

# Smart Learning Desk: Towards an Interactive Classroom

Francisco R. Ortega\*

Ruben Balcazar†

Naphtali D. Rishe‡

Armando Barreto §

Florida International University  
Miami, FL.

## ABSTRACT

The classroom needs to be upgraded. With many advances in Augmented Reality projects for education and with the explosion of more interactive input devices (touch, vision), we describe our position that smart desks should be part of the vision of the 21st century classroom. We introduce the Smart Learning Desk to showcase our position about smart desks in the classroom. We also describe two possible uses and a way forward into the near future.

**Index Terms:** H.5.1 [Multimedia Information Systems]: Augmented reality—Mixed Reality; H.5.2 [User Interfaces]: Input devices and strategies—Interaction Styles

## 1 INTRODUCTION

We have a personal belief that the introduction of many commodity input and output devices that provide more intuitive user interaction (e.g. touch), in itself, can provide a motivation for students in K-12 and universities to become interested in different STEM fields. We started giving different projects to senior students in Computer Science and Engineering with the hope that Human-Computer Interaction could provide an extra motivation. In this quest, we designed the Smart Learning Desk (SLD), which we believe can help to provide better education (in any subject) for K-12 and universities. We present in this paper the reason why smart desks are needed and provide information about our first prototype. At the end, we have been motivated to create more interactive and intuitive systems, following the dream of Weiser [19]: “The most profound technologies are those that disappear”.

We introduce the Smart Learning Desk as a proof-of-concept where we will expose our position that a desk is still needed in the classroom and that it does not compete with smaller and portable devices that provide an Augmented Reality (AR) experience. On the contrary, the SLD allows a student to experience AR in the classroom and when needed, some components can be taken to the outdoors to continue experiencing this new trend.

The average K-12 classroom has not changed much while technology has continued to advance. While some schools have been able to adapt some technology (e.g., tablet, smart boards), the statement by Spence is a very accurate picture of today’s education in K-12 and universities [16]: “Plop a medieval peasant down in a modern dairy farm and he would recognize nothing but the cows. A physician of the 13th century would run screaming from a modern operating room. Galileo could only gape and mutter touring NASA’s Johnson Space Center. Columbus would quake with terror in a nuclear sub. But a 15th-century teacher from the University of Paris would feel right at home in a Berkeley classroom.”

While the statement by Spence [16] is accurate in many respects, advances in technology for education are evident, in par-

ticular AR [11], but not pervasive in the classroom. The media of choice remains the white board, slides, and videos. It is true that efforts in a “flipped classroom” [18] have tried to use additional technology and sites like Coursera and Udacity have provided more interactive videos to help students. However, there still a long road ahead.

## 2 BACKGROUND

Interactive Tabletops have been researched [3, 8] and manufactured for quite a few years (e.g. zSpace and Microsoft Surface). In particular, the use of capacitive touch systems is pervasive in phones and tablets [9, Ch. 8]. Vision-based touch has also been successful but it has not become as pervasive as capacitive touch due to its additional requirements.

Some examples of tabletops include Han’s frustrated total internal reflection (FTIR) display [3]. Han demonstrated how to develop a tabletop using FTIR [3]. Weiss developed the interaction between horizontal and vertical display with an innovative display called BendDesk [20]. Other approaches for tabletop include diffused illumination (DI), diffused surface illumination (DSI) [17], and laser light plane (LLP) [10]. While vision-based systems require a more complex setup than capacitive touch they also provide additional benefits, such as tangible support. Furthermore, infrared vision-based system have become more compact as demonstrated by PQLabs G5<sup>1</sup> infrared thin layer for displays (with 4K touch fidelity). Of course, depending on the requirements, each setup provides its advantages over others. In addition, because of price and configuration, it is easier to integrate a non-stereoscopic tabletop. Nevertheless, 3D stereoscopic displays provide an immersive experience while adding problems such as selecting objects in midAir (see [9, Ch. 9]).

