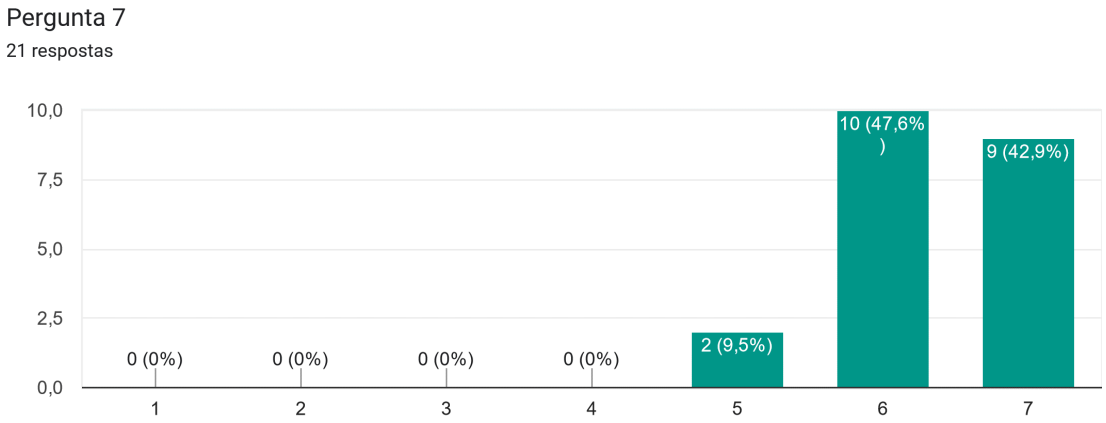


Figure D.51: Total results of the seventh question

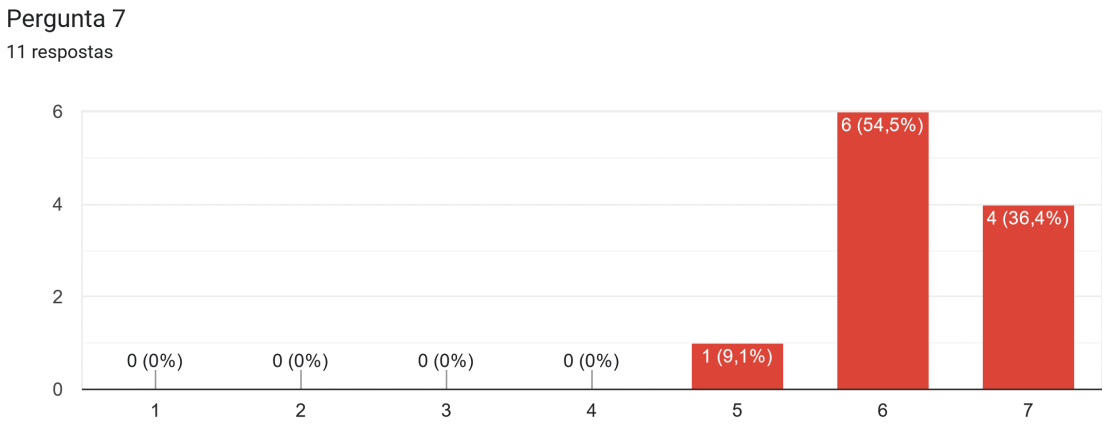


Figure D.52: Results of the first group in relation to the seventh question

D.2.8 Difficult to Learn-Easy to Learn

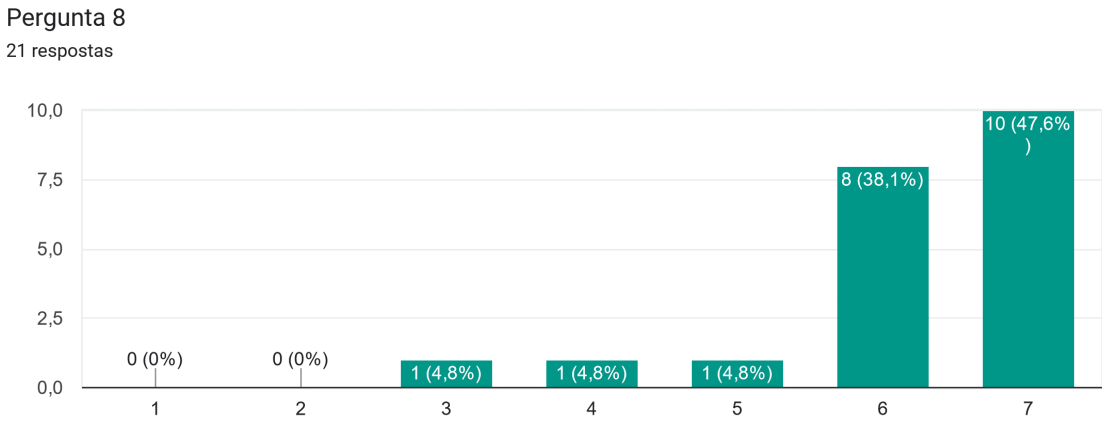


Figure D.53: Total results of the eighth question

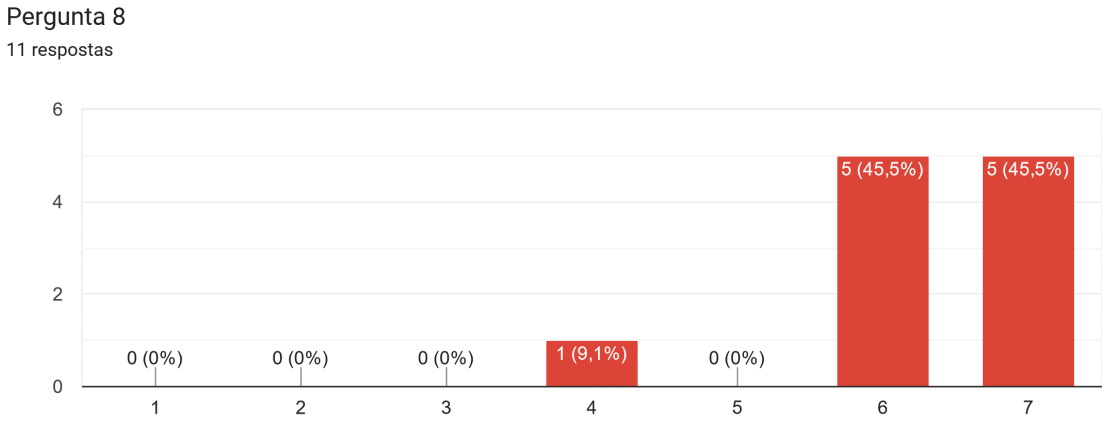


Figure D.54: Results of the first group in relation to the eighth question

D.2.9 Worthless-Valuable

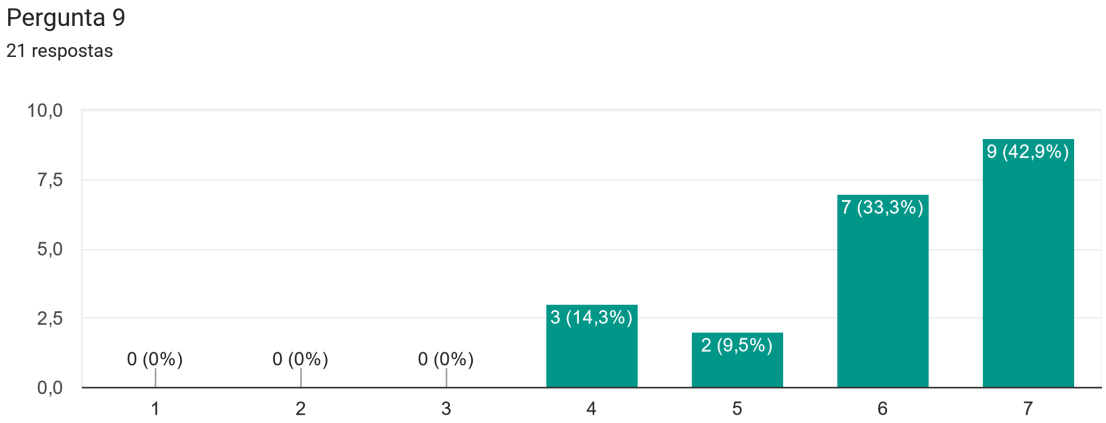


Figure D.55: Total results of the nineth question

