



Jomara Mota Bindá

**“Affordable Solutions for Classroom Response  
Systems  
(Soluções Acessíveis para Sistemas de Resposta  
em Sala de Aula)”**

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Universidade Estadual de Campinas  
Faculdade de Engenharia Elétrica e Computação

Jomara Mota Bindá

**“Affordable Solutions for Classroom Response Systems  
(Soluções Acessíveis para Sistemas de Resposta em Sala de  
Aula)”**

Supervisor: Prof. Dr. Eduardo Alves do Valle Jr.

Co-supervisor: Prof. Dr. Renato da Rocha Lopes

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Prof. Dr. Eduardo Alves do Valle Junior (Presidente):

*Eduardo Valle*

Profa. Dra. Raquel Oliveira Prates:

*Raquel Prates*

Prof. Dr. Rickson Coelho Mesquita:

*Rickson*



# Abstract

Classroom response systems enable the gathering, in real time, of reactions and answers from the audience during a presentation or class. Ordinarily, classroom response systems are implemented with small devices called clickers. Those systems are expensive, due to costs of acquisition, installation, and maintenance. Therefore, alternative solutions have been presented, such as solutions based on image processing, or on the “bring your own device” concept, where students bring their own devices to the classroom and the physical clicker is replaced by an application. In this dissertation, we present the challenges to develop a low-cost solution of classroom response system, including technological and user-interaction challenges. We propose two low-cost design interaction solutions based on the available options and present the results obtained so far.

**Keywords:** Classroom Response Systems, Image Processing, Human-Computer Interaction, Mobile applications.





# Resumo

Sistemas de resposta em sala de aula permitem a coleta, em tempo real, de reações e respostas da plateia durante uma apresentação ou aula. Ordinariamente, os sistemas de respostas em sala de aula são implementados com pequenos aparelhos conhecidos como “clickers”. Estes sistemas são de alto custo, devido aos valores de compra, instalação e manutenção. Portanto, soluções alternativas tem sido apresentadas, como aquela baseada em processamento de imagens ou, a solução baseada no conceito de “traga seu próprio dispositivo” onde os alunos trazem seus próprios dispositivos para classe, e o clicker físico é substituído por uma aplicação. Nesta dissertação, apresentamos os desafios para o desenvolvimento de solução de baixo custo de um sistema de resposta em sala de aula, incluindo os desafios tecnológicos e de interação do usuário. Propomos duas soluções de design de interação acessível baseado nas opções disponíveis e apresentamos os resultados obtidos até o momento.

**Palavras-chaves:** Sistemas de Resposta em Sala de Aula, Processamento de Imagem, Interação Homem-Máquina, Aplicações móveis.



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*“You are never too old to set another goal or to dream a new dream”*  
*C.S Lewis*





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# Nomenclature

BYOD Bring Your Own Device

CLI Command Line Interface

CRS Classroom Response Systems

GUI Graphical User Interface

HCI Human-Computer Interaction

ISO/IEC 9126 International Organization for Standardization / International Electrotechnical Commission 9126

NUI Natural User Interface

OUI Organic User Interface

PI Peer Instruction

PSF Point Spread Function

TOPCODES Tangible Object Placement Codes

TUI Tangible User Interface

WIMP Window, Icon, Menu, Pointing device





# 1 Introduction

An important success factor in teaching and learning is the capability to keep students interested and active during class, participating and contributing with their answers and opinions [Fulford and Zhang, 1993].

Active pedagogical practices, like peer instruction, are easier to implement if the instructor has a quick, non intrusive, and personal way to obtain the feedback and answers from the students during class [Kay and LeSage, 2009]. Combining peer instruction with available technology results in innovative teaching approaches that improve teacher–student relationship in class, increasing the interaction between them [Fulford and Zhang, 1993].

Classroom response systems (CRS) have been around for over a decade, starting with the system Classtalk I [Beatty, 2005]. Frequently, CRS are implemented with clickers. Clickers are small remote-controls that send the answers to an infrared or radio frequency receiver, making them available to the presenter or teacher. Other solution apply the concept of “bring your own device” (BYOD), where students bring their own smartphones, tablets, netbooks, or notebooks to the classroom, and the physical clicker is replaced by an application. Also, another family of solutions employ image-processing to identify the students’ answers captured by a camera.

In this dissertation, we propose two affordable classroom response systems solutions aiming those low-cost implementations of CRS broaden their adoption. In addition, we present the challenges to develop those solutions, including technological and user interaction challenges. We conclude the dissertation by presenting the results obtained up to date.

## 1.1 Motivation

Classroom response systems are valuable to support active teaching, providing real-time feedback from students. Active teaching is one of the most effective tools for improving learning at all levels: primary, secondary and higher, especially for complex content such as Mathematics and Physics [Crouch and Mazur, 2001]. However, the high cost of CRS implementation prevents wider adoption by public education, rural or, remote communities.

Allowing low-cost implementations of CRS in order to broaden their adoption is one important motivation of our work. Another important motivation is to understand better the technological challenges in providing those solutions, and the user interaction with those alternative low-cost systems.

## 1.2 Objectives

Our main objective is to better understand the challenges in creating low-cost alternatives to CRS, including technological and user-interaction ones.

Our **Specific Objectives**, therefore, are:

- Understand the user interaction with image-processing and “bring your own device” solutions;
- Create a prototype implementation demonstrating the feasibility of the solutions developed during the research;
- Improve barcode recognition at distance for image-processing based solutions.

## 1.3 Contributions

The major contributions in my dissertation are as follows:

- Study of pedagogical and human-computer interaction context: We performed a literature review of active learning as peer instruction method which allowed us to certify about the positive contributions of that method. The review also included researchers thoughts and opinions based on their experience while applying active methods during their lecture. Also we reviewed classroom response system concept, applicability and latest available solution. In addition, we reviewed human-computer interaction concepts which helped on the interface development. Based on studies recommendation, we realized our project design.
- Design Interaction proposition: based on the studies, we came up with two low-cost design proposal idea, trying to adapt the CRS available solution to get a practicable alternative. Consequently, Brazilian public, rural communities, or short-budgeted schools can have access to this active learning tool.
- Experimental evaluation: using user-interaction tests and software usability analysis. The design proposed is the most important aspect to be considered. We executed the experiments changing the parameters aiming to find an adequate fit according to the context. Also we executed detection and image-processing experiments using image enhancement to improve bi-dimensional barcodes recognition.

## 1.4 Reading Guide

The dissertation is organized as follows:

- **Chapter 2 - Literature Review** We present a general review of the pedagogical context that underlies this project which includes peer instruction method, impact of active learning on education and the classroom response system available solutions. We emphasize on the topics relevant to classroom response system applicability. And we disclose about user-computer interaction concepts, interfaces overview and describe experimental procedure to evaluate design interaction feasibility.
- **Chapter 3 - Proposed Solutions** We introduce our project overview. And we present our proposed solutions, describing the project design and development steps, project scenario, and machine encoding overview. Our purpose is to emphasize the interaction design proposed and its applicability.
- **Chapter 4 - Experiments and Results** We show the results obtained by image processing experiments, through detection and image enhancement experiments. Also we present our proposed solutions user-interaction plan tests, user validation experiment and results obtained.
- **Chapter 5 - Conclusion** We point out the conclusions, discussing the experiments results, design parameters and points of improvement. We also suggest topics for future work, show the project highlights and publications.



## 2 Literature Review

### 2.1 Pedagogical Context

Petty [2004] affirmed: “We learn by doing”. Considering this thought, teaching strategies are studied to motivate scholars to apply what they have learned in daily activities. One of these strategies is the addition of activities during lecture. These activities could be problem-solving exercise, cooperative students projects and, group work [Meyers and Jones, 1993].

When the students put their hands-on an activity, they develop their own ideas and logical thoughts which help them to understand the concepts that they are studying. While the students are exposed to passive methods (e.g.listening), the students passively receive information from the instructor [Petty, 2004; Prince, 2004]. According to Petty [2004] comparing passive methods with active methods, the active learning method has important advantages to focus, such as:

- Students thinking skills are developed (e.g. analysis problem solving, and evaluation);
- Students are more conscious on their incomplete understandings and are encouraged to fix them;
- The teacher can identify who needs help or does not.

Prince [2004] mentioned that the core elements of active learning are introducing activities during lecture and promoting students engagement. Prince affirms that introducing activities during lecture can significantly remind passed information, giving a fresh start and keeping students attention longer. This statement is in agreement with studies [Hartley and Davies, 1978; Wankat, 2002] that have confirmed students attention last approximately 15 minutes during lecture, after that they start to lose attention, prejudicing content assimilation. So, this approach is helpful and can be repeated up to three times in a class according to teacher decision. However, the type of the activity passed during lecture should be considered because this activity may influence how much information will be retained by students. Then, as Prince mentioned, applying activities that encourage students to think about what they have learned are an essential feature of active learning.

Applying active learning in class can propitiate a communicative environment. A communicative environment occurs when students interact with the teacher. It indicates

that they are more engaged in learning which may impact on their learning outcome such as attitude and achievement [Haseman et al., 2002]. Yet, students are more motivated and attentive in class, they are more likely to exchange ideas with their classmates [Liu et al., 2003; Haseman et al., 2002] enhancing a more effective learning [Siau et al., 2006]. For instance, an active approach occurs when instructor proceeds an oral questioning and the student answers. This is the most common format of interaction and can be used to motivate students to be more dynamic in class, to assess students' learning and give feedback [Liu et al., 2003]. Due to the contributions of an active approach in class, efforts have been made to increase classroom interactivity [Siau et al., 2006].

On the literature, there is a wide range of reports on classroom experiences and faculty suggestions using active learning. Our project will focus on Mazur [1997] active learning experience. Mazur reported a ten-years experience of teaching with Peer Instruction method. Peer Instruction method has been successfully applied in class [Crouch and Mazur, 2001] with positive and encouraging results [Fagen et al., 2002].

In the following section, we shall present Peer Instruction method, explaining the steps to apply and use each one detailed to reinforce its importance to the method effectiveness.

### 2.1.1 Peer Instruction

Educators [Petty, 2004] have recognized that students do not retain enough information about a given topic on traditional lectures. And studies [Crouch and Mazur, 2001] have shown that student's understanding of main concepts have been more satisfactory when they are actively involved in class. This finding have motivated Mazur to change traditional lecture format and present an alternative method. Mazur, then, introduced Peer Instruction method on two introductory physics courses for non majors at Harvard University and reported ten-years experience data using this format [Crouch and Mazur, 2001]. Mazur's Peer Instruction (PI) improves classroom interactivity and students' participation [Mazur, 1997]. PI differs from traditional lecture format by questioning the students to reveal hidden doubts and misunderstandings. PI method proposes the following [Mazur, 1997; Li, 2007]:

- Starting class with a topic presentation;
- Asking conceptual question called "concept test" aiming to verify students understanding about the topic presented;
- Waiting the student commits with an answer for a moment;
- Polling the students; if the majority answer is right, the instructor moves on to the next topic. If the majority answer is wrong, the instructor should present the topic again; if

the answers are divided, the instructor should stimulate the students to participate on a small discussion group.

PI has been extensively used, and one of the reasons is that PI can be adapted to class context according to the teacher style and topic presented. The teacher defines the number of questions and which ones, the time amount spent on each question and the lecture duration. Also, the teacher can collect concept tests applied in other institutions or create new ones [Crouch and Mazur, 2001; Mazur, 1997]. However, it is noteworthy that creating a conceptual question should not be ordinary; on the contrary, it takes time to elaborate an effective question [Kay and LeSage, 2009] because a question which leads to a misinterpretation or ambiguous understanding does not give a useful response [Crouch et al., 2007]. Carlsen [1991] proposed a socio linguistics perspective that the question should focus on: context, content and responses to reactions by speakers. Consequently, the environment context, the question content and the responses affect the meaning of a question. When students learn, they develop meanings in a social context.

The kind of question made by teacher and the way it is asked to the students can influence the process of constructing knowledge. Teachers should be conscious that they are guiding the student through learning process, and questioning may be a key component to establish a dialogue discourse [Chin, 2007]. So, when teacher encourages students to collaborate in class, exposing their ideas and debating a point of view, student's response reflects an active state of mind since their thoughts are consequence of a productive thinking [Chin, 2007]. Also, it is very important to create a cooperative atmosphere in class since some students can have a negative reaction to this active approach and influence others. This collaborative environment provides a safe feeling that the method works and produces good results [Crouch et al., 2007].

PI includes polling on its procedure as mentioned before. Polling students is a common resource to know students' views and thoughts. There is no single way to perform polling, the format choice will depend on the questioning purpose. According to Crouch et al. [2007], getting the answers can be done by:

1. Show of Hands: this is the simplest format where the students stand their hand up in response to the teacher question. This method gives the teacher a quick feedback since the entire class responds at once. But, this approach has limitations as shy students may have difficulty in presenting their ideas and lack of accuracy.
2. Flashcards: this format requires each student has a card and after the question, they can lift the card up with their answer. The advantage is this method makes difficult to

the students realize the major response. But it addresses the same problem from the previous method.

3. Scanning forms: this approach provides a better accurate result since the students use a scanning form to give their answer. Yet, this method will request more effort since it is necessary to scan each student form causing a delay on result.
4. Classroom network: this method includes technological options such as clickers, cell phones and, web sites. It allows the student to give their answer using the chosen technology and the teacher receives the result immediately after. The result can be showed in a graph to a better view, and the student's information is available only for the instructor. Also this network method facilitates to collect data for research purpose.

After questioning, students' response can give an insight on what they learned. A quick feedback contributes to analyze the results and adapts the lecture direction. If we compare traditional paper-based questioning systems with peer instruction, the traditional systems can lost the question meaning because it takes time to evaluate and return the quiz result to the student. While peer instruction uses an immediate feedback and gives the students opportunity to explain the question meaning to each other; thereby the students also learn about the subject matter [Yourstone et al., 2008].

Peer instruction adopts small group discussion as a method step after analyses the majority response. Teacher should stimulate students to discuss their answer. Lasry et al. [2009] review mentioned that the discussion between peers is a very important aspect of peer instruction method and should be adopted as much possible. When students discuss about the topic, they have more time to work on the concept and consolidate their own thoughts. Discussing about a topic with others can help the student to see a situation from a different angle or perspective [Chin, 2007]. In addition, unlike traditional classes, where students tend to ignore questions and comments done by classmates, group discussion leads the students to pay attention and listen the arguments said. So, group discussion also contributes to reduce or eliminate the lack of attention tendency [Beatty et al., 2006; Yourstone et al., 2008].

Peer Instruction has leaded the way to new ideas of active learning approaches. As mentioned, PI is a flexible and adaptable method [Crouch et al., 2007]. One of these approaches is known as Classroom Response Systems. Classroom response systems (sometimes called audience response systems, student response systems, or personal response systems) propose an interactivity model by enabling peer instruction [Beatty et al., 2006]. Classroom response systems have been used in different courses formats, from formal lecture to cooperative learning and different levels, from introductory classes to graduated majors [Caldwell,



2007; Fies and Marshall, 2006]. The literature presents applications and classroom outcome of using CRS, showing benefits but also challenges that will be addressed on the following topic.

### 2.1.2 Impacts of Classroom Response Systems on Education

Classroom Response Systems are quite popular in education settings. Typically, they are used with technological support to collect student's response. CRS implementation has profits that worthwhile its use, but also instructors report difficulties applying it [Fies and Marshall, 2006].

Studies [Fies and Marshall, 2006; Yourstone et al., 2008] mentioned that students attendance increases when use CRS. And reviews [Yourstone et al., 2008] have suggested that students are more attentive during class when classroom response systems are applied. Since the students know that they will be polled, they tend to be more prepared for class. So, students read the subject material before class to improve their performance. And there-with, instructor can reduce time for introductory topics and basic concepts [Crouch et al., 2007]. In addition, CRS allow an anonymous response which may motivate the student to participate more by sharing his opinion without the judgment of his classmates [Bergtrom, 2006; Caldwell, 2007; Horowitz, 2008; Lat, 2005].

Also, studies [Bergtrom, 2006; Caldwell, 2007; Kay and LeSage, 2009] mentioned that a frequent and positive interaction occur when CRS is used during topic discussion session and reported a greater articulation on the student thinking [Beatty, 2005] since he needs to commit to an answer and defends his idea and if required, he should try to convince his classmates about his commitment rightness. And students [Bergtrom, 2006] reported being more interested in the topics presented or discussed.

Besides, there are potential benefits for the instructor due the fact that he can analyze the learning level during class [Yourstone et al., 2008] and changes the lecture depending on student's feedback [Caldwell, 2007; Cutts, 2006]. If the feedback shows a misunderstanding or misinterpretation of the topic from a majority of the class, the instructor can attempt a different explanation to remedy this issue. In addition, researchers [Caldwell, 2007; Carnaghan and Webb, 2007; Horowitz, 2008; Lat, 2005; Yourstone et al., 2008] suggested that learning performance increases due to the benefits of the immediate feedback. Participants also report that both instructors and students are more informed of the student's insight, leading to a more accessible instruction and to a better understanding [Fies and Marshall, 2006].

However, there are several challenges on using CRS. Technological problems can occur (e.g. when the device does not work properly or it presents signal transmission problems)

making difficult to the instructor receives the results [Hat, 2005; Siau et al., 2006]. Also, the students population are diverse and some of them may react more unfamiliar to the technology than others [Fies and Marshall, 2006], even though it is more required from the instructor a technological easiness than students [Yourstone et al., 2008].

Beyond that, applying CRS without pedagogical preparation does not benefit the student learning process and can harm the positive perception of this method [Blodgett, 2006]. Another concern is the content coverage, since group discussion can take much time and lead away to a different direction from the topic proposed [Bergtrom, 2006; Caldwell, 2007]. Also, preparing question to help the identification of misconception could be defiance. Finally, the lack of standardized set of questions to be used in CRS will demand an effort of the instructor to choose the more appropriate questions depending on the current lecture [Bergtrom, 2006; Caldwell, 2007].

Furthermore, CRS benefits can only be achieved with an appropriate classroom culture that supports student engagement and interaction [Penuel et al., 2005; Scornavacca et al., 2009]. Perhaps, more effort will be necessary to avoid resistance from the students with this active method. Since the students should adapt to and accept the additional work requested [Caldwell, 2007]. Thus, the student must feel his answers are important in order to encourage their engagement and they should take the CRS seriously to avoid adverse situations like inappropriate use of the device or giving wrong answers on purpose [Siau et al., 2006].

## 2.2 Classroom response systems

In this section, we will present the most relevant CRS solutions available highlighting their main advantages and disadvantages. CRS solutions can be divided in: Clickers solution, BYOD solution and Clicker with Image processing. Table 1 provides a comparative summary of these different approaches showing the main advantages and disadvantages of each one.

### 2.2.1 Clickers Solution

This classroom response system solution uses a hardware called “clickers”. Clicker is a small transmitter (the size of a remote control) where the signal is transmitted by infrared, wireless or radio frequencies. Each device has a unique signal to identify the student’s answer [Caldwell, 2007].

Classroom response systems can work together with a clicker device. The system functions as described below [CMU]:

Table 1 – Summary of classroom response system technologies

Method	Advantages	Disadvantages
Clickers solution	<ul style="list-style-type: none"> <li>- Keep students anonymity;</li> <li>- Allow multiple-choice questions;</li> <li>- Wide commercial options;</li> </ul>	<ul style="list-style-type: none"> <li>- Device cost;</li> <li>- Prior investment on training how to use the system and store data;</li> <li>- Technical support, equipment update and maintenance;</li> </ul>
BYOD solution	<ul style="list-style-type: none"> <li>- Student may use personal device;</li> <li>- Student can use local network to announce their answer;</li> <li>- Wide range of devices can be used (e.g. portable, fixed).</li> </ul>	<ul style="list-style-type: none"> <li>- Device can distract the student during class;</li> <li>- Student without personal device may not participate;</li> <li>- Require safe and efficient school network infrastructure;</li> </ul>
Clicker with Image Processing	<ul style="list-style-type: none"> <li>- Low-cost technique;</li> <li>- Create an unique ID for respondent;</li> <li>- Use machine encoding to keep anonymity;</li> </ul>	<ul style="list-style-type: none"> <li>- Body or hand occlusion;</li> <li>- Classroom lighting;</li> <li>- Camera reach;</li> </ul>

1. The teacher or instructor presents the multiple-choice/ true or false question (orally or with presentation);
2. The students select their answer on the device (anonymously);
3. The software system instantly computes and tabulates the results. These results can be saved or displayed as wished by the instructor.

There are many commercially available clickers device systems such as i>Clicker<sup>1</sup>, Qwizdow<sup>2</sup>, E-instruction<sup>3</sup>, Turning Point<sup>4</sup>. Figure 1 illustrates the clicker solution. Figure 1 images were obtained on i>Clicker site. Figure 1a represents the clicker device available by i>Clicker and Figure 1b represents the use of clicker in class where teacher presents a question and students give their response using the clicker device. These devices have been commercially successful and adopted by over a thousand higher institutions and are used by over two million students, in North America alone as mentioned on i>Clicker website.

However, studies [Beatty, 2005; Beatty et al., 2006; Bergtrom, 2006; Caldwell, 2007; CMU] have noted potential trade-offs of using clickers, such as:

<sup>1</sup> i>Clicker website: [www.iclicker.com](http://www.iclicker.com)

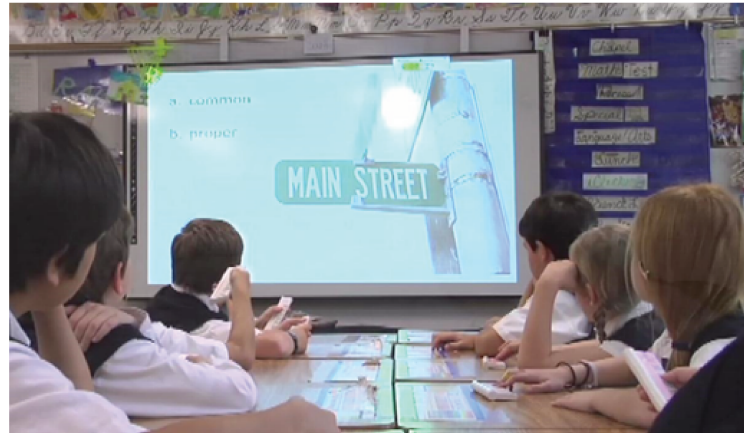
<sup>2</sup> Qwizdow website: [qwizdow.com](http://qwizdow.com)

<sup>3</sup> E-instruction website: [www.einstruction.com](http://www.einstruction.com)

<sup>4</sup> Turning Point website: [www.turningtechnologies.com](http://www.turningtechnologies.com)



(a) Clicker device available by i>Clicker



(b) Using clicker solution in class available by i>Clicker

Figure 1 – Illustration of clicker solution using a physical device in a classroom. (Images credits on the text)

- It takes a prior investment of training how to use the system and store the data;
- Analyzing the students' understanding and response would require flexibility and management on the lecture delivery, since the long discussion could easily drift away from the main idea;
- It takes class time to use clickers if the instructor does not explain properly how to use the device during lecture which could hinder the content coverage;

In addition, if clicker device uses radio frequency, then it will be necessary to have a base-station on each class. Besides clicker device requires IT support, equipment update and maintenance [Li, 2007]. Therefore, schools with short budget would hardly afford to buy clickers device and cover all costs to use them in class.

## 2.2.2 BYOD Solution

This solution embraces the concept “bring your own device” (BYOD). BYOD is a technological model where students bring their own personal device to school in order to use it during class [Stavert, 2013]. This solution replaces the need for a personal hand-held clicker device, and it also provides a software or an application to use with networked client devices. Figure

2 demonstrates the use of BYOD solution in class where each student owns their device and uses it during lecture.



Figure 2 – Illustration of “bring your own device” (BYOD) solution which each student has his own device in class. Reproduced from [Cattelain \[2014\]](#).

BYOD solution works very similarly with the clickers solution (as described on subsection 2.2.1), but the main differences are:

1. The student may use a personal device (e.g. mobile phone) or social network (e.g. Twitter) or web browsers;
2. The students can send message (SMS) or access Internet by Wifi or 3G networks to announce their answer.

BYOD solution advantages are numerous since a wide range of devices can be used: smartphones, tablets, netbooks, notebooks and desktop computers. Besides obsolete or donated equipment can also be used since the software or application requirements are not demanding. Also, an easy-to-use web-based system reduces the instruction-time and the input answer can be rapidly given. For instructors, the preparation-time for any class decreases as compared to the use of traditional clickers [[McCreath and Leimich, 2009](#)].

But BYOD solution faces challenges depending on the equipment used. When BYOD solution is applied with **portable devices**, these devices can easily distract the student

during class and impose fees usage. The portable device approach assumes that students have their own devices and they feel safe to move with them to school and within these [Meyer, 2013]. Also students without a personal device cannot fully participate. Besides portable devices approach places the responsibility on the student to bring his gadget to class, which can propitiate the device absence in class or loss [Caldwell, 2007].

And when BYOD solution is applied with **fixed devices**, this approach requires an appropriate infrastructure to support numerous network connections and depends on a reliable local lab network from school. Beyond that, sometimes, it is necessary to use a cloud-based solution which may cause both an organizational and technical problem [Lennon, 2012]. From an organizational point of view, many schools - for safety reasons, privacy and even legal restrictions – demand to have control over the students acquired data and resist using external services.

### 2.2.3 Clickers with Image-Processing Solution

This section presents relevant solutions found on the literature proposing a low-cost approach using image processing techniques. These works are related to our image-processing proposed solution.

Cross et al. [2012] presented a low-cost technique in response to CHI 2004 Student Design Competition. In this competition, they challenged the participants to propose an audience voting system for the Olympic Games. Three submissions suggested using image processing to recognize printed sign in an audience [Hawkey et al., 2004; Schalleck et al., 2004; Unger et al., 2004]. Despite the resemblance, Cross' solution presents three main differences as compared to CHI audience voting system submissions:

1. Used machine encoding (printed qCard<sup>5</sup>);
2. Created a unique ID for the respondent;
3. Applied the idea in the classroom.

So, their system initiates with a qCard, a laptop and an off-the-self webcam with software that recognize and collect the students' answers and display results to the teacher. The project experiment is illustrated on Figure 3. According to the paper, they did initial trials on secondary schools in Bangalore, India with 99.8% recognition accuracy and 97% captures response in a 25-student classroom.

<sup>5</sup> qCard. <http://research.microsoft.com/en-us/projects/qcards/>



Figure 3 – Illustration of Cross proposal. The students lift up the qCard and a webcam capture the class’ response and display the results to the teacher. Reproduced from Cross et al. [2012].

A similar work is presented by Miura and Nakada [2012] which followed the same research proposal but they used printed cardboard with fiducial marker<sup>6</sup> as machine encoding. Figure 4 shows the project experiment. This project implementation included the ARToolkitPlus [Wagner et al., 2008] as tracking engine with two modules: a recognition module and user interface. First module processed the captured images, and the second module accessed the recognition modules and displayed the result. This project also proposed a multiple choice response but they also proposed a pointing response where the student controls his cursor using pitch and yaw. As a preliminary experiment, they counted with 19 participants and asked each one of them to hold up the fiducial marker cardboard in a small classroom. In addition, they used two cameras to capture the response (front and back responses). As result, their system could track 18 of 19 markers and they mentioned that the pointing response needs improvements.

Gain [2013] approached classroom response system image-processing solution using colored blocks printed in a cardboard instead of machine encoding. And another important highlight, in this project they used a camera-phone in a panoramic mode to capture images. So, the camera-phone captured the class image and the image was processed using computer vision techniques to count and classify students’ response. The project considered different colors to each option response, providing, then, a multiple-choice answer. As result, this project had 85% recognition accuracy in a medium-size class (up to 125 students). Figure

<sup>6</sup> Fiducial. <http://www.roborealm.com/help/Fiducial>



Figure 4 – Illustration of Miura proposal which uses a printed cardboard with fiducial marker. Reproduced from [Miura and Nakada \[2012\]](#).

5 demonstrates this project application in class with the students holding up the colored blocks cardboard. Although, this project did not support the peer anonymity factor because students' response were visible to the entire class and per-student response tracking whereas the solution limited individualized response and diagnostics, this project approach is still appropriated when only cost factor matter to adopt this solution.



Figure 5 – Illustration of Gain proposal with colored blocks instead of machine encoding. Reproduced from [Gain \[2013\]](#).



Finally, there is Plickers approach presented by [Amy and Kim \[2013\]](#). Plickers is a tool that allows teachers to collect real-time responses without students device. First, teacher should insert the student information on Plickers web-site, associating an ID with a student name. Then, teacher should print the cards with a sign (fiducial marker). Each student should have one card, the sign has four sides which correspond to one answer (A, B, C, D). Also, teacher should have an application installed on his smartphone. Plickers are available on Android and iOS version. The application recognizes the code and records the answers. The result appears on teacher device and also there is an option to visualize the results on the Plicker web-site [\[Wylie, 2014\]](#). [Figure 6](#) shows a class using Plickers obtained on *The Compass* (Newton-conover's online newsletters for educators)<sup>7</sup>. This newsletter wrote a report about Plickers and suggested their use in class as a formative assessment.



Figure 6 – Illustration of Plickers usage in class as a formative assessment. (Image source on the text)

## 2.3 Human-Computer Interaction Context

When computers were created, users manipulated directly machine hardware since there was no interface to interact with [\[Dix, 2009\]](#). In the last decades, computer interface became relevant because through interface users can execute their tasks and access the system functions [\[Barros et al., 2003\]](#). Software quality can be determined depending on the user effort

<sup>7</sup> Plickers image source: <http://nccscurriculum.org/2014/10/07/plickers-formative-assessment/>

to use it and individual opinion of using it by a particular user group, according to standard ISO/IEC 9126 [ISO/IEC, 1991].

The human-computer interaction has changed significantly since the first computer developed on forties. In those years, computers were manipulated by specialists who connected cables on central board. As years passed, in the end of fifties started to emerge more efficient programming languages allowing one computer to be used by multi-users and to execute multi-tasks. Then, human-computer interaction concept arose. User could interact with the machine through typed commands and could use an external tool, what we call now, keyboard. On the seventies, users expanded by appearing non-specialists ones. The non-specialists users had personal machine called personal computer. Those non-specialists users started to interact with the software by menus and trigger actions by keyboards. Also, computers evolved the hardware using integrated circuits, including graphical screen and aggregating innovative external device (e.g. mouse, keyboard) [Barros et al., 2003; Nielsen, 1994a].

Study area that considered all aspects related to people and computer interaction is known as Human-Computer Interaction (HCI) [Preece et al., 1994]. The HCI area is primarily engaged in providing to researchers and developers explanations for user-application interaction along with the phenomena associated with its use [Barros et al., 2003]. As Carroll [2003] affirmed HCI study is interested to know how people use computational systems and devices, and how such systems/devices should be more useful and usable. Thus, HCI study does not involve only computers but also people who use them. This study field is considered multidisciplinary covering computer and information science, social and human sciences subjects [Prates and Barbosa, 2007]. But, also can include others areas of study, such as: psychology and cognitive science, ergonomics and human factors, sociology and engineering [Lester, 2008]. Figure 7 represents the disciplines that contribute on HCI area and help to understand how extensive and inclusive this research field can be.

Human-Computer Interaction title is composed by three significant terms. The human term refers an individual or a group of people. The computer term represents the technology or technological systems. The communication process between user (human) and system (computer) is called Interaction [Lester, 2008]. In interaction process, user performs, acts and receives answers from these actions. Based on the results, the user defines his next steps. So, it is necessary input and output devices to trigger these actions. User can interact with the system by software (e.g. dialog windows) and by hardware (e.g. keyboard, mouse) [Garbin, 2010; Prates and Barbosa, 2007; Preece et al., 1994]. As follows, Figure 8 demonstrates user-computer interaction, illustrating how human-computer interaction occurs. The human triggers an action and the system disposes of interface and application that are connected

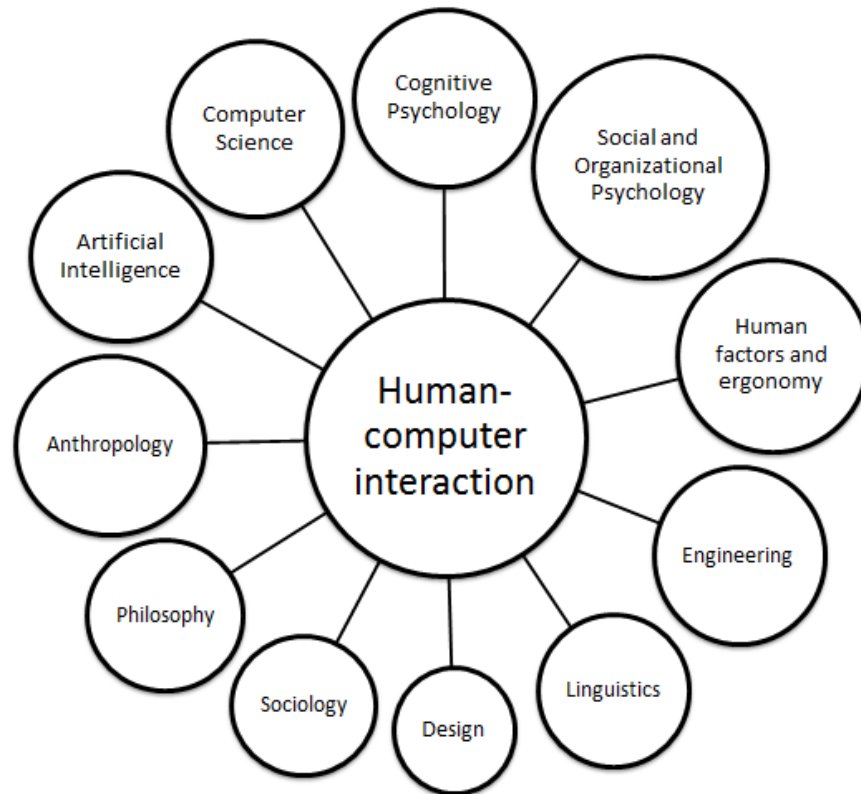


Figure 7 – Illustration of multidisciplinary HCI field that includes computer and information science, social and human sciences among other disciplines. Adapted from [Preece et al. \[1994\]](#).

and produces a response to the request. Then, the human visualizes the result obtained and interprets it.

HCI area also includes the study of interface development, focusing on user point of view. Interfaces are developed based on human-factors studies. Questions like what would the interface look like? or which interaction design to use (e.g. menu, forms or, icons)? should be answered during this interface development process. These issues are important considerations and can influence on system result [[Rogers et al., 2011](#)]. On next topic, we will detail interfaces, exploring the interfaces style, main characteristics and visual components that should be considered on their development process.