It is also important to look at previous work in the area of education using AR [11]. For example, Radu and MacIntyre [12] created an AR environment that allows pre-teens to create Scratch programs that utilize both real and virtual elements. The system aimed to provide information on children’s spatial cognition and interaction with AR via the works authored by the children themselves. Another example, by Radu et al. [13] was a study involving children creating AR games as a method of exploring the type of interactions children expect, intuitively understand, and find comfortable in terms of an AR system. The children were given a set of physical cards and were introduced to an AR environment that featured basic interactions with the cards. The children were then instructed to create a game that incorporated the interactions, the cards, and other assets such as images and craft materials to represent entities and actions in their AR game. The activity revealed that AR can be used to discover how children formulate knowledge and metaphors between physical and virtual action as well as how they map motion to ideas and concepts. Sin and Zaman provided an augmented book experience to teach the structure of the Sun [15]. Also, Lindgren and Moshell demonstrated that [6] a Mixed Reality (MR) environment enhances learning in children via body-based metaphors (physical interaction). The study suggests

\*e-mail: fortega@cs.fiu.edu

†e-mail:rbalc001@fiu.edu

‡e-mail:ndr@acm.org

§e-mail:barreto@fiu.edu

<sup>1</sup><http://multitouch.com/g5-series-touch-screen.html>

that paring physical motion with concepts (body-based metaphor) increases understanding and recall, which has been shown in other experiments conducted without technology (see [1] for a large set of examples and literature). In general, AR has shown that it can provide several advantages including real world annotation, contextual visualization, and vision-haptic visualization, among others [14].

### 3 WHY DO WE NEED A SMART LEARNING DESK?

Having portable devices that provide AR (or MR) experiences, do we still need desks in the classroom? It is our position that we do need a desk, but an interactive desk targeted for educational purposes and at an affordable price. The price will help schools to have a larger incentive to adopt the technology by using their own funds or in other cases, assisted by grants provided by different organizations (e.g., NSF<sup>2</sup> or Melinda and Bill Gates foundation). There are many instances in which the classroom requires the use of desks. This may include writing, reading, drawing, or working with tangibles. We believe that our proposed solution, SLD, will provide one way forward (among other methods).

We believe that classrooms (K-12 and universities) will remain having desks (either in the classical setup or rounded table for “flipped classes”) for the foreseeable future. In addition, there are multiple reasons why working on a display can provide multiple benefits to students. For example, the benefit of using touch and pen [4, 5] and the benefit of multi-modal interaction [2, 7] have been demonstrated. Additional advantages include the haptic feedback of the display, the use of tangibles, and a common interface that students are already used to (laptops, phones, tablets, etc.). This is not to say that portable and outdoor devices for augmented reality or in-class augmented reality should not be used. On the contrary, AR (and MR) systems have shown clear benefits. The Smart Learning Desk becomes a complement to existing (and new) AR applications.

We looked at different possible interactive desks developed in research labs or by industry. The one that called our attention was the BendDesk [20] (the HP Sprout provides a similar interface to a lesser extent than the BendDesk<sup>3</sup>.) It does provide a very intuitive system, however, the initial feedback by some of the instructors from a K-8 school was that the BendDesk in a classroom setting may block the instructor from viewing the students and vice-versa (but in a library setting it is ideal). We believe that a modified BendDesk may provide a solution for the classroom and this should be evaluated with other solutions.

We decided to create a few iterations of the SLD to be able to perform user studies and focus groups (with educators) to find an optimal solution. The cost is specially important when dealing with low-income neighborhoods or countries where the income per-capita is not at par with developed nations.

### 4 PROPOSED SMART LEARNING DESK

We proposed three types of smart desks, where the ideal target is \$2,500 US dollars for a prototype (SLD v1.0). However, the same prototype once sent for manufacturing in larger numbers could be reduced to half of the initial prototype cost. One important feature that we are proposing is that the research community (starting with us) may want to provide an easy know-how procedure for people wanting to integrate the desktops on their own. Additional features may be included, such as stereoscopic displays, augmented reality glasses, and other input devices. Ideally, the system should run at least in Microsoft Windows and Linux operating systems (the latter provides a lower cost of licenses). While at this point we are only working on SLD v1.0, we hope to have additional prototypes (or