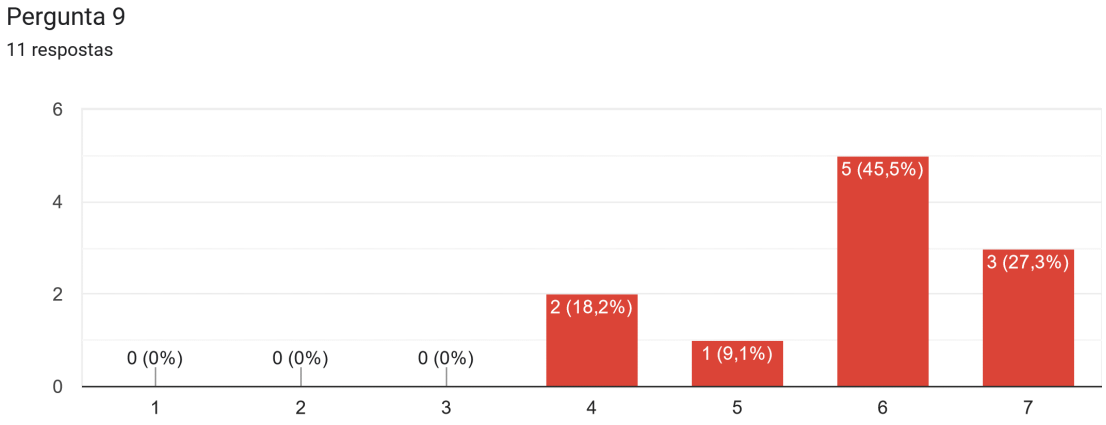


Figure D.56: Results of the first group in relation to the nineth question

D.2.10 Unpredictable-Predictable

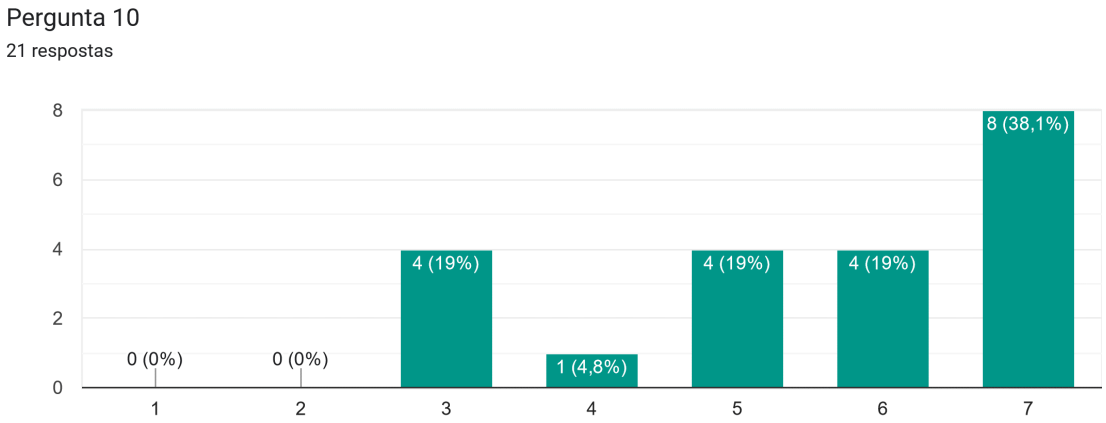


Figure D.57: Total results of the tenth question

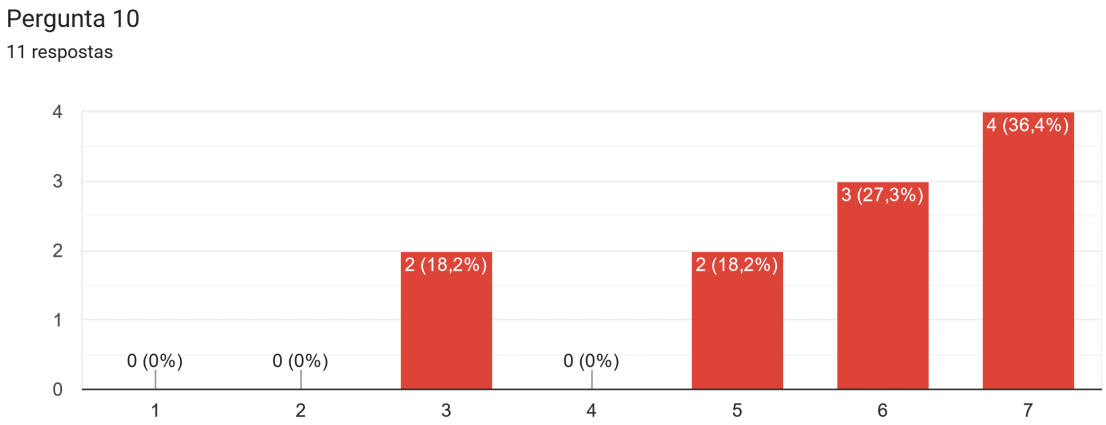


Figure D.58: Results of the first group in relation to the tenth question

D.2.11 Slow-Fast

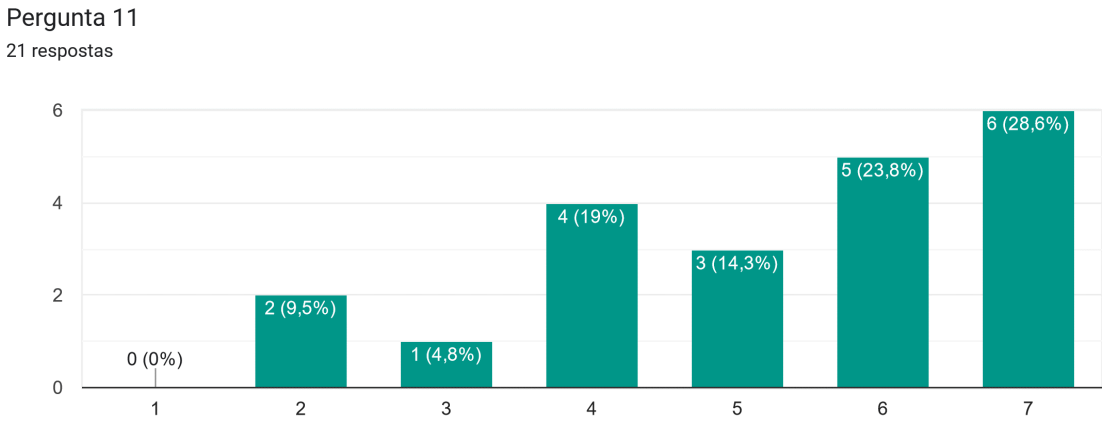


Figure D.59: Total results of the eleventh question

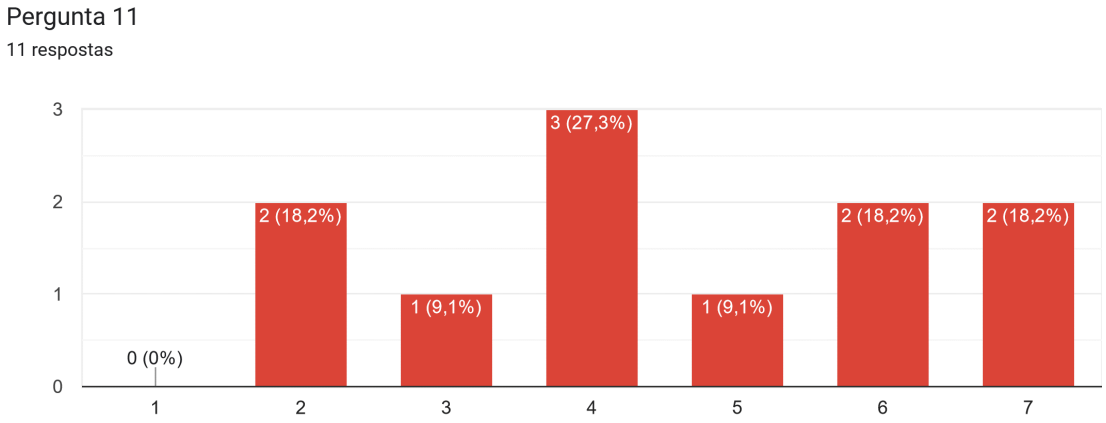


Figure D.60: Results of the first group in relation to the eleventh question