## 2.4 Interface Overview

Interface is a part of the computer system where user contacts to access the system itself, actively or passively. An interface is considered the system packing, due that it should have some features like: easy to use, pass clarity and ease of learning [[Barros et al., 2003](#)]. These

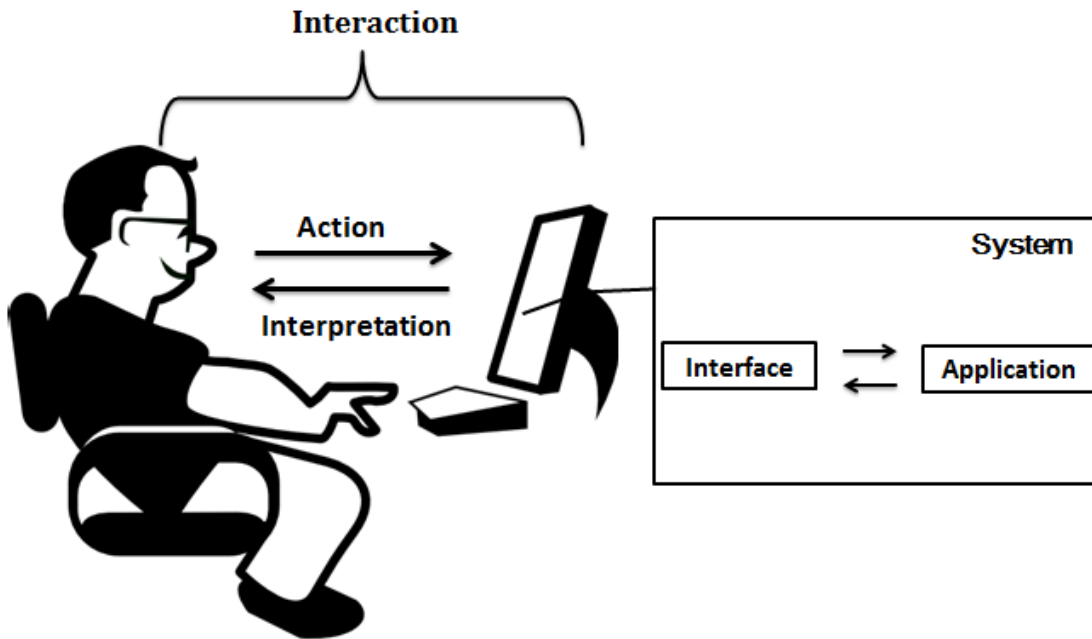


Figure 8 – Illustration of human - computer interaction. The human triggers an action and the system produces a response to the request showing it through the interface. Adapted from Prates and Barbosa [2007].

features can make difference when we considered if an interface proposition was successful or not. Pressman [2011] affirmed, all users have found confusing and/or frustrating interfaces. This frustration happens when user perception of interface does not correspond of user's expectations. Thus, users approval is the goal in human-computer relation. The human factors study should be as important as the technology study [Barros et al., 2003]. If human factors have been ignored, consequently, the system will be considered as “not friendly” [Pressman, 2011].

Interface researchers [Garbin, 2010] suggested to balance user needs and technological innovations, trying to hide the operational system and devices manipulations, enabling human-computer interaction to be more fluid, natural, efficient and accessible to existent needs. A positive approach to succeed during interface development process is taking into account functionality and interactivity aspects because it would help to decide which interface style to use [Barros et al., 2003]. On next section, it will be presented interfaces' style and its interaction.

### 2.4.1 Interface Style

Due the numerous number of users and variety of their devices, applications should adequate to run in many configurations and provide a satisfactory virtual environment. These con-

figurations could be: typing commands, selecting object by menu or, touch screen [Rogers et al., 2011; Wiecha and Boies, 1990]. The way user interacts with a system defines the interface style he will use. Researchers [Barros et al., 2003; Garbin, 2010; Holman and Vertegaal, 2008] mentioned that the interface style could be mainly divided in: Command Line Interface, Graphical User Interface, Natural User Interface, Tangible User Interface and Organic User Interface. Figure 9 shows an illustration of each interface style. The illustration will help to understand the concepts that will be established and visualize how user interacts with each interface, besides the diversity of interface styles must be adapted to user validation experiments as will be addressed further.

- **Command Line Interface (CLI):** user interacts with the machine by typing text commands. These commands are temporary and produce immediate results. Sometimes, it was necessary to memorize these commands. For instance, the command DOS<sup>8</sup> screen from Linux as illustrated on Figure 9a.
- **Graphical User Interface (GUI):** allows user direct manipulation by moving objects or selecting menus. This interface is composed by "Window, Icon, Menu, Pointing device" (WIMP). And provide visually based options that user can seek until they find the operation they are looking for. As example, the graphical interface presented by Windows<sup>9</sup> uses GUI style as demonstrated on Figure 9b.
- **Natural User Interface (NUI):** based on non-computer abilities that user has by nature or communication familiarity with others users interaction. This interaction can be by gesture, touch or, speech. Figure 9c shows a NUI style. This image represents a Microsoft Natural User Interface project<sup>10</sup> that allows not only pen and voice input but also touch-less gestures and eye-tracking to interact.
- **Tangible User Interface (TUI):** represents an interaction where user manipulates virtual objects by physical ones. So they manipulate tools, holding directly them, to interact with applications, giving a sensation of tangible interaction by a dynamic feedback. For example, Reactable<sup>11</sup> project uses blocks with a marker on a table to create music as an electronic musical instrument. Figure 9d illustrates a Reactable.
- **Organic User Interface (OUI):** uses a non-planar display as input and output. So, the same object represents input/output data and this information can change

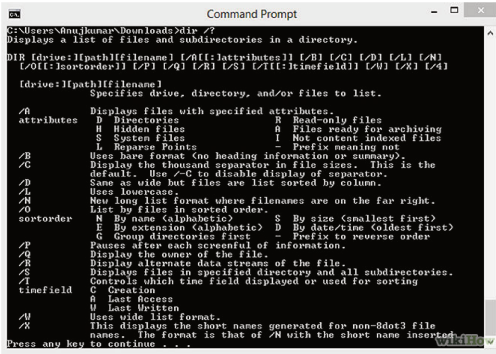
<sup>8</sup> Image Command DOS source: <http://www.wikihow.com/Use-the-Command-Line-Interface>

<sup>9</sup> Windows Image source: <http://www.defit.org/gui/>

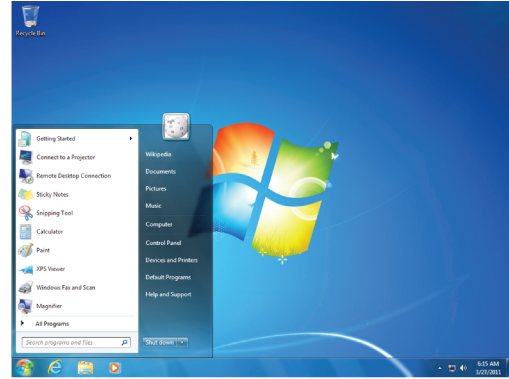
<sup>10</sup> Microsoft NUI Image Source: <http://hothardware.com/news/Microsofts-Natural-User-Interface-Lets-Your-Body-Do-The-Talking> credit: Microsoft

<sup>11</sup> Reactable Image source: <http://www.reactable.com/>

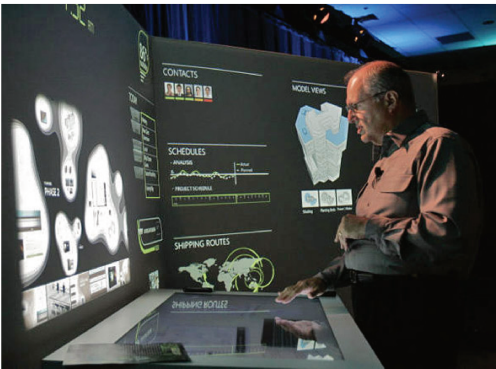
by manipulation as multi touch. As demonstrated on Figure 9e, a flexible display<sup>12</sup> technology uses OUI style.



(a) Command Line Interface (CLI)



(b) Graphic User Interface (GUI)



(c) Natural User Interface (NUI)



(d) Tangible User Interface (TUI)



(e) Organic User Interface (OUI)

Figure 9 – Illustration of the diversity interface styles. User validation experiment must be adapted to each one. (Credits on the text)

There is interface style where the interaction is graphical orientated. Meaning, the user interacts directly with objects which represents entities according to application context

<sup>12</sup> Flexible Display Image source: <http://www.unwir3d.com/887184/flexible-display-technology-adds-new-dimension-computing>

[Petry, 1993]. These styles can be divided in:

- **What you see is what you get:** the visual representation that user interact on interface is basically the final image result. So, in this interface, user can create, modify and, as result, visualize a print preview. It can be represented by text editors;
- **Icons representation:** in this representation, icons are chosen symbols to express, for resemblance or analogy, an object. Sometimes, an icon is more representative than words;
- **Direct-manipulation:** the objects, attributes and relations can be operated directly by graphs or views. These operations are visually shown and should be simple and intuitive, so user can understand quickly his task and how operate it.

Therefore, as general concept, an interface needs to represent an information in a suitable form to facilitate the perception and recognition of its meaning. This representation could be by icon, sound, text or, speech. Consequently, the interaction would be smooth and natural. Analyzing only user's perspective, the system interface would represent the system itself, user would not realize the difference [Hasan and Ahmed, 2007; Rogers et al., 2011]. That is the main purpose and the reason behind the decision to adopt a specific interface style. Together with an interface style, researchers and specialists [Wiecha and Boies, 1990] have suggested main features presentation and interaction behaviors that will be presented next.

## 2.4.2 Interface Main Features

As mentioned, an interface style should relate with features to obtain an harmonious interaction. Passing through a process of understanding user's wish helps to design a highly productive system to reach this desirable interaction. We can call this process as usability goals and user experience goals [Rogers et al., 2011]. Several studies [Barros et al., 2003; Nielsen, 1994a; Petry, 1993; Prates and Barbosa, 2007] have proposed that the system usability should consider to satisfy the following aspects:

- **Diversity:** an interface should support a various range of users and adapt to him. Also, it should provide various helpful functionality to accomplish a task.
- **Adaptability:** an interface should allow to recover from an error, unexpected behavior or, unfavorable conditions. Also, consider whether it should keep history information or not.

- **Efficiency:** an interface should not require much effort to execute a task. Also, the system should execute well what it was designed to do.
- **Convenience:** an interface should allow ease access to all operations. And facilitate the operation completeness without errors.
- **Flexibility:** an interface should provide flexible options to execute an operation. It integrates different ways to achieve a task.
- **Consistency:** an interface presentation and behavior should follow defined rules known by user.
- **Helpfulness:** an interface should be helpful and provide support when needed.
- **Imitation:** an interface should copy a human dialog, not in natural language but in use of examples or analogies.
- **Plainness:** an interface should communicate naturally, not requiring a high-level knowledge referring to the task.
- **Satisfaction:** an interface should satisfy an user, not frustrates him. It can take into account user personal preferences.
- **Directness:** an interface should assume a passive role, giving all interaction control to the user.

### 2.4.3 Interface Visual Elements

There is a strong relation between the interface project and the design, considering that an interface is composed by visual elements [Barros et al., 2003]. User interacts with the system using visual components (e.g. icons, menus) and these components should send a clear message, otherwise, the communication may fail.

Consequently, concepts of human-factors and design are related on the creation of human-computer interfaces. Vision is specially important, for example, researchers [Shneiderman, 1992] have studied human capacity to recognize an object in a context, or to determine velocity or direction of a moving point. Also, they have considered situations, such as: visual systems react differently to various colors and some people are color-deficient, there are visual fatigue situations, depth perception, viewing angles and distances. Besides, there are physical elements such as a touch on a keyboard, hearing abilities or, input/output speech. All these human-factors influence elements of the interactive system design. The result of these studies has contributed to develop guidelines and propositions of design shape.



Visual elements can be manipulated to get a diverse emphasis corresponding to the message goal [Barros et al., 2003]. According to de Abreu Cybis [1994], the most meaningful visual elements are: color, line, typeface and arrangement.

Color is an important factor on interface communication because it has the capability of influence people by causing reactions on their feelings, emotions and intellect [Marcus, 1991]. Researchers [Zhang, 2007] mentioned that the color has emotional connotation, for example black and yellow combined can suggest warning and blue color represents the most likable color. In visualization, the color should be used to transmit information, focus attention and group interactive objects. Color should not be used as interface cosmetic [de Abreu Cybis, 1994]. But how many distinct colors are acceptable on a visual system? User studies [Healey, 1996] found that users did quite well when the number of colors was 5 or less. As Tokumaru et al. [2002] mentioned on his study: “We can enjoy colorful life, but it may cause new problem to combine colors”. As consequence, if we use incorrect colors an interface, it may cause a delay on user response time. Marcus [1991] suggested some recommendations to consider before using colors in an interface, such as:

- Carefully select colors to use in an interface because they influence interface legibility;
- Group, with the same color, visual elements that are related;
- Use the maximum number of five colors;
- Evaluate the cultural and professional environment to choose colors.

Line is related to the notion of movement and direction, and symmetrical shapes (e.g. circles, squares) used as visual elements that composes an interface. According to Kandinsky, the Russian plastic artist that introduced visual art abstraction, lines are classified in three basics types: horizontal as representing a cold and flat support; vertical as representing a hot and warm possibility of movement and diagonal as a combination of cold and warm [Barros et al., 2003; Zhang, 2007]. Most part of interaction objects are delimited by borders (lines) which might help in guiding the design of aesthetic as well as meaningful information visualization systems [Zhang, 2007]. de Abreu Cybis [1994] suggested to use lines format which ensure objects balance. This could be accomplished by using simple line style and proportional distance between borders and text used on titles, headers and dialog box. Zhang [2007] affirmed a proper use and manipulation of planes (lines) on a system visualization send higher quality information.

Typeface is the letters study aiming to produce a legible information. This typographic study can be divided into two groups: extrinsic and intrinsic. The first group, extrinsic aspects

include: font, font size and font style . The second group, intrinsic aspects correspond to shape (e.g. case, width, declination) and serif [de Abreu Cybis, 1994; Reimer et al., 2012]. When a designer is creating an interface, he should consider the typographic style whereas it influences how information will be transmitted, reading speed and legibility. If the information is unreadable, user reacts negatively to the interface [Oman and Cook, 1990; Reimer et al., 2012]. Studies [de Abreu Cybis, 1994] suggested to consider aspects as serif and characters spacing before choosing a typographic design. In addition, Cybis' guidelines proposed to use fonts with serif in texts while fonts without serif should be used in titles and short labels.

Arrangement accorded to the way that the interface visual elements are organized, in others words, it represents how the objects are grouped, aligned, or diagrammed in the interface aiming to take advantage of the surface space [Barros et al., 2003]. de Abreu Cybis [1994] mentioned that arrangement should:

- Define functional clear areas;
- Being presented in a balance format(on screen empty areas);
- Not have alignment problems.

Observing how the interface surface is arranged, it becomes clear the screen dimensions (height, width) and the screen space organization. Depending on the interface used, this arrangement may change. On Web interfaces commonly use thick client, window-based interface. While mobile displays have been presented a wide number of frameworks as proposed by Zhao et al. [2006] which provided a dynamic diagrammed display.

In conclusion, for the user's interaction occurs properly, the communication between user and the designer interface should exist. The designer interface should send a clear message to the user through signs (e.g. graphs, images, icons) and he can use all convenient visual elements to succeed. The study of this communication channel is called Semiotics Engineering [Barros et al., 2003; Prates and Barbosa, 2007] as will be detailed on the next section.

#### 2.4.4 Semiotics Contribution on Human-Computer Interaction Development

The word semiotics came from Greek vocabulary and means *symptom*. Charles Sanders Peirce founded semiotics as the “*formal doctrine of signs*” [Liu, 2000], in other words, semiotics are the signs science. De Souza [2005] asserted about semiotics: “Semiotics is the study of signs, signification processes and how signs and signification take part in communication”. The

attempt of bringing together semiotics and HCI derived Semiotics Engineering. Conforming [Prates and Barbosa \[2007\]](#) semiotics engineering allows to understand the experience related to design, uses and validation of an interactive system. And also semiotics engineering proposes and develops qualitative models and methods to evaluate different types of interface and interaction elements [[de Souza and Leitão, 2008](#)].

One important aspect of semiotics engineering is considering that the software is an intellectual artifact. [De Souza \[2005\]](#) defined intellectual artifact as the developed product resulted from the developer understanding of the problem and proposed solution. And [De Souza \[2005\]](#) suggested that an intellectual artifact should have the following features:

- Encoding an specific understanding of a problem situation;
- Encoding a group of solutions for the noted problem;
- The encoding of the problem situation and the correspondent solution is linguistic, in other words, based in signs (e.g. verbal, visual or, other) that can be interpreted by coherent semantics guideline;
- The final artifact's goal can only be fully accomplished if users can formulate it within the linguistics system in which the artifact is encoded(i.e. users must be able to understand and use a specific linguistic system to explore and effect the solutions enabled through the artifact).

In agreement with intellectual artifact definition, a chair is not an intellectual artifact since it does not have a linguistic code related. But logic truth tables are intellectual artifact since we can think that the tables are proposed solution to understand the relation between logical elements. Thereby, semiotics engineering considers an interactive system as an intellectual artifact. And a system interface is considered as a meta-communication case because an interface is a message from the designer to the user containing his interpretation and understanding of a problem situation. And the system interface is the solution proposed by the designer which can be utilized to reach the user goal facilitated by the system [[De Souza, 2005](#); [Prates and Barbosa, 2007](#)].

Signs are used on interface to represent familiar objects. These objects are daily current on users' life. These representations are called metaphors [[Barros et al., 2003](#)]. Considering [Baranauskas and Rocha \[2000\]](#), creating a metaphor requires to contemplate the existing representations and try to include an identification or feature related to real events. Metaphors are useful to make mental models on user's mind which help the communication with the system [[Barros et al., 2003](#)]. Knowing user's need (e.g physical, mental, intellectual),

considering his diversity (e.g. age, social-cultural) requires methods to come close designer and user. Thus, with the requirements defined, it will be possible to find the proper solution that facilitate the wide use of the application [Da Rocha and Baranauskas, 2003]. Finally, an interface evaluation is an important aspect during the interface development process for the reason that through evaluation is possible to estimate the designer hypothesis success or not. An interface evaluation process will be explored on next section.

## 2.5 Interface Evaluation

Baranauskas and Rocha [2000] affirmed as much information the designer has about the users, the best quality of the design of his products. Interface evaluation aims to know what user really needs and also, verifies the problems occurred during the assessment process. It can help to clarify doubts about the system, supporting the creation of a usable and useful system. During evaluation, Barros et al. [2003] suggested to focus on:

- Evaluate the system functionality;
- Evaluate the interface effect on user;
- Identify the system specific problems.

The developer group should select an adequate method of assessment depending on the purpose of the interface evaluation. As Da Rocha and Baranauskas [2003] affirmed, it is important to know these available methods and their differences to assist choosing the most appropriate one. The assessment method could be software tools or framework. Applying a professional framework may help to define the planning and organization evaluation steps. Also, another option is applying a group of methods and orientate the user how to handle the application [Neves and Andrade, 2012].

The type of evaluation methods could be divided in: heuristic evaluation, cognitive route, guideline and patterns accordance, consistence inspection of features and formal evaluation [Prates and Barbosa, 2003]. In addition, these methods participants can include specialists or non-specialists (users), depending on the procedure adopted. First, methods based on specialists, Nielsen [1994b] proposed an usability inspection based on inspector evaluation of the interface following a criteria. These inspectors could be specialists, software development consultants, experts on a particular standard interface, final users, and others [Da Rocha and Baranauskas, 2003]. These specialists, generally, have the objective to find problems on the interface design [Neves and Andrade, 2012]. Second, methods based on non-specialists, Prates

and Barbosa [2003] suggested an empirical method counting with users participation to collect data that will be analyzed by specialists focusing to find usability problems. Empirical method requires to use a real application version (beta test or basic prototype) enabling a scenario or the application complete functionality. But, empirical methods are flexible about the experiment location allowing their application on a field or lab [Da Rocha and Baranauskas, 2003].

In conclusion, Hix and Hartson [1993] proposed a model which recommended that the application of evaluation should be considered as the main step and should receive and pass information to the others development step, such as: Implementation, Task / Formal Review, Requirements Specification, Conceptual/ Formal Design and Prototyping. Figure 10 illustrates the model mentioned which it is possible to observe how the development phases should interact.

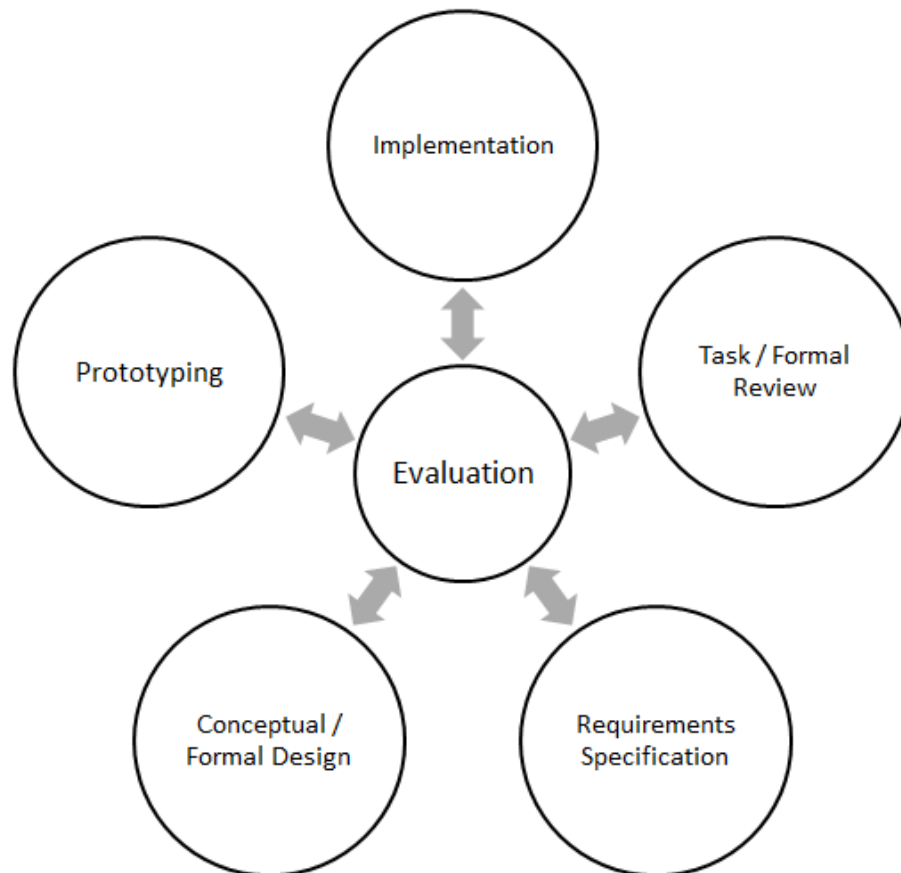


Figure 10 – Illustration of Hix proposed model considering interface evaluation as the central step. Adapted from Hix and Hartson [1993].

Despite the evaluation method used to validate the interface and the application of several methods or framework, there is a certain level of uncertainty [Baranauskas and Rocha, 2000]. Consequently, a good practice would be that the life cycle of an interface development

should have a periodic follow up. And according to Barros et al. [2003] committing with an appropriated interface evaluation method may require to choose, combine and adapt available techniques as long as the methods and combinations applied would generate a satisfactory result.

## 2.6 Conclusion

In this chapter, we presented the state-of-art of the main concepts applied in this dissertation. We introduced the concept of active learning and presented its main characteristics. Based on active learning benefits, we introduced the method proposed by Mazur called Peer Instruction considering step-by-step of this method application. Consequently, we presented the Classroom Response Systems approach as an interactive model applied in several classes format. We reported the impacts of classroom response system on education pointing up the profits and defiance on applying this model according to the literature publishes. Then, we mentioned the classroom response systems available solutions underlining the advantages and disadvantages of each option.

We also introduced the Human-Computer Interaction concepts related to this dissertation. Beginning with a brief summary of human-computer interaction history and study field, referring to the importance of this research area. Therefore, we focused on interface development, as this part is an important aspect related to this dissertation. We did an interface overview by describing interfaces style, main characteristics and visual elements. In addition, we presented the Engineering Semiotics contribution on HCI expansion. Concluding the chapter by describing concepts related to interface evaluation.

Finally, in Chapter 3 we will introduce our project proposition which takes into account the concepts approached. In this dissertation, we are proposing two low-cost solution focusing on the extensive acceptance of classroom response systems. We will present both solutions development process and prototypes results.

## 3 Proposed Solutions

In this dissertation, we propose two affordable solutions for classroom response system, aiming at teachers and students' use of active learning tools as part of classroom reality which may cause positive impact [Orlandi and Isotani, 2012]. One solution uses BYOD idea which was presented on Subsection 2.2.2 and the other solution approaches image-processing idea as presented on Subsection 2.2.3. In both cases, we divided the development process into analysis, project and implementation [Guimarães et al., 2002].

First, in the analysis, we did a brainstorm with our research group and created a storyboard for both projects. This storyboard represents visually the application screens and defines the software tasks. We decided to develop a clean and intuitive application as much as possible, so the application prototype will incorporate few visual artifacts. This process helped us to keep sight on the application flow and context. Second, in the project phase, we decided the system requirements considering that we will use mobile and web platforms and database. In this project phase, a fundamental requirement was the interface design and interactions decisions, after all we were working with two different approaches so we should consider each user need independently. Consequently, these definitions helped us on the implementation phase when we started coding and developing both projects prototype.

In the following sections, we will describe the two proposed projects, highlighting their main features, exploring the design interaction proposed, applied scenario and presenting the prototype result obtained.

### 3.1 Our BYOD proposition: virtualclicker

In this section, we will describe our BYOD proposition for classroom response system. This perspective uses the concept of BYOD as presented on Subsection 2.2.2, where the students are responsible for bringing their devices. Our BYOD proposition is called Virtualclicker. Figure 11 illustrates virtualclicker design interaction in class. Virtualclicker proposes a solution that creates a local network so the teacher will not depend on school network infrastructure. The instructor could access the system using a portable or fixed device. So, he will use virtualclicker through a device and the class will send their response using the local network service. This local service contributes to avoid the student web distraction and limits the web service content. After the class response, the result will appear on the instructor interface. Virtualclicker project was designed to provide a system to fulfill the instructor and learner

specifications requirements.

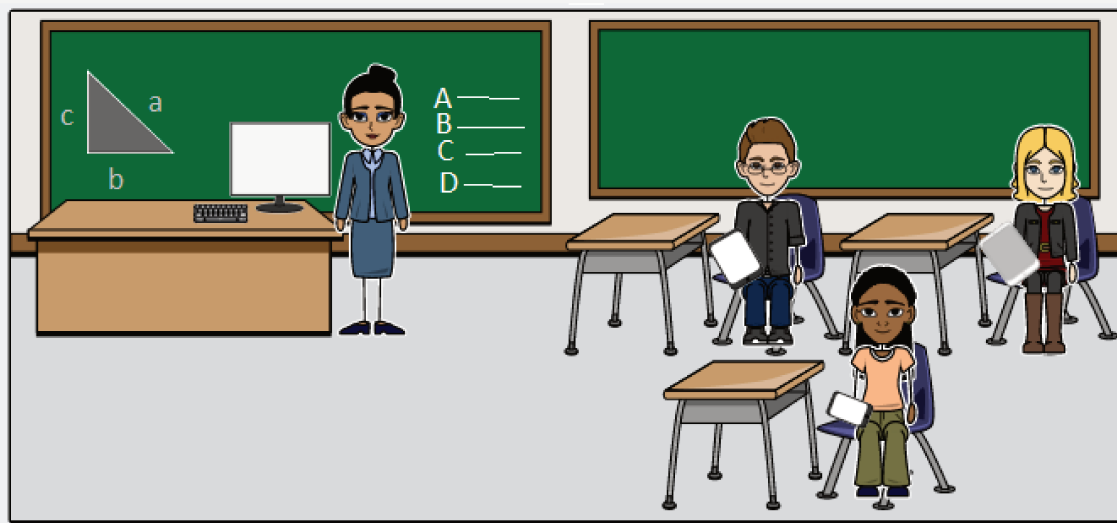


Figure 11 – Illustration of Virtualclicker design interaction using the concept of BYOD, which the students bring their devices to class.

First step on design interaction creation was drawing a mock interface in a piece of paper telling the storyboard. On group brainstorm, we discussed about how the application would work and its visual artifacts. Figure 12 demonstrates the storyboard created for each interface. We decided to put a picture of the storyboard draft to illustrate the group work and pass a realistic point of view about the development process. Despite the fact that the storyboard drawings were very rough draft, they were an effective communication tool for the development group to produce the prototype of the interaction design.

For visualizations proposals, we decided to include images that show a better view of the storyboard. Virtualclicker project is divided in two independent interfaces: the instructor interface as demonstrated on Figure 13 and the learner interface as demonstrated on Figure 14.

Each one with distinct characteristics thought to supply the students and the instructors needs with specific features. During the brainstorm, we agreed that the instructor and the learner interfaces would share the same database, so all the communication between them will be done by it. In addition, as a system specification, the instructor would be able to close the class event by clicking in the log out button at any time he prefers.

The learner interface was designed optimized to work in the small screen of a smartphone. We considered that the student would not have a big screen, so the features designed for the student interface was simpler and would not occupy much space. Yet, the learner interface would fit in a notebook screen. We also defined that the instructor interface would



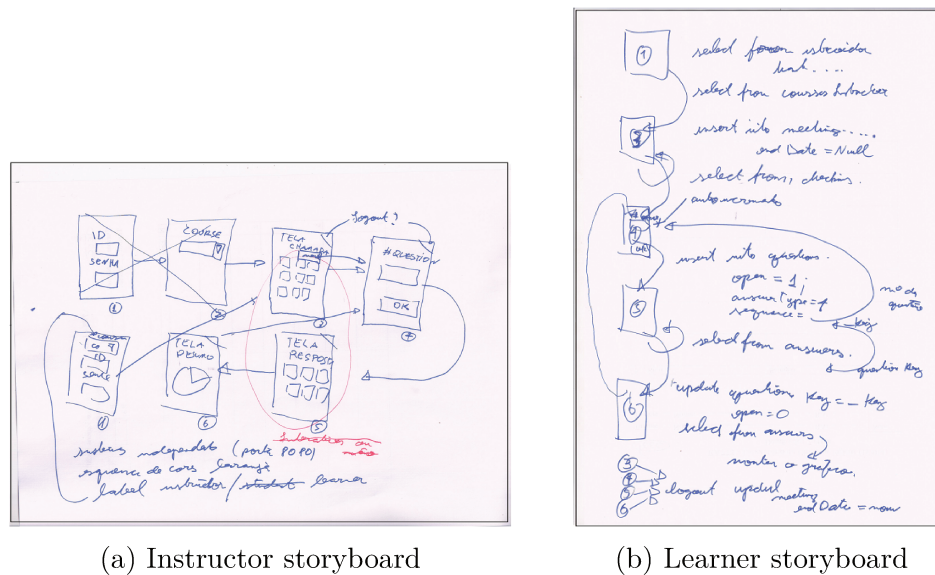


Figure 12 – Illustration of the storyboards created on the group brainstorm to represent virtualclicker tasks.

have features like attendance screen, responses screen and charts showing the students' answers, consequently the interface was optimized to work in a bigger screen (e.g tablet or notebook).

### 3.1.1 Project Prototype

After creating the storyboard, we started the project phase that included the interface design and definition of the system requirements. Initially, we defined the interface design and interactions which helped on virtualclicker prototype implementation. Virtualclicker interface is divided into two types of interface: student and instructor, as mentioned before. We decided to use two different colors to help on the identification of the interfaces. The first interface is the student as illustrated on Figure 15. We decided to use the color blue as main color due to its appealing [Zhang, 2007]. The student's flow will have four main screens: (a) Log in screen; (b) Main screen; (c) Collect answer screen and (d) Confirmation screen.

On log in screen, the students should introduce their unique identification and password. Each student will have an identification and password registered on the database to use the system. After logging in, the student may verify if the information is correct (e.g. course ID, last check-in, total of check-ins) on main screen. When we were deciding about the student interface, we agreed to use the clicker device metaphor on collect answer screen, so we included buttons to remind the physical devices on that screen. Finally, the student can confirm the answer and finish the task. As an alternative flow, the student can choose the option change and select a different answer and then, he finishes the task.

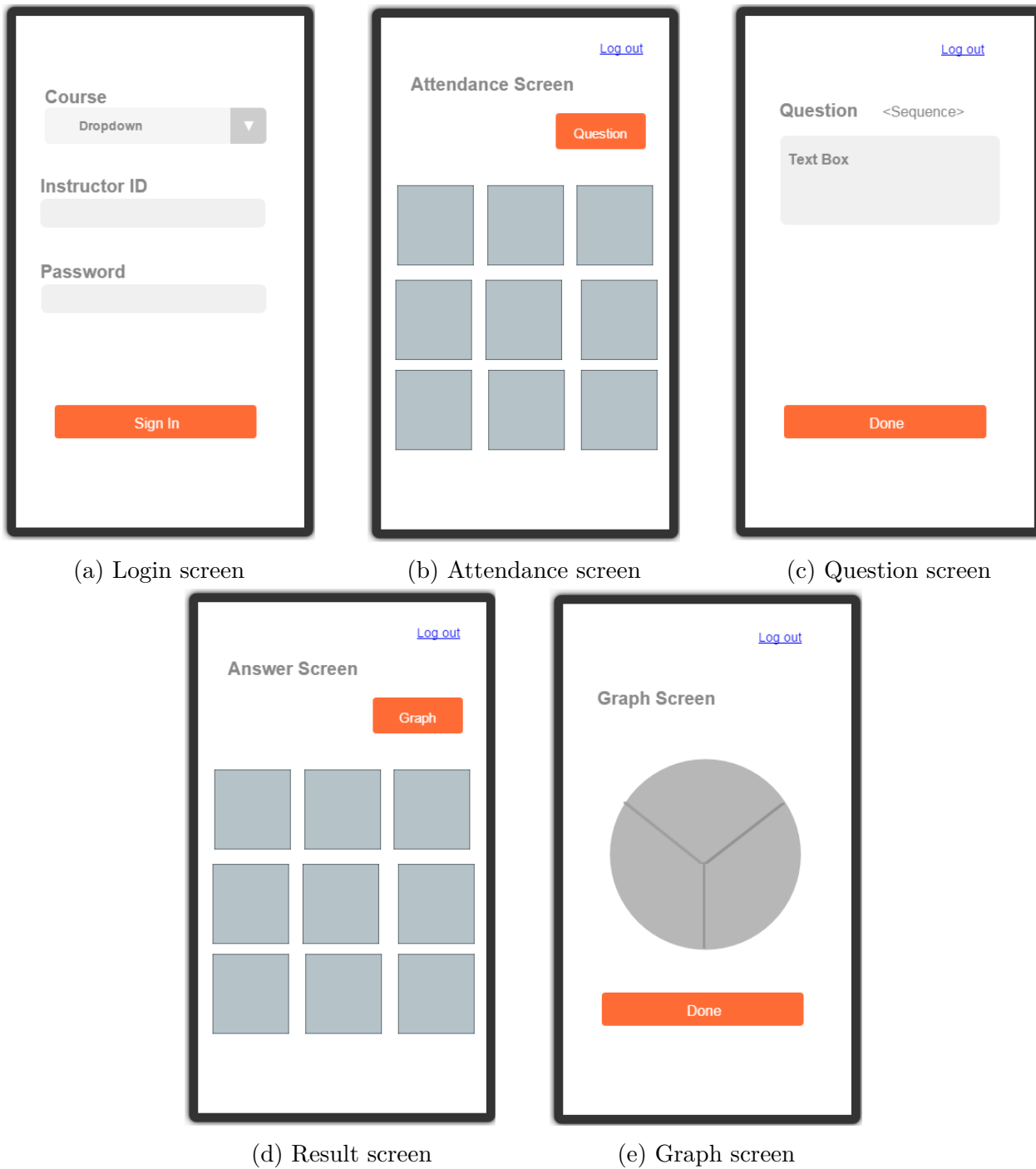
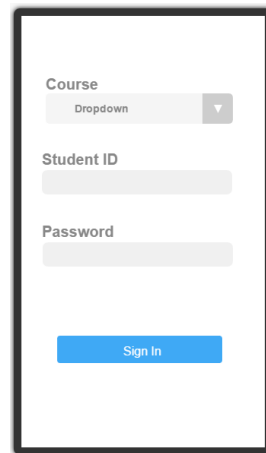
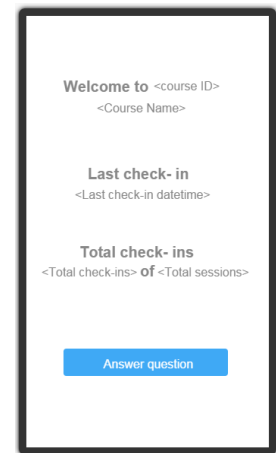


Figure 13 – Illustration of Virtualclicker storyboard: Instructor Interface. This storyboard shows the visual elements and interface flow defined on the group brainstorm.