Table 1: Prototype SLD v 1.0 for \$2,445 US Dollars

| Component                       | Price    |
|---------------------------------|----------|
| Projector Optoma GT1080         | \$699.99 |
| PlayStation Eye (4)             | \$99.96  |
| ACRYLITE LED (Endlighten T)     | \$107.43 |
| ACRYLITE LED (Resist Impact)    | \$32.53  |
| Carls Gray Rear Projection Film | \$69.95  |
| IR Flexible LED Strip           | \$35.38  |
| Desk with Motor System          | \$900.00 |
| Computer Small Form Factor      | \$400.00 |
| Leap Motion                     | \$49.00  |
| Intel Real-Sense front camera   | \$99.00  |

other researchers may want to take the initiative in creating some of the proposed versions). The following list provides a road map for the iterations needed to have a few systems to evaluate with K-12 schools and higher-learning institutions:

- SLD v1.0: This version includes a motor system to move the tabletop from a horizontal position to a vertical position, providing different positions in between. This system works with a projector, vision-based cameras, speakers, small form-factor computer, and additional input devices as needed (e.g., Leap Motion, Intel Real Sense camera for mid-air interaction). The system supports at a minimum: multi-touch, tangible objects.
- SLD v1.5: This provides a setup similar to version 1.0 but it is circular with a radius between 6 to 8 feet (recommended for “flipped classrooms”). Another major difference is that it is always in a horizontal position.
- SLD v2.0: Similar to version 1.0 but it removes the need for projector and vision-based cameras, in favor for a PQ-Labs G5 (or G4 depending on cost) multi-touch system. In addition, it adds a vision-based camera for tangible objects.
- SLD v 3.0: This version should be similar to the BendDesk but provide a retractable system for part of the display, to ensure easy integration between students and instructors.
- SLD 3D: This version will provide Stereoscopic vision, using either of the form-factors mentioned before.

#### 4.1 Smart Learning Desk v 1.0

Our current version of the Smart Learning Desk has been developed with the feedback of instructors from a K-8 school (Conchita Espinosa Academy), the integration by four undergraduate students (three computer engineering and one electrical engineering students), and the design and implementation by the authors of this paper. The first prototype cost below \$2,500 dollars, with the custom desk being the most expensive part, as shown in Table 1. Future versions will come down in price significantly. This version of the SLD will provide an adjustable display from the horizontal position (0°) to an inclination of 45°. The system includes pen and multi-touch (using infrared strips) interaction, tangible object support, and additional add-ons including Leap Motion and Intel Real-Sense front camera for additional mid-Air interaction.

The original design started with the desk having a box with the components that will move with the display (actual moving mechanism not shown). The components will go inside of the box, which will include cameras for multi-touch and tangibles (system can work with only one camera if needed), as shown in Figure 1. The actual measurements of the box are shown in Figure 2. The box allows all this moving parts to move with the display; nevertheless, in the next iteration we will be integrating a display with

<sup>2</sup>In particular, the ITEST program from NSF.

<sup>3</sup><http://www.pcmag.com/article2/0,2817,2471169,00.asp>

PQLabs infrared layer (or similar component), in order to have an additional prototype with less moving parts. A capacitive display, which is pervasive, was not chosen because of the extra information that the vision-based system provides, but it is an option that may be considered in future versions.

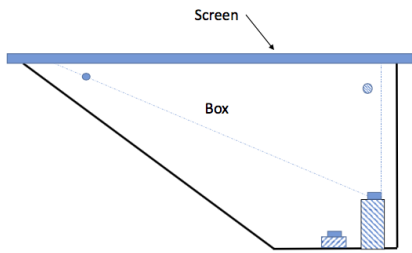


Figure 1: Illustration of SLD: Box View with Components

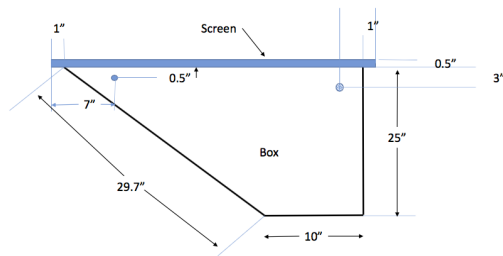


Figure 2: Illustration of SLD: Box View

Once we decided on the design, the question was how to move the display and its components to a different position from the horizontal one. Air pistons were considered because of the price but we wanted to have more control in the desired degree position of the display, allowing the user to set it anywhere between  $0^\circ$  to  $45^\circ$ . Therefore, we decided to use motors to move the display. Finally, the front view and top view are shown in Figures 3 and 4, respectively.