D.2.12 Inefficient-Efficient

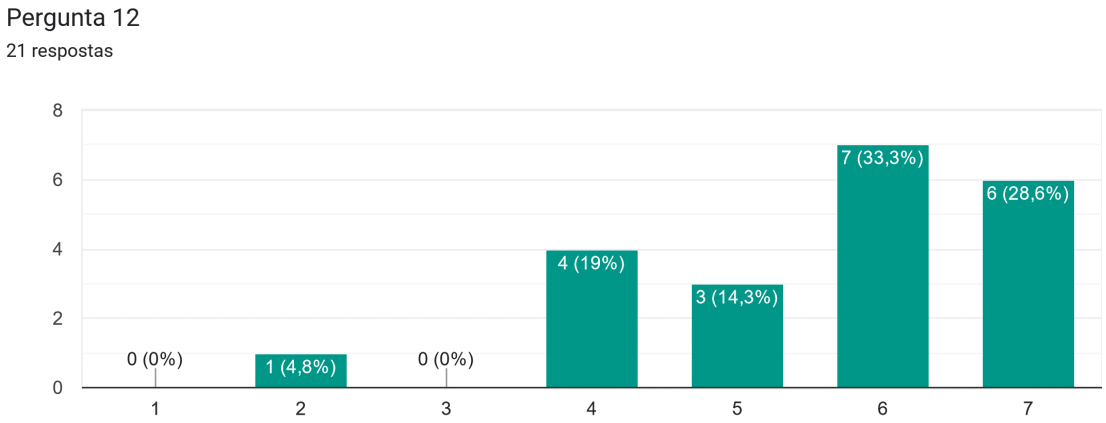


Figure D.61: Total results of the twelfth question

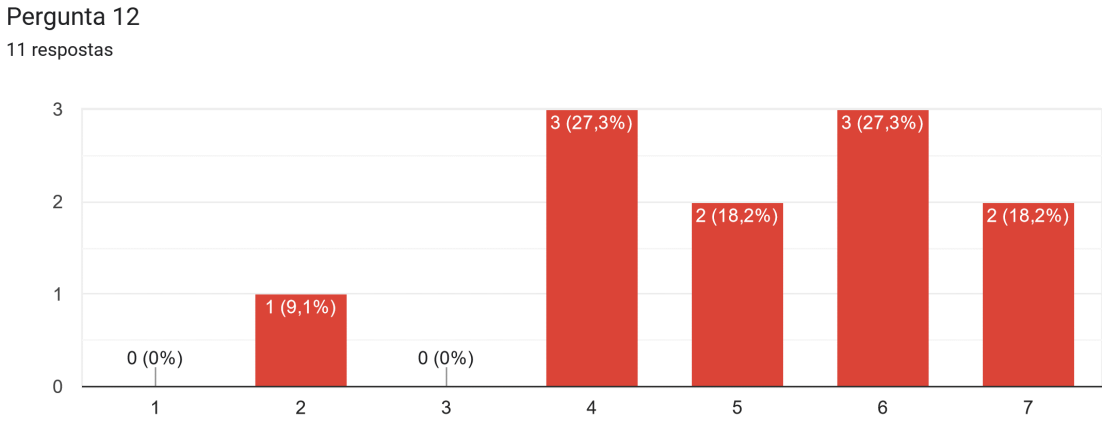


Figure D.62: Results of the first group in relation to the twelfth question

D.2.13 Impractical-Practical

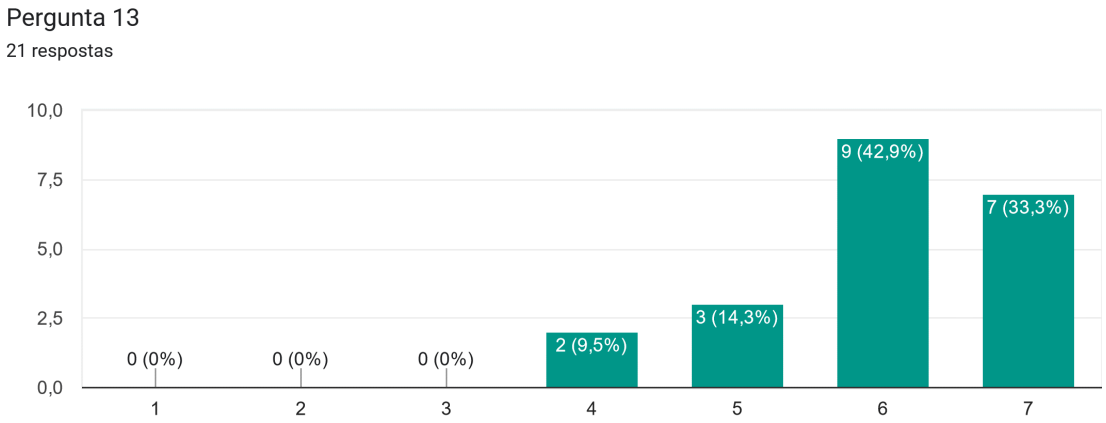


Figure D.63: Total results of the thirteenth question

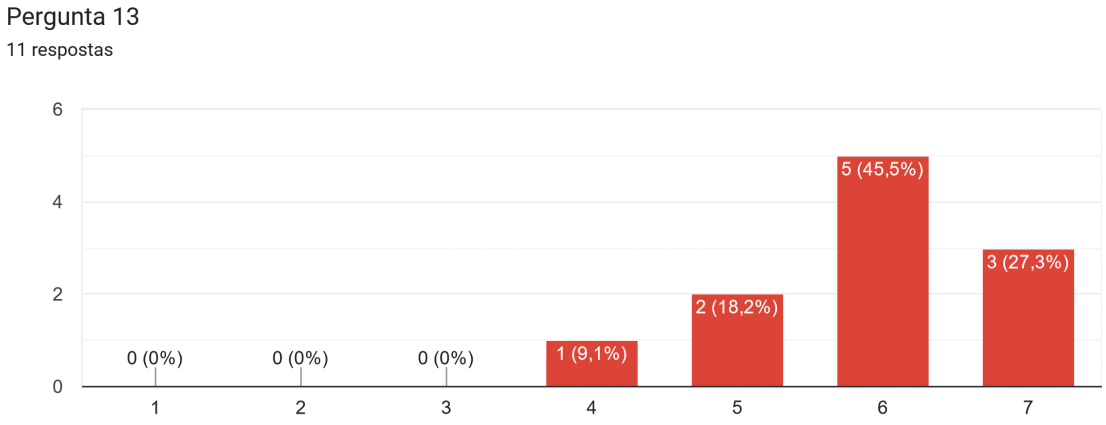


Figure D.64: Results of the first group in relation to the thirteenth question

D.2.14 Disorganized-Organized

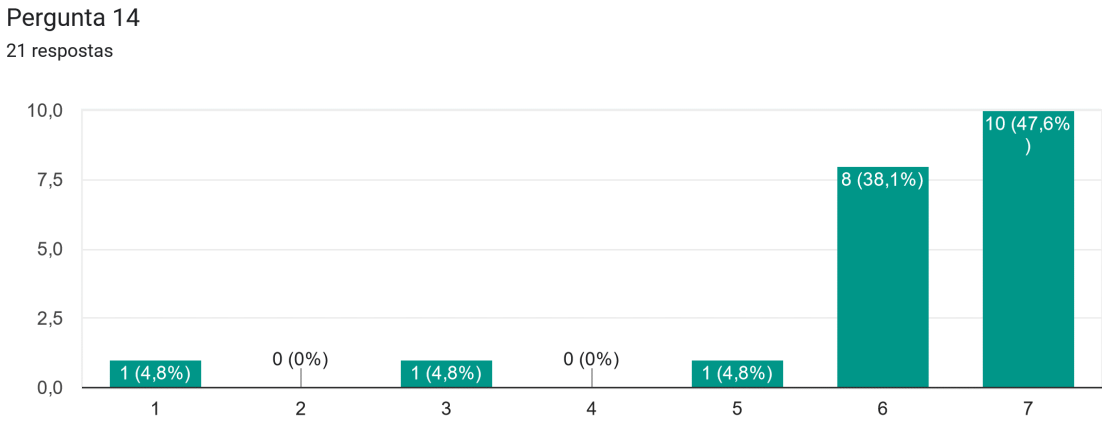