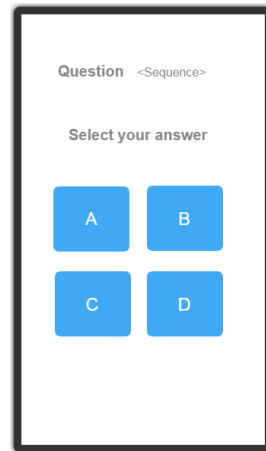
The second interface will be used by the instructor as demonstrated on Figure 16. In this interface, we selected the orange color as main color to contrast with the student interface. The instructor flow will have five main screens: (a) Log in screen; (b) Attendance screen; (c) Question screen; (d) Answers screen; (e) Graph screen.



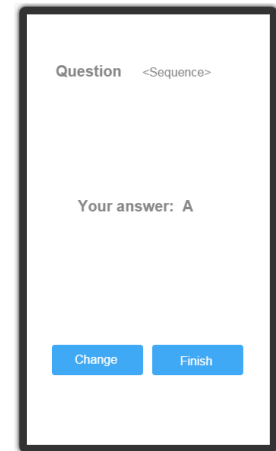
(a) Log In interface



(b) Main interface



(c) Collect answer interface



(d) Confirmation interface

Figure 14 – Illustration of Virtualclicker storyboard: Learner Interface. This storyboard shows the interface idea defined by the group brainstorm.

On log in screen, the instructor will also need an identification and password, stored on the system database. On attendance screen, the instructor can register the students absence/presence in class to verify later which students participated. Also, the instructor can analysis the attendance data collected to research purpose. After registering the students, the instructor can create the questions that he will ask during lecture on question interface. The entire class will just have access to the question after the teacher creates it, otherwise, the student stays in stand by waiting for the teacher releases. Afterwards, the class will see the question so they can choose an answer. According to the students feedback, the result will be exhibited on answer screen. Also, the instructor can visualize the results summary on graph screen with the statistics. Finally, it is up to the instructor decides if he will present the result to the class or not.

As part of the project phase, we also decided the system requirements. Virtualclicker

(a) Log In interface

(b) Main interface

(c) Collect answer interface

(d) Confirmation interface

Figure 15 – Illustration of Virtualclicker prototype: Learner Interface. The learner interface was designed to fit on small screen and attend the students' needs.

uses a web system server that create a local network as a simple wireless router. In this way, the student is able to connect to the system through any device equipped with web browser (e.g. notebook, netbook, smartphone, tablet). Rich interfaces can be achieved using HTML5, CSS3 and Javascript, according to the system requirements, we would choose the better fit. Virtualclicker requirements also include an offline module. The offline module has the initial information needed to use the system (e.g. user ID, password, class name) stored in a database. The database was developed thinking in the future of the application which the instructor would be able to create different types of questions with different types of answers. The questions can be multiple choice and the students would be able to answer

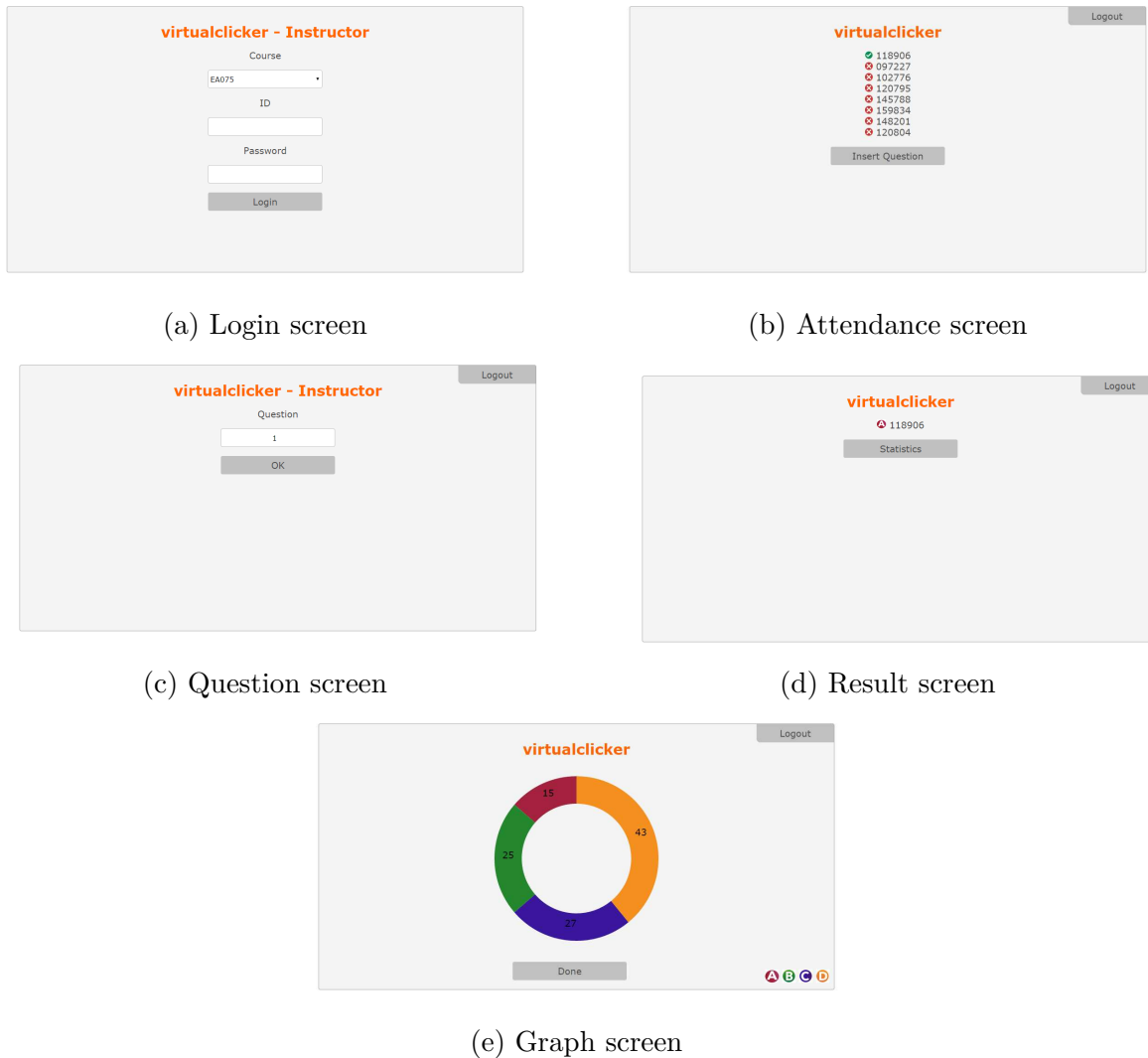


Figure 16 – Illustration of Virtualclicker prototype: Instructor Interface. The instructor interface was developed to supply teacher' s requirements in class.

them using text and numbers. After defining the project interface using storyboards and the project requirements, we started the prototype implementation. In addition, we ran some internal tests, to verify the application and fix bugs. The presented interface is not the final one because we intend to execute validation experiments as will be explained further.

Virtualclicker uses a local network hosted by a Raspberry Pi model B <sup>1</sup> with Apache 2.4 embedded as a server. Virtualclicker was developed mainly on PHP 5.5.23<sup>2</sup> and the database was created on MySQL 5.5.42<sup>3</sup>. Virtualclicker used D3.js<sup>4</sup> to create the graph.

<sup>1</sup> Raspberry Pi source: <https://www.raspberrypi.org/>

<sup>2</sup> PHP source: <http://php.net/>

<sup>3</sup> MySQL source: <https://www.mysql.com/>

<sup>4</sup> D3.js source: <http://d3js.org/>

D3.js is a javascript library that facilitates the web development. Virtualclicker prototype represents an important aspect of this project proposing a BYOD solution however, the application development did not represent the scientific aspect of the project. As demonstrated before, we created storyboards, made interface decisions according to the users (instructor / learner) need and decided the application flow. But, we intend to validate this application by running formal software tests. Our purpose includes to do users validation experiments to testify virtualclicker prototype interface for both main users (instructor / learner) and to evaluate its visual elements.

Virtualclicker development had contribution of the undergraduate student Vinicius Ribeiro, partially allocated as a member of an institutional program for scientific initiation scholarship known as PIBIT.

### 3.1.2 Project Scenario

After the prototype was ready and stable, and we were prepared to execute user experiments, we sat down to write the project scenario. Scenario is a simple story that describes a hypothetical situation to raise questions and makes developers group think how the proposed project will work in adverse situations [Rosson and Carroll, 2001].

Using scenarios during development process are a good practice since software development is more than writing a code [Rosson and Carroll, 2001], even though our group created the scenario after prototype implementation, this step was helpful to establish our user validation experiments. Also, the scenario helped us to visualize the alternative flows created and evaluate them as useful to the application. Scenarios include actors or agents, and each agent has a purpose. Also, scenarios have a story line that combine what actors do, what happen to them, and situation changing. This representation facilitates to expose the design use and helps to define/change goals, focusing on people expectation and assignment. In addition, scenarios contribute on interaction design decisions and evaluation in terms of a specific plot [Carroll, 2000].

The following case study illustrates virtualclicker applicability in a classroom scenario, considering that the local network is settled up and all the previous configurations are working.

*Scenario:*

*Mr. Silva is the instructor of AA001A class at UNICAMP. He is waiting in class to the students arrival. After all students arrived, Mr. Silva opens in his computer a browser to use Virtualclicker. He logs in the instructor's interface, choosing a class to start. The students immediately can check this new event and start to register their user. While the students are*

logging in the system, the instructor is able to visualize the attendance of the class in the attendance screen. After registering the class attendance, the instructor goes to the question screen to create a question. Once a question is opened, the students can answer it in the learner interface.

The student goes to the answer screen which provides a multiple choice answer. The student can commit with an answer by clicking in one option. If he changes his mind, he can modify his answer before finishing it. While the students are answering the questions, Mr. Silva is able to visualize their answers in the response screen, which show the student ID and an icon element identifying their answers. After the entire class answered the question, the instructor can close the question and generate a graph showing the statistics result of the class response. In the end, Mr. Silva has the option to go back to the question screen and start a new question.

## 3.2 Our image-processing solution: paperclickers

Our image-processing proposition is called Paperclickers. Our proposition is related to the work presented on Subsection 2.2.3. Paperclickers kept the BYOD idea, but in this case the instructor has to be the one to bring the device instead of the student. That way, we will avoid student distraction during lecture and also will guarantee all students participation. In addition, the instructor will carry on his device through all his classes and may use the application when appropriated. The instructor will use his smartphone camera to scan the class, then he will visualize the results on his device. Figure 17 illustrates paperclickers proposed design interaction in class.

As said, the instructor will use his personal phone with an application to capture the class response. Instead of a personal device for each student in class, the students will hold up a cardboard with a sign. This sign will represent the student identification and can be printed in a small sheet of paper. Also, the sign orientation represents multiple-choice answer. The result of class response will be shown on the device in real time. Then, as a contribution of our project, we will provide a mobile application to recognize the codes accomplishing the system requirement.

The development group did a brainstorm to define the paperclickers application flow and tasks relations besides the visual elements as illustrated on Figure 18. This storyboard was used as communication tool since it gave a visual support to the group, showing the application project. The storyboard drawing represents the application flowchart and how the group interacted to develop the prototype for real. All ideas were considered and the contributions were productive.

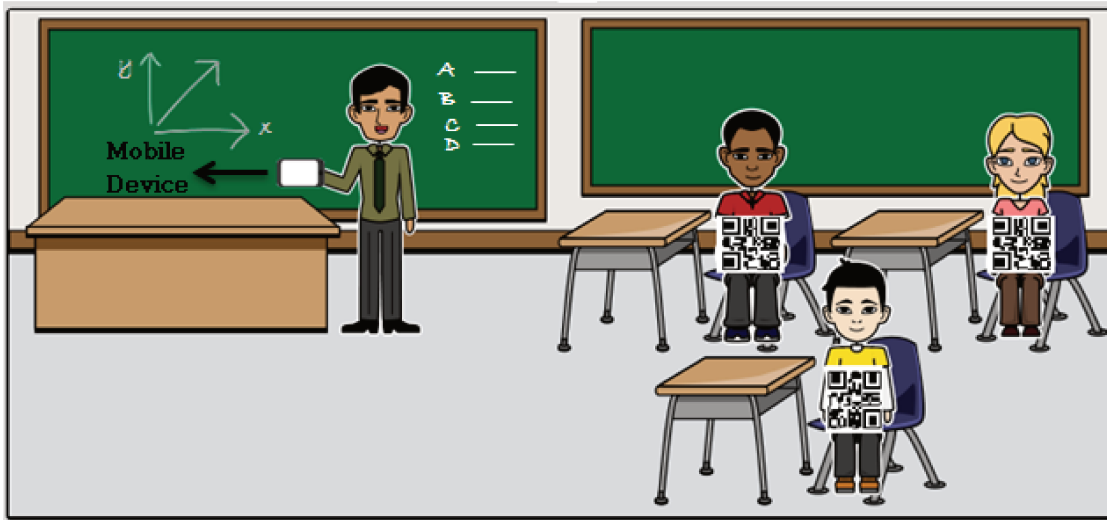


Figure 17 – Illustration of paperclickers design interaction. The instructor will use his own phone with an application installed to capture the class response.

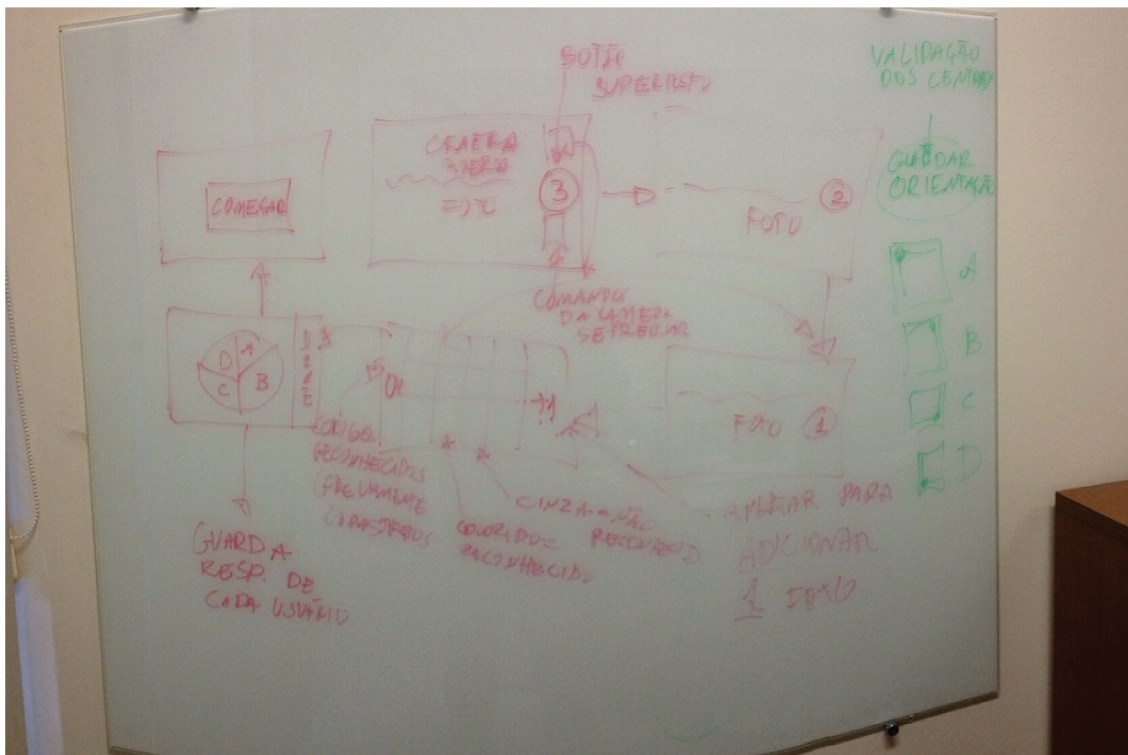


Figure 18 – Illustration of the storyboard created to define paperclickers visual artifacts, tasks and flowchart.

For visualization purpose, Figure 19 shows a better view of the storyboard draft. During this project process, we did interface decisions and defined the application flowchart. And we also realized that would be necessary an offline module to store preliminary information (e.g. class name, student ID). This storyboard phase helped on prototype implementation



and provided an idea of how the interaction design would work in a class. We tried to develop an intuitive application using few visual artifacts, since this application would be used on mobile platforms. This analysis allowed the group to project the prototype and facilitated its implementation as will be addressed.



Figure 19 – Illustration of paperclickers storyboard showing the visual elements and screen flow decided on group brainstorm.

### 3.2.1 Project Prototype

On paperclickers project phase, we defined interface elements and system requirements. Paperclickers project requests only the teacher interface design whereas an application will be

installed on his mobile device. We decided that paperclickers main color should be green. We selected this color as a reminder of the class board. And we defined the fundamental elements of paperclickers application, as follows:

1. **Preliminary definitions:** the instructor should select the class and question number.
2. **Attendance:** this module identifies which student is present in class and save this information, so the instructor can verify later who have participated.
3. **Image capture:** it activates the device camera and scans the entire class.
4. **Result view:** after capturing the codes, the application shows the students' answers.
5. **Graph view:** the application displays the result in a graph.

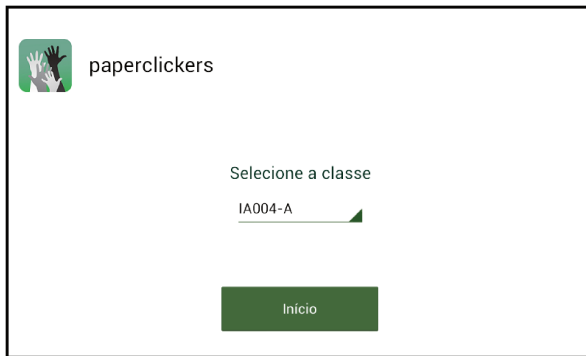
Figure 20 demonstrates the interface designed for our image-processing solution and how the interface looked like after implementation. When the paperclickers application is installed on the device, it is created a paperclickers folder. In this folder, the instructor should insert a file containing a list of classes that he is lecturing. This file is loaded on class selection screen. Also, the user can click on the application icon and a dialog box with the application information and visual elements credit is shown. On question definition screen, the instructor can choose the question number. In addition, we included an attendance alternative flow, so the instructor has the option to register the class attendance. On camera screen, the instructor can scan the entire class. The application will give a visual feedback of the identified codes. When finishes the scan, the instructor can click on the screen to go forward. On result screen, the instructor can visualize the students' answers. If there is a not detected report, the instructor can click on the item and change the response. In addition, the instructor has the option to go back to the previous screen to scan the class again. Finally, on graph screen the instructor will see the result statistics. And he has the option to try again or start a new question.

The paperclickers interface includes icons, buttons, labels, etc as visual elements. Paperclickers icons were obtained online which are available on FlatIcon<sup>5</sup> site. The icons were referred on paperclickers application about session. On graph view screen, we used the MPAndroidChart<sup>6</sup> library developed by Phillip Jahoda. This library allows to create several graphs on Android. In addition, the colors were selected based on the palettes colors disposable on Palettes:Colourlovers<sup>7</sup>.

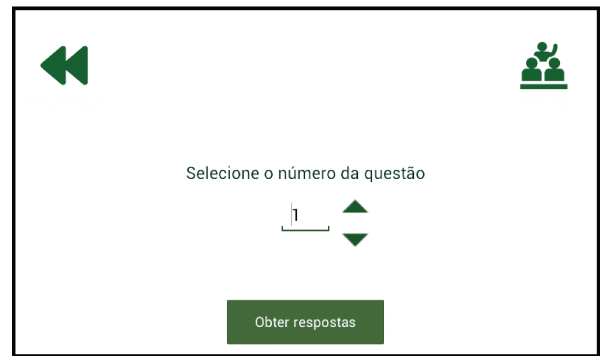
<sup>5</sup> FlatIcon source: <http://www.flaticon.com/>

<sup>6</sup> MPAndroidChart source: <https://github.com/PhilJay/MPAndroidChart>

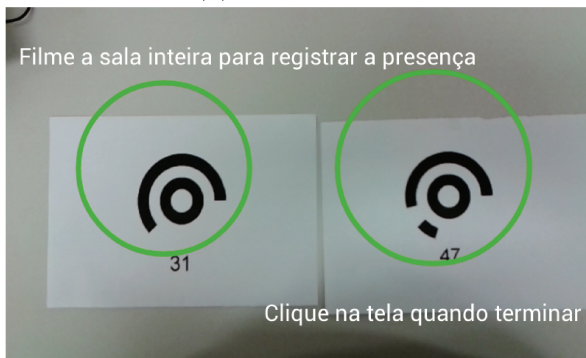
<sup>7</sup> Colors source: <http://www.colourlovers.com/palettes/search/new>



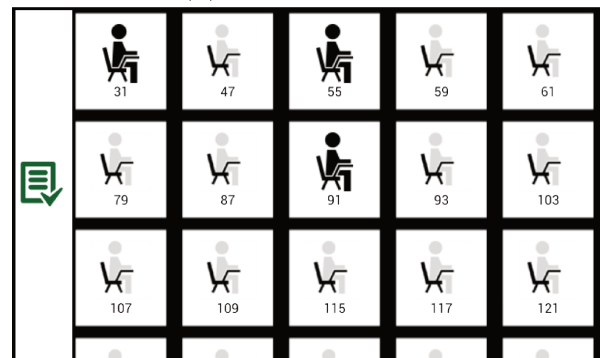
(a) Initial screen



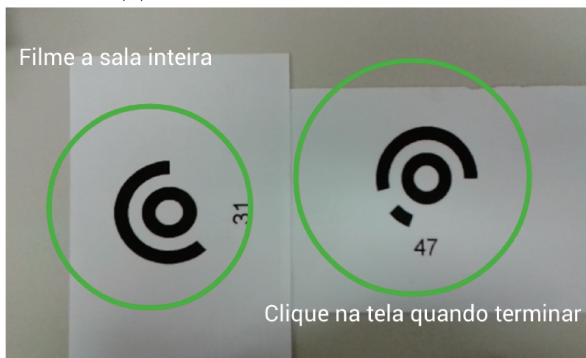
(b) Question screen



(c) Collect attendance screen



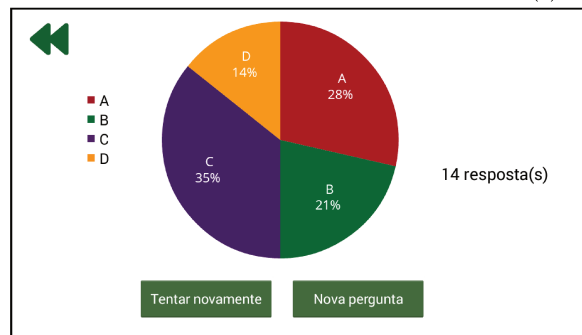
(d) Attendance result screen



(e) Collect answer screen



(f) Result screen



(g) Graph screen

Figure 20 – Illustration of paperclickers interface implemented based on storyboard and project decisions.

As system requirement, we defined paperclickers prototype as a mobile application which would embed the Qr Codes and Top Codes recognition, detection and decoding function. In addition, this application was developed on Android platform. After the application development, we did some internal tests, asking people from the group to use paperclickers. This procedure helped to find bugs and fix errors. Paperclickers prototype is an important part of this project, even though the application development did not represent the scientific aspect of the project but, as mentioned before, we invested time creating storyboards, making interface decisions and defining the application flowchart. Still, it is necessary to run formal software tests in the application before releasing it. The application usability needs to be validated. We intend to execute users tests to verify paperclickers application interface and to evaluate its visual elements.

Paperclickers development had contribution of the undergraduate student Lucas Tejada, as part of his final project. He helped on the development of the attendance module and augmented reality.

### 3.2.2 Project Scenario

According to the group development process, we decided to write down paperclickers scenario. Paperclickers project scenario presents a case study to illustrate our image-processing solution applicability in a real case. This scenario demonstrates the actors (instructor / students) interaction. Our group invested time creating this scenario after the prototype implementation and internal tests, when we were prepared to start the user validation experiments.

Paperclickers scenario considers that the teacher is in a classroom environment applying CRS concept with image processing solution, in other words, using a printed code instead of clicker devices. And the preliminary parameters are already configured.

*Scenario:*

*Mrs. Lima is the instructor of MO446A class at UNICAMP. She is in a classroom waiting for the students arrival. After all the students arrived, she distributes the student's cardboard which contains a code with the student's identification. Then she launches the paperclickers application, chooses the class and clicks on button Start. Mrs. Lima can click on attendance icon, then she can tell the students to put their cardboard up and start to scan the class. The application identifies the presence or absence of the student and shows the result. If any student present in class is not detected, the teacher can change his status from absent to present by clicking the item on the screen. During the class, the teacher can ask a question to verify the students understanding of a topic. So the next step is to define the question number on the application. The students may have some time to commit to an answer and*

then lift up the cardboard following the code orientation standard.

*At this point, the instructor click on collect answer button and the application accesses the smartphone camera. After capturing the answers, the application processes the images and shows the result. The teacher could continue by pressing the graph button. If the result presents a wide number of not detected students, she can choose to go back, so the camera is opened again and it is possible to scan the class again. But if she chooses to continue, she will see the students answers presented in a graph, with the total of answers and percentage by answers.*

*In this last step, Mrs. Lima could keep using the application and press the button new question, so the application saves the result in a file and returns to define question screen. But if the teacher wants to repeat the process with the same question, she can press the button try again and she will repeat all the procedure.*

### 3.2.3 Project Machine Encoding

Paperclickers application was designed to recognize two machine encoding signs. The first sign is a two-dimensional barcode called Qr Code<sup>8</sup>. We chose to use Qr Code due to its popularity and increasing usage. Qr Code has a good free open source decoder called Zxing<sup>9</sup>. This barcode can storage information both horizontally and vertically. As a result of that construction, the two-dimensional barcodes can store up to 7,089 characters, significantly greater storage than is possible with the 20-character capacity of a one-dimensional barcode. These barcodes are also known as quick response codes because they enable fast data access and are often used in smartphones. The user simply takes a picture of a two-dimensional barcode with a smartphone camera equipped with a barcode reader. The reader interprets the encoded data and shows the results [Belussi and Hirata, 2013; Liu et al., 2008].

Qr Code is capable of storing numerical and alphabetic characters. It has error correction capability, so the data can be restored even if the symbol is partially dirty or damaged and also it is readable from any direction in 360 degrees due to the position of the detection pattern located at the tree corners of the symbol, which guarantees stable high-speed reading and avoids the negative background interference [Wakahara and Yamamoto, 2011].

Qr Code must have function patterns. These squared shape patterns, known as finder patterns, should be included in specific areas of Qr Code to ensure that the scanner will correctly identify and orient the code for decoding. The finder patterns are the tree blocks in the corners of Qr Code: at the top-left, top-right and bottom-left [Belussi and Hirata, 2013].

The Qr Code printed sign will follow the model illustrated on Figure 21. On cardboard

<sup>8</sup> Qr Code. <http://www.qrcode.com/en/>

<sup>9</sup> Zxing. <https://github.com/zxing/>

front view, a Qr Code with the student encrypted identification will be printed and the orientation of Qr Codes markers will determine the student's answer. On cardboard back view, it will have the student identification and the multiple-choice option according to the sign orientation. The student will be instructed to rotate the cardboard and put his final answer at the cardboard top.

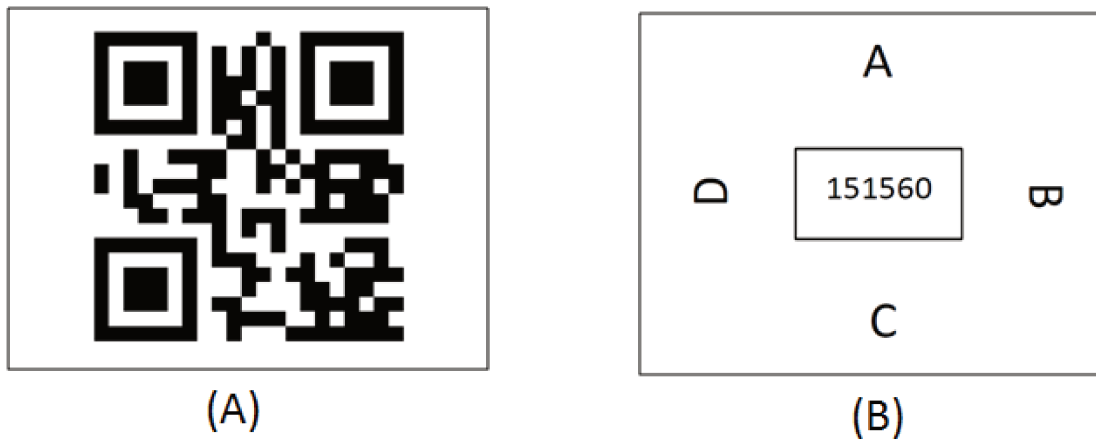


Figure 21 – Illustration of Qr Code cardboard model. (A) On front view, the Qr Code eyes are used to detect and decode the answer and determine the orientation. The student ID is encrypted on the code. (B) On back view, the student's answer is on the top, so he can rotate the card to choose an option and then, raise the card with the front view facing the camera. The student ID is printed on the back.

The second sign is known as Top Codes (Tangible Object Placement Codes)<sup>10</sup>. Top Codes were invented by Michael Horn from Northwestern University. Top Codes sign was designed to recognize tangible objects on a surface. These signs are circular black and white symbol. This code also provides a unique ID, angular orientation and tag diameter. Top Codes are limited to recognize only 99 unique codes but they are capable to recognize codes up to 25x25 pixels. The core Top Codes library is free and open source, and it has available Java classes [Interactive, 2013].

Top Codes have been used in diverse projects including marketing, just like QR Codes. These codes use image-processing algorithms that can work on several lightning conditions without user calibration. Consequently, the feedback is fast and accurate. The Top Codes printed sign is illustrated on Figure 22. During project phase, we decided to keep the Qr Code standard. However, the sign cardboard will be smaller size.

Top Codes and Qr Codes have complementary advantages. While Qr Codes allow to create a unique identifier per student for a very large number of students, Top Codes allow only 99 different codes, demanding a unique code per classroom not per student. On the

<sup>10</sup> Top Code: <http://users.eecs.northwestern.edu/~mhorn/topcodes/>

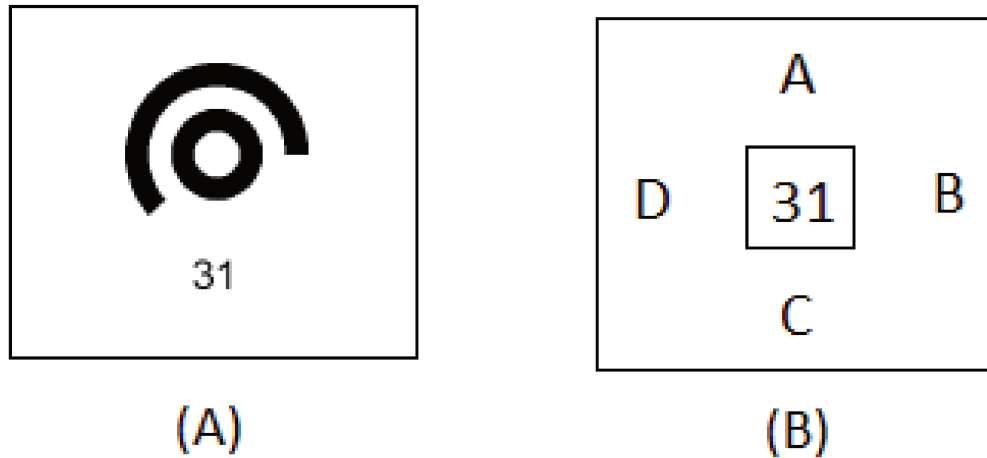


Figure 22 – Illustration of Top Code cardboard model. (A) On front view, the Top Code is detected by camera. The student ID is below the code. (B) On back view, the student’s answer is on the top, so he can rotate the card to choose an option and then, raise the card with the front view facing the camera. The student ID is printed on the back too.

other hand, Top Codes are extremely robust and very fast to detect, while Qr Codes have issues for the geometric transformations and have expensive computational requirements to detect.

### 3.3 Conclusion

In this chapter, we presented two low-cost solutions of classroom response system. First solution was called Virtualclicker. Virtualclicker is based on BYOD concept. On BYOD concept, the student brings to class his personal device and uses it during lecture. In our proposition, Virtualclicker disposes of two interfaces: instructor and learner. These interfaces were basically designed to correspond users need. So, the instructor interface allows to proceed with student’s attendance and dispose a question to the class. The student interface allows to collect an answer from the class. Finally, we proposed to create a local network using a Raspberry Pi. Consequently, the teacher would not need to count on school infrastructure.

Second solution was called Paperclickers. Paperclickers is based on image-processing proposition. On image-processing proposition, we use image-processing techniques to detect and recognize a symbol, receiving the result on real-time. Paperclickers application has two versions. One version recognizes Qr Code and other, Top Codes. This application was developed on Android platform and should be installed on the instructor personal device.

Both projects follow existing concepts as presented on Chapter 2 to establish a review foundation. Decisions regarding to design interaction, scenarios, storyboards, interfaces visual elements, development process and implementation features were made by the development group. According to each project specifications, the group defined the project features as described along this chapter from both solutions. As result, we produced the two-solution models.

In conclusion, in Chapter 4 we will present the project experiments and results. During the development process of the project were executed detection experiments, image enhancement experiments and design interaction experiments. On design interaction experiment were performed tests to verify the project feasibility and evaluate the proposed solutions visual elements.



## 4 Experiments and Results

In this chapter, we present our experiments and results. We executed detection experiments, image-enhancement experiments and user experiments. For Virtualclicker, we executed users experiment to validate the design interaction and to evaluate the interface proposed.

For Paperclickers, we performed experiments related to image-processing techniques. Our preliminary proposal was to implement a prototype that detect and decode a bi-dimensional code known as Qr Code. Consequently, we started to execute detection experiments to verify the available library used to detect and decode bi-dimensional codes. Then, we decided to apply image enhancement techniques to get better results on barcode recognition and decoding. The image enhancement experiments were exploratory. We wanted to check how these techniques may help on code decoding. Finally, we also executed users experiments on paperclickers prototype to validate the proposition design and interface.

In order to demonstrate how the experiments were conducted, we report the experiments setup, presenting the parameters used and script applied. Therefore, the results obtained are presented for each experiment executed.

### 4.1 Detection Experiments

Detection experiments were conducted to verify bi-dimensional barcodes recognition feasibility. We started using Zxing library version 2.2 and developed a simple test-project prototype to validate its function.

As first experiment, we wanted to do a proof of concept to know if the library is able to identify various Qr Codes at once since this functionality is not default. So, we did a simple experiment, using three codes and adopting conditions which may happen in a classroom environment and could be problematic. In these tests, we used three numerical Qr Codes and defined conditions for image capture, such as:

1. Camera Distance: short (2 meters) / long (4 meters);
2. Camera baseline: direct / oblique;
3. Code orientation: align / rotate;
4. Code Occlusion: yes / no;

The conditions were combined among them and we took five pictures from each combination to verify if the library could recognize the barcodes. All images captured by the application are illustrated on Appendix A.1. During the detection experiment, we followed script below:

**Method: Zxing Original code**

1. Printed three codes;
2. Fixed the codes in a flat surface;
3. Used a smartphone (Galaxy Nexus) with an Android application. The application detected and decoded the code presenting the result;
4. Changed the acquisition conditions;
5. Got five pictures from each acquisition conditions.

