Process Pad: a Multimedia Multi-touch Learning Platform

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ABSTRACT
This paper introduces Process Pad, an interactive, low-cost multi-touch tabletop platform designed to capture students' thought process and facilitate their explanations. The goal of Process Pad is to elicit students' think-aloud narratives that would otherwise be tacit, in other words, "learn to explain," and "explain to learn." Our focus is on identifying and understanding key design factors in creating opportunities for students to externalize and represent their mental models using multimodal data. From our user observations, we gleaned four design principles as essential criteria based upon which we refined our design: flexibility, tangibility, collaboration and affordability.

ACM Classification: H5.2 [Information interfaces and presentation]: User Interfaces. - Graphical user interfaces.

General terms: Design

Keywords Tangible User Interfaces, embodied and embedded learning, design rationale, self-explanation, scaffolding.

INTRODUCTION

This paper introduces Process Pad, an interactive, low-cost multi-touch tabletop platform designed to capture students' thought process and facilitate their explanations. Process Pad is designed based on the assumption that much of students' sense-making process in classroom activities remains invisible for educators and researchers. Constructivists believe that students construct knowledge by adapting their schema when they are exposed to new information through their experiences in the world [1, 5]. Thus, learning does not simply occur through knowledge transmission from the educator to students. Instead, it occurs when students themselves are in charge of building their own knowledge by interacting with the world, departing from existing models and schemata towards more sophisticated understanding [2, 3, 4]. Process Pad is designed to provide a scaffolded environment, which facilitates students' knowledge construction process through enabling multimodal, trackable, detailed explanations of students' sense-making process. By using Process Pad students are able to verbally and visually explain different phenomena, as well as view model explanations provided by peers or educators. This allows Process Pad to aid a child's knowledge construction instead of only providing instant feedback of whether her answer is right or wrong. It also provides users with opportunities to enhance students' metacognitive skills at their own pace, and acknowledging unique learning styles. Finally, it does not limit students to a single medium and enables for multiple entry points into learning [6]. We tried to explore how to leverage the combination of the physical and digital worlds to give students well-structured environments to practice their explanation skills.

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Design Principles

Process Pad is designed to help students improve their sense-making skills and meta-cognition in many different areas, such as explaining a math problem, outlining a story, solving a physics problem, or describing the parts of the cell. In building the system, we tried to follow four main perspectives:

- Flexibility: Process Pad is designed to be an open generic platform onto which researchers and educators can build and customize activities, aimed at externalizing learners' thought process, in any discipline, and easily add to the activity library.
- Tangibility: Process Pad can be used with *common classroom objects* – worksheets, papers, and other manipulatives. Teachers can add activities in a digital format to the library, but also just bring the worksheet they are using every day in the class. Tangibility and use of familiar objects is an aspect that significantly differentiates Process Pad from other digital tools, such as tablets or smart phones.
- Collaboration: The system is designed to encourage both individual and group work. We chose to use multi-touch technology with sizeable surface space so that multiple users can be on Process Pad simultaneously. Furthermore, it supports asynchronous collaboration, and teachers or peers can review the recorded and saved sessions.
- Affordability: As a principle, the hardware is built using low-cost materials and do-it-yourself (DIY) technologies. The software is developed based on open-source, free resources. The price of hardware including the price of a short throw projector is about sixteen hundred dollars. However, Process Pad is fully functional using conven-

tional projector and implementing a mirror under the table, in which case the price drops to less than five hundred dollars. Both prices can be considered reasonable in comparison with the price of similar product, Microsoft surface, which is between seven to ten thousands dollars.

Technology

Process Pad is a multimedia, multi-touch platform where students can place a piece of paper and other tangible articles on the surface and mark them with digital "dots" by just using their fingers. These "dots" may include audio, image and video recordings. The way we implemented the finger touch surface, considering cost-minimization issues, was by using Frustrated Total Internal Reflection (FTIR) technique [7]. In this method, a grid of infrared (IR) lights is generated from IR LEDs. When users put their fingers on the surface, the grid of IR lights would be interrupted and the IR camera would detect the disturbance. Then the software would analyze the signal from the camera. With this mechanism, there is no theoretical limit on the simultaneous touches on the surface that can be captured by the system allowing for many students to work on it at the same time.

The main components of the hardware are: a strip of IR LEDs, silicon-treated surface, short-throw projector, low-cost DIY infrared camera, transparent acrylic sheet, and custom-made frame. The software for Process Pad takes advantage of hardware's multi-touch ability by using the Multi-touch for Java (MT4J) library and the Community Core Vision (CCV) software. CCV bridges the visual signals from the hardware to the Java program; it receives outputs from the IR camera and sends them as inputs to the main program. According to these inputs the program supports the following actions:

- User can leave "dots": Users place a "dot" on the surface by touch-and-hold, and then create an audio, picture, or video recordings which are associated with the physical location spot on the surface.
- Users can load scaffolding activities: Instructors or designers can load activities to scaffold students' learning; these activities can be in several subjects and with different objectives. An activity could be about practicing a particular skill or could be designed to help students improve explaining and externalizing their thought process.
- User Login: Users are required to login so that saved work can be associated with the individual users for documentation, asynchronous review, and research.
- Customizable Menus: Menus are customizable in sizes, layout and orientation so that they can be accessed from any side of table.
- Different Modes: Two modes have been defined for the system, explanation mode and drawing mode. In an explanation mode, the surface is sensitive to touches and each touch fires a correspondent action. In the drawing mode, however, surface does not respond to touches except on the menus, thus students can easily draw and write without accidently triggering the system.
- Simple Gestures: The software uses intuitive multi-touch gestures to interact with the "dots" and menus on the multi-touch surface, such as drag, pinch, swipe, turn, and zoom.

User study

We tested the initial prototypes of Process Pad with three groups of students. The aim of these studies was to observe its use and collect insights for further improvements. The main purpose was to explore how our design decisions impacted users' interactions. Our studies were with 2nd graders, a 3rd grader and a 5th grade student. We also had some early unstructured tests with children as young as 4 years old, as well as graduate students.

The result of those studies showed that the user interface and interaction modes we easily manipulated by students, and that most of the students could intuitively navigate within the system with little instruction. Such studies are being expanded and systematized to inform the next iteration of Process Pad.

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