Figure D.65: Total results of the fourteenth question

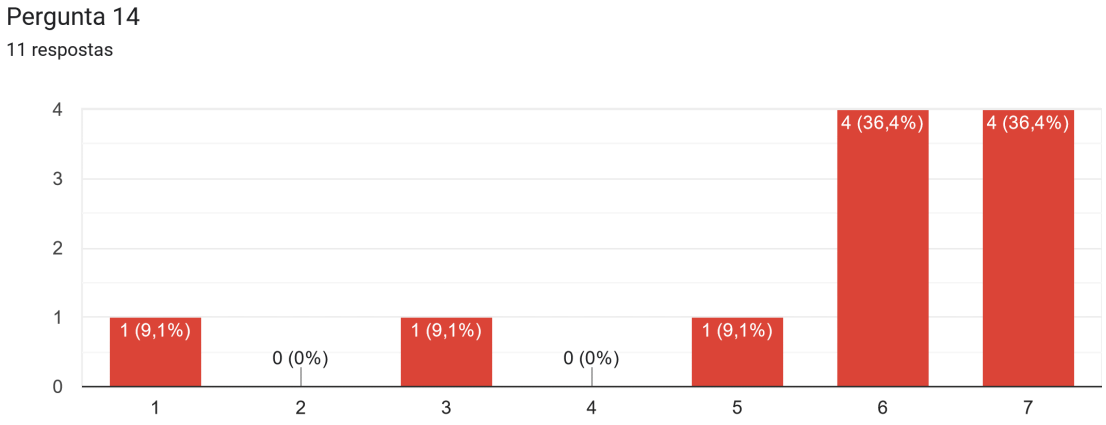


Figure D.66: Results of the first group in relation to the fourteenth question

D.2.15 Confusing-Clear

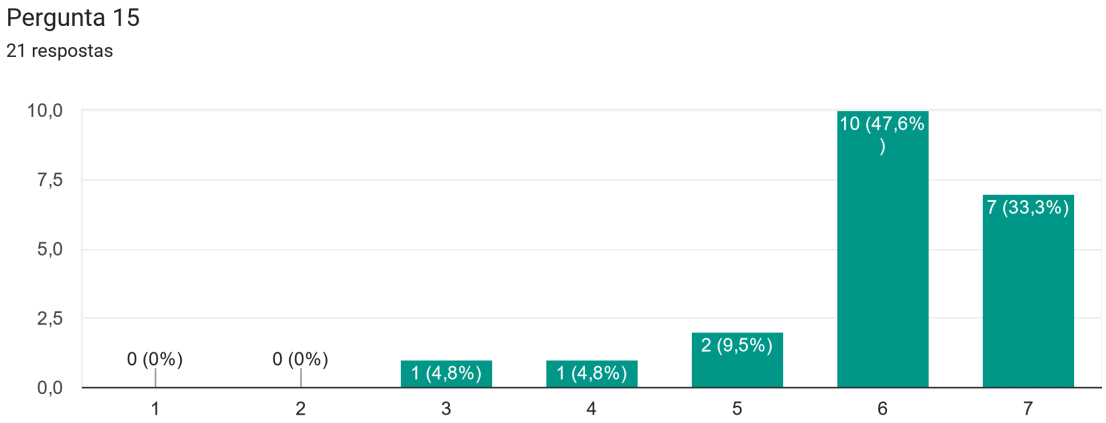


Figure D.67: Total results of the fiftheenth question

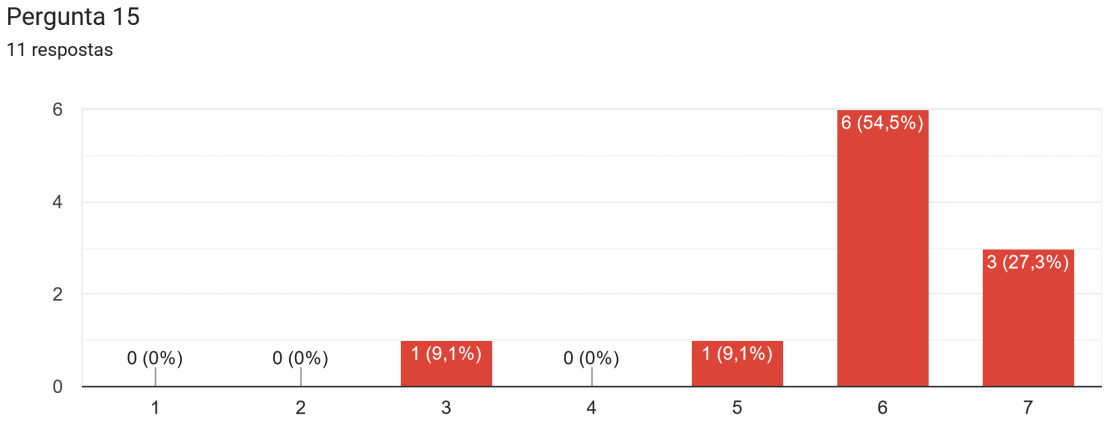


Figure D.68: Results of the first group in relation to the fiftheenth question

D.2.16 Obstructive-Supportive

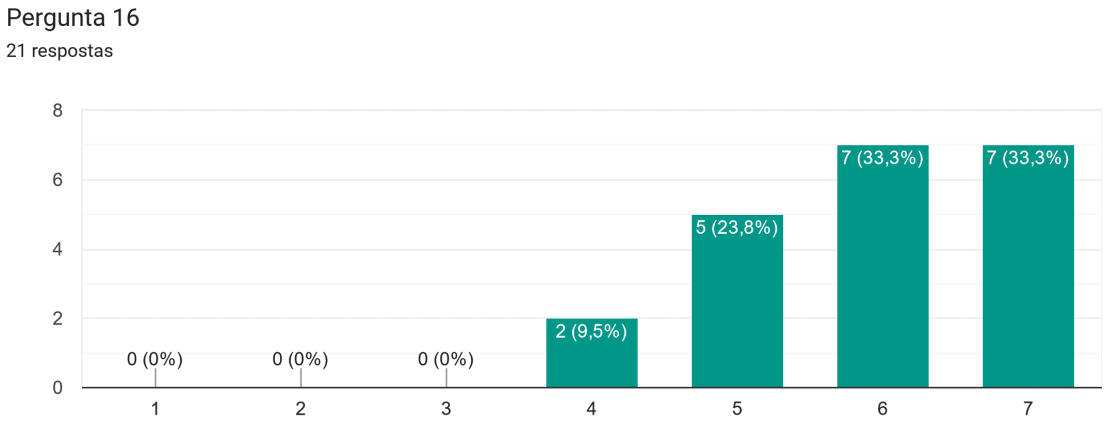


Figure D.69: Total results of the sixteenth question

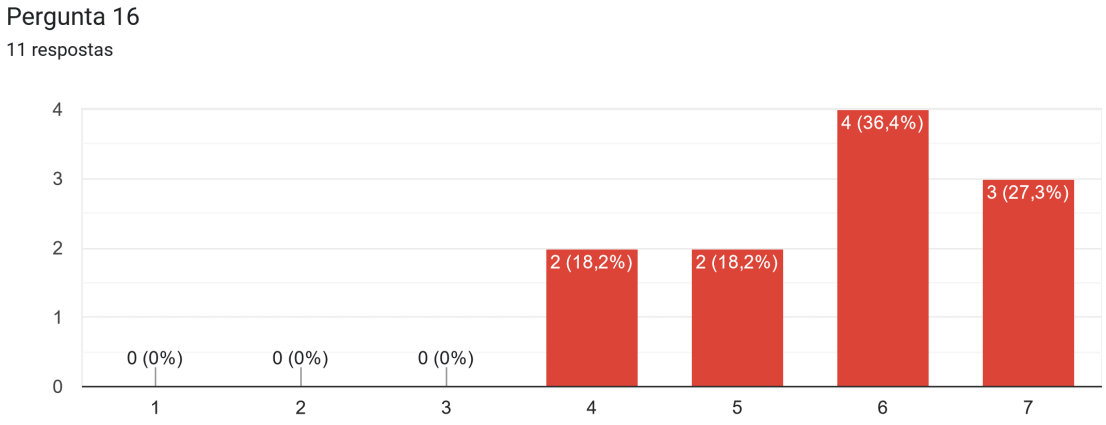