As result for this first experiment, we obtained 16 conditions. And a **total of 15 pictures** from each. Table 2 demonstrates the conditions and the percentage of the total. The results from original code were not satisfactory because the library was not able to deal with adverse conditions that we knew may happen in class. However, the results were good only on “best case scenarios” according to the conditions 1 and 5. Consequently, we investigated why there was a wide number of unrecognized codes by selecting the worst cases as study case. After the investigations, we computed that the most frequent errors were: Reed Solomon exception and not finding the code centers error. Thus, we decided to modify the Zxing library. We loose the code markers detection conditions called: the multi finder patterns method which is responsible to find the Qr Code markers on an image and the multi reader method which is responsible to recognize a Qr Code. We also loose the proportion condition so that we changed false positives, in other words, we switched false positives by false negatives to improve the results. It is important to highlight that we changed the code, not the images.

After the modifications, we executed the experiment again considering the images already obtained. Thus, the results substantially improved in most scenarios as demonstrated on Table 2, even though there were conditions such as the condition 9 and 11 (highlighted on Table 2) kept the same result as before. Also, we observed that the library had better results with not occluded codes although it can still identify the code partially occluded which may happen in a classroom environment.

Still in this phase, we wanted to exam the library decoding module since we would use the Qr Code orientation to identify the student’s answers. Accordingly, we identified how

Table 2 – Summary of experiment results. Comparing results from Zxing original and modified code

#	Condition					Recognition (Percent of 15)	
	Distance	Camera	Baseline	Code Orientation	Occlusion	Original	Modified
1	short	direct		align	no	100	-
2	long	direct		align	no	6,7	100
3	short	oblique		align	no	33,3	100
4	long	oblique		align	no	13,3	100
5	short	direct		rotate	no	100	-
6	long	direct		rotate	no	6,7	93,3
7	short	oblique		rotate	no	26,7	53,3
8	long	oblique		rotate	no	6,7	93,3
<b>9</b>	<b>short</b>	<b>direct</b>		<b>align</b>	<b>yes</b>	<b>66,7</b>	<b>66,7</b>
10	long	direct		align	yes	20	60
<b>11</b>	<b>short</b>	<b>oblique</b>		<b>align</b>	<b>yes</b>	<b>26,7</b>	<b>26,7</b>
12	long	oblique		align	yes	13,3	53,3
13	short	direct		rotate	yes	60	60
14	long	direct		rotate	yes	20	66,7
15	short	oblique		rotate	yes	0	40
16	long	oblique		rotate	yes	13,3	66,7

the library decodes the Qr Code and created a Python script to transform the data in a real image for visual purposes. Based on this information, we created a method to identify the Qr Code orientation and included it on Zxing library's content.

## 4.2 Image Enhancement Experiments

In this step, we tried to improve the recognition and decoding of two-dimensional barcodes using image enhancement. To that end, we used deconvolution techniques to test if they are able to improve the code decoding. In addition, we increased the codes number and established detection concept to a more realistic condition. This Matlab step was exploratory since we wanted to verify if this approach could produce better results. Depending on these experiments result, we would start thinking of how embed the solution. We decided to execute efficiency tests, following the activities below:

1. Compute how many Qr Codes candidates are detected before and after changes on Zxing library;
2. Compute how many Qr Codes candidates are decoded before and after using image

enhancement.

First, we executed the experiment described above on item 1. We organized a room distributing codes all over it. We distributed 20 Qr Codes in a classroom and took 3 pictures. We also distributed 25 Qr Codes and took three pictures. The experiment development environment used the Zxing library on Android platform. We developed a Java code to get the Qr Code finder pattern coordinates. Finally, we considered the code detections as follows:

- True positive: correct detections;
- False positive: false detection;
- False negative: lost detections;

We computed all three pictures together for each number of codes (20 and 25 Qr Codes). Table 3 demonstrates the results obtained with 20 codes. And Table 4 demonstrates the results obtained with 25 codes. We observed an increase of false positive after the modifications but a decrease of false negative.

Table 3 – Summary of experiment results with 20 QR Codes

Average Detections	Original	Modified
True Positive	83,3 %	85%
False Positive	0%	1,7%
False Negative	16,7%	15%

Table 4 – Summary of experiment results with 25 QR Codes

Average Detections	Original	Modified
True Positive	72%	80%
False Positive	0%	28%
False Negative	28%	20%

In addition, we identified a problem during this detection process. The detection process mixed the code markers as shown on Figure 23. Figure 23 demonstrates the correct detection (true positive) in color blue and false detection (false positive) on color red. This false detection issue limited the experiment to get a better result but this situation was expected due to the modifications done on Zxing library as described on Subsection 4.1.

Second, as described on item 2, we wanted to know how many codes are decoded before and after using image processing techniques. Image processing techniques generally



Figure 23 – Illustration of correct detection (true positive) on Blue and false detection (false positive) on Red in a class with 20 Qr Codes.

use a photographed picture. This picture is a distorted version of image and this distortion can be modeled as a convolution between the reference image and the point spread function (PSF), which models the process whereby the picture is obtained: the lenses, sensors, etc.

In order to evaluate the deconvolution, we compared the reference (original, ideal) barcode, the actual barcode (as photographed), and enhanced versions of the barcode using the following strategies, which will be described in the sequel:

- Simple image filtering;
- Deconvolution;
- Blind deconvolution.

For that effect, we needed to have a way to relate the actual and the reference barcodes.

For the registration procedure, we employed local-descriptor/points-of-interest matching, followed by the rectification of the actual barcode to the coordinates of the reference

barcode. OpenSurf<sup>1</sup> was employed as the local-descriptor extractor and the result is illustrated on Figure 24. We used the OpenSurf function available on Matlab as referred on footnote.

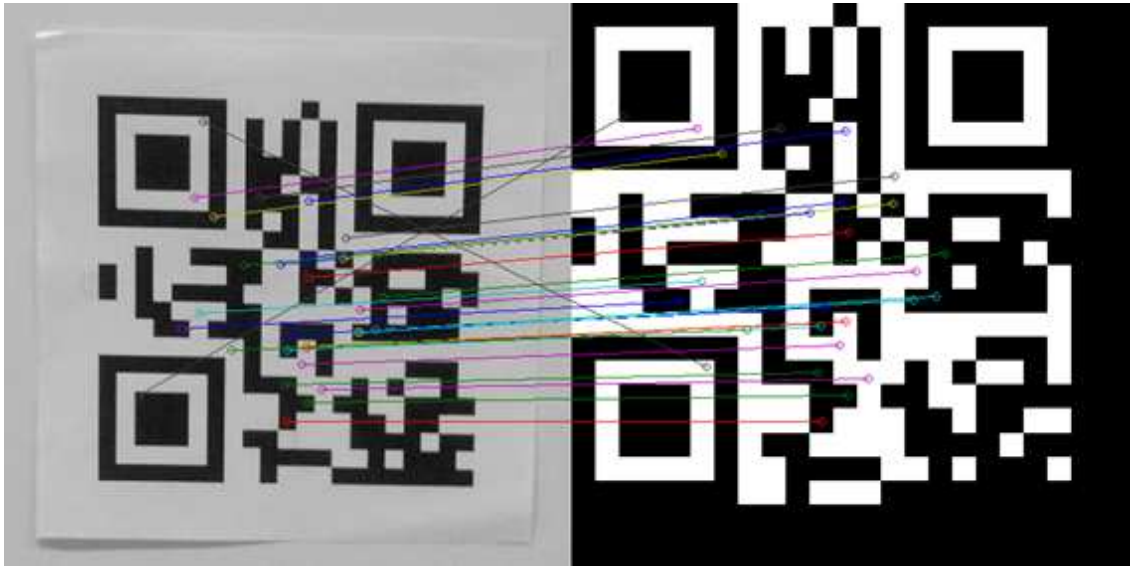


Figure 24 – Illustration of points-of-interest matching of the actual barcode to the coordinates of the reference barcode obtained by OpenSurf function available on matlab.

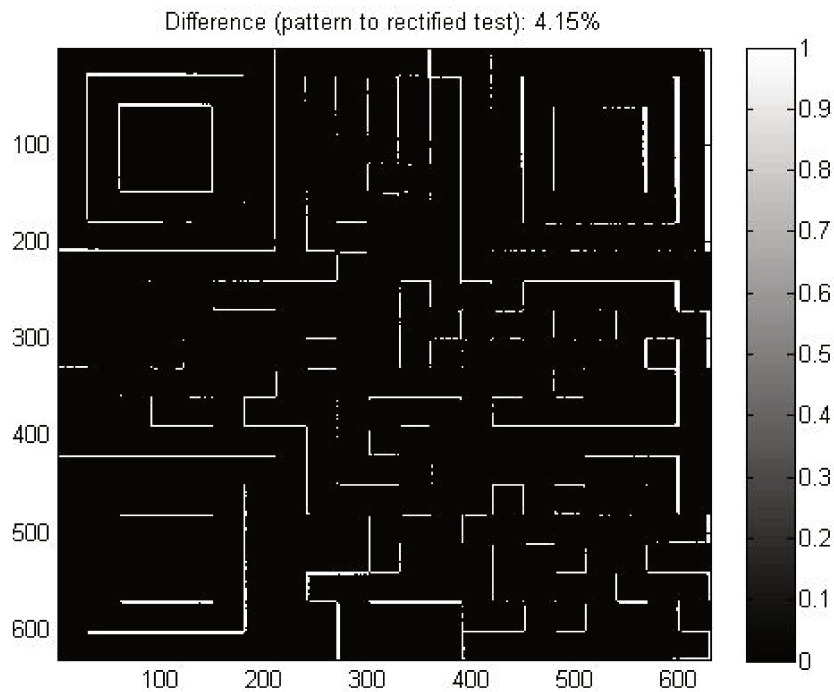
Simple image filtering consists in applying a non-linear filter to reduce the “salt and pepper” noise and conserve the edges. Figure 25 illustrates the result of the image filtering technique. On Figure 25a (A), we have the original image (photo). On Figure 25a (B), it shows the reference image and on Figure 25a (C), it illustrates the image crop. The image crop is based on the matching points mentioned before. The image crop procedure was necessary to guarantee that the image enhancement technique would be applied only on the code, not the entire image. Figure 25b demonstrates the image filtering result. We had 4,15% difference from original image to the filtered image.

For the (non-blind) deconvolution, we used the reference barcode to project the deconvolution filter. The Otsu’s method was used as a global image threshold [Otsu, 1979]. And to deconvolve the image, we used the Wiener filter algorithm [Gonzalez and Others, 1992] to calculate the point spread function (PSF). This PSF was then used to design a deconvolution filter. Figure 26 illustrates the deconvolution test described. Figure 26a shows the deconvolution technique applied in a photo. It is important to mention that this is just a benchmark; after all, in a real application we will have to project the filter without the

<sup>1</sup> OpenSurf source: <http://www.mathworks.com/matlabcentral/fileexchange/28300-opensurf-including-image-warp/content/OpenSurf.m>



(a) (A) Original Image (photographed image); (B) Reference Image (ideal image); (C) Crop Image

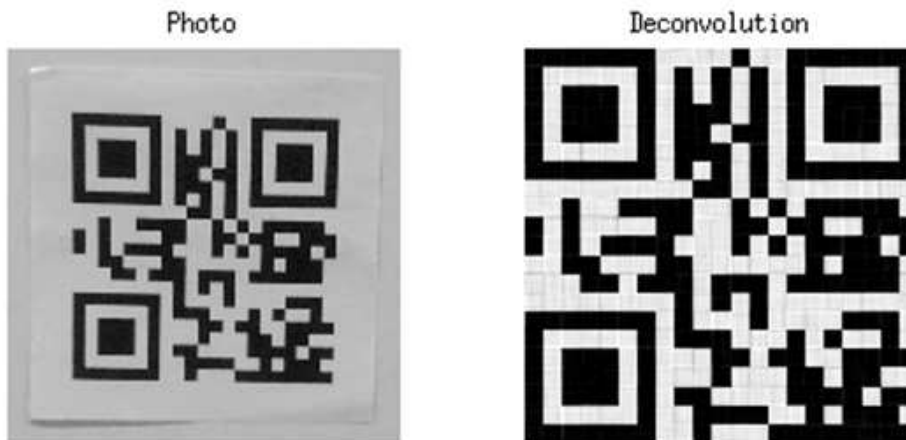


(b) Image filtering technique result

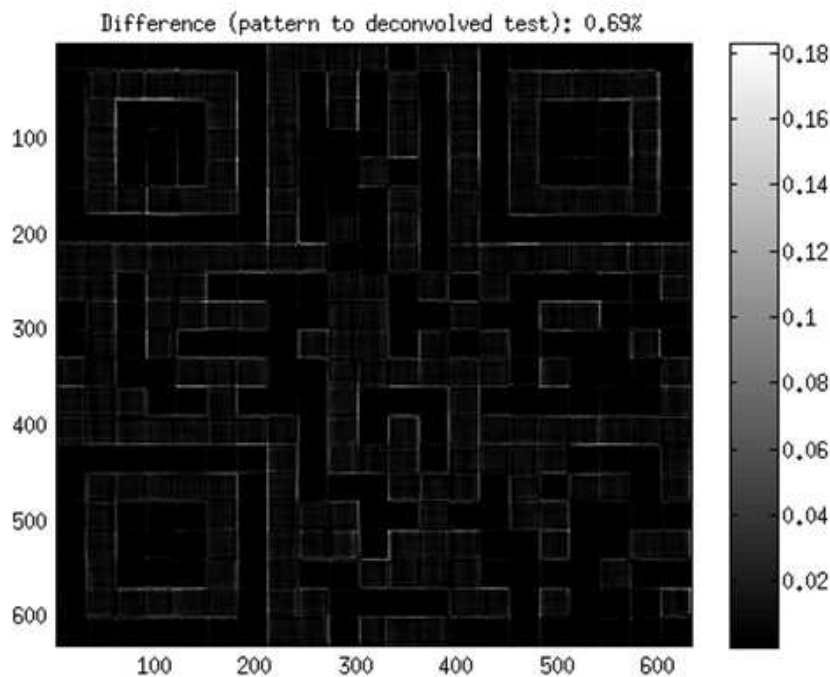
Figure 25 – Illustration of Image Filtering experiment which we used a non-linear filter to reduce the noise and conserve the edges.

reference image. Figure 26b demonstrates the deconvolution design. We had 0,69% difference from original image to the deconvolved image.

The blind deconvolution algorithm should be used when no information about the distortion (blurring and noise) is known, in other words, there is no reference image to



(a) Deconvolution technique



(b) Deconvolution technique result

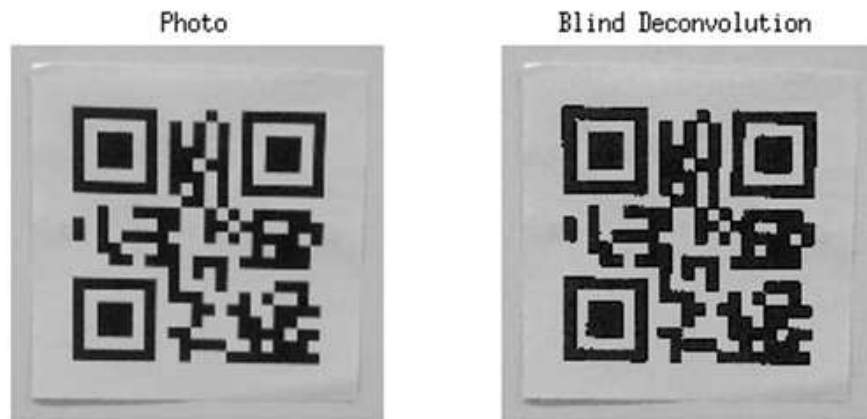
Figure 26 – Illustration of Deconvolution experiment which we used the reference image to project the deconvolution filter.

compare with [Gonzalez and Others, 1992]. We used the `deconvblind`<sup>2</sup> function available on Matlab and followed their example. This function restores the image and the PSF at the same time, using an iterative process. We decided to apply this blind deconvolution function as comparative experiment even knowing that the deconvolution result would be better. Figure

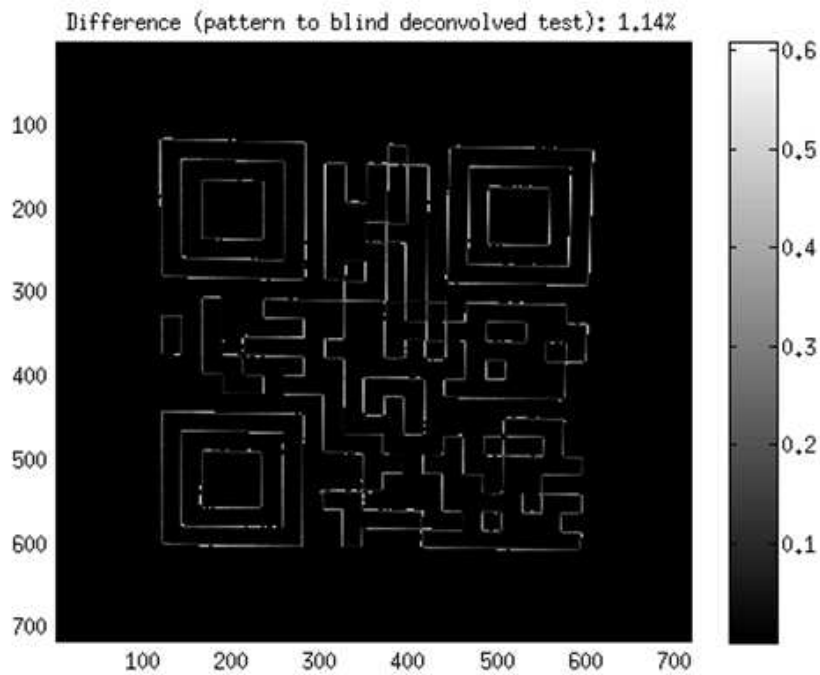
<sup>2</sup> Deconvblind source: <http://www.mathworks.com/help/images/deblurring-with-the-blind-deconvolution-algorithm.html>



27 represents the experiment done. Figure 27a illustrates the blind deconvolution applied on an image (photo). And on Figure 27b, we have the result of the image enhancement. We obtained 1,14% of difference between the original and modified image.



(a) Blind Deconvolution technique



(b) Blind Deconvolution technique result

Figure 27 – Illustration of Blind Deconvolution experiment with no reference image to compare.

Finally, we intend to verify the efficiency of simple filtering, deconvolution and blind deconvolution techniques to improve the recognition and decoding of a larger number of Qr

Code, similar to the experiment executed on item 1. We aim to get a comparative analysis of using these techniques. This continuity experiments will be executed on future works.

### 4.3 User Experiments

In this section, we present the user experiments. We executed experiments to validate the design interaction and to evaluate the interface for both projects. These experiments have the objectives to verify the following hypothesis:

- **Evaluation of the readability of data visualization: detailed answers.** *Hypothesis:* results of individual screens, with or without augmented reality are legible and readily explainable to the user.
- **Evaluation of the readability of data visualization: answers summarized.** *Hypothesis:* Summarized results screens (graphics and others) are legible and readily explainable to the user.

We defined the test would consider the following features:

1. Interface usability:
  - User/ System interaction quality;
  - Pleasant and efficient use, easy to learn how to use the system.
2. Application functionality:
  - Matching quality to the user's problem;
  - Design allows user to perform easily and efficiently the required tasks .

And these user's experiments would **not** considered:

1. Device hardware:
  - Battery charging or native features;
  - Quick response system.
2. Marketing: comparison between similar products.

These experiments used Empirical Evaluation as detailed on Section 2.5. Empirical evaluation requires a prototype enabling a scenario [Prates and Barbosa, 2003]. Then, we provided the application prototype and a script with the scenario. In addition, we defined that the participant should be older than 18 but we would not consider the user characteristics such as gender or education level as parameter during this experiment. User characteristics (e.g. education level, research area) will be consider during larger experiment on future work.

The experiment was conducted in a controlled environment, based on the volunteer will. The experiment local was on a room located at UNICAMP. And the artifact nature was the application prototype. The evaluation techniques involved:

- Recording and analyzing user interaction;
- Observation and monitoring of user interactions;
- Interviewing and Questioning user's opinion.

We decided to put a camera in front of the user to capture the participant interaction with the application. Also, we recorded the participant actions on the mobile device for paperclickers experiment. We used an application called Recordable<sup>3</sup>. This application captures the user gestures, voice and actions (e.g. clicks, selection, movements). For questioning phase, we created a Google form with questions related to the application interface. And the participant had also answered questions as an informal interview where he pointed out his opinion about the experiment and the application presented.

As mentioned, we defined a script to the applier and to the subject. This script should be followed during the experiment. The applier script contained instructions (e.g lines, environment configuration, general recommendation). And this script helped us to predict possibles adverse situations that could happen during the experiment. Also, we defined the participant script. So, the participant should follow the instructions during the experiment. We clarified to each participant if he feels uncomfortable or intimidated by the experiment video record, he can leave without any previous notification or prejudice. We used the same applier script for both prototypes experiments and this script is presented on Appendix B.1. For subject script, we defined according to the prototype. Virtualclicker subject script was divided in two: instructor and learner. The subject played both roles, switching scripts when finished the tasks. The instructor and learner script is presented on Appendix B.2. Paperclickers subject script is presented on Appendix B.7.

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<sup>3</sup> Recordable source: <http://recordable.mobi/>

Finally, we created a research project and a consent form to submit to the Ethical Committee. These documents were required to be analyzed by the committee containing information such as the summary of the project, benefits and risks, confidentiality compromise. We received the approval of the UNICAMP Ethical Committee to execute the users tests. This file is attached on this dissertation.

User experiments had contribution of the undergraduate student Wilson Prata, as part of his final project. Wilson helped to create the test plan, to write the script, to create the questioning form and to call up the volunteers.

### 4.3.1 Virtualclicker User Experiments

Virtualclicker design interaction requires at least two people (one instructor / one learner) using the system at the same time as explained on Subsection 3.1. The experiment procedure was defined to include one person as instructor and another as learner. Besides, each experiment had the presence of other group member to provide support and additional information when necessary.

The virtualclicker environment settings used:

- Video camera;
- Computers: one for instructor and other for the learner interface;
- Proper environmental conditions: light and air-conditioner, table and chair;
- Supervisor: this person provided the consent form, experiment information and help to the volunteer if necessary. In the end, he was responsible to give the user a question form and proceed with the interview.

Figure 28 illustrates the proposal experiment configuration. Figure 28a demonstrates the top perspective from the class. Figure 28b gives a back perspective view. These images help to visualize how we first defined the class organization, but during the experiment we have to do some modifications. The group were responsible to make sure that all environmental needs were prepared on time, avoiding delays or inconveniences. In addition, the group made all the efforts to not involve predictable risks, as the participant would be only filmed with a common digital camera, without special lighting. This experiment was a simple procedure with no risk or harm to the participant physical integrity.

We used two rooms to execute the experiment. One room was designed to use the application and another to interview and to fill the question form. First room, we created



(a) Class top perspective



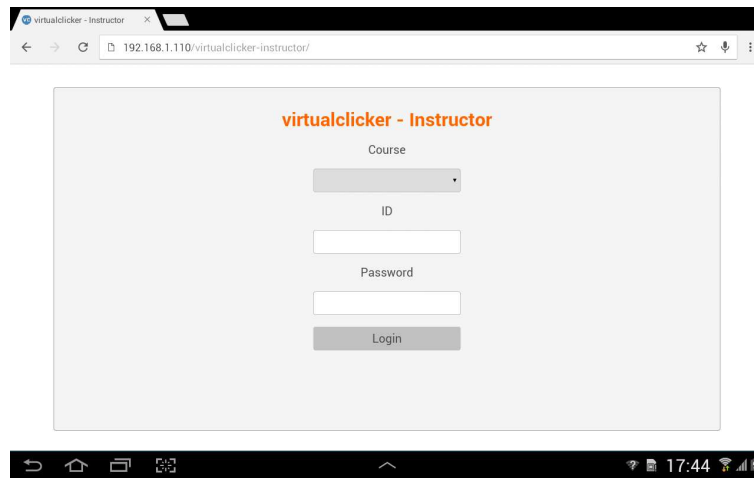
(b) Class back perspective

Figure 28 – Illustration of Virtualclicker proposal experiment. These images illustrate how we decided to organize the class during the experiment.

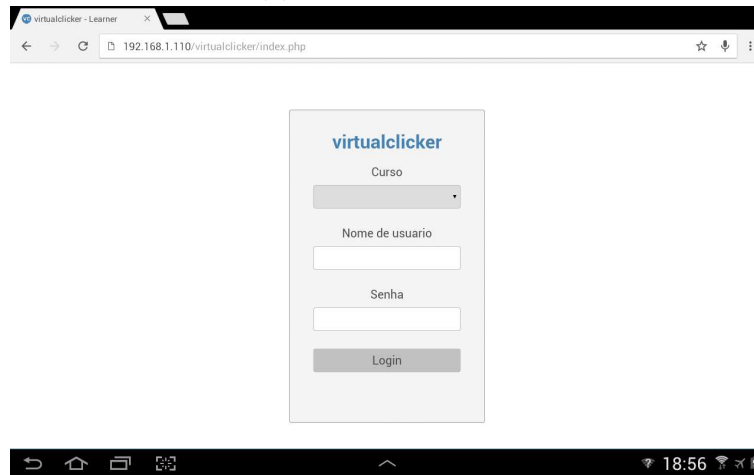
a local network with a Raspberry Pi as preliminary configuration, the local address was previous defined and we included this information on the subject script. Then, we put one tablet device on a table together with the subject script. In front of the table, we put a chair with a mobile device together with the subject script. As mentioned, we needed at least two participants to execute the experiment. Figure 29 illustrates the interfaces used during the experiment with the local network. Figure 29a illustrates the instructor interface for the experiment and Figure 29b illustrates the learner interface for the experiment.

Due the lack of volunteers, we requested to the supervisor to play a role during the experiment. This supervisor was a member of the development group. We put the camera in the class front to capture the subject reactions. In addition, we certified the conditions were appropriated (e.g. lights, climate) and all participants received the same instructions, following the script. During this experiment, we counted with a presence of a supervisor to provide any extra help that the subject may need.

Second room, we put two computers with the questioning form to optimize the experiment. When the participant finished the experiment on first room, a supervisor indicated to the subject to move to the other room. Then, the supervisor asked if the subject wanted to



(a) Instructor screen



(b) Learner screen

Figure 29 – Illustration of Virtualclicker experimental screen. These images illustrate how the participant visualize the interface.

participate in an informal interview. This interview was voice recorded and we asked questions related to the participant experience such as “What did you think about the experiment?” and “Did you find any difficulty during the experiment?”. During the interview, we tried to keep it informal and short, our intention was to give the participant the opportunity to point out any extra comment, opinion or, suggestion related to the prototype. Right after the interview, the supervisor asked if the subject wanted to answer the form. This questioning phase was not recorded (video or voice) but the data was saved for further analysis. We elaborated two forms: one form to the teacher interface and another to the learner interface. The form contained questions related to the interface visual elements (e.g. icons, buttons). We also left a blank space where the participant could include suggestions, ideas or, review.

On questioning form, we created two different forms (one instructor / one learner). We

put images according to the each interface and asked questions about specific visual element from each, such as “What do you think about absence and presence icon?” on instructor interface. And the participant had a scale option from 1 to 5 where 1 corresponds to Very Bad and 5 corresponds to Very Good. In addition, we included on the form questions referring to the interaction such as “Evaluate the question conclusion (Intuitiveness, Interaction easiness, etc)”. The answer options were a scale from 1 to 5 where 1 corresponds to Very Bad and 5 corresponds to Very Good. The complete questioning form is presented on Appendix B. Appendix B.3 presents questions about instructor interface and Appendix B.4 presents questions about learner interface.

As experiment result, we analysed all the data: video captured, interview and questioning form together according to each participant. We had **5 participants** on virtualclicker experiment, 3 of 5 participants were undergraduate students. This experiment was considered as trial because we need more volunteers to collect a reliable data. The summary of the questioning form result is presented on Appendix B, with all the numbers, percentages and graphs to each question. Appendix B.5 presents the results for the instructor questioning <sup>4</sup> and Appendix B.4 presents the result for the learner questioning. However, analysing the data obtained we had significant results according to each interface. On instructor interface, we summary:

- **First screen: Attendance** All participants liked the idea of starting the application with the Attendance screen. And 4 of the participants said the attendance module was easy to understand and intuitive. In addition, all participants liked the absence and presence icon.
- **Second screen: Question** 3 of the participants had difficulties inserting questions on this screen. One participant mentioned: “The question screen is not intuitive. I can not say what to put on the blank space.” We will verify how to improve this visual element.
- **Third screen: Result** 3 of the participants said the result screen was easy to understand and all of the participants said the answer icons were Very Good. But, one participant mentioned that was not clear how to finish the class. So, we will try to improve this task clarity.
- **Fourth screen: Graph** All participants said the easiness to understand the graph was Very good. In addition, one participant suggested to emphasize the correct answer and to increase the icons size for better view.

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<sup>4</sup> Instructor result note: the file presents 6 answers because we did a test to the form to check if it was saving the results. This extra answer was disregarded on the data analysis

On learner interface, we analysed the following aspects:

- **First screen: Status** One participant suggested to include an How to on the application. And this suggestion corresponds to others answers since 2 of the participants answered it was necessary to include an introduction screen and 2 of the participants answered it was reasonable.
- **Second screen: Question** 4 of the participants evaluated the question screen as Very good.
- **Third screen: Confirmation** All participants evaluated the confirmation screen easiness and intuitiveness as Very good. They also did not have any doubt on how to confirm an answer. But only 4 of the participants said the question termination as Very good. We asked if the participants thought it was necessary to include a log out option and all of the participants said Yes. Based on the result, the group will consider the suggestion and apply the modification in the future.

In conclusion, the participants liked the application flow and interaction, saying virtualclicker is a very good application. One mentioned: “This application is very useful and easy to use.” confirming the positive feedback. But we considered some negatives reports. One participant reported a network problem during the experiment which was expected. Also, the participants suggested to increase the icons size. As mentioned, this user evaluation was a trial experiment. However, the group was very satisfied with the participants comments and suggestions. We will considered this information to improve the application and to avoid mistakes during a larger experiment.

### 4.3.2 Paperclickers User Experiments

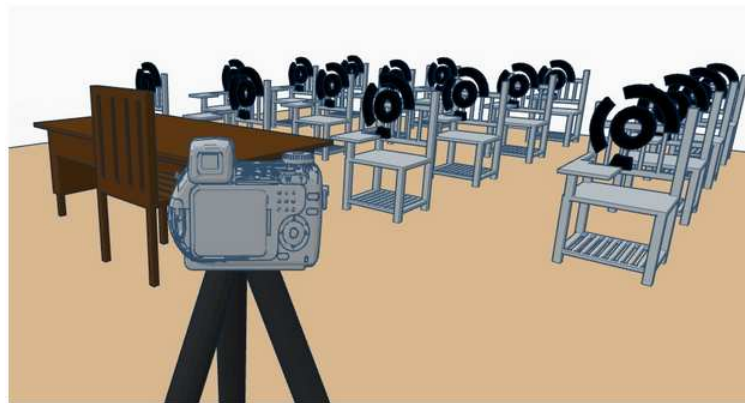
Paperclickers design interaction requires at least one person to use the application on a mobile phone as explained on Subsection 3.2. The experiment procedure was defined to count with one participant using the application. And we distributed along the class the codes simulating the students performance in class. Similar to virtualclicker experiment procedure, we also counted with a presence of a group member during the experiment to provide support and information when necessary. The paperclickers environment settings used, as follows:

- Video camera;
- Recordable application: application installed on the phone to record participant action and voice while using the prototype;



- Smartphone with the prototype installed;
- Proper environmental conditions: light and air-conditioner, table and chair;
- Supervisor: this person provided the consent form, experiment information and help to the volunteer if necessary. In the end, he was responsible to give the user a question form and proceed with the interview.

Figure 30 illustrates paperclickers experiment proposal configuration, presenting different perspective from the class. Figure 30a demonstrates the front perspective view and the Figure 30b gives a top perspective view. These images help to visualize how we decided to organize the local experiment for the paperclickers user's test, however during the experiment we did some change.



(a) Class front perspective



(b) Class top perspective

Figure 30 – Illustration of Paperclickers proposal experiment. These images illustrate how we decided to organize the class during the experiment.

We used two rooms to execute the experiment. One class was designed to use the application and other to collect the participation opinion. First room, we distributed 9 codes all over the class. The topcode sign was attached on the chair to simulate the students holding the cardboard. The sign had a half page size. On the table, we put the subject script as presented on Appendix B.7. And we put the camera in the class front to capture the subject reactions. Figure 31 illustrates how the room was organized for the experiment. We certified the conditions were appropriated (e.g. lights, climate) and all participants received the same instructions, following the script. During this experiment, we counted with a presence of a supervisor to provide any extra help that the subject may need.

Second room, we put two computers with the questioning form to optimize the experiment. When the participant finished to use the application, a supervisor indicated to the subject to move to the other room and the supervisor asked if the subject wanted to participate in an informal interview. This interview was voice recorded and we asked questions related to the participant experience such as “What did you think about the application?” and “Did you find any difficulty during the experiment?”. During the interview, we tried to keep it informal and simple, leaving the participant free to expose his opinion. Right after the interview, the supervisor asked if the subject wanted to answer the form. This questioning phase was not recorded (video or voice) but the data was saved for further analysis. The form contained questions related to the interface visual elements (e.g. icons, buttons). We also left a blank space where the participant could include suggestions, ideas or, review. Figure 32 illustrates the organization of the second room, showing how we organized the first computer on Figure 32a and the second computer on Figure 32b.

On questioning form, we put interface images and asked questions about specific visual element on the interface, such as “What do you think about that icon?”. And the participant had answer options like: Ugly, Beautiful, Suggestive, Confusing, Unintelligible, Hidden, Too small, Too big, Inconvenient position, Easy to understand, Easy to click, Easy to use and Other. In addition, we included on the form questions referring to the interaction such as “What did you think of the way to finish the film in the presence capture screen / answers (Check all)”. The answer options were: The instructions are not clear on how to end shooting, The screen does not respond well to click, The screen is too sensitive to click, It’s easy to finish by accident, I had to make several attempts to end, It is easy to understand what must be done, It is easy to perform the operation. Our purpose was to know if the participant had interaction difficult using the prototype modules. The complete questioning form is presented on Appendix B.8, showing all questions and answers option.