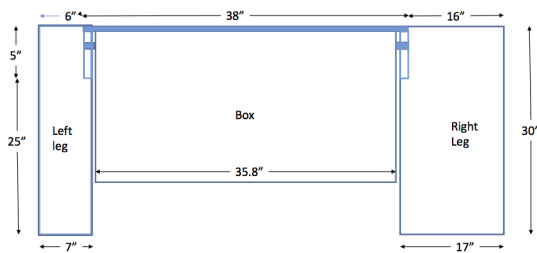


Figure 3: Illustration of SLD: Front View

## 4.2 Smart Learning Applications

Our initial applications include one for K-8 and one for a multi-disciplinary course at Florida International University (FIU) design for people in Architecture, Civil Engineering, and Construction Management.

The first application, is a simple interactive painting utility (called Interactive Paint) that allows students to create multiple figures and shapes (using tangible objects as well) with touch, pen,

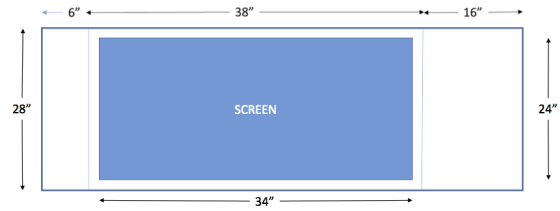


Figure 4: Illustration of SLD: Top View

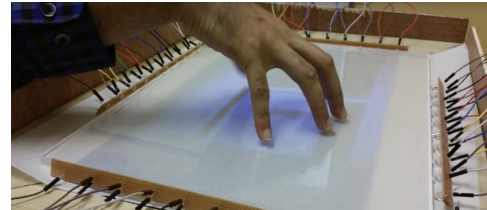


Figure 5: Testing Glass and LED for SLD v 1.0

midAir interaction (leap motion and Intel Real-Sense front camera), and eye gaze tracking (Tobii EyeX). The objective is to have a fun application that kids from all ages can use. The initial prototype version (developed using C++ and LibCinder) of this application is shown in Figure 6. It is important to note that the application will allow more complex drawings using hand, body, and eye movements exclusively through modern input devices. Finally, AR can provide additional information for this application, such as showing additional colors, objects, and shapes, among others.



Figure 6: Interactive Paint

The second application will complement an existing effort led by Professor Shahin Vassigh of the College of Architecture and the Arts (CARTA), that will allow students to visualize super-imposed structures in top of real buildings. As if having interactive x-ray vision, students move around the building and view through the building material, looking at various components such as the façade system, structure, foundation, mechanical systems, etc. Student teams gather critical information on the building by combining pictures of the actual building and the screen captures of their handheld device. The information is then used to complete interdisciplinary team assignments. This provides a complete experience in the classroom, using SLD, students observed lessons and play with the models to later visit the structures *insitu*. While this application is still in development, a mock-up is shown in Figure 7. One of the more interesting parts about this project collaboration is that the class is composed from students from three different majors (with different technical background), which includes Architecture, Mechanical Engineering, and Construction Management. The combination



Figure 7: Mock-up: Super Imposed Structures

of the outdoor experience plus the classroom experience will be evaluated with standard lecturing. We believe that the result, based on previous AR benefits shown in the classroom will also provide benefit to this particular set of students.

## 5 POSITION SUMMARY AND QUESTIONS

Our position is that the Smart Learning Desk and similar approaches in the classroom are key to a better educational experience. We have supported our position with our SLD prototype and ideas, as well as literature configuring certain key points. The following questions could start a healthy debate in terms of what is needed for the classroom in relation to smart desks: (1) The BendDesk [20] provides a very interesting workstation for studying. How would you approach the problem that the instructor may be blocked in a regular classroom? (2) Do you think desks are still needed in the classroom? (3) What would be your ideal class configuration?

## 6 CONCLUSION

We presented the Smart Learning Desk v1.0 and its initial applications to demonstrate that the classroom requires a desk, but a smart one. We hope the paper has provided enough motivation to other researchers to take the challenge to continue pushing the envelope in smart desk systems and AR applications. The desk is not going away from the classroom but the class may leave the room from time to time or may use AR applications while utilizing the desk. Our future work will include the design of the following prototypes and evaluation with instructors and systems. We have found an additional school (W.R. Thomas public middle school) to have an additional set of subjects for our evaluations.

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