Figure D.70: Results of the first group in relation to the sixteenth question

D.2.17 Boring-Exciting

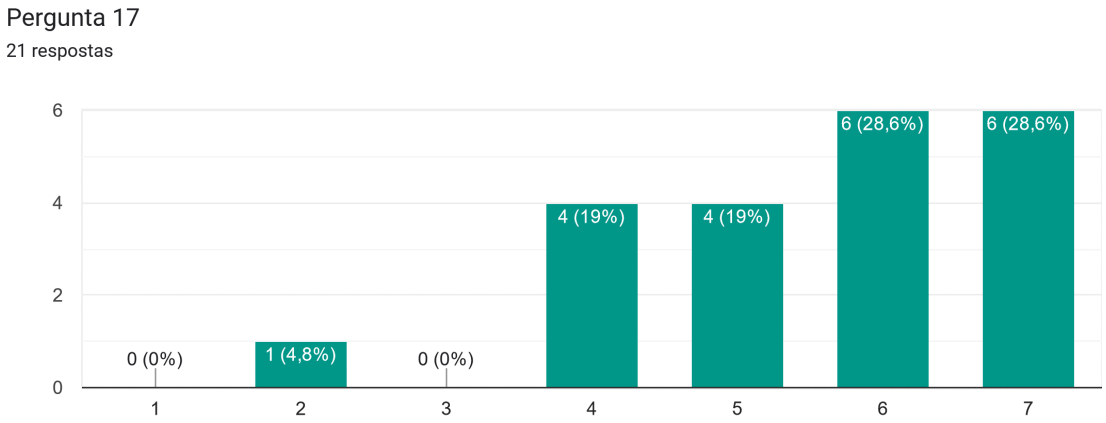


Figure D.71: Total results of the seventeenth question

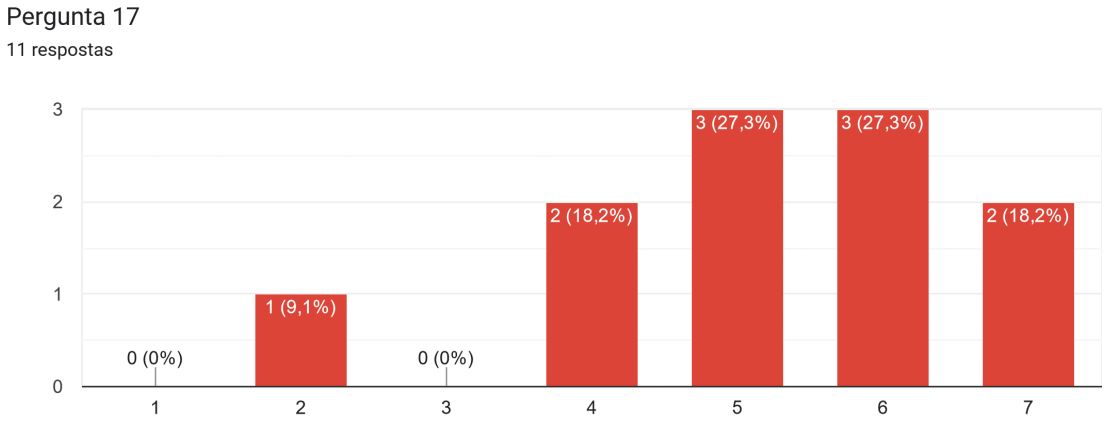


Figure D.72: Results of the first group in relation to the seventeenth question

D.2.18 Uninteresting-Interesting

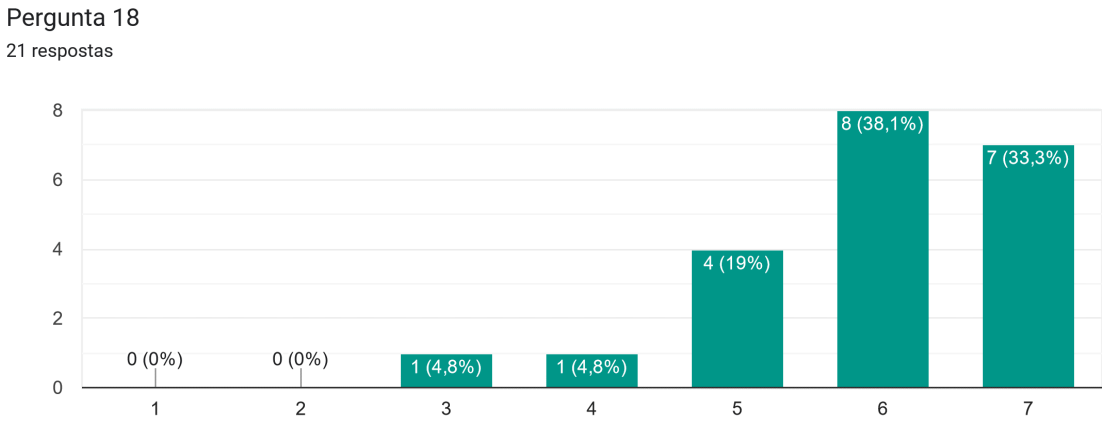


Figure D.73: Total results of the eighteenth question

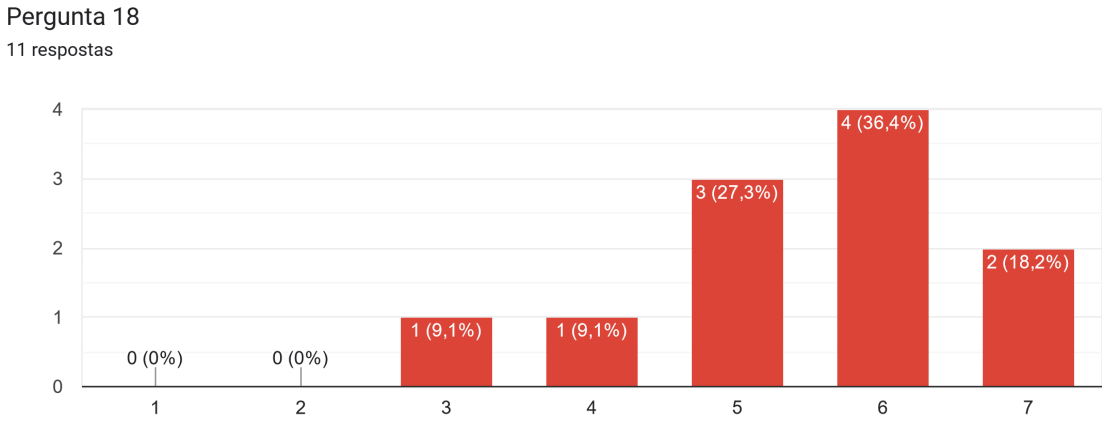


Figure D.74: Results of the first group in relation to the eighteenth question