As experiment result, we analysed all the data: video captured, interview and questioning form together according to each participant. We had **11 participants** on paperclickers



(a) Class right perspective



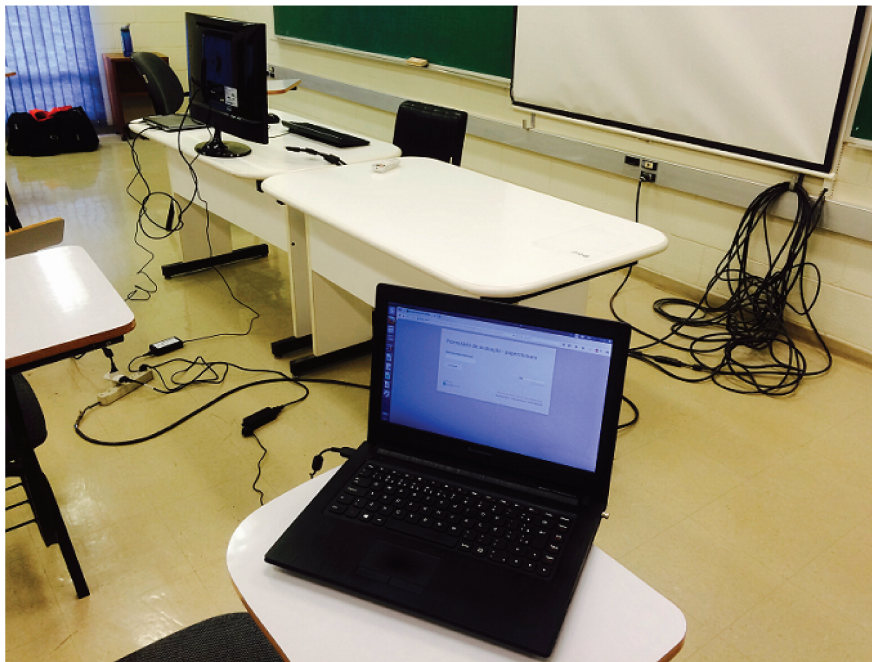
(b) Class left perspective

Figure 31 – Illustration of Paperclickers real experiment with the signs attached on chairs and the camera position to get subject's reaction.

experiment, 3 of the 11 participants had teaching experience. 2 of the 11 participants work with mobile development. 8 of the 11 participants were undergraduate students. The summary of the questioning form result is presented on Appendix B.9, with all the numbers, percentages and graphs to each question. Finally, analysing the data we concluded:



(a) First computer



(b) Second computer

Figure 32 – Illustration of Paperclickers real experiment with the computers prepared containing the questioning form.

- **First screen: Class selection** We suggested an introductory screen but the answer was not definitive since the participants liked the idea but it was not considered as an important modification. However, the application orientation always in landscape caused a significant impact with 5 of the participants were annoyed about the landscape

screen. In addition, the participants were favored with the multiple class option with 8 of the answers saying they liked the idea and found the option practical.

- **Second screen: Preliminaries definition** 5 of the participants found the attendance icon as Suggestive but 3 participants found the icon Confuse. 5 of the participants said the icon was Easy to click but 3 of the participants said the icon position was inconvenient. Based on the participants suggestions, we concluded that this icon passes the message but this message should be more clear. One participant suggested to put a description below the icon, then the description would clarify any user doubt. In addition, during the video analyses, we realized that the participants got confused because the attendance icon is too close of the collect answer text which we will consider a new layout for the screen on next application release.
- **Third screen: Attendance capture** 7 of the participants liked the capture screen instructions and 5 participants said the instructions were clear. In addition, 8 of the participants understood the capture feedback (green circles around the code). However, 6 participants said the capture feedback was slow. The feedback speed depends on the device and we defined not to analyse this aspect in this experiment, but due the participants comments, we will verify an alternative to improve this response.
- **Fourth screen: Attendance result** 9 of the participants said that was easy to understand presence / absence message and 5 understood the item click option easily. But, the Attendance conclusion icon caused confusion on 5 of the participants. And one participant commented: “ I do not understand this icon meaning”. Although, 4 subjects said this icon was Easy to understand, we decided to change this visual element.
- **Fifth screen: Answers screen** 10 of the participants liked the answers colors an options. And 6 subjects understood easily that was possible to change the answer by clicking on it. 10 of the participants found the Graph icon as Suggestive, 9 subjects said the icon was Easy to understand and 7 participants said the icon was Easy to use. However, some participants got confused with the Back icon. 4 of the participants did not understand that the Back icon was to come back to capture screen.
- **Sixth screen: Graph screen** 6 of the participants said the Graph was Very good. We asked about “Try Again” button and 6 of the participants voted on Keep question and come back to capture screen concluding that the message passed by this button text is correct. And we asked about “ New question” button and 8 of the participants chose End the question and come back to selection question number screen option concluding the message on the text button is correct. In addition, the Home icon was not clear

enough since the answers were balanced with 3 participants voting on Ending question and come back to select class screen, 4 participants voting on Ending question and come back to select question screen and 3 voted Keeping question and come back to Answer screen. We concluded the application needs review on back options.

Finally, the participants gave suggestions on application color. The participants contributed with the interface style saying the application could be more attractive with a different color. One participant affirmed: “I did not like the colors” and other commented: “The color passed a boring impression”. These suggestions will be considered on the next application release. However, in general, the participants liked the design interaction proposed, saying the application is useful. One participant mentioned in the interview: “I think this design would work on class”. And other participant found the idea very interesting. This experiment was successful and the comments were important and productive, helping our developing group to better understand the user view and improve our prototype interface.

## 4.4 Conclusion

This chapter presented the experiments executed in this dissertation and the results obtained. First, we did detection experiments, trying an open source library called Zxing. Zxing library can recognize two-dimensional codes. Our intention was to do a proof of concept, figuring out if the library would work in our image-processing proposal. In addition, we set adverse conditions which may happen in a classroom environment. As result, the Zxing library did not work properly as expected. Consequently, we decided to modify the library code. We loose the code markers detection conditions and we also loose the proportion condition to switch false positives by false negatives to improve the results. Consequently, the results improved and the detections number increased.

Second, we did exploratory experiments focusing on image-enhancement techniques because we wanted to improve recognition and decoding of two-dimensional barcode. So, we explored detection aspects trying deconvolution, blind deconvolution, simple image filtering techniques to verify if they were able to improve decoding rate. In addition, we increased the codes number and established detection concept to a more realistic condition. Therefore, we computed how many Qr Codes candidates are detected before and after changes on Zxing library and presented the numbers with a significant increase However, we just initiate the second part of the experiment that aiming to compute how many Qr Codes candidates are decoded before and after using image enhancement. The first results were presented, extending this work for the future.

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Lastly, we executed user experiments with virtualclicker and paperclickers prototype. The experiment objectives were to validate the readability of the data, verifying if the information (e.g. individual result screens and summarized results screens) were legible and readily explainable to the user. We decided to execute an empirical evaluation, using an application prototype and asking the subjects their opinion about the prototype. We defined the experiment script and prepared a controlled environment to execute the procedure. All participants were volunteers and agreed to be recorded. Accordingly, we presented the question form and result with percentage summary. The collected data was analysed by research group.





## 5 Conclusion

In this chapter, we provide a summary of the major contributions of this dissertation. In addition, we discuss some interesting points that we could not focus on this dissertation due to our limited time and scope, consequently we left directions as future work.

### 5.1 Contributions

The main objective of this work was to better understand the challenges in creating low-cost alternatives to CRS, including technological and user-interaction ones which we can affirm: we accomplished our goal. This dissertation presented two low-cost alternatives of CRS as prototype result. One called Virtualclicker and other, Paperclickers. Both prototypes were idealized based on literature review, designed conforming related work, implemented by researchers involved and experimental evaluated during this project time. Further improvements will be necessary, as will be addressed on future work, however the project proposed aims were successfully achieved. Accordingly, we emphasize our work contribution:

- **Study of pedagogical and human-computer interaction context** After a detailed literature review on classroom response systems, we realized the benefits of active learning. Also, we collected information about the solutions available to help on our project proposition to provide CRS alternatives solutions. In addition, we did a fundamental study of human-computer interaction as guidance to this work development.
- **Definition and implementation of two low-cost proposal of CRS** After analysing the studies reports, we defined our proposals aiming the broaden adoption of CRS. The development process was divided into analysis, project and implementation. Resulting in the proposed prototypes: Virtualclicker and Paperclickers. Virtualclicker is based on BYOD solution where each student brings to class his own device. On virtualclicker proposition, we used our own network created trough a raspberry pi. This network is protected and configured by the teacher, providing a local connection independent from school network. Paperclickers is based on image-processing solution where each student would hold up a cardboard with his unique code to give his answer and the teacher would install an application in his device and use it to capture the class response. On paperclickers proposition, we implemented an application with attendance module, collect answer module and answer summary module.

- **Experimental evaluation of bi-dimensional detection using Zxing library to detect Qr Code** We tested the available version of Zxing library. We started with a library trial differing conditions to verify the library robustness. Based on the results, we made modifications to increase the codes detections. The modifications took effect comparing with original code, we improved the detection numbers. We also included an orientation module to adapt the library according to paperclickers proposal.
- **Preliminaries experiments with image-enhancement** These experiments focused to verify the improvements we may reach using image-processing techniques to increase the recognition rates. We decided to perform tests using simple filtering, deconvolution and blind deconvolution techniques on a matlab script. First, we wanted to compute how many Qr Codes candidates are detected before and after changes on Zxing library. As result, we obtained a higher number of true positive but, as consequence of the modifications, the number of false positive increased. As second step, we wanted to compute how many Qr Codes candidates are decoded before and after using image enhancement. However, we proceeded with this second step with one Qr Code with satisfactory results. In the future, an experiment similar to the first step will occur.
- **Experiments with Top Code** Due the difficulties found with Qr Code detections and decoding, we looked for an alternative code to use on paperclickers application. We found a code called Top Code. Top Code sign can be recognized in real time which facilitated to collect the students answer on capture result module. We decided to develop a paperclickers application version adapting the original idea to this new code. We decided to change the application flow. We changed the capture module of taking 3 pictures to use video frames to detect the sign. This modification improved the time response and increased the code recognition rate. Despite the fact Top Code had a limited number of different codes, Top Code had a extremely robust algorithm that identifies codes really fast which contributed to our application purpose.
- **Empirical evaluation of Virtualclicker proposed interface and design interaction** We called volunteers to try our prototype following a script. We defined script for each interface (instructor and learner). We recorded the experiment, made an informal interview and asked to respond a question form. We got 5 participants for our trial experiment. The participants signed a consent form to allow the experiment recording. We considered each subject report on video voice and form data. In general, the application was well-evaluated, receiving positive feedback. The participants gave interesting suggestions and proposed some modification that will be considered for the next application release.

- **Empirical evaluation of Paperclickers proposed interface and design interaction** We got 11 subjects to contribute with the experiment. These subjects signed a consenting term and allowed the group to film the procedure. We also did an interview and requested the participants to answer a question form. The data was analysed according to each participant comment and reaction using the application. In general, the application was well-evaluated by the subjects, receiving positive feedback of its use and applicability. Further, the participants gave suggestions about the application color and icons which will be considered on the next release.

## 5.2 Future Works

Furthermore the contributions presented in this dissertation, we suggest additional investigations as continuity work.

- Image-enhancement experiments to compute how many Qr Codes are decoded before and after using techniques like deconvolution, blind-deconvolution and simple image filtering. These experiments may result in an embedded code to improve recognitions rates;
- Two-dimensional barcodes proposal based on available solutions, creating a code patent;
- A new version of virtualclicker and paperclickers prototype considering the participants suggestions and questioning results obtained on the experiments;
- New round of users experiments considering the interface modifications, counting with a larger number of participants with different profile (e.g. professors, educators, researchers);
- Virtualclicker and paperclickers design interaction experiment in a real classroom, with students and teacher using the prototype during a lecture;
- Paperclickers code distribution to the community. In addition, paperclickers publishes on Play store to wide the prototype adoption on schools;
- Including new answering modules: text answering, numbers answering and true/false answering expanding the polling options;
- Including different data visualization according to type of the answer: if the answer is text, the graph shows the most used terms. In addition, we could include bars graphs, sections graphs, etc.

- Virtualclicker and paperclickers offline module: develop an offline module which teacher can insert the data (e.g. student ID, class info) and access the database to analyse the class attendance and response;
- Paperclickers cardboard study and design: proceed with a study related to the cardboard material, size, font and others features to use in class.
- Paperclickers iOS version to reach Apple users.

### 5.3 Highlights

This project had important achievements such as:

1. Santander's international scholarship from August 2014 to December 2014 at The Pennsylvania State University, PA – EUA;
2. Undergraduate student Lucas Tejada contributed on the project implementation process as part of his final project;
3. Undergraduate researcher Vinicius Ribeiro was partially allocated in this project and contributed with Virtualclicker solution. Vinicius had a PIBIT scholarship;
4. Undergraduate student Wilson Prata contributed with the user validation experiments as part of his final project;
5. Project promoted video.

### 5.4 Publications

As a result of this work, it was submitted a paper entitled “Affordable Solutions for Classroom Response Systems” (Binda et al.,2015) to the XXVI Simpósio Brasileiro de Informática na Educação (SBIE). The paper proposes two design interaction solutions based on the CRS available options and present the results obtained so far.

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# Appendix



# APPENDIX A – AppendixA

## A.1 Detection Experiments



(a) Short, direct, align, not occluded



(b) long, direct, align, not occluded



(c) short, oblique, align, not occluded



(d) long, oblique, align, not occluded



(e) short, direct, rotate, not occluded



(f) long, direct, rotate, not occluded

Figure 33 – Detection experiment images part A. Conditions: distance, camera baseline, code orientation and occlusion.



(a) short, oblique, rotate, not occluded



(b) long, oblique, rotate, not occluded



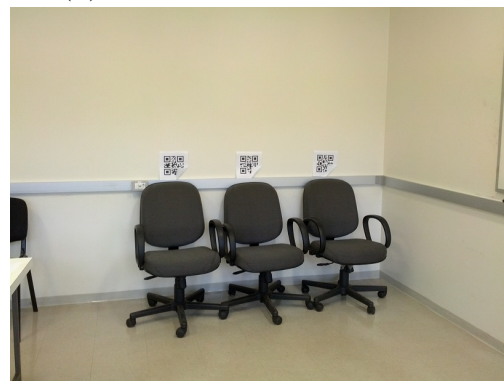
(c) short, direct, align, occluded



(d) long, direct, align, occluded



(e) short, oblique, align, occluded



(f) long, oblique, align, occluded



(g) short, direct, rotate, occluded



(h) long, direct, rotate, occluded

Figure 34 – Detection experiment images part B. Conditions: distance, camera baseline, code orientation and occlusion.





(a) short, oblique, rotate, occluded

(b) long, oblique, rotate, occluded

Figure 35 – Detection experiment images part C. Conditions: distance, camera baseline, code orientation and occlusion.



# APPENDIX B – AppendixB

## B.1 Applier Script

## Roteiro de Testes com Usuários

### 1. Roteiro geral do aplicador

1. Configurações preliminares
  1. Distribuir na sala os códigos para os testes com o paperclicker
  2. Verificar se o sistema virtualclicker esta preparado
  3. Preparar a camera para filmagem
  4. Verificar se o questionário esta funcionando
2. Relação de materiais para cada participante
  1. um Termo de Consentimento
  2. um smartphone / computador
  3. um formulario de coleta de opiniao
3. Recepção do participante
  1. Cumprimentar o participante. O aplicador diz: Bom dia / Boa tarde / Boa noite
  2. Perguntar se o participante esta pronto para participar do experimento. O aplicador diz: "Você esta pronto?"
  3. Perguntar se o participante precisa de algo. O aplicador diz: ""Você gostaria de um copo de água? Precisa ir ao banheiro?"
4. Procedimento geral:
  1. Após a recepção do participante, fazer um resumo geral do projeto. O aplicador diz:

*“Imagine um programa de auditório em que o apresentador deseja obter uma resposta da plateia a respeito de uma enquete, por exemplo na Dança dos Famosos quando a platéia vai votar, no Domingo do Faustão, da Rede Globo. Muitas vezes são usados dispositivos chamados clickers para receber um grande número de respostas simultâneas. Paperclickers / Virtualclicker são projetos que visam a criação de sistemas de resposta a audiência de baixo custo e complexidade de implantação. O objetivo é levar às escolas rurais ou periféricas a possibilidade de trabalhar com técnicas pedagógicas ativas, sem a necessidade de adquirir um sistema de "clickers", cujo custo é proibitivo para essas instituições.”*
  2. Colocar o sujeito na atitude mental correta: *“Quem está sendo avaliado neste experimento é o aplicativo, não é você. Se houver alguma dificuldade em executar uma tarefa, não se preocupe, isso é sinal de que o aplicativo precisa ser melhorado, e nós queremos muito descobrir isso agora. Não fique preocupado ou constrangido com as dificuldades pois trata-se de um software que ainda está em desenvolvimento, então suas facilidades e dificuldades serão indicativas do que precisa mudar.”*
  3. Fazer um resumo geral do experimento. O aplicador diz: *“Queremos fazer testes de validação do design de interação e interface do projeto, simulando uma sala de aula, e para isso, precisamos de "professores" nessa sala. Tudo o que você precisará fazer é usar o aplicativo e seguir o roteiro que será dado para os testes.*

*Você irá representar o professor na nossa simulação. Os alunos serão representados pelos códigos visuais distribuídos nas carteiras a sua frente.*

*Você irá utilizar a aplicação para obter as respostas dos nossos alunos.”*

4. Assegurar o participante quanto à confidencialidade do experimento, ressaltando que os vídeos não serão divulgados. O aplicador diz: *“Esse teste será filmado para análise da pesquisa. Gravaremos tanto o que acontece na sala de aula, quanto a tela do celular, as ações e o áudio do usuário. Você tem a garantia de que sua identidade será mantida em sigilo e nenhuma informação será dada a outras pessoas que não façam parte da equipe de pesquisadores. Na divulgação dos resultados deste estudo, seu nome **não** será citado e o vídeo **não** será divulgado. Os vídeos serão destruídos em 24 meses a partir da data de hoje.”*
  5. Falar sobre o termo de consentimento. O aplicador diz: *“Por favor, leia este termo de consentimento cuidadosamente.” O participante faz isso silenciosamente.*
  6. Após aproximadamente 3 minutos, o aplicador faz a pergunta: *“Alguma dúvida com relação ao termo de consentimento?”* O aplicador esclarece as informações do termo ao participante.
  7. Finalizado essa etapa, o aplicador entrega nas mãos do participante o smartphone / mostra o computador com o sistema e o roteiro do experimento.
  8. Então, o aplicador se dirige ao canto da sala, deixando o participante à vontade para executar o experimento.
5. Finalizando o experimento
1. Ao final, confirmar com o participante se o roteiro do experimento foi seguido. O aplicador diz: *“Você terminou o experimento? Você completou o roteiro?”*
  2. Perguntar ao participante se ele aceitaria de fazer uma avaliação informal do experimento. O aplicador diz: *“Gostaríamos de saber sua opinião com relação ao paperclickers / virtualclicker. Vamos começar com uma entrevista informal? Você se importaria em conversarmos alguns minutos? A participação nessa entrevista é opcional. Você aceita?”*
  3. Se o participante aceitar a entrevista informal, o aplicador irá fazer as seguintes perguntas. Lembrar o participante que a entrevista será gravada para análise da pesquisa (reforçar confidencialidade):
    1. O que você achou da ideia proposta?
    2. Você acha que essa proposta funcionaria numa sala de aula?
    3. O que você faria para melhorar a ideia proposta?
  4. Perguntar ao participante se ele aceitaria fazer uma avaliação mais formal do experimento. O aplicador diz: *“Seria importante agora para nós que você respondesse esse questionário com perguntas um pouco mais específicas. Isso também é opcional. Essa etapa não será gravada. Você tem a garantia de que sua identidade será mantida em sigilo e nenhuma informação será dada a outras pessoas que não façam parte da equipe de pesquisadores. Você aceitaria?”*

5. Se o participante aceitar responder o questionário, o aplicador diz: “Por favor, responda esse questionário. Você pode escrever sua sugestão, crítica ou opinião de cada tela ao final do formulário. E também você tem a opção de responder o questionário de forma anônima. Não hesite em ser sincero e fazer críticas, pois nesta etapa estamos em busca disso.” O aplicador, então, se afasta do participante, para que ele possa responder o questionário de forma privada.
6. Terminada essa etapa, o aplicador se despede com um agradecimento. O aplicador diz: “Obrigado por contribuir com nosso trabalho. Sua ajuda foi muito importante.”

## B.2 Virtualclicker Subject Script

## Roteiro experimento Virtualclicker - Participante

O participante irá receber o seguinte roteiro:

Bem vindo ao experimento do Virtualclicker! Sua ajuda é muito importante. Gostaríamos de pedir sua contribuição para analisar o design de interação e interface da aplicação. Lembre-se que estamos avaliando a aplicação, e não você! Se houver alguma dificuldade em executar uma tarefa, não se preocupe, isso é sinal de que o aplicativo precisa ser melhorado. Não fique preocupado ou constrangido com as dificuldades pois trata-se de um software que ainda está em desenvolvimento, então suas facilidades e dificuldades serão indicativas do que precisa mudar. Ao final do teste, se você topar, faremos algumas perguntas sobre o que você achou.

Você irá fazer dois testes. O primeiro você fará o papel de **Instrutor**. Por favor, siga os seguintes cenários:

### 1. Instrutor

Cenário 1:

“Suponha que você seja professor da disciplina EA879C, seu RA é 111101 e sua senha de acesso ao sistema é 1234. Você deseja iniciar uma nova aula da matéria. Acesse a aplicação com sua identificação. Informe os alunos de que a aula está aberta e aguarde até que eles façam login. Verifique o que ocorre.”

Cenário 2:

“Suponha que seus alunos já estão presentes na aula e, como professor, você deseja inserir uma nova questão a ser respondida pelos seus alunos. Insira uma nova questão. Informe os alunos de que uma nova questão foi aberta e aguarde a resposta deles. Verifique o que ocorre.”

Cenário 3:

“Uma vez que a questão foi respondida pelos alunos presentes, você deseja apresentar graficamente a distribuição de respostas dos alunos. Gere um gráfico contendo as respostas da turma. Em seguida, finalize a questão.”

Cenário 4:

“Suponha que a aula acabou. Finalize a aula saindo da aplicação e informe os alunos do fim da aula.”



## 2. Aluno

Agora, iremos começar a segunda parte do experimento. Você fará o papel de **Aluno**. Por favor, siga os seguintes cenários:

Cenário 1:

“Suponha que você é um aluno da matéria EA879C, seu RA é 123423 e sua senha de acesso é 1234. Suponha que você acabou de entrar na aula. Aguarde a criação de uma nova aula pelo professor. Em seguida faça seu login na aula.”

Cenário 2:

“Suponha que o professor criou uma nova questão a ser respondida. Acesse e responda a questão.”

Cenário 3:

“Suponha que você não está totalmente certo da sua resposta. Altere a sua resposta e confirme sua opção. Aguarde até o professor finalizar a aula.”

Cenário 4:

“Suponha que a aula acabou. Finalize sua participação na aula.”

Terminou o teste da aplicação! Muito obrigado a nos ajudar a testá-lo.

### B.3 Virtualclicker Questioning Form - Instructor

## Referente a primeira tela - Presença

\* Required



### 1. Como você avalia a forma de seleção da turma? \*

Não sei se essa pergunta cabe aqui, talvez seja necessário colocar em outro lugar  
Mark only one oval.

1	2	3	4	5		
Muito ruim	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Muito bom

### 2. O que você achou sobre a primeira tela do aplicativo ser a tela de presenças? \*

Mark only one oval.

1	2	3	4	5		
Muito ruim	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Muito bom

### 3. Você acha necessário o acréscimo de uma tela introdutória? \*

Logotipo do aplicativo, uma apresentação, etc  
Mark only one oval.

	1	2	3	4	5	
Completamente desnecessário	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Completamente necessário

**4. Como você avalia o método de captura de presença dos alunos? \***

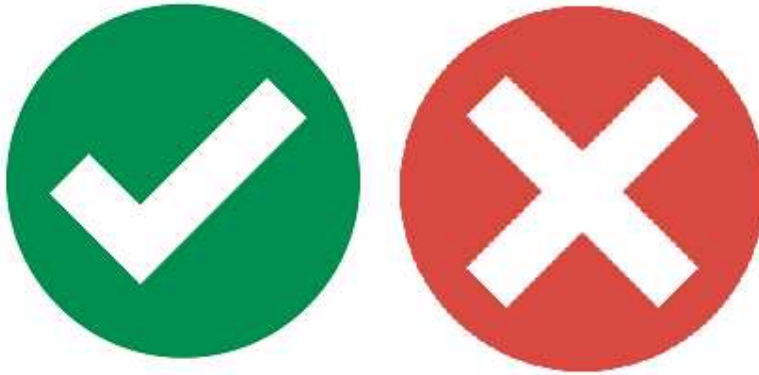
Foi suficientemente intuitivo, foi difícil de entender o que estava acontecendo e como a presença é identificada, etc.

*Mark only one oval.*

1      2      3      4      5

---

Muito ruim                  Muito bom

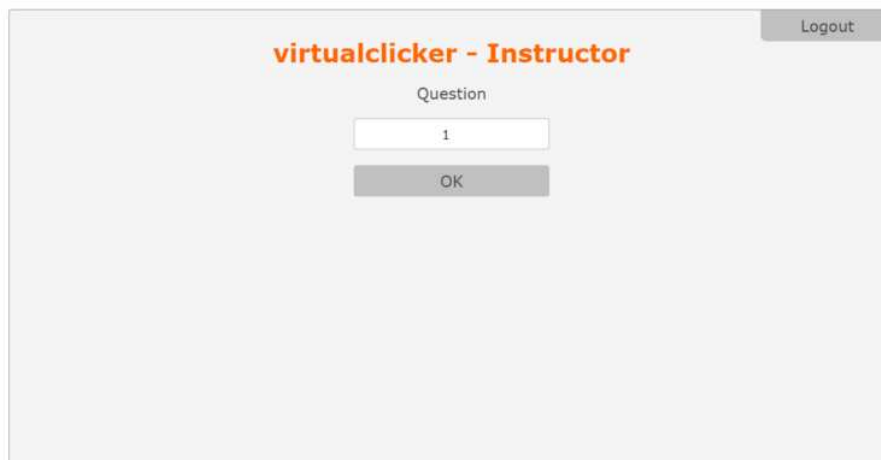
**5. O que você achou do ícone de presença e ausencia? \***

*Mark only one oval.*

1      2      3      4      5

---

Muito ruim                  Muito bom

**Referente a segunda tela - Inserção de questões****6. O que você acha da possibilidade de se escolher o número da questão? \***

*Mark only one oval.*

1      2      3      4      5

---

Completamente desnecessário                  Completamente necessário

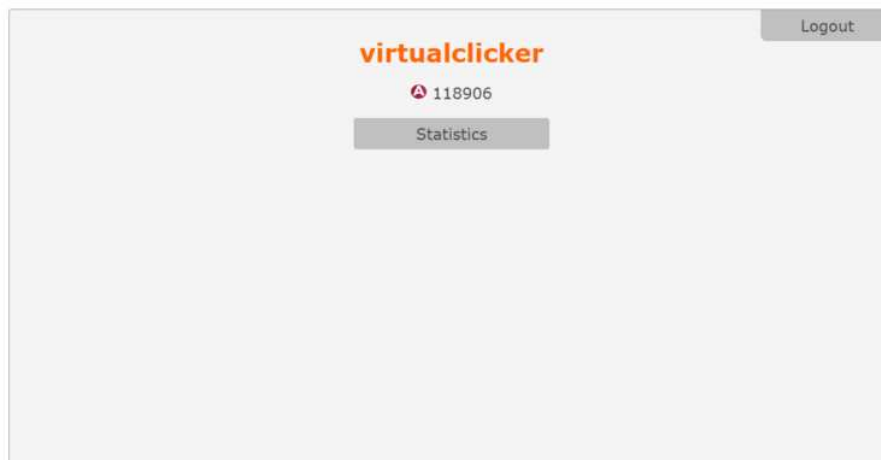
**7. Avalie o método de inserção de novas questões \***

Avalie se é intuitivo, funciona corretamente e teve facilidade em utilizar *Mark only one oval.*

1      2      3      4      5

---

Muito ruim                  Muito bom

**Referente a terceira tela - Resposta dos alunos****8. O que você acha da facilidade de entendimento dos resultados? \***

*Mark only one oval.*

1      2      3      4      5

---

Muito ruim                  Muito bom

**9. A geração dos gráficos apresentaram algum problema evidente? \***

*Mark only one oval.*

- Sim
- Não
- Other: .....

**10. Avalie a finalização da questão \***

Intuitividade, facilidade de interação e etc.  
*Mark only one oval.*

1      2      3      4      5

---

Muito ruim                  Muito bom

**11. Avalie a finalização da aplicação**

Intuitividade, facilidade de interação e etc.

*Mark only one oval.*

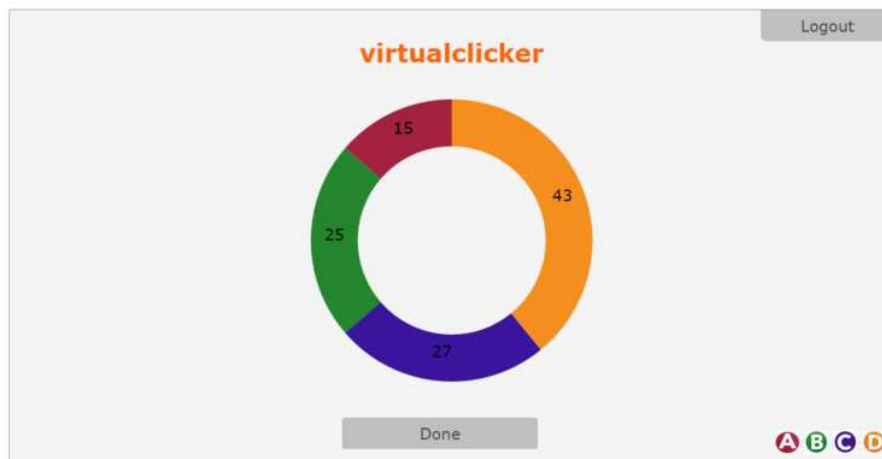
1      2      3      4      5

Muito ruim                  Muito bom

**12. O que você achou dos ícones de respostas? \****Mark only one oval.*

1      2      3      4      5

Muito ruim                  Muito bom

**Referente a quarta tela - Estatísticas**

**13. Avalie a facilidade de entendimento das estatísticas das respostas \***

Mark only one oval.

	1	2	3	4	5	
Muito ruim	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Muito bom

**14. Você encontrou erros na geração dos gráficos \***

Mark only one oval.

- Sim  
 Não

## Sobre a experiência geral com a aplicação

**15. Avalie a intuitividade e facilidade de interagir com a aplicação \***

Pense na facilidade de interação com o programa sem ter nenhuma informação prévia.

Mark only one oval.

	1	2	3	4	5	
Muito ruim	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Muito bom

**16. Avalie o fluxo geral da aplicação \***

Mark only one oval.

	1	2	3	4	5	
Muito ruim	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Muito bom

**17. Avalie a qualidade da aplicação em relação a problemas técnicos encontrados \***

Mark only one oval.

	1	2	3	4	5	
Muito ruim	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Muito bom

**18. Utilize esse espaço para fazer comentários gerais sobre a aplicação \***

Comente problemas encontrados durante a execução e possíveis melhorias que podem ser feitas

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## B.4 Virtualclicker Questioning Form - Learner

## Referente a primeira tela - Status

\* Required



1. O que você achou sobre a primeira tela do aplicativo ser a tela de status? \*

Mark only one oval.

1	2	3	4	5	
Muito ruim	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Muito bom

2. Você acha necessário o acréscimo de uma tela introdutória? \*

Logotipo do aplicativo, uma apresentação, etc

Mark only one oval.

	1	2	3	4	5	
Completamente desnecessário	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Completamente necessário

3. Como você avalia a forma de seleção da turma? \*

Não sei se essa pergunta cabe aqui, talvez seja necessário colocar em outro lugar

Mark only one oval.

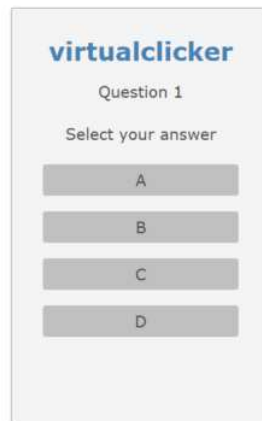
1	2	3	4	5	
Muito ruim	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Muito bom

4. O que você achou do aspecto geral da tela de status? \*

Mark only one oval.

1	2	3	4	5	
Muito ruim	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Muito bom

## Referente a segunda tela - Resposta das questões



virtualclicker

Question 1

Select your answer

A

B

C

D

### 5. Avalie o método de resposta às questões \*

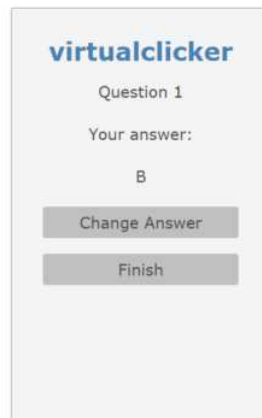
Avalie se é intuitivo, funciona corretamente e teve facilidade em utilizar  
*Mark only one oval.*

1 2 3 4 5

---

Muito ruim      Muito bom

## Referente a terceira tela - Confirmação de resposta



virtualclicker

Question 1

Your answer:

B

Change Answer

Finish

### 6. Avalie a interatividade das telas de resposta e confirmação \*

Intuitividade, facilidade de interação e entendimento, etc.  
*Mark only one oval.*

1 2 3 4 5

---

Muito ruim      Muito bom

**7. Você teve alguma dúvida de como proceder durante a resposta e confirmação de uma questão? \***

Mark only one oval.

- Sim
- Não
- Other: .....

**8. Avalie a finalização da questão \***

Intuitividade, facilidade de interação e etc.

Mark only one oval.

	1	2	3	4	5	
Muito ruim	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Muito bom

**9. Avalie a finalização da aplicação \***

Intuitividade, facilidade de interação e etc.

Mark only one oval.

	1	2	3	4	5	
Muito ruim	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Muito bom

**10. Você acha necessária uma função de logout para a interface? \***

Mark only one oval.

- Sim
- Não

## Sobre a experiência geral com a aplicação

**11. Avalie a intuitividade e facilidade de interagir com a aplicação \***

Pense na facilidade de interação com o programa sem ter nenhuma informação prévia.

Mark only one oval.

	1	2	3	4	5	
Muito ruim	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Muito bom

**12. Avalie o fluxo geral da aplicação \***

Mark only one oval.

	1	2	3	4	5	
Muito ruim	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Muito bom

**13. Avalie a qualidade da aplicação em relação a problemas técnicos encontrados \***

*Mark only one oval.*

	1	2	3	4	5	
Muito ruim	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Muito bom

**14. Utilize esse espaço para fazer comentários gerais sobre a aplicação \***

Comente problemas encontrados durante a execução e possíveis melhorias que podem ser feitas

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Powered by

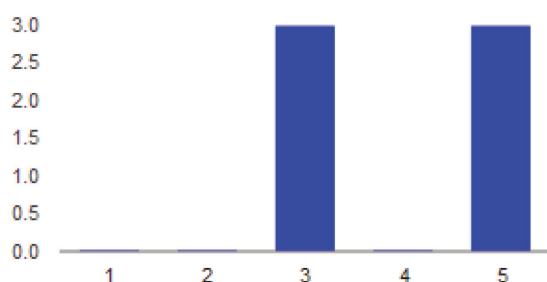


## B.5 Summary of Virtualclicker Questioning Form Results - Instructor

# Resumo

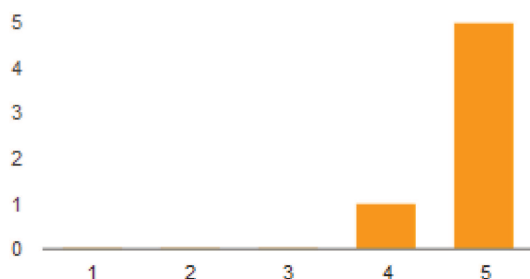
## Referente à primeira tela – Presença

Como você avalia a forma de seleção da turma?



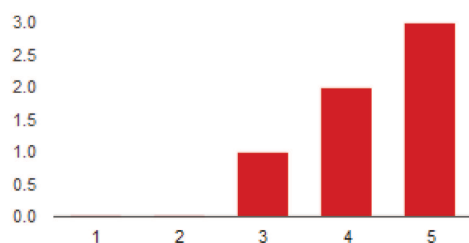
Muito ruim: 1	0	0%
2	0	0%
3	3	50%
4	0	0%
Muito bom: 5	3	50%

O que você achou sobre a primeira tela do aplicativo ser a tela de presenças?



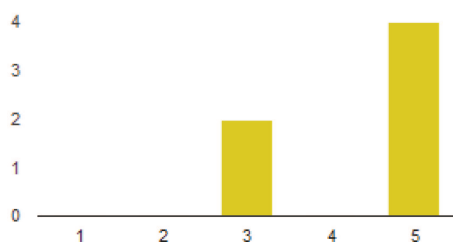
Muito ruim: 1	0	0%
2	0	0%
3	0	0%
4	1	16.7%
Muito bom: 5	5	83.3%

Você acha necessário o acréscimo de uma tela introdutória?



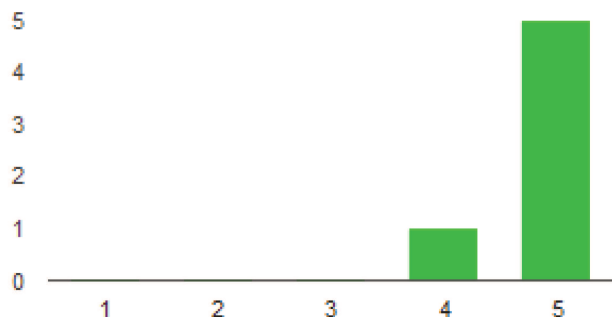
Completamente desnecessário: 1	0	0%
2	0	0%
3	1	16.7%
4	2	33.3%
Completamente necessário: 5	3	50%

Como você avalia o método de captura de presença dos alunos?



Muito ruim: 1	0	0%
2	0	0%
3	2	33.3%
4	0	0%
Muito bom: 5	4	66.7%

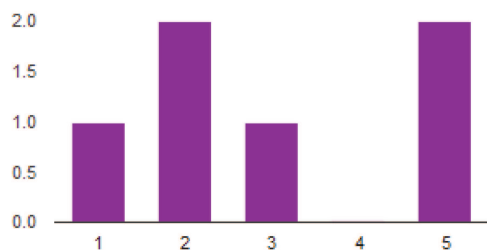
### O que você achou do ícone de presença e ausencia?



Muito ruim:	1	0	0%
	2	0	0%
	3	0	0%
	4	1	16.7%
Muito bom:	5	5	83.3%

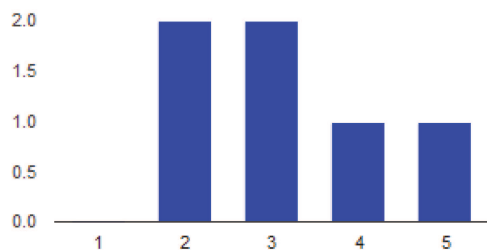
### Referente a segunda tela - Inserção de questões

#### O que você acha da possibilidade de se escolher o número da questão?



Completamente desnecessário:	1	1	16.7%
	2	2	33.3%
	3	1	16.7%
	4	0	0%
Completamente necessário:	5	2	33.3%

#### Avalie o método de inserção de novas questões

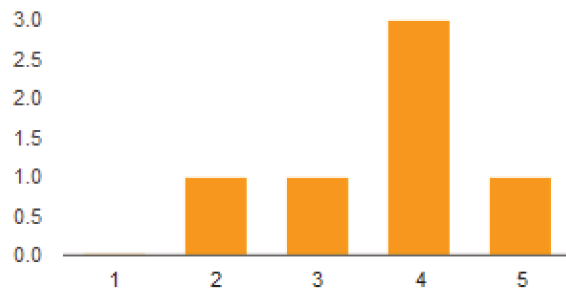


Muito ruim:	1	0	0%
	2	2	33.3%
	3	2	33.3%
	4	1	16.7%
Muito bom:	5	1	16.7%



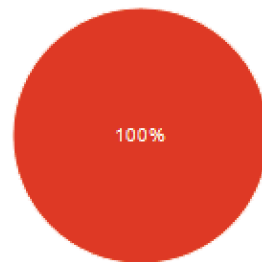
## Referente a terceira tela - Resposta dos alunos

O que você acha da facilidade de entendimento dos resultados?



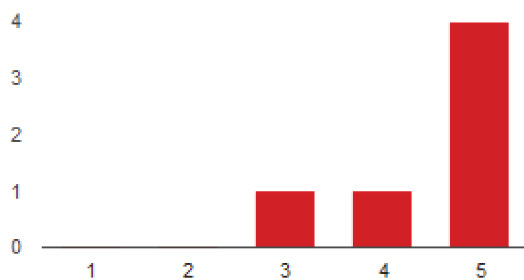
Muito ruim:	1	0	0%
	2	1	16.7%
	3	1	16.7%
	4	3	50%
Muito bom:	5	1	16.7%

A geração dos gráficos apresentaram algum problema evidente?



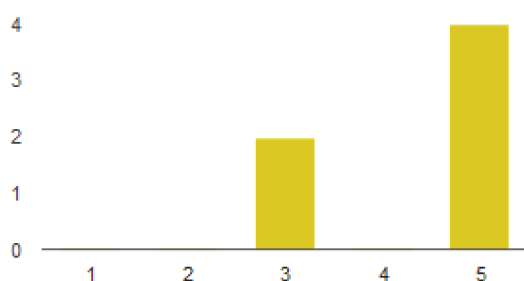
Sim	0	0%
Não	6	100%
Other	0	0%

Avalie a finalização da questão



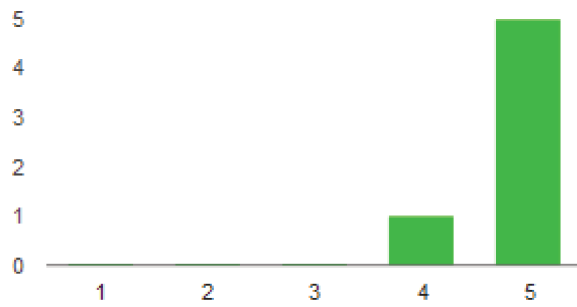
Muito ruim:	1	0	0%
	2	0	0%
	3	1	16.7%
	4	1	16.7%
Muito bom:	5	4	66.7%

Avalie a finalização da aplicação



Muito ruim:	1	0	0%
	2	0	0%
	3	2	33.3%
	4	0	0%
Muito bom:	5	4	66.7%

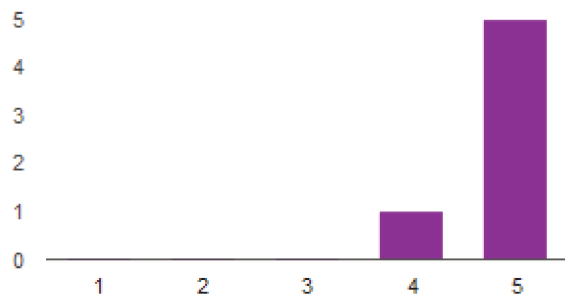
### O que você achou dos ícones de respostas?



Muito ruim:	1	0	0%
	2	0	0%
	3	0	0%
	4	1	16.7%
Muito bom:	5	5	83.3%

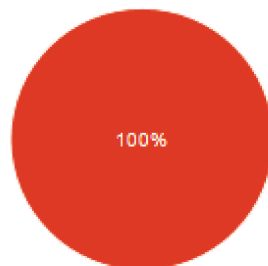
## Referente a quarta tela - Estatísticas

### Avalie a facilidade de entendimento das estatísticas das respostas



Muito ruim:	1	0	0%
	2	0	0%
	3	0	0%
	4	1	16.7%
Muito bom:	5	5	83.3%

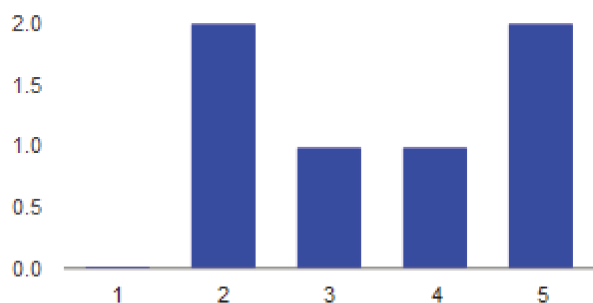
### Você encontrou erros na geração dos gráficos



Sim	0	0%
Não	6	100%

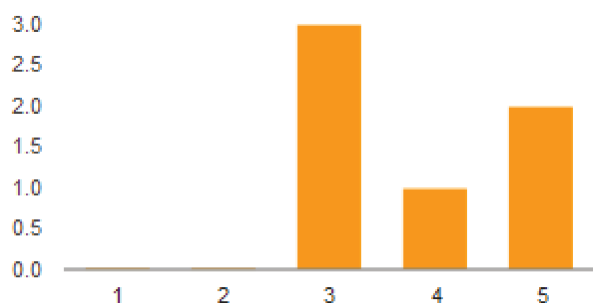
## Sobre a experiência geral com a aplicação

### Avalie a intuitividade e facilidade de interagir com a aplicação



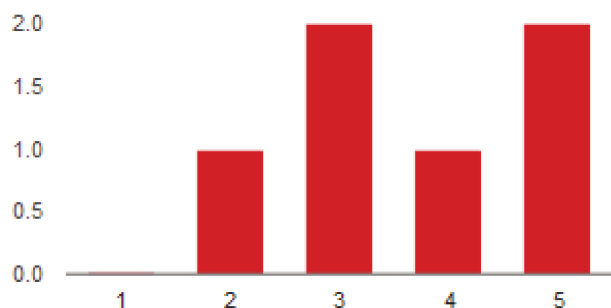
Muito ruim:	1	0	0%
	2	2	33.3%
	3	1	16.7%
	4	1	16.7%
Muito bom:	5	2	33.3%

### Avalie o fluxo geral da aplicação



Muito ruim:	1	0	0%
	2	0	0%
	3	3	50%
	4	1	16.7%
Muito bom:	5	2	33.3%

### Avalie a qualidade da aplicação em relação a problemas técnicos encontrados



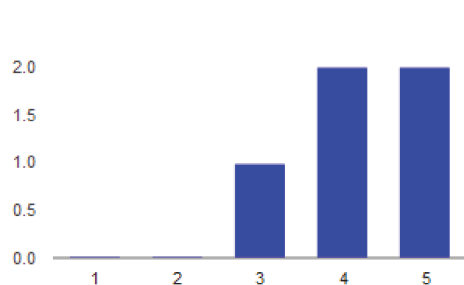
Muito ruim:	1	0	0%
	2	1	16.7%
	3	2	33.3%
	4	1	16.7%
Muito bom:	5	2	33.3%

## B.6 Summary of Virtualclicker Questioning Form Results - Learner

# Resumo

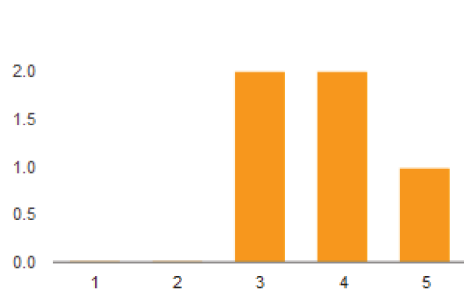
## Referente à primeira tela - Status

O que você achou sobre a primeira tela do aplicativo ser a tela de status?



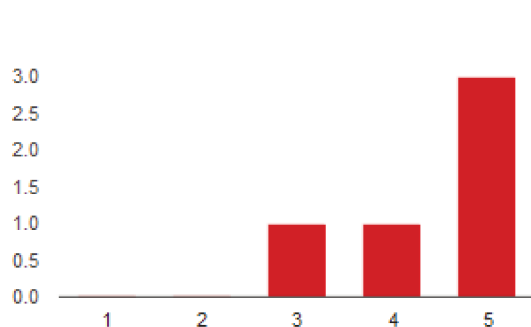
Muito ruim: 1	0	0%
2	0	0%
3	1	20%
4	2	40%
Muito bom: 5	2	40%

Você acha necessário o acréscimo de uma tela introdutória?



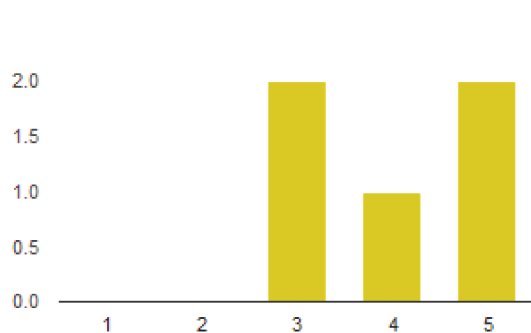
Completamente desnecessário: 1	0	0%
2	0	0%
3	2	40%
4	2	40%
Completamente necessário: 5	1	20%

Como você avalia a forma de seleção da turma?



Muito ruim: 1	0	0%
2	0	0%
3	1	20%
4	1	20%
Muito bom: 5	3	60%

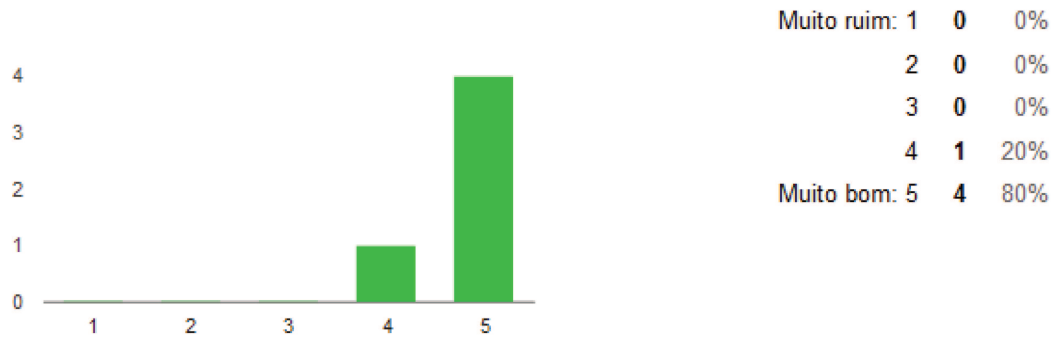
O que você achou do aspecto geral da tela de status?



Muito ruim: 1	0	0%
2	0	0%
3	2	40%
4	1	20%
Muito bom: 5	2	40%

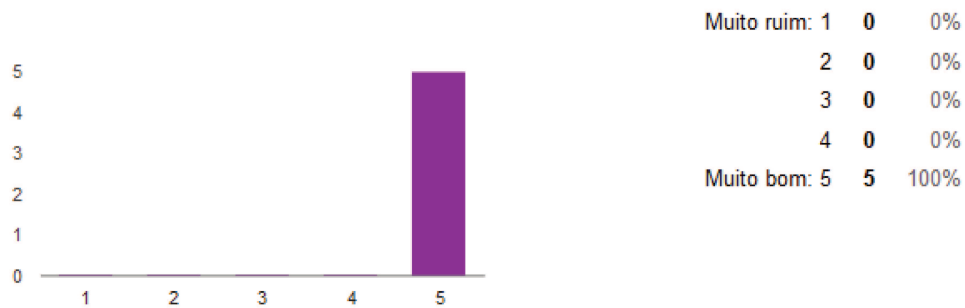
## Referente a segunda tela - Resposta das questões

Avalie o método de resposta às questões

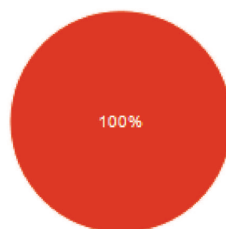


## Referente a terceira tela - Confirmação de resposta

Avalie a interatividade das telas de resposta e confirmação

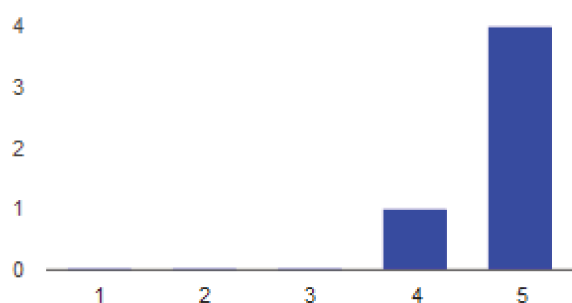


Você teve alguma dúvida de como proceder durante a resposta e confirmação de uma questão?



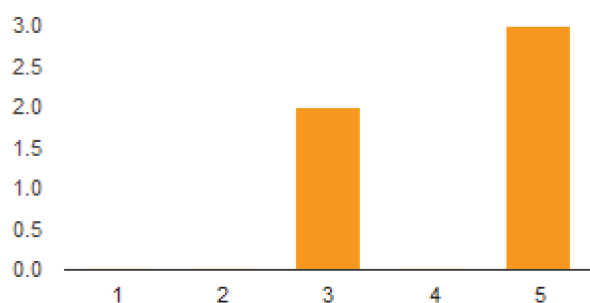
Sim	0	0%
Não	5	100%
Other	0	0%

### Avalie a finalização da questão



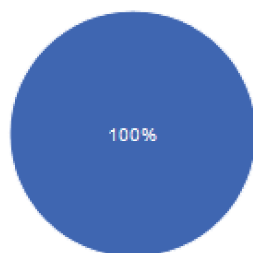
Muito ruim:	1	0	0%
	2	0	0%
	3	0	0%
	4	1	20%
Muito bom:	5	4	80%

### Avalie a finalização da aplicação



Muito ruim:	1	0	0%
	2	0	0%
	3	2	40%
	4	0	0%
Muito bom:	5	3	60%

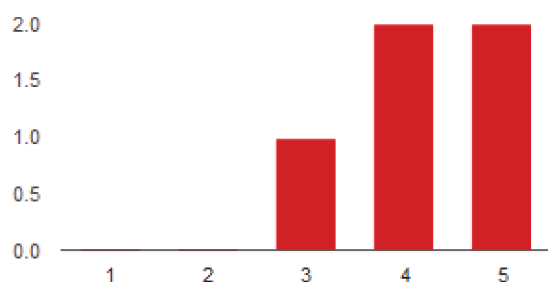
### Você acha necessária uma função de logout para a interface?



Sim	5	100%
Não	0	0%

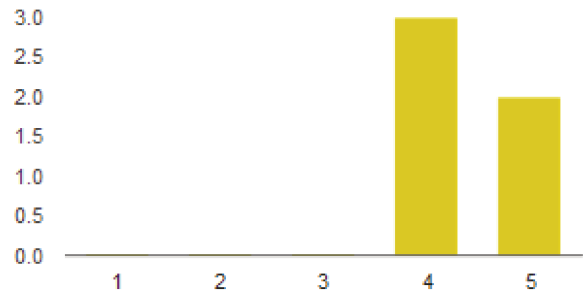
## Sobre a experiência geral com a aplicação

### Avalie a intuitividade e facilidade de interagir com a aplicação



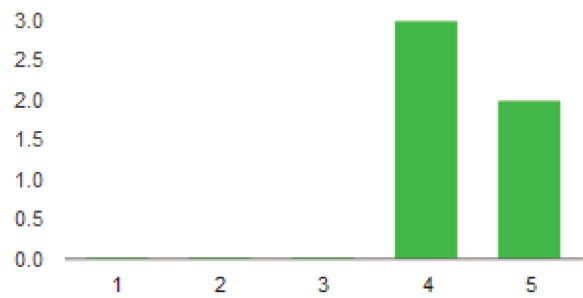
Muito ruim:	1	0	0%
	2	0	0%
	3	1	20%
	4	2	40%
Muito bom:	5	2	40%

### Avalie o fluxo geral da aplicação



Muito ruim:	1	0	0%
	2	0	0%
	3	0	0%
	4	3	60%
Muito bom:	5	2	40%

### Avalie a qualidade da aplicação em relação a problemas técnicos encontrados



Muito ruim:	1	0	0%
	2	0	0%
	3	0	0%
	4	3	60%
Muito bom:	5	2	40%



## B.7 Paperclickers Subject Script

## Roteiro experimento Paperclickers - participante

Bem vindo ao experimento do Paperclickers! Sua ajuda é muito importante. Gostaríamos de pedir sua contribuição para analisar o design de interação e interface da aplicação. Lembre-se que estamos avaliando a aplicação, e não você! Se houver alguma dificuldade em executar uma tarefa, não se preocupe, isso é sinal de que o aplicativo precisa ser melhorado. Não fique preocupado ou constrangido com as dificuldades pois trata-se de um software que ainda está em desenvolvimento, então suas facilidades e dificuldades serão indicativas do que precisa mudar. Ao final do teste, se você topa, faremos algumas perguntas sobre o que você achou.

Você irá fazer 3 testes da aplicação. Por favor, siga as seguintes instruções:

Cenário 1:

“No início do experimento, você recebeu um smartphone. Neste smartphone está instalado uma aplicação chamada Paperclickers. Abra esta aplicação.

Suponha que você seja professor da **turma IA004-A**.

Verifique se o nome da turma aparece na tela do paperclickers. Então, comece a aplicação abrindo uma sessão para essa turma.

Imagine que seus alunos já estão na sala de aula e que você deseja realizar a chamada. Através do aplicativo verifique quem são os alunos presentes.

Perceba que a presença do **aluno 155** não foi detectada. Altere a situação do **aluno 155** de ausente para presente. Após alterar a situação do **aluno 155**, finalize a chamada.

E volte para a tela inicial.”

Você terminou o primeiro teste do aplicativo. Vamos para o próximo!

Cenário 2:

“Suponha agora que você está em uma sala de aula diferente da anterior.

Então, selecione a **turma IA012-A** e abra uma sessão para essa nova turma.

Imagine que você como professor gostaria de saber a opinião da turma sobre um tópico. Então, suponha que você fez uma pergunta para a turma e deseja obter a resposta.

Colete as respostas da questão e analise os resultados. Você pode dizer

quantos alunos responderam “A”?

Perceba que a resposta dada pelo **aluno 151** não foi detectada. Altere a resposta do **aluno 151** para “C”.

Estas respostas podem ser sumarizadas num gráfico. Então, use o aplicativo para visualizar o gráfico.

Suponha agora que você gostaria de fazer uma nova questão para a turma. Então, inicie uma nova questão na aplicação e colete as respostas desta segunda questão.

Analise os resultados, verifique o gráfico e volte para a tela inicial.”

Cenário livre :

Agora você está livre ! Brinque com o aplicativo por alguns minutos, tente coisas diferentes. Não se preocupe : não há nada que você possa fazer dentro do aplicativo que vá causar problemas irreversíveis.

Terminou o teste do aplicativo ! Muito obrigado a nos ajudar a testá-lo.

## B.8 Paperclickers Questioning Form

[Editar este formulário](#)

Responda às perguntas que deseja preencher automaticamente e pressione "Enviar".

## Formulário de avaliação - paperclickers

Insira seu nome (Opcional)

### Primeira tela - Introdução/Escolha da classe



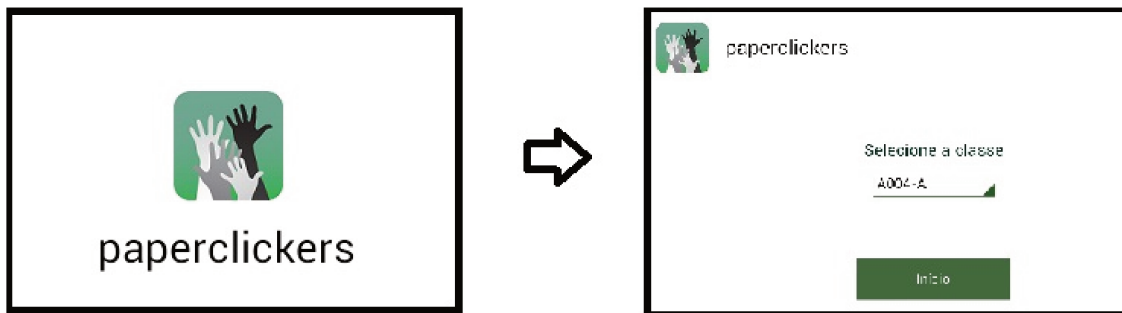
paperclickers

Selecione a classe

IA004-A

Início

**Contraste a tela inicial atual do sistema (acima) com a alternativa mostrada abaixo**



### 1 - "Prefiro a forma atual." (o sistema abre direto na tela de seleção de classe)

Concordo totalmente    Concordo parcialmente    Não concordo nem discordo    Discordo parcialmente    Discordo totalmente

### 2 - "Preferiria a forma alternativa, com uma tela de introdução separada."

(A tela introdutória iria ser a primeira tela a aparecer, duraria menos de 1 segundo e passaria automaticamente para a tela de seleção de classe)

Concordo totalmente    Concordo parcialmente    Não concordo nem discordo    Discordo parcialmente    Discordo totalmente

### 3 - O aplicativo atualmente obriga o usuário a usar o modo horizontal (paisagem)

(A alternativa seria o leiaute mudar automaticamente quando o dispositivo é reposicionado)

Nem reparei nisso    Notei e achei bom    Notei e achei indiferente    Notei e me incomodou um pouco    Notei e achei ruim : preferia a alternativa

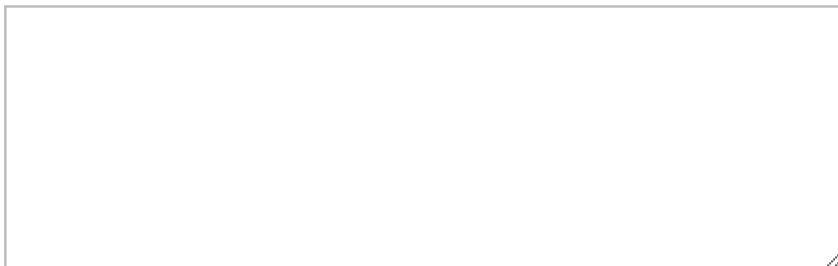
### 4 - O aplicativo atualmente oferece múltiplas turmas e pede ao usuário para selecionar uma. O que você achou ?

Acho desnecessário o controle de várias turmas    Gosto da idéia de várias turmas, mas achei confuso o jeito atual    Gosto da idéia de várias turmas e achei prático o jeito atual

### Sugestões ou críticas para a seleção de classe

Por favor, digite aqui qualquer idéia, sugestão ou crítica para a seleção de classe



Página 2

## Segunda tela - Escolha do número da questão



Selecione o número da questão



Obter respostas

### 1 - o que você achou da caixa de seleção do número da questão? (Marque todas as alternativas relevantes)

- Achei importante cada questão ter um número único
- É fácil entrar o número da questão pelo teclado virtual
- Não entendi a necessidade de selecionar o número da questão
- Fiquei surpreso quando o número da questão mudou sozinho
- Os controles são chatos de clicar e usar
- Achei bom o número da questão aumentar automaticamente
- Os controles são fáceis de usar
- Outro:

### 2 - A opção de fazer a chamada separadamente das outras perguntas é conveniente/importante

Concordo totalmente    Concordo parcialmente    Nem concordo nem discordo    Discordo parcialmente    Discordo totalmente

## A pergunta 3 se refere ao seguinte ícone



### 3 - O que você achou do ícone acima? (Marque todas as alternativas relevantes)

- Sugestivo
- Posição inconveniente
- Ininteligível
- Fácil de usar
- Feio
- Grande demais
- Fácil de clicar
- Bonito
- Escondido
- Fácil de entender
- Confuso
- Pequeno demais
- Outro:

## A pergunta 4 se refere ao seguinte ícone



### 4 - O que você achou do ícone acima? (Marque todas as alternativas relevantes)

- Grande demais
- Ininteligível
- Bonito
- Pequeno demais
- Sugestivo



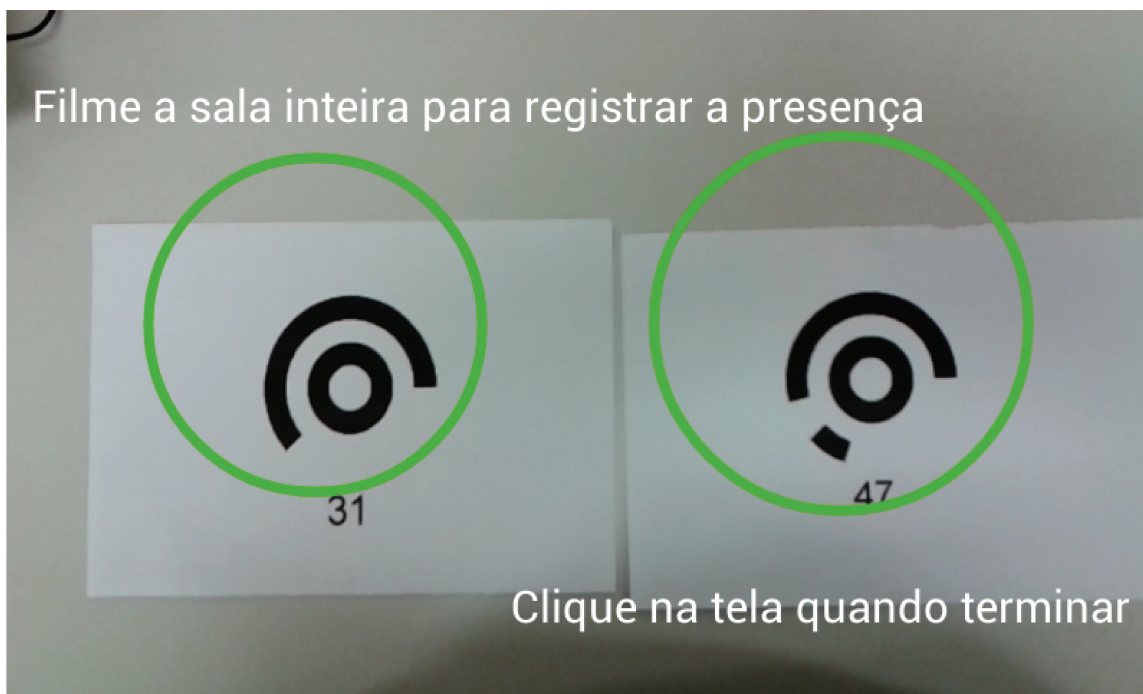
- Fácil de usar
- Feio
- Posição inconveniente
- Escondido
- Fácil de clicar
- Confuso
- Fácil de entender
- Outro:

#### Sugestões ou crítica sobre esta tela

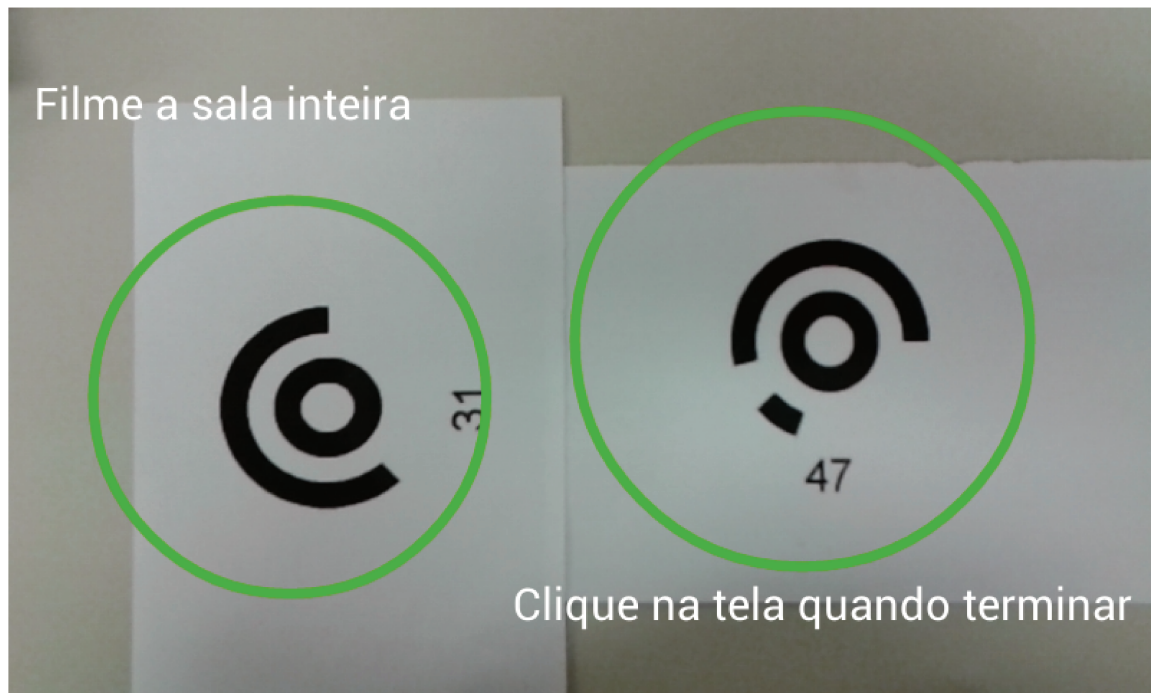
Digite aqui qualquer sugestão, crítica, dica, informação sobre esta tela – será valioso para nós

## Página 3

### Terceira tela - Captura de presenças/chamada



### Terceira tela - Captura de respostas



**1- O que você achou das instruções na tela de captura de presença/respostas? "Filme a sala inteira [para registrar a presença] / Clique na tela quando terminar" (Marque todas as alternativas relevantes)**

- Claras
- Atrapalham a filmagem
- Confusas
- Fáceis de entender
- Difíceis de ler
- Não incomodam
- Outro:

**2- Você percebeu que de vez em quando aparecem círculos nessas telas ? O que você achou ? (Marque todas as alternativas relevantes)**

- Notei, mas nem me importei
- Achei legal a idéia dos círculos
- Achei confusos os círculos
- Nem notei os círculos
- Entendi a função dos círculos
- O feedback dos círculos é muito lento
- Outro:

**3- O que você achou da forma de finalizar a filmagem na tela de captura de presença/respostas (Marque todas as alternativas)**

(Queremos saber se você encontrou alguma dificuldade)

- A tela não responde bem ao clique
- Tive que fazer várias tentativas para finalizar
- A tela é sensível demais ao clique

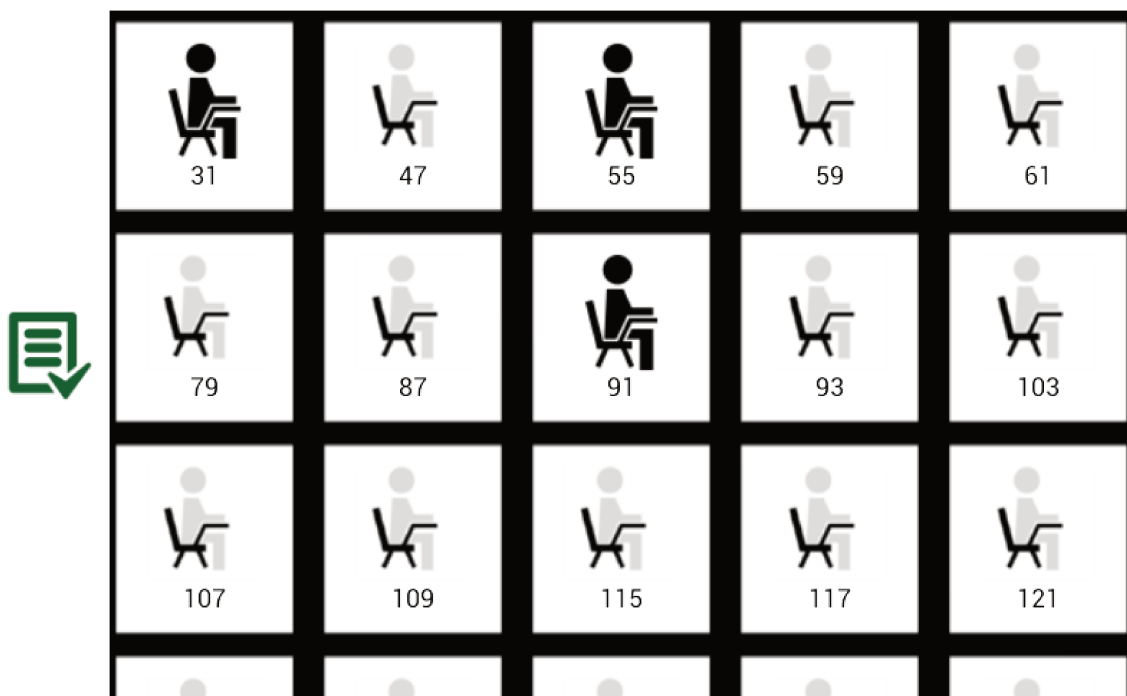
- As instruções não são claras de como se termina a filmagem
- É fácil finalizar por acidente
- É fácil de executar a operação
- É fácil de entender o que deve ser feito
- Outro:

### Sugestões ou críticas para esta tela

Por favor, digite aqui qualquer informação, crítica, sugestão para esta tela

Página 4

### Quarta tela - tela de grade da presença



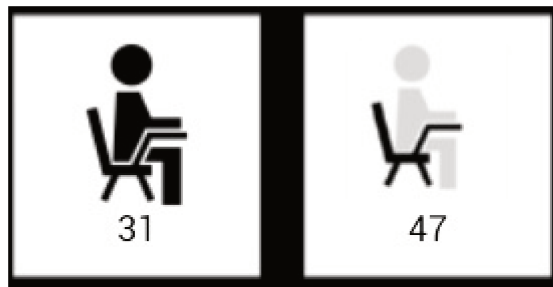
1- O que você achou da disposição dos resultados? (Marque todas as alternativas relevantes)

- Foi fácil entender quem estava presente e quem estava ausente
- É fácil clicar por acidente nos ícones
- A informação é bem organizada
- A tela deveria conter mais alunos
- Entendi facilmente que os ícones podiam ser clicados

Os ícones deveriam ser maiores

Outro:

## Ícones para a pergunta 2



**2 - O que você achou dos ícones de presente / ausente ? (Marque todas as alternativas relevantes)**

- Pequeno demais
- Fácil de clicar
- Preferia ter a foto dos alunos no lugar dos ícones
- Fácil de entender
- Feio
- Confuso
- Sugestivo
- Preferia ter o nome dos alunos no lugar dos números
- Grande demais
- Bonito
- Outro:

**3- O que você achou da forma de alterar manualmente a presença dos alunos (ausente para presente, por exemplo)?**

Muito Ruim	Ruim	Irrelevante	Bom	Muito Bom
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

## A pergunta 4 se refere ao seguinte ícone



**4 - O que você achou do ícone ? (Marque todas as alternativas relevantes)**

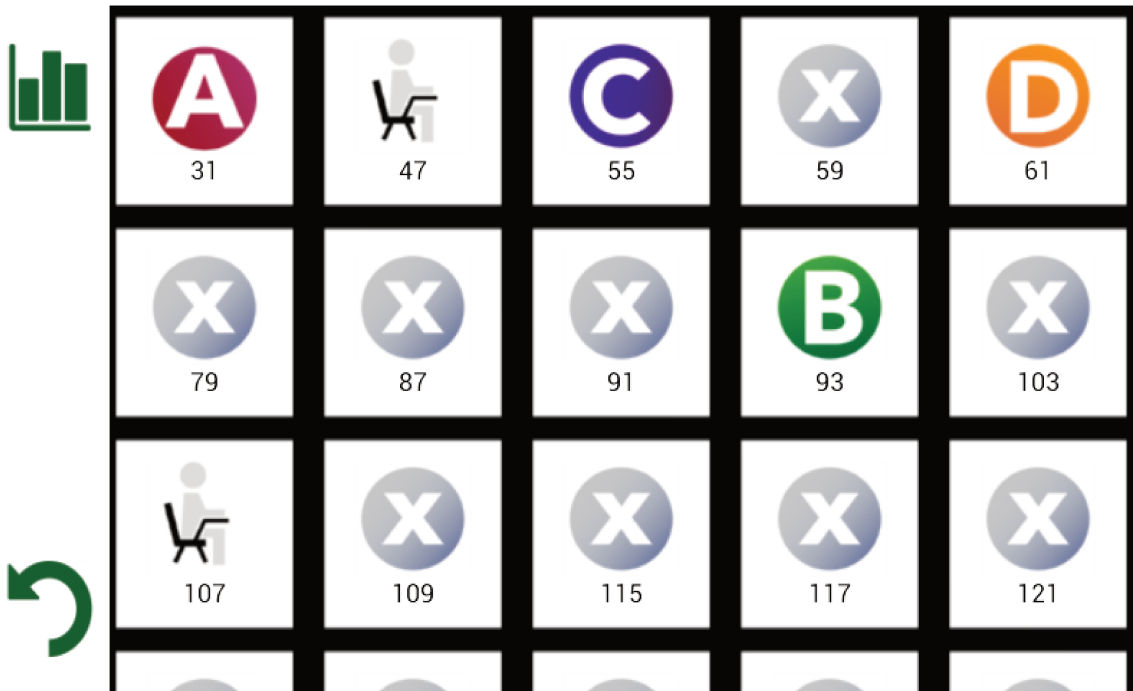
- Fácil de entender
- Feio
- Sugestivo
- Fácil de clicar
- Bonito
- Pequeno demais
- Posição inconveniente
- Confuso
- Fácil de usar
- Ininteligível
- Grande demais
- Escondido
- Outro:

**Sugestões ou críticas**

Digite aqui qualquer informação que você ache relevante nessa tela para o melhor desenvolvimento do aplicativo.