D.2.19 Demotivating-Motivating

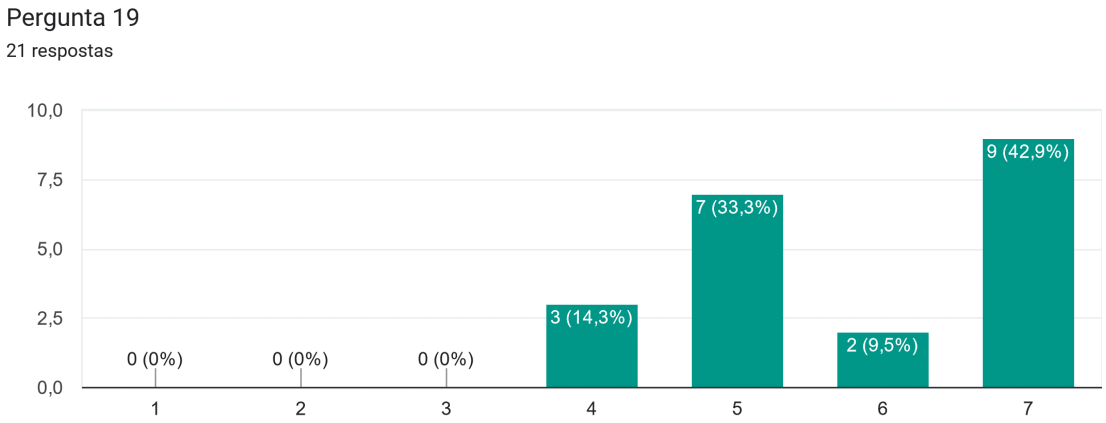


Figure D.75: Total results of the nineteenth question

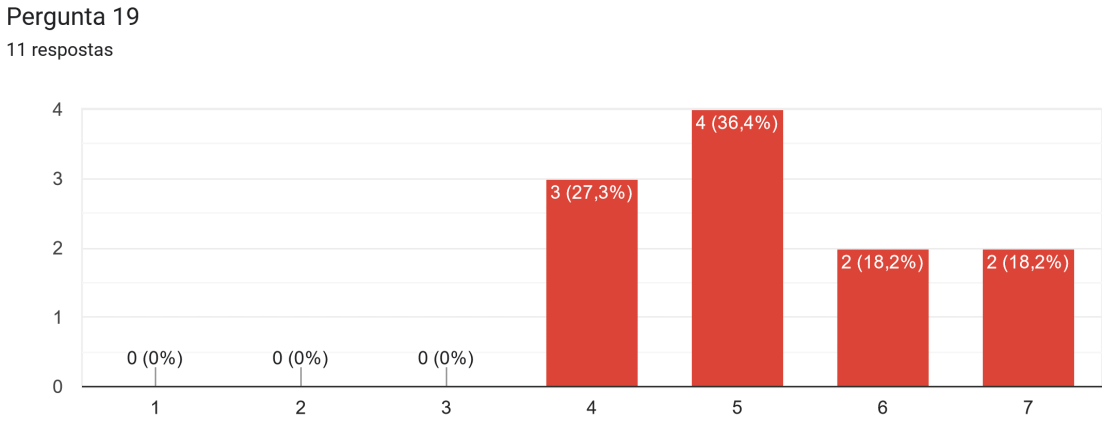


Figure D.76: Results of the first group in relation to the nineteenth question

D.2.20 Unattractive-Attractive

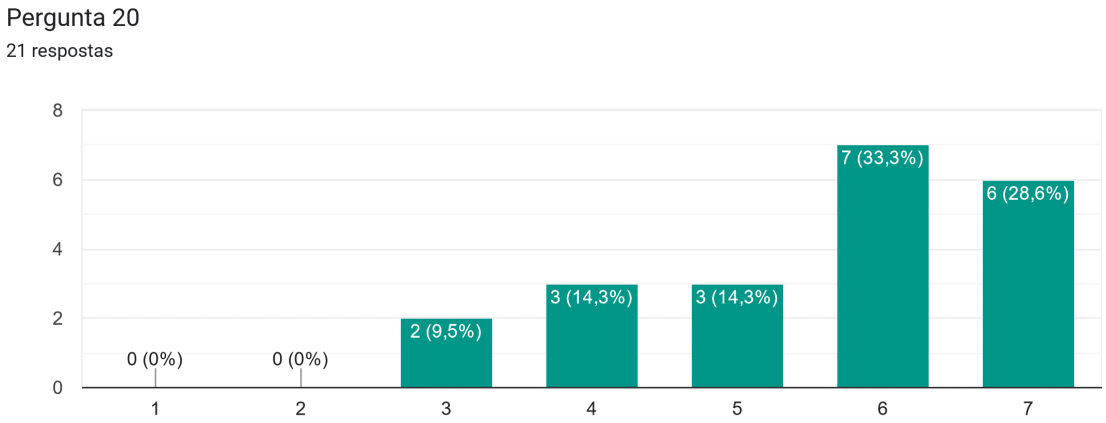


Figure D.77: Total results of the nineteenth question

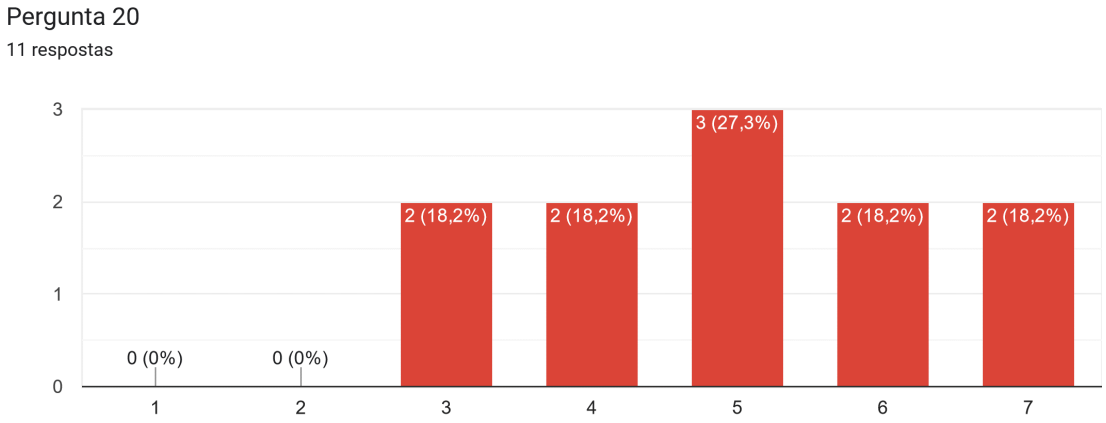


Figure D.78: Results of the first group in relation to the nineteenth question

D.2.21 Uncreative-Creative

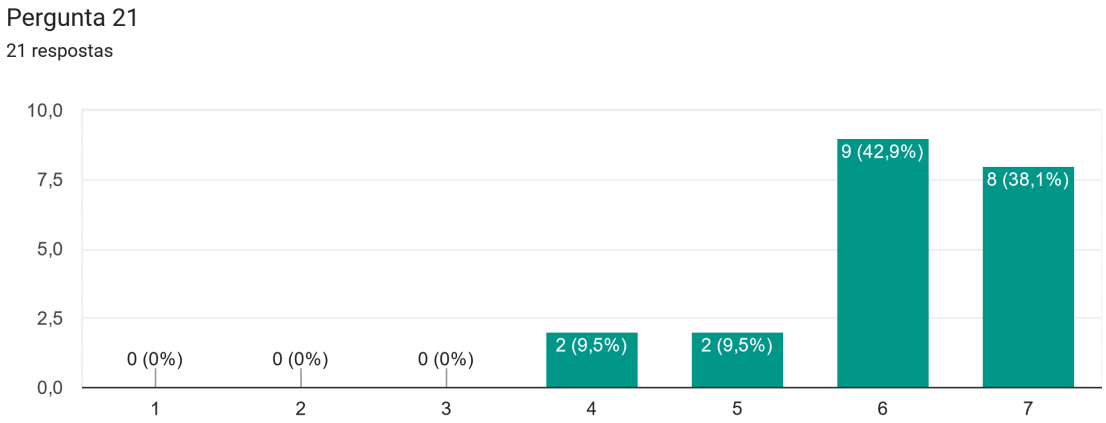