Página 5

**Quinta tela - grade das respostas dadas pelos alunos**



**1- O que você achou da disposição dos resultados? (Marque todas as alternativas relevantes)**

- As cores das alternativas A, B, C e D são bem distintas
- É fácil entender o que o ícone com o "x" significa
- Entendi facilmente que os ícones podiam ser clicados
- Os ícones deveriam ser maiores
- A tela deveria conter mais alunos
- A informação é bem organizada
- É fácil clicar por acidente nos ícones
- Outro:

**2- O que você achou da forma de alterar a resposta dada por um aluno? (Marque todas as alternativas relevantes)**

- Os ícones são fáceis de clicar
- Achei importante : melhor que lutar com a câmera por causa de um ou dois alunos
- Achei difícil perceber que é possível alterar manualmente
- É inútil : prefiro insistir com a câmera
- Modifiquei por acidente uma resposta e fiquei confuso
- Outro:

**Pergunta 3 referente ao seguinte ícone**



### 3 - O que você achou do ícone? (Marque todas as alternativas relevantes)

- Confuso
- Ininteligível
- Fácil de entender
- Escondido
- Fácil de clicar
- Bonito
- Sugestivo
- Fácil de usar
- Pequeno demais
- Feio
- Grande demais
- Posição inconveniente
- Outro:

### Pergunta 4 referente ao seguinte ícone



### 4 - O que você achou do ícone? (Marque todas as alternativas relevantes)

- Bonito
- Feio
- Grande demais
- Fácil de entender
- Ininteligível
- Fácil de clicar
- Confuso
- Fácil de usar
- Escondido
- Sugestivo
- Pequeno demais

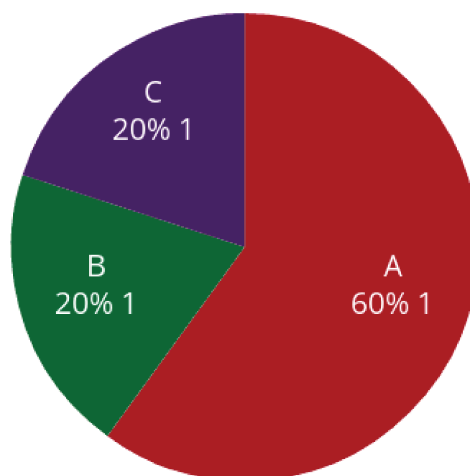
Posição inconveniente Outro: **5 - Sobre o retorno para a tela de filmagem:** Não usei, não entendi que podia fazer isso Não usei, não precisei filmar mais Usei, e entendi que acrescentaria as respostas faltantes àquelas já reconhecidas Usei, e entendi que o processo recomeçava do zero Outro: **Sugestões ou críticas**

Digite aqui qualquer informação que você ache relevante nessa tela para o melhor desenvolvimento do aplicativo.

Página 6

**Sexta tela - gráfico de resultados**

■ A  
■ B  
■ C



5 resposta(s)

Tentar novamente

Nova pergunta

**1- O que você achou do gráfico?**

(Gostaríamos de saber se foi fácil a sua interpretação)

Ruim

Irrelevante

Bom



Muito Ruim

Muito Bom

**2 - O que você achou (no primeiro uso) que o botão "Tentar novamente" faria ?**

(Caso não tenha usado, imagine agora o que ele faria.)

- Encerraria a questão e voltaria à tela de seleção de turma
- Encerraria a questão e voltaria à tela de seleção do número da questão
- Manteria a questão e voltaria à tela de filmagem das respostas
- Manteria a questão e voltaria à tela de grade de respostas
- Outro:

**3 - O que você achou (no primeiro uso) que o botão "Nova pergunta" faria ?**

(Caso não tenha usado, imagine agora o que ele faria.)

- Encerraria a questão e voltaria à tela de seleção de turma
- Encerraria a questão e voltaria à tela de seleção do número da questão
- Manteria a questão e voltaria à tela de filmagem das respostas
- Manteria a questão e voltaria à tela de grade de respostas
- Outro:


**A pergunta 4 se refere ao seguinte ícone****4 - O que você achou que o ícone acima faria ?**

(Caso não tenha usado, imagine agora o que ele faria.)

- Encerraria a questão e voltaria à tela de seleção de turma
- Encerraria a questão e voltaria à tela de seleção do número da questão
- Manteria a questão e voltaria à tela de filmagem das respostas
- Manteria a questão e voltaria à tela de grade de respostas
- Outro:

**Sugestões ou críticas**

Digite aqui qualquer informação que você ache relevante nessa tela para o melhor desenvolvimento do aplicativo.



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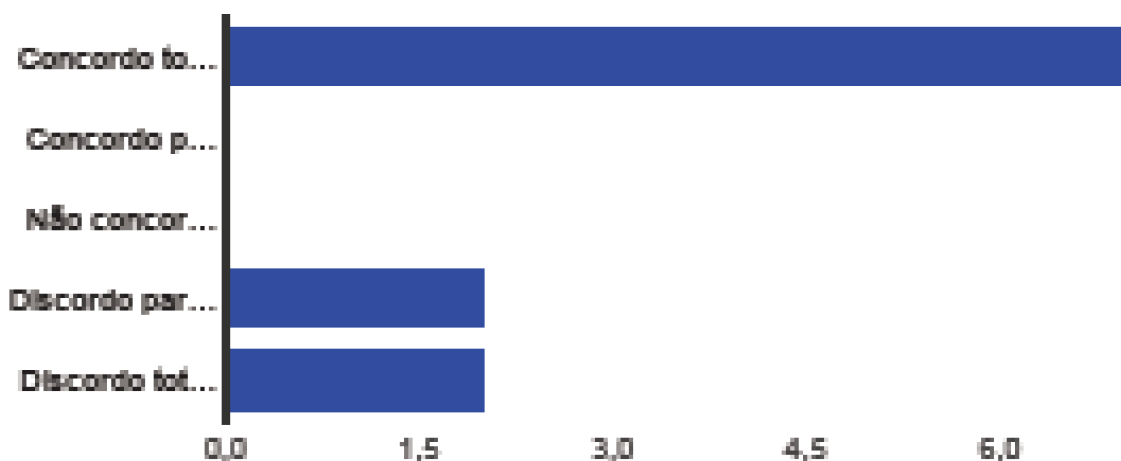
## B.9 Summary of Paperclickers Questioning Form Results

# Resumo

## Primeira tela - Introdução/Escolha da classe

**Contraste a tela inicial atual do sistema (acima) com a alternativa mostrada abaixo**

**Linha sem nome 1 [1 - "Prefiro a forma atual." (o sistema abre direto na tela de seleção de classe)]**



**Concordo totalmente 7 63.6%**

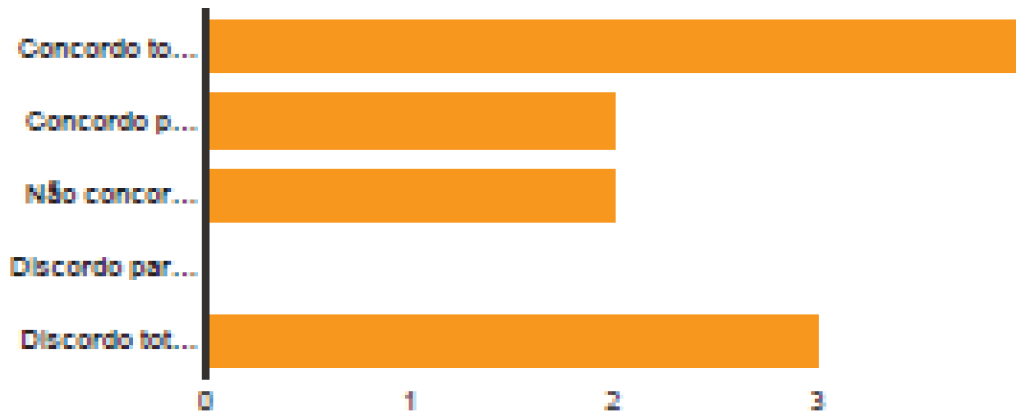
Concordo parcialmente 0 0%

Não concordo nem discordo 0 0%

Discordo parcialmente 2 18.2%

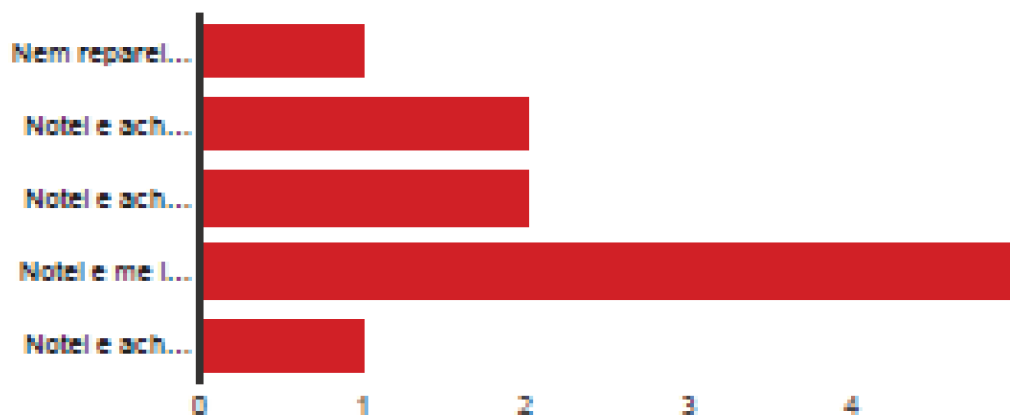
Discordo totalmente 2 18.2%

**Linha sem nome 1 [2 - "Preferiria a forma alternativa, com uma tela de introdução separada."]**



Concordo totalmente	4	36.4%
Concordo parcialmente	2	18.2%
Não concordo nem discordo	2	18.2%
Discordo parcialmente	0	0%
Discordo totalmente	3	27.3%

**Linha sem nome 1 [3 - O aplicativo atualmente obriga o usuário a usar o modo horizontal (paisagem)]**



Nem reparei nisso	1	9.1%
Notei e achei bom	2	18.2%
Notei e achei indiferente	2	18.2%
Notei e me incomodou um pouco	5	45.5%
Notei e achei ruim : preferia a alternativa	1	9.1%

**Linha sem nome 1 [4 - O aplicativo atualmente oferece múltiplas turmas e pede ao usuário para selecionar uma. O que você achou ?]**

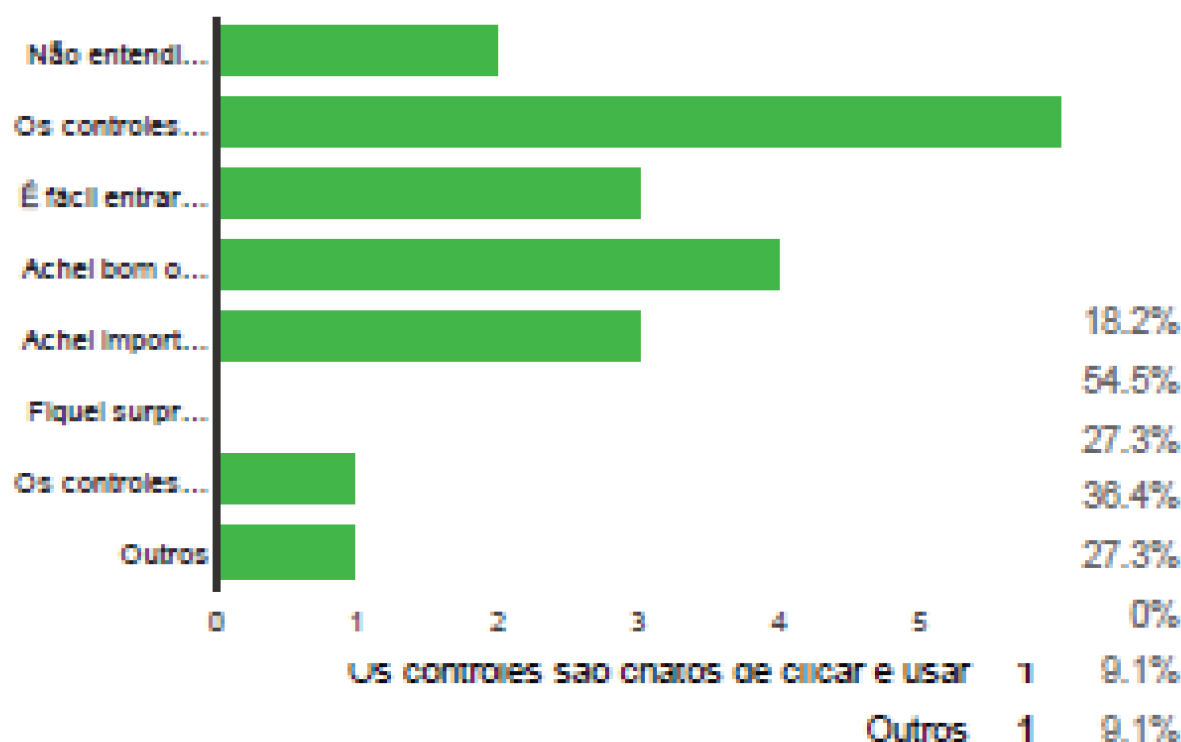


Acho desnecessário o controle de várias turmas	0	0%
Gosto da idéia de várias turmas, mas achei confuso o jeito atual	3	27.3%
Gosto da idéia de várias turmas e achei prático o jeito atual	8	72.7%

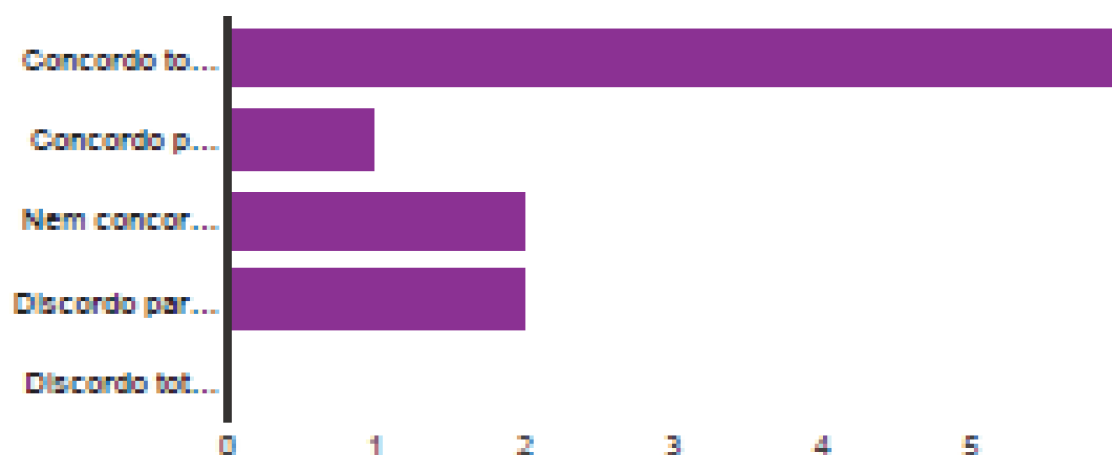
## Página 2

### Segunda tela - Escolha do número da questão

**1 - o que você achou da caixa de seleção do número da questão? (Marque todas as alternativas relevantes)**



**Linha sem nome 1 [2 - A opção de fazer a chamada separadamente das outras perguntas é conveniente/importante]**



Concordo totalmente	6	54.5%
Concordo parcialmente	1	9.1%
Nem concordo nem discordo	2	18.2%
Discordo parcialmente	2	18.2%
Discordo totalmente	0	0%

**A pergunta 3 se refere ao seguinte ícone**

**3 - O que você achou do ícone acima? (Marque todas as alternativas relevantes)**



Confuso	3	27.3%
Ininteligível	1	9.1%
Escondido	1	9.1%
Pequeno demais	0	0%
Grande demais	0	0%
Posição inconveniente	3	27.3%
Fácil de entender	2	18.2%
Fácil de clicar	5	45.5%
Fácil de usar	2	18.2%
Outros	0	0%



## A pergunta 4 se refere ao seguinte ícone

4 - O que você achou do ícone acima? (Marque todas as alternativas relevantes)

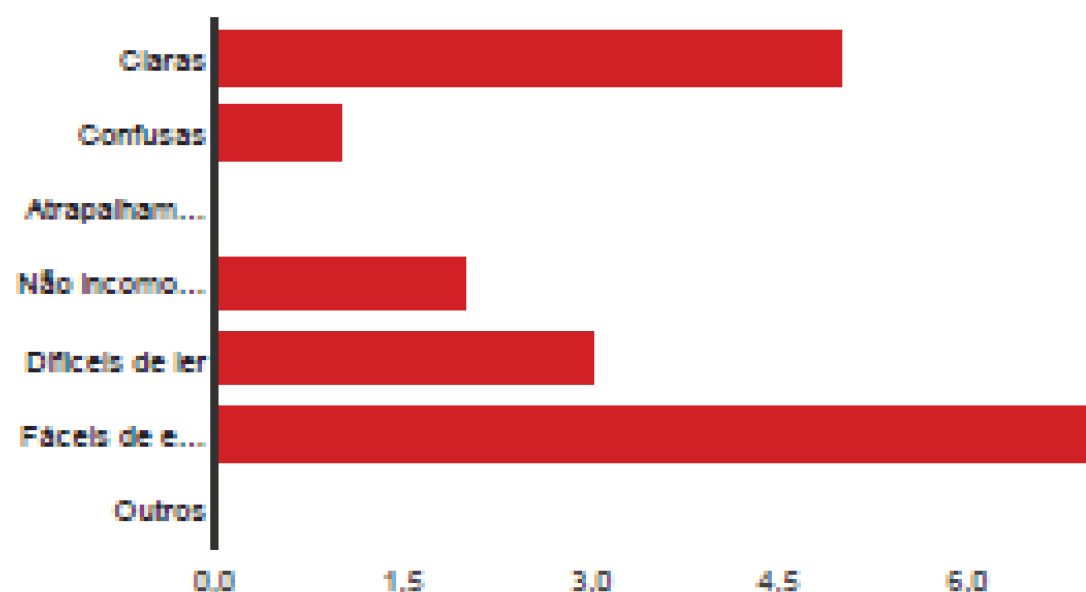


Grande demais	2	18.2%
Posição inconveniente	0	0%
Fácil de entender	5	45.5%
Fácil de clicar	5	45.5%
Fácil de usar	5	45.5%
Outros	0	0%

## Terceira tela - Captura de presenças/chamada

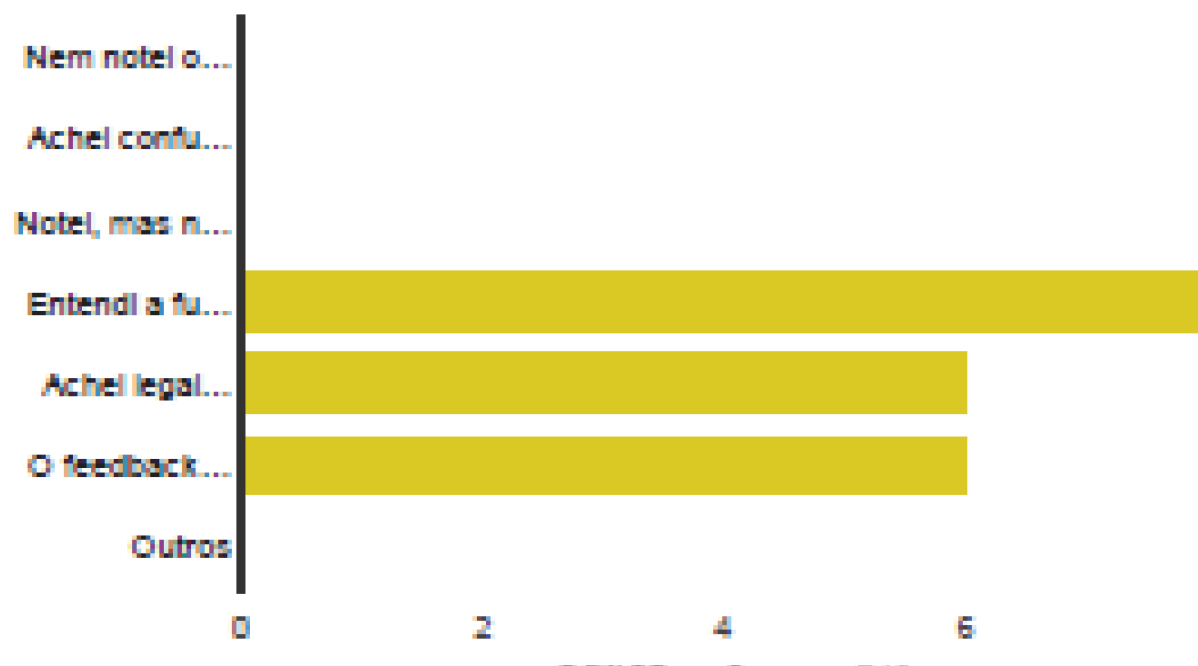
## Terceira tela - Captura de respostas

1- O que você achou das instruções na tela de captura de presença/respostas? "Filme a sala inteira [para registrar a presença] / Clique na tela quando terminar" (Marque todas as alternativas relevantes)

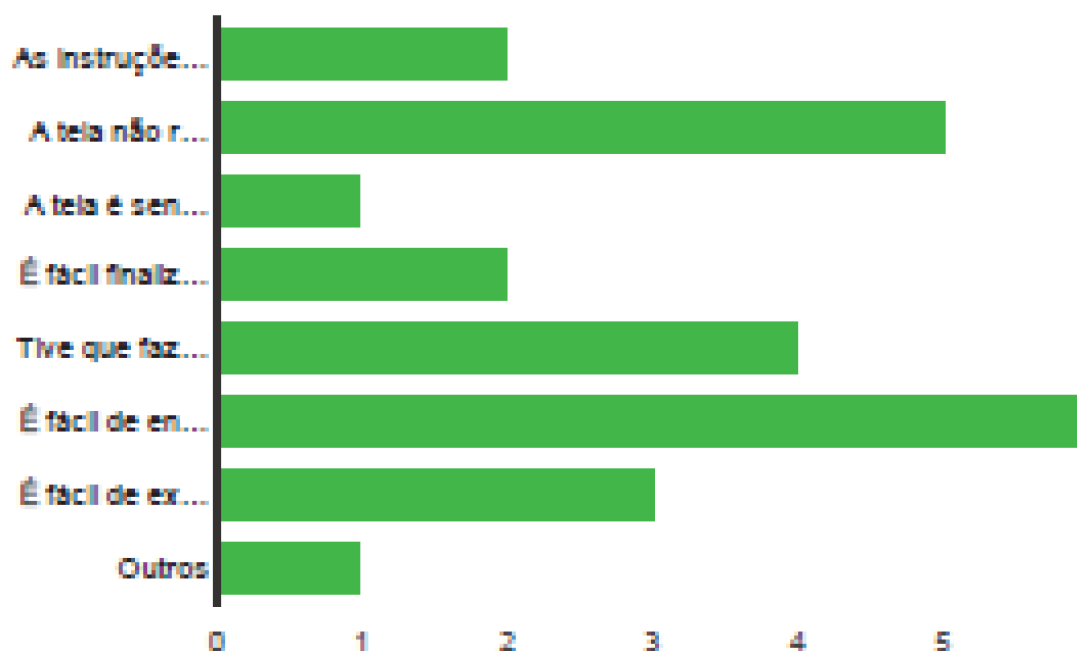


Claras	5	45.5%
Confusas	1	9.1%
Atrapalham a filmagem	0	0%
Não incomodam	2	18.2%
Difíceis de ler	3	27.3%
Fáceis de entender	7	63.6%
Outros	0	0%

2- Você percebeu que de vez em quando aparecem círculos nessas telas ? O que você achou ? (Marque todas as alternativas relevantes)



3- O que você achou da forma de finalizar a filmagem na tela de captura de presença/respostas (Marque todas as alternativas)

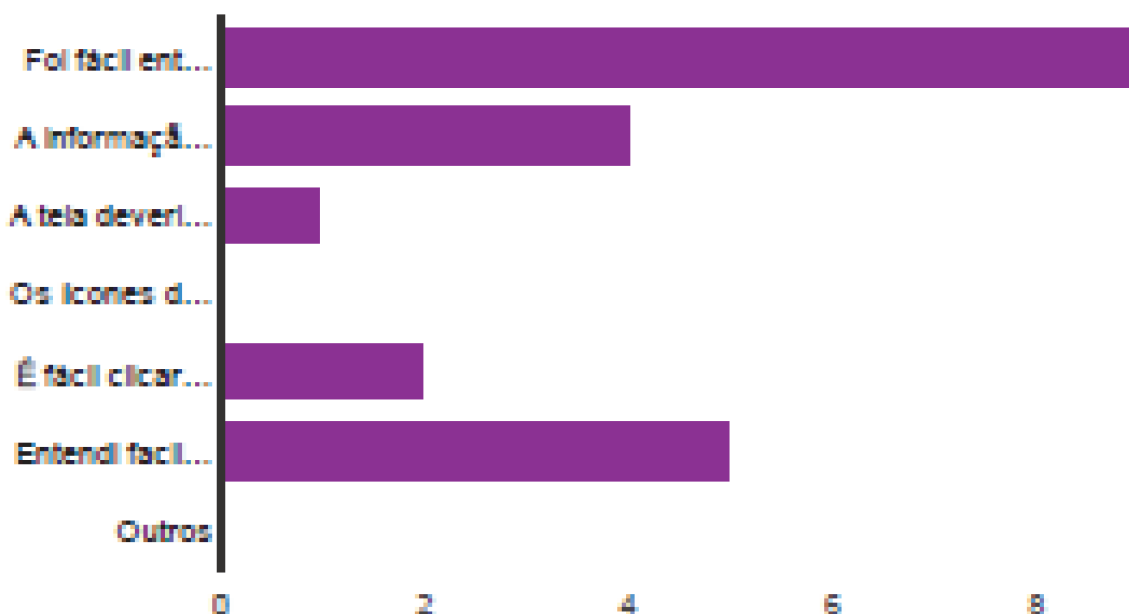


As instruções não são claras de como se termina a filmagem	2	18.2%
A tela não responde bem ao clique	5	45.5%
A tela é sensível demais ao clique	1	9.1%
É fácil finalizar por acidente	2	18.2%
Tive que fazer várias tentativas para finalizar	4	36.4%
É fácil de entender o que deve ser feito	6	54.5%
É fácil de executar a operação	3	27.3%
Outros	1	9.1%

## Página 4

### Quarta tela - tela de grade da presença

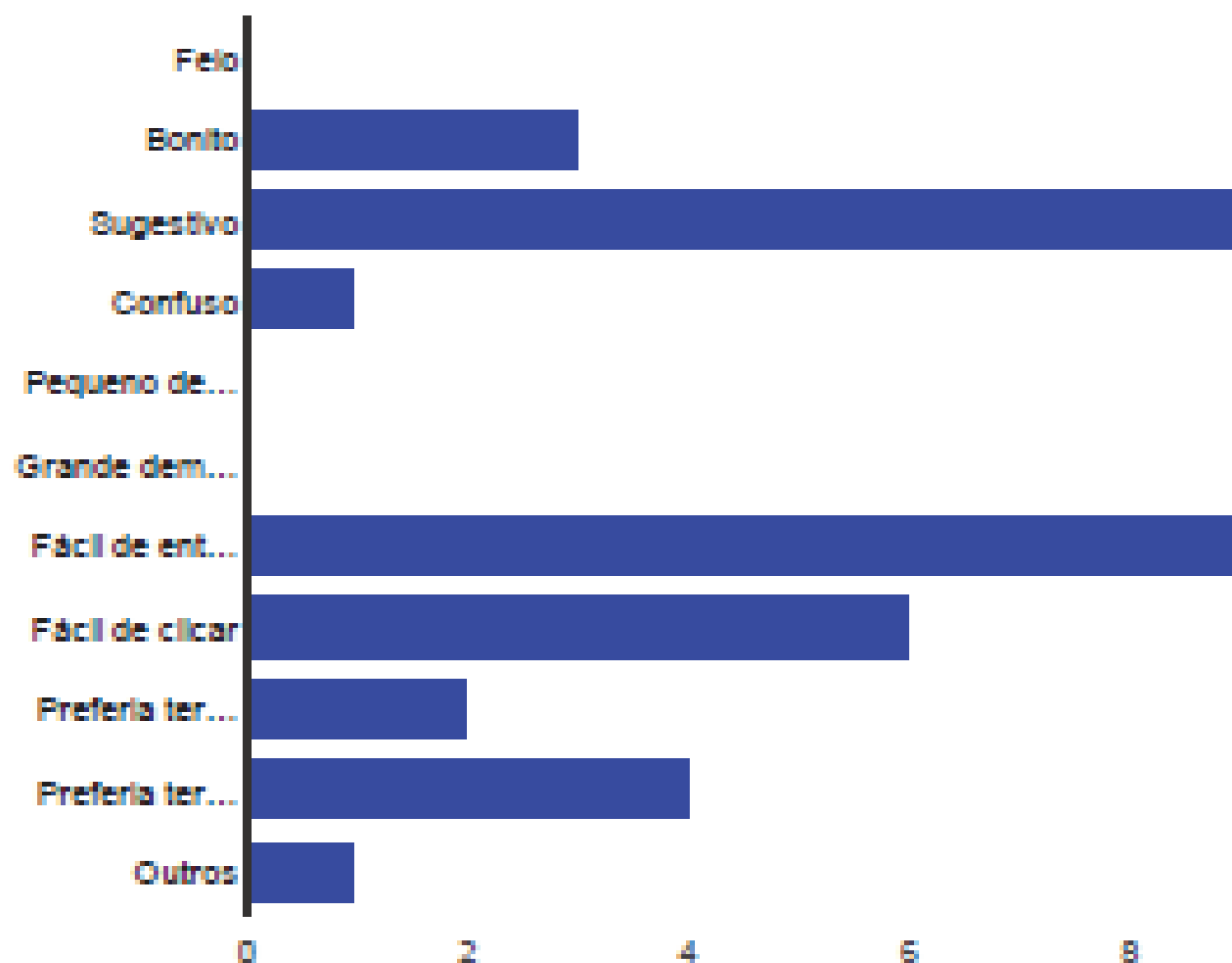
1- O que você achou da disposição dos resultados? (Marque todas as alternativas relevantes)



Foi fácil entender quem estava presente e quem estava ausente	9	81.8%
A informação é bem organizada	4	36.4%
A tela deveria conter mais alunos	1	9.1%
Os ícones deveriam ser maiores	0	0%
É fácil clicar por acidente nos ícones	2	18.2%
Entendi facilmente que os ícones podiam ser clicados	5	45.5%
Outros	0	0%

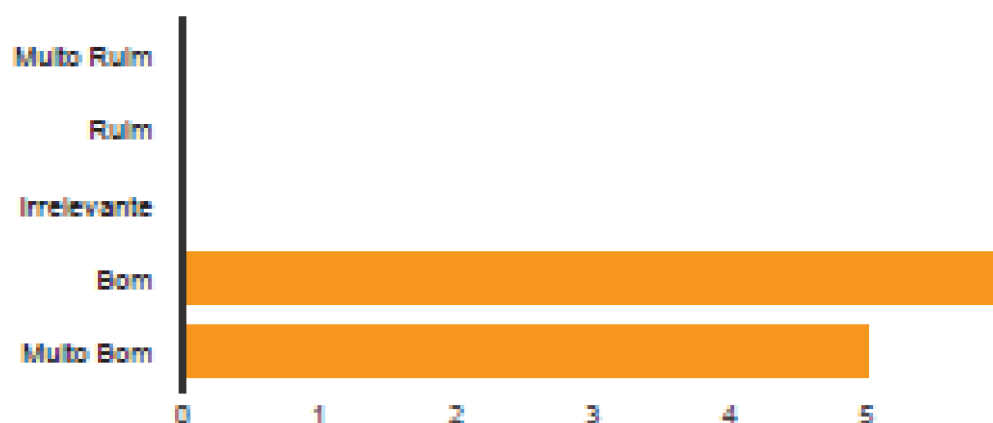
## Ícones para a pergunta 2

2 - O que você achou dos ícones de presente / ausente ? (Marque todas as alternativas relevantes)



Pequeno demais	0	0%
Grande demais	0	0%
Fácil de entender	9	81.8%
Fácil de clicar	6	54.5%
Preferia ter a foto dos alunos no lugar dos ícones	2	18.2%
Preferia ter o nome dos alunos no lugar dos números	4	36.4%
Outros	1	9.1%

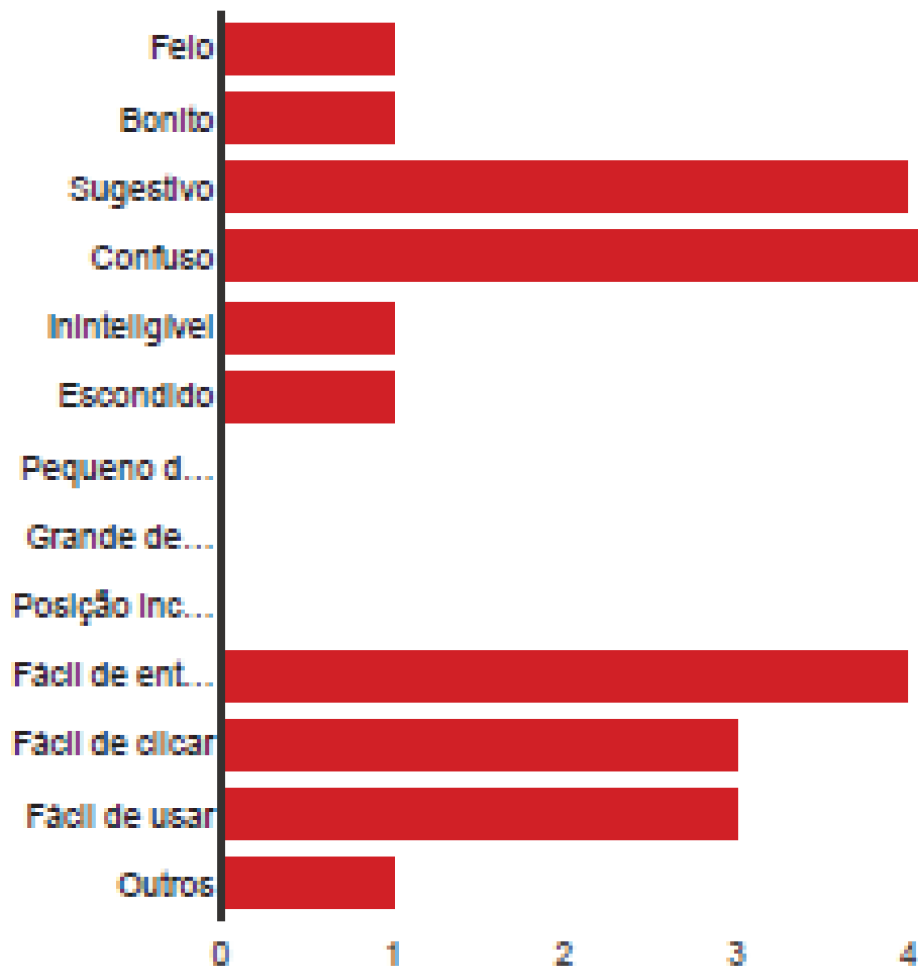
**Linha sem nome 1 [3- O que você achou da forma de alterar manualmente a presença dos alunos (ausente para presente, por exemplo)?]**



Muito Ruim	0	0%
Ruim	0	0%
Irrelevante	0	0%
Bom	6	54.5%
Muito Bom	5	45.5%

**A pergunta 4 se refere ao seguinte ícone**

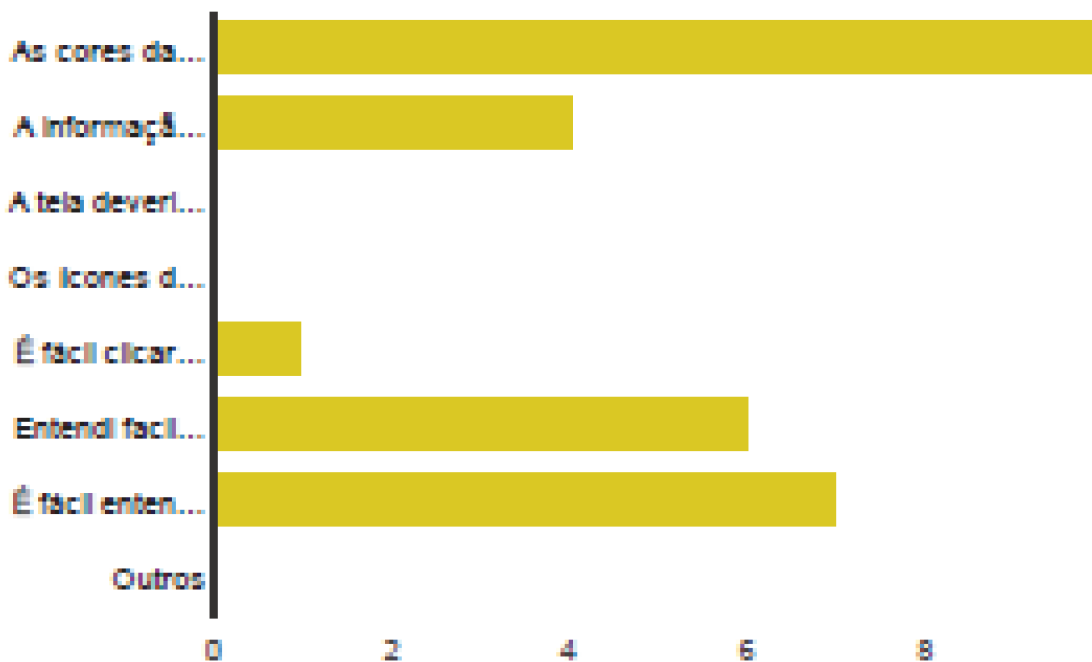
**4 - O que você achou do ícone ? (Marque todas as alternativas relevantes)**



Feio	1	9.1%
Bonito	1	9.1%
Sugestivo	4	36.4%
Confuso	5	45.5%
Ininteligível	1	9.1%
Escondido	1	9.1%
Pequeno demais	0	0%
Grande demais	0	0%
Posição inconveniente	0	0%
Fácil de entender	4	36.4%
Fácil de clicar	3	27.3%
Fácil de usar	3	27.3%
Outros	1	9.1%

## Quinta tela - grade das respostas dadas pelos alunos

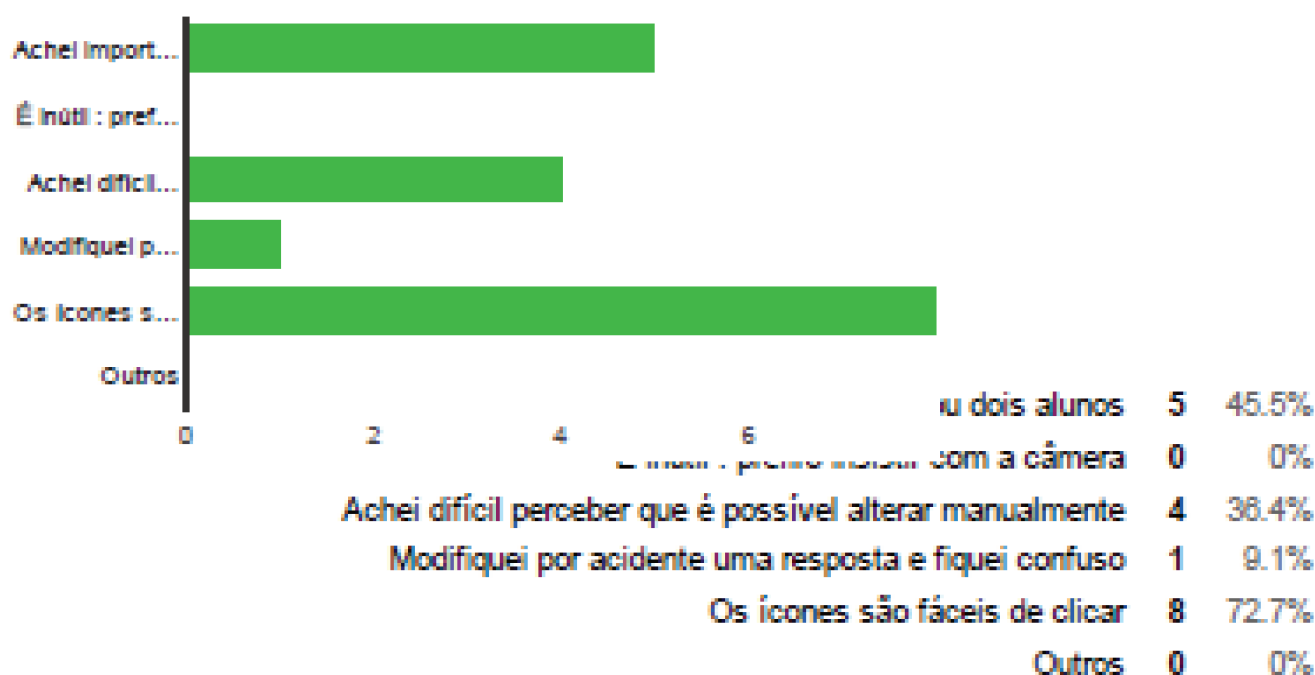
1- O que você achou da disposição dos resultados? (Marque todas as alternativas relevantes)



As cores das alternativas A, B, C e D são bem distintas	10	90.9%
A informação é bem organizada	4	36.4%
A tela deveria conter mais alunos	0	0%
Os ícones deveriam ser maiores	0	0%
É fácil clicar por acidente nos ícones	1	9.1%
Entendi facilmente que os ícones podiam ser clicados	6	54.5%
É fácil entender o que o ícone com o "x" significa	7	63.6%
Outros	0	0%

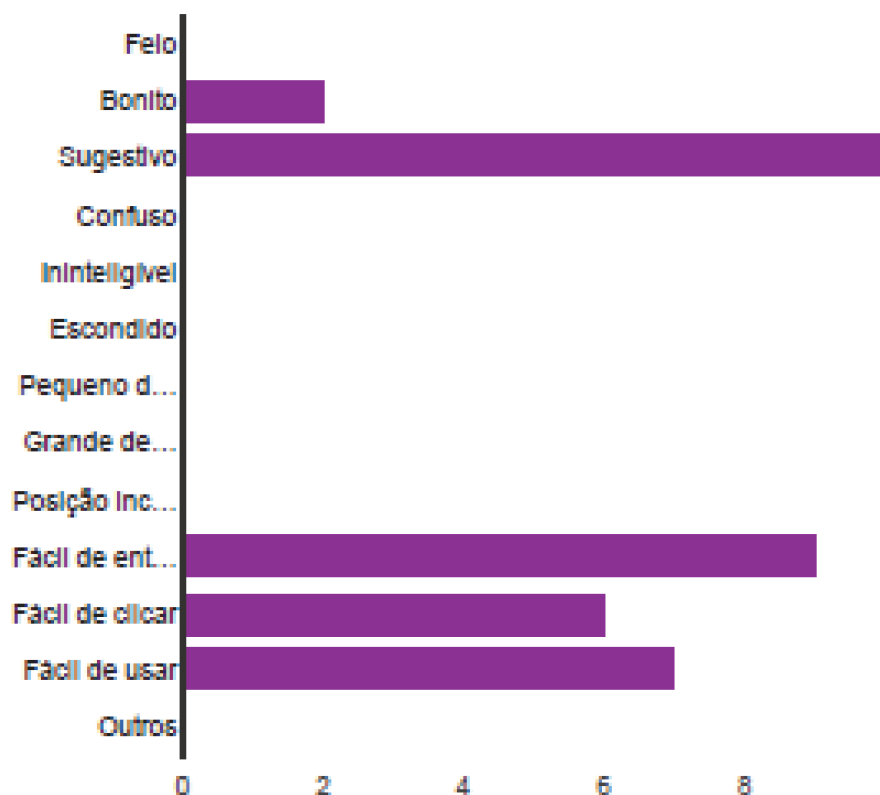


**2- O que você achou da forma de alterar a resposta dada por um aluno?  
(Marque todas as alternativas relevantes)**



**Pergunta 3 referente ao seguinte ícone**

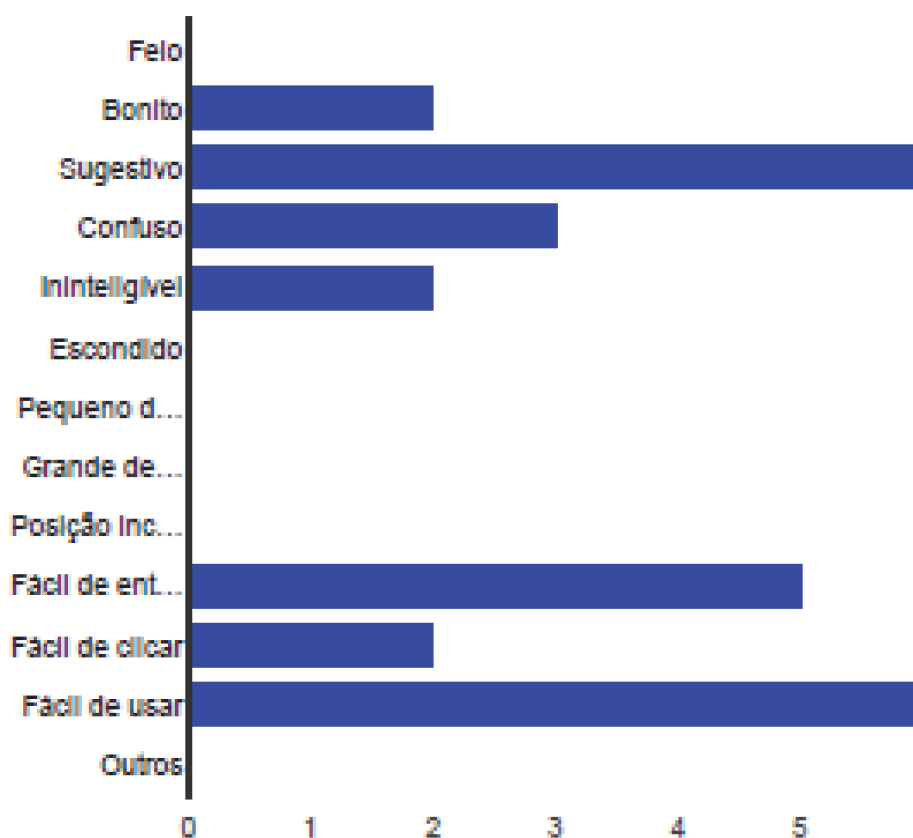
**3 - O que você achou do ícone? (Marque todas as alternativas relevantes)**



Feio	0	0%
Bonito	2	18.2%
Sugestivo	10	90.9%
Confuso	0	0%
Ininteligível	0	0%
Escondido	0	0%
Pequeno demais	0	0%
Grande demais	0	0%
Posição inconveniente	0	0%
Fácil de entender	9	81.8%
Fácil de clicar	6	54.5%
Fácil de usar	7	63.6%
Outros	0	0%

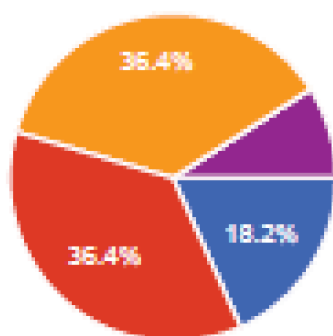
## Pergunta 4 referente ao seguinte ícone

4 - O que você achou do ícone? (Marque todas as alternativas relevantes)



Feio	0	0%
Bonito	2	18.2%
Sugestivo	6	54.5%
Confuso	3	27.3%
Ininteligível	2	18.2%
Escondido	0	0%
Grande demais	0	0%
Posição inconveniente	0	0%
Fácil de entender	5	45.5%
Fácil de clicar	2	18.2%
Fácil de usar	6	54.5%
Outros	0	0%

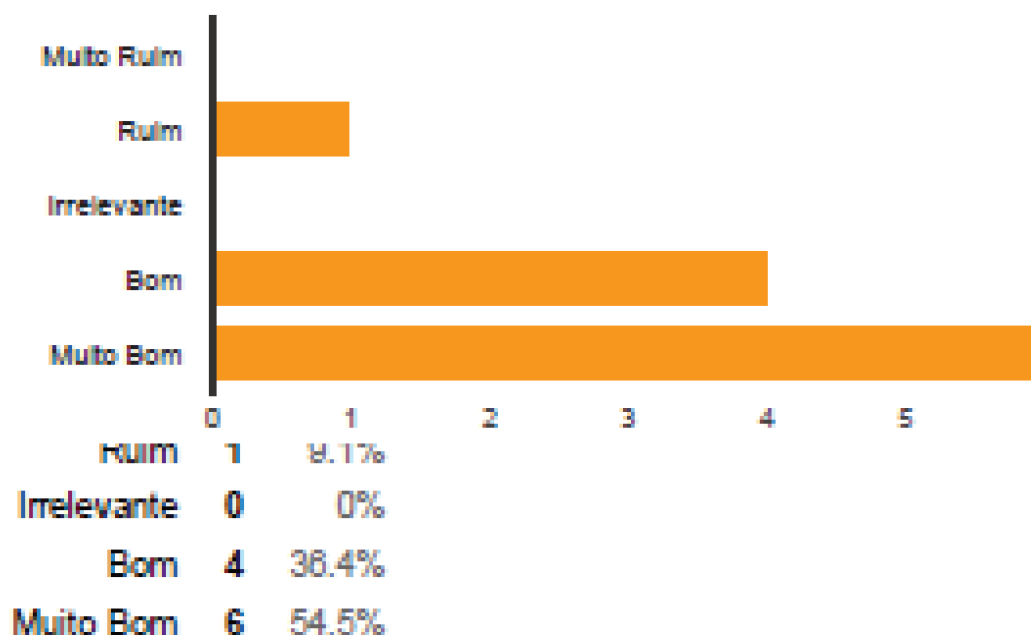
### 5 - Sobre o retorno para a tela de filmagem:



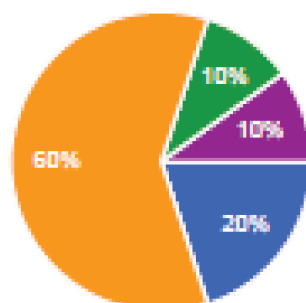
Não usei, não precisei filmar mais	2	18.2%
Não usei, não entendi que podia fazer isso	4	36.4%
Usei, e entendi que o processo recomeçava do zero	4	36.4%
Usei, e entendi que acrescentaria as respostas faltantes àquelas já reconhecidas	0	0%
Outros	1	9.1%

## Sexta tela - gráfico de resultados

### Linha sem nome 1 [1- O que você achou do gráfico?]

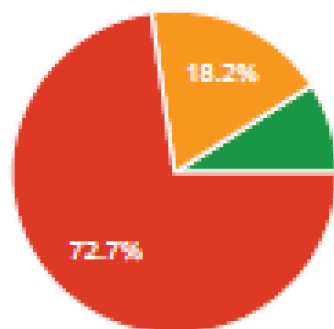


### 2 - O que você achou (no primeiro uso) que o botão "Tentar novamente" faria ?



Encerraria a questão e voltaria à tela de seleção de turma	2	20%
Encerraria a questão e voltaria à tela de seleção do número da questão	0	0%
Mantiveria a questão e voltaria à tela de filmagem das respostas	6	60%
Mantiveria a questão e voltaria à tela de grade de respostas	1	10%
Outros	1	10%

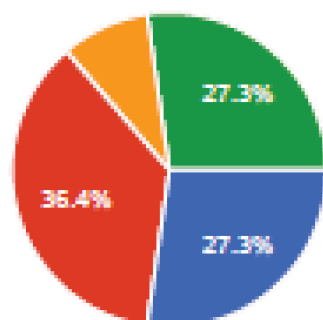
3 - O que você achou (no primeiro uso) que o botão "Nova pergunta" faria ?



Opção	Contagem	Porcentagem
Encerraria a questão e voltaria à tela de seleção de turma	0	0%
Encerraria a questão e voltaria à tela de seleção do número da questão	8	72.7%
Manteria a questão e voltaria à tela de filmagem das respostas	2	18.2%
Manteria a questão e voltaria à tela de grade de respostas	1	9.1%
Outros	0	0%

A pergunta 4 se refere ao seguinte ícone

4 - O que você achou que o ícone acima faria ?



Opção	Contagem	Porcentagem
Encerraria a questão e voltaria à tela de seleção de turma	3	27.3%
Encerraria a questão e voltaria à tela de seleção do número da questão	4	36.4%
Manteria a questão e voltaria à tela de filmagem das respostas	1	9.1%
Manteria a questão e voltaria à tela de grade de respostas	3	27.3%
Outros	0	0%



# Annex





COMITÊ DE ÉTICA EM  
PESQUISA DA UNICAMP -  
CAMPUS CAMPINAS



**PARECER CONSUBSTANCIADO DO CEP**

**DADOS DO PROJETO DE PESQUISA**

**Título da Pesquisa:** Captura de Dados para Avaliação de Usabilidade em Sistema de Resposta em Sala de Aula

**Pesquisador:** Jomara Mota Binda

**Área Temática:**

**Versão:** 2

**CAAE:** 43819315.5.0000.5404

**Instituição Proponente:** Faculdade de Engenharia Elétrica e de Computação

**Patrocinador Principal:** Financiamento Próprio

**DADOS DO PARECER**

**Número do Parecer:** 1.073.125

**Data da Relatoria:** 21/05/2015

**Apresentação do Projeto:**

Um importante fator de sucesso no ensino e aprendizagem é manter os alunos interessados e ativos durante a aula, participando e contribuindo com as suas respostas e opiniões.

Práticas pedagógicas ativas, como o peer instruction, são fáceis de implementar, se o instrutor tem uma forma rápida, não intrusiva e pessoal para obter as reações e respostas dos estudantes durante a aula [1].

Combinando o peer instruction com as tecnologias disponíveis teremos abordagens pedagógicas inovadoras que melhoram a relação professor-aluno em sala de aula, aumentando a interação entre eles.

Sistemas de resposta em Sala de Aula (em inglês Classroom Response System - CRS) já existem a mais de uma década, começando com o sistema Classtalk I. Frequentemente, CRS são implementados com clickers, pequenos controle-remotos que enviam o respostas dos alunos a um receptor via infravermelho ou rádio frequência, tornando-os disponíveis para o apresentador ou professor. Outras soluções aplicam o conceito de "traga seu próprio dispositivo" (em inglês Bring your own device - BYOD), onde os alunos trazem seus próprios dispositivos - smartphones, tablets, netbooks, notebooks - para a sala de aula, e o clicker físico é substituído por uma aplicação.

Este projeto estuda os sistemas de resposta em sala de aula acessíveis, explorando também uma

**Endereço:** Rua Tessália Vieira de Camargo, 126

**Bairro:** Barão Geraldo

**CEP:** 13.083-887

**UF:** SP

**Município:** CAMPINAS

**Telefone:** (19)3521-8936

**Fax:** (19)3521-7187

**E-mail:** cep@fcm.unicamp.br

# COMITÊ DE ÉTICA EM PESQUISA DA UNICAMP - CAMPUS CAMPINAS



Continuação do Parecer: 1.073.125

outra família de soluções que utilizam processamento de imagem para identificar as respostas dos estudantes captadas por uma câmera. O sistema baseia-se no reconhecimento de códigos de barras bidimensionais por um dispositivo de baixo custo.

Sistemas de resposta em sala de aula apoia o ensino ativo, fornecendo feedback em tempo real dos alunos. O ensino ativo é uma das ferramentas mais eficazes para melhorar a aprendizagem em todos os níveis: primário, secundário e superior, especialmente para conteúdo complexo, como Matemática e Física.

No entanto, o alto custo de implementação deste sistema impede sua maior adoção na educação pública, rural ou comunidades remotas. Este trabalho se justifica pela possibilidade de permitir a implementação de baixo custo do sistema de resposta em sala de aula, a fim de ampliar a sua adoção. Outra motivação importante é entender melhor os desafios tecnológicos no fornecimento dessa solução de baixo custo, além de prover uma ferramenta que poderá aumentar a interação aluno-professor em sala de aula.

## **Objetivo da Pesquisa:**

Objetivo Primário:

O objetivo geral do trabalho é entender melhor os desafios para o desenvolvimento de solução acessível de sistemas de resposta da audiência em sala de aula, incluindo os desafios tecnológicos e de interação do usuário.

Objetivo Secundário:

Os objetivos específicos do experimento são: Validação da interatividade com o aluno Validação da interatividade com o professor Avaliação da legibilidade da visualização de dados: respostas detalhadas Avaliação da legibilidade da visualização de dados: respostas sumarizadas.

## **Avaliação dos Riscos e Benefícios:**

Desconfortos e riscos:

Você não deve participar deste estudo se for menor de 18 anos de idade. Ressalta-se que a participação é voluntária e o interessado pode desistir sem prejuízos em qualquer momento sem necessidade de justificativa prévia. Em caso de desistência de um candidato, o candidato subsequente será chamado sem maiores prejuízos à pesquisa ou às partes envolvidas.

Durante a realização da pesquisa, poderá haver desconforto devido à timidez dos participantes durante a filmagem. Também ao final da pesquisa será entregue um questionário para o voluntário apresentar sua opinião sobre o projeto proposto, o que pode também causar desconforto ao voluntário de apresentar sua opinião franca. A pesquisa não envolve riscos previsíveis, visto que o participante será apenas filmado com um câmera digital comum, sem iluminação especial,

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**Bairro:** Barão Geraldo

**CEP:** 13.083-887

**UF:** SP

**Município:** CAMPINAS

**Telefone:** (19)3521-8936

**Fax:** (19)3521-7187

**E-mail:** cep@fcm.unicamp.br

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procedimento simples que não oferece risco ou dano à integridade física, psíquica, moral ou de outra natureza.

Os voluntários podem aceitar ou negar participar da filmagem. Os voluntários intimidados pela filmagem podem abandonar a pesquisa sem maiores constrangimentos, represálias, ou penalidade alguma. Durante a entrega do questionário explicaremos que a opinião do voluntário (positiva ou negativa) é importante para a pesquisa e será levada em consideração para melhoria dos resultados. O voluntário terá a opção de responder ao questionário de forma anônima.

#### Benefícios:

O participante não se beneficiará diretamente da participação nessa pesquisa, sendo essa participação totalmente altruísta. O benefício esperado da pesquisa se aplica à população de estudantes brasileiros. Não oferecemos nenhuma remuneração ou presentes.

#### Acompanhamento e assistência:

Todos os participantes serão esclarecidos antes, durante e após a realização da pesquisa. Os participantes poderão entrar em contato, a qualquer momento, com os pesquisadores responsáveis da pesquisa.

#### **Comentários e Considerações sobre a Pesquisa:**

Este protocolo se refere ao Projeto de Pesquisa intitulado “Captura de Dados para Avaliação de Usabilidade em Sistema de Resposta em Sala de Aula”, cuja Pesquisadora responsável é a Jomara Mota Bindá . A pesquisa foi enquadrada na Área Temática Ciências Exatas e da Terra e embasará a Dissertação de Mestrado da pesquisadora, A Instituição Proponente é a Faculdade de Engenharia Elétrica e Computação – FEEC. Segundo as Informações Básicas do Projeto, a pesquisa tem orçamento estimado em R\$ 50,00 (cinquenta reais), com financiamento próprio e o cronograma apresentado contempla início do estudo para 11 de maio de 2015, com término em 12 de maio de 2016. Serão abordados ao todo 30 alunos de graduação e pós-graduação da FEEC, maiores de 18 anos. Este projeto de pesquisa tende a colaborar na formação de uma base de dados visual da aplicação do design de interação, validando seu uso e aplicabilidade. Esses dados serão analisados para identificação de pontos de melhoria do design e mudança de parâmetros, adequando melhor a idéia a um cenário real de sala de aula. Também sera obtida uma base de dados com as respostas dos participantes ao questionário que será entregue ao final do procedimento, com as opiniões e sugestões dos voluntários referente ao procedimento.

#### **Considerações sobre os Termos de apresentação obrigatória:**

1) Folhas de Rosto adequada;

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2) Autorização da CPG da unidade para realização da pesquisa, condicionada a aprovação do CEP está adequada;

2) Projeto detalhado descreve procedimento para realização da pesquisa na unidade: "Os participantes serão filmados por uma câmera digital, pelo período que durar o procedimento, dentro de uma sala de aula da universidade, sem iluminação especial, fazendo uma simulação de participação de aula. Para que o procedimento seja feito de forma adequada, diminuindo ao máximo o desconforto e risco ao participante, o mesmo será instruído a seguir o roteiro apresentado e atenção durante o procedimento, seguindo as solicitações feitas como, por exemplo, mostrar a resposta para a pergunta feita pelo professor na hora certa. Para a filmagem da interação do participante com o aplicativo móvel, será fornecido o dispositivo de teste – smartphone, tablet, notebook – e será gravado sua interação, como: clique no botão, arraste de componentes. As filmagens dos participantes poderão ocorrer durante o dia ou à noite, conforme a disponibilidade dos participantes. Ao final do procedimento será entregue um questionário com perguntas. Recrutaremos apenas participantes que possam participar do experimento sem prejuízo às suas atividades primárias de ensino, pesquisa, ou outras. referente ao procedimento e o participante poderá contribuir com sua opinião franca, propor ideias, fazer críticas e/ou sugestões à pesquisa feita."

3) O cronograma está adequado conforme compromisso do pesquisador com a resolução 466/12 do CNS/MS, com a data de início da pesquisa posterior a aprovação do projeto pelo CEP, descrevendo as etapas de recrutamento, seleção de voluntários, preparação da sala de aula e execução dos experimentos.

Etapas de recrutamento

11/06/2015

24/06/2015

Seleção de voluntários

25/06/2015

30/06/2015

Preparação da sala de aula

01/07/2015

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02/07/2015

Execução dos experimentos

03/07/2015

31/07/2015

4) O TCLE está adequado, com esclarecimento sobre acompanhamento e assistência ao objeto de pesquisa, sigilo e privacidade e ressarcimento:

"Acompanhamento e assistência:

Todos os participantes serão esclarecidos antes, durante e após a realização da pesquisa. Os participantes poderão entrar em contato, a qualquer momento, com os pesquisadores responsáveis da pesquisa.

Sigilo e privacidade:

Você tem a garantia de que sua identidade será mantida em sigilo e nenhuma informação será dada a outras pessoas que não façam parte da equipe de pesquisadores. Na divulgação dos resultados deste estudo, seu nome não será citado e o vídeo com a imagem dos participantes não será divulgado. Você tem garantia de que seus dados capturados não sofrerão nenhuma manipulação que possa lhe causar eventuais constrangimentos ou danos morais e psíquicos. As imagens dos participantes serão armazenadas em dispositivos acessíveis apenas pelos pesquisadores envolvidos na pesquisa e serão destruídas após 24 meses da data da filmagem.

5) O texto como foi descrito no TCLE foi retificado para garantir a garante indenização por danos decorrentes da pesquisa, bem como estabelece o não ressarcimento de gastos relacionados à participação no estudo (passagem e uma refeição), sendo contrário ao disposto na Resolução CNS n.466/2012.

Ressarcimento:

Caso você incorra em despesas de transporte e alimentação para participar do experimento, comunique aos pesquisadores, pois você tem direito a um ressarcimento dessas despesas. Em caso de dano decorrente da pesquisa, está garantida a assistência integral e imediata, de forma gratuita, pelo tempo que for necessário. Você também tem direito a indenização em caso de danos.

6) Foi apresentado o Termo de Autorização de Imagem citado no projeto detalhado do

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pesquisador, dentro do TCLE:

Autorização para uso de imagem:

O participante autoriza a utilização de sua imagem apenas para o uso interno do grupo de pesquisa. A autorização é dada com o entendimento de que as imagens do participante filmadas durante o experimento serão destruídas 24 meses após a data filmagem."

**Conclusões ou Pendências e Lista de Inadequações:**

Todas as pendências listadas no parecer inicial foram atendidas, sem nenhuma observada.

**Situação do Parecer:**

Aprovado

**Necessita Apreciação da CONEP:**

Não

**Considerações Finais a critério do CEP:**

- O sujeito de pesquisa deve receber uma via do Termo de Consentimento Livre e Esclarecido, na íntegra, por ele assinado.
- O sujeito da pesquisa tem a liberdade de recusar-se a participar ou de retirar seu consentimento em qualquer fase da pesquisa, sem penalização alguma e sem prejuízo ao seu cuidado.
- O pesquisador deve desenvolver a pesquisa conforme delineada no protocolo aprovado. Se o pesquisador considerar a descontinuação do estudo, esta deve ser justificada e somente ser realizada após análise das razões da descontinuidade pelo CEP que o aprovou. O pesquisador deve aguardar o parecer do CEP quanto à descontinuação, exceto quando perceber risco ou dano não previsto ao sujeito participante ou quando constatar a superioridade de uma estratégia diagnóstica ou terapêutica oferecida a um dos grupos da pesquisa, isto é, somente em caso de necessidade de ação imediata com intuito de proteger os participantes.
- O CEP deve ser informado de todos os efeitos adversos ou fatos relevantes que alterem o curso normal do estudo. É papel do pesquisador assegurar medidas imediatas adequadas frente a evento adverso grave ocorrido (mesmo que tenha sido em outro centro) e enviar notificação ao CEP e à Agência Nacional de Vigilância Sanitária – ANVISA – junto com seu posicionamento.
- Eventuais modificações ou emendas ao protocolo devem ser apresentadas ao CEP de forma clara

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e sucinta, identificando a parte do protocolo a ser modificada e suas justificativas. Em caso de projetos do Grupo I ou II apresentados anteriormente à ANVISA, o pesquisador ou patrocinador deve enviá-las também à mesma, junto com o parecer aprovatório do CEP, para serem juntadas ao protocolo inicial.

- Relatórios parciais e final devem ser apresentados ao CEP, inicialmente seis meses após a data deste parecer de aprovação e ao término do estudo.

CAMPINAS, 21 de Maio de 2015

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**Assinado por:**  
**Renata Maria dos Santos Celeghini**  
**(Coordenador)**

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