Figure D.79: Total results of the nineteenth question

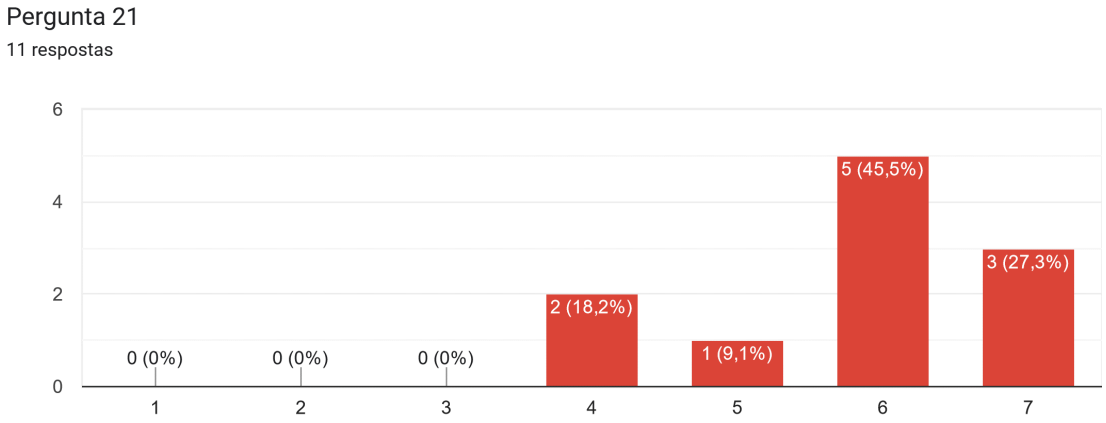


Figure D.80: Results of the first group in relation to the nineteenth question

D.2.22 Conservative-Innovative

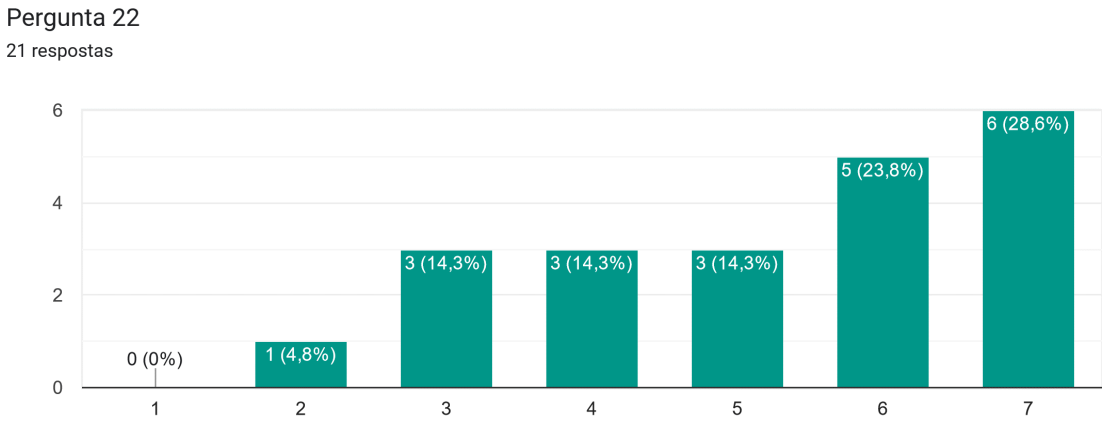


Figure D.81: Total results of the nineteenth question

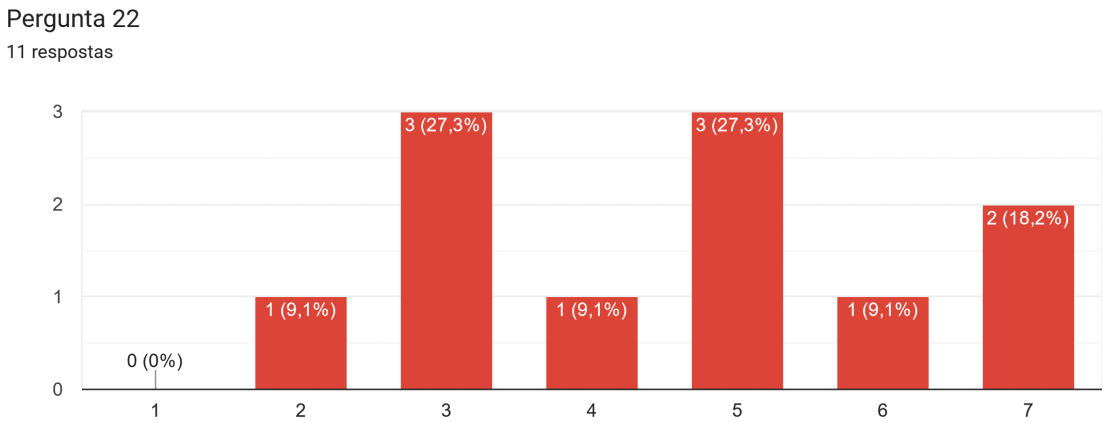


Figure D.82: Results of the first group in relation to the nineteenth question

D.2.23 Common-Inventive

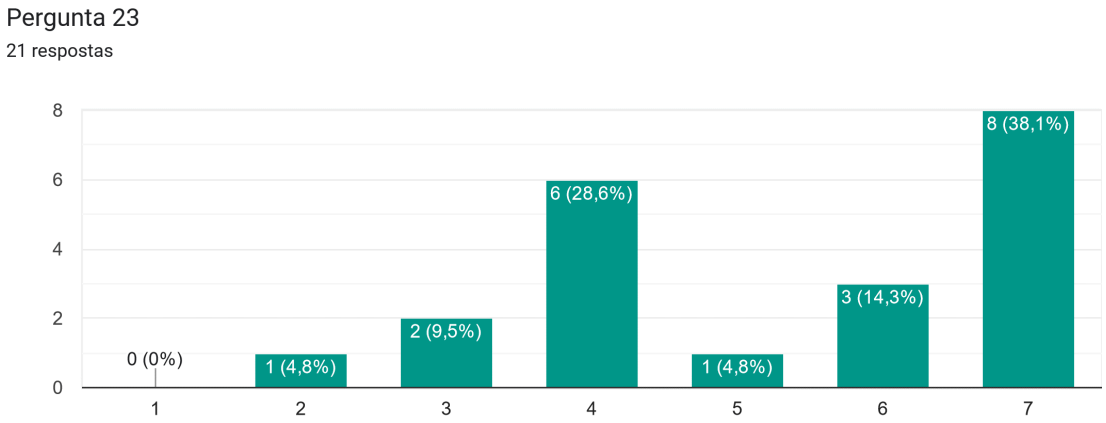


Figure D.83: Total results of the nineteenth question

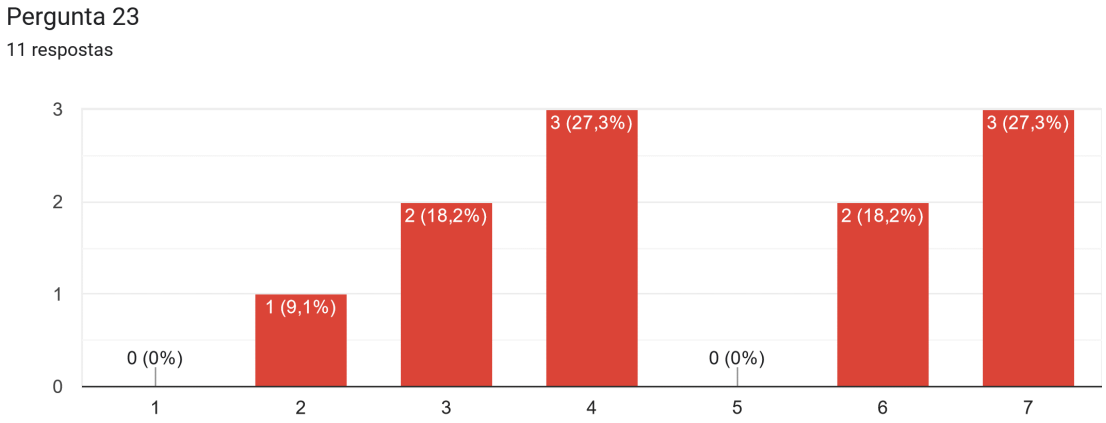


Figure D.84: Results of the first group in relation to the nineteenth question

D.2.24 Conventional-Original

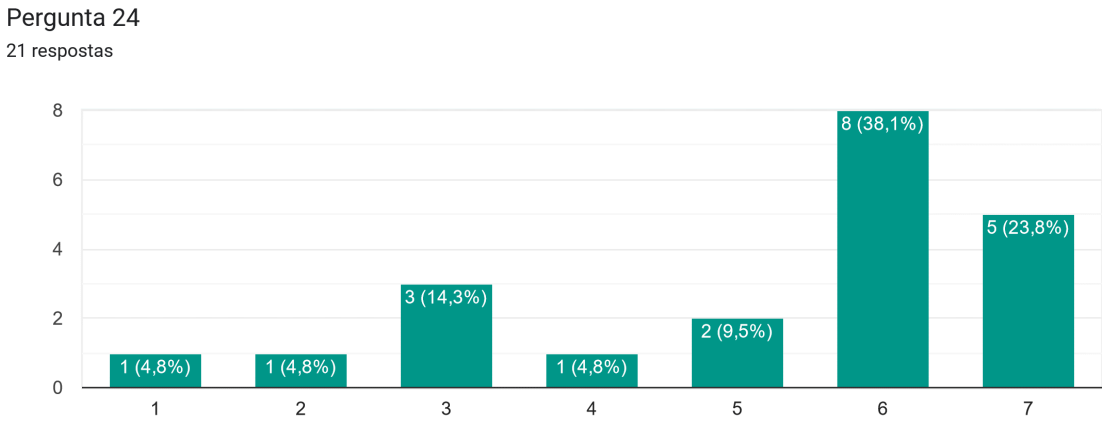


Figure D.85: Total results of the nineteenth question

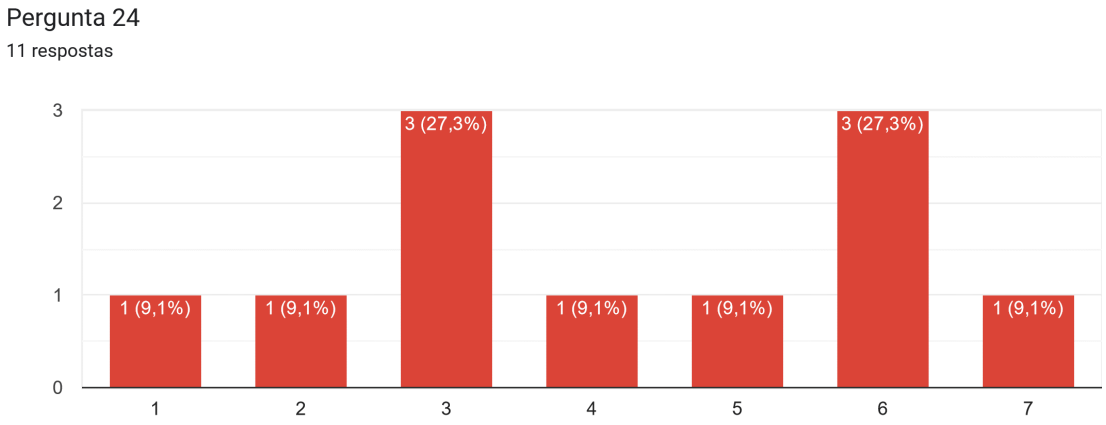


Figure D.86: Results of the first group in relation to the nineteenth question

D.2.25 Does not meet expectations-Meets expectations

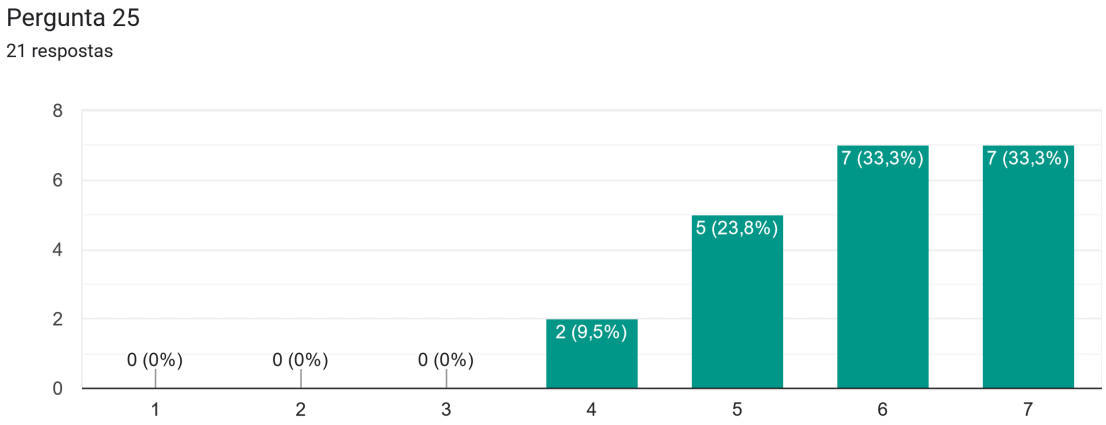


Figure D.87: Total results of the nineteenth question

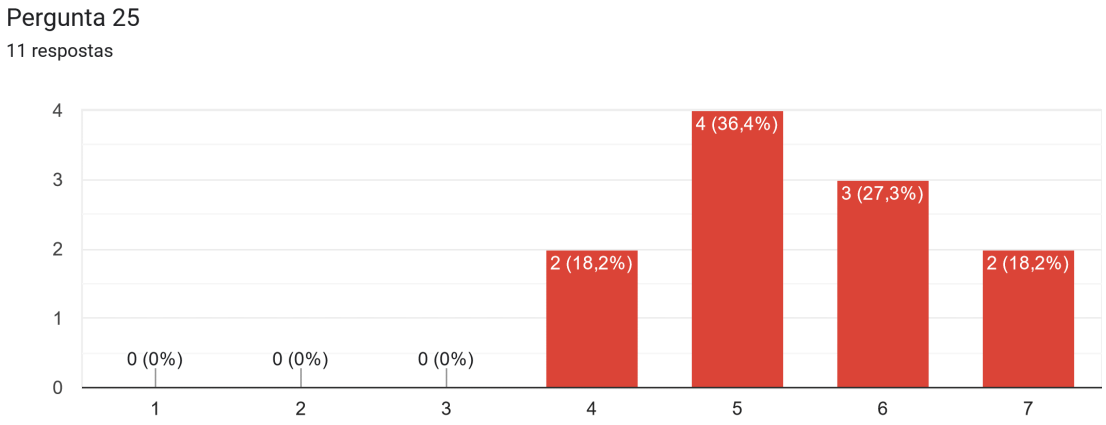


Figure D.88: Results of the first group in relation to the nineteenth question