Smörgåsbords for Physical Computing

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ABSTRACT

Physical computing concerns the design of systems that can sense and respond to the world around them, which is why it is often used in interaction design projects in educational settings. However, students who encounter physical computing for the first time are typically not aware of the form factors and the potential for interaction of the various sensing and actuating possibilities. To complement existing touchpoints that these students have with physical computing, we present electronic smörgåsbords: boards that display collections of physical computing components that are available in-house in an organised and interactive way to support the initiation of interaction design projects. The development of the boards allowed us to articulate four principles for their design, which are intended to inspire the development of future educational material.

Authors Keywords

Physical Computing; Interaction Design; Educational Material.

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CSS Concepts

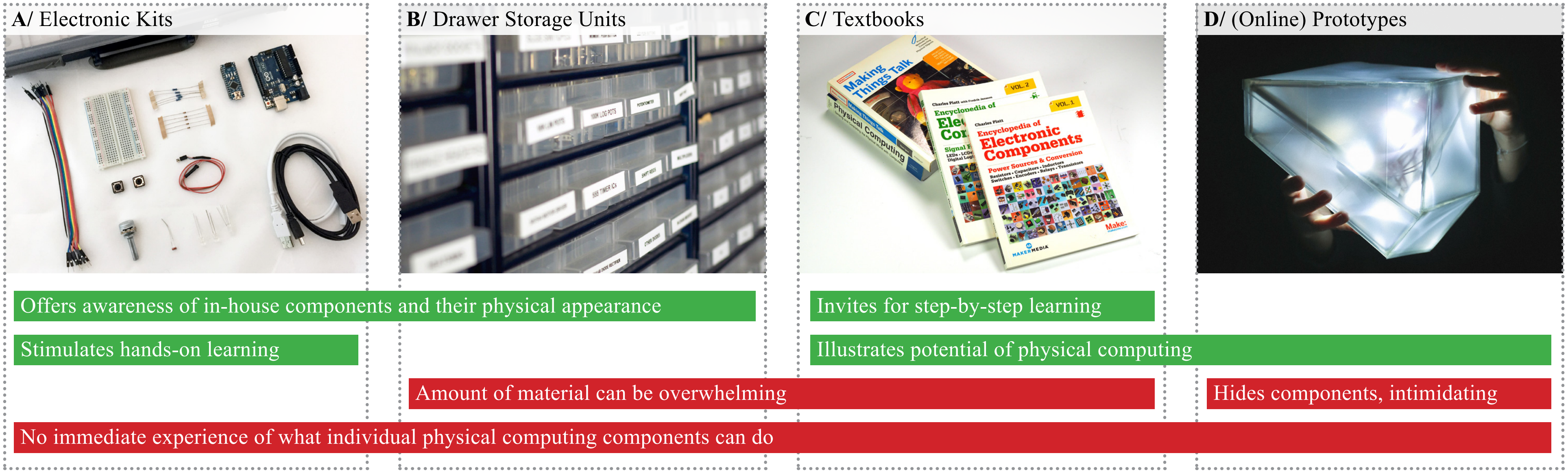
- Human-centered computing~Human computer interaction (HCI)

INTRODUCTION

Physical computing is a term used to describe the making of interactive systems that consider physical expression in addition to digital information. It is typically regarded as the design of input and output in human-computer interaction that goes beyond the keyboard, the mouse and the screen [1,2]. The practice of physical computing has increased in popularity since the introduction of microcomputers such as Arduino (since 2004) or Raspberry Pi (since 2012), and the possibility to combine these with rapid prototyping techniques such as laser cutting and 3d printing.

Physical computing has a large practice base in what could be termed inventive leisure practices [5], such as DIY, maker, crafts or tinkering communities. Physical computing is also often included in educational programs in interaction design, albeit not necessarily by this name [8,9]. A physical computing approach invites students to think about how humans can interact with computers through physical expression. It stimulates experiential learning [7], as working with microcomputers affords hands-on experience with sensing input, actuating output, and shaping relations between the two. It thus requires to design the temporal relation between what is being sensed and what is being actuated. As these temporal form elements distinguish interaction design from other forms of design [6], there is merit in bringing the practice of physical computing into this educational domain.

However, through years of teaching physical computing in the context of an interaction design education, we have observed that first encounters with existing learning materials could be complemented. We will start by presenting our analysis of existing learning materials to identify what they offer newcomers, and what they lack. We will then zoom in on electronic components that are available in our learning environment for physical computing projects, and present how this closer look at the design materials of physical computing initiated the development of a collection of electronic smörgåsbords. These boards display collections of physical computing components that are available in-house in an organised and interactive way to support the initiation of interaction design projects. We illustrate the practical value of the boards through a scenario of use, and articulate design principles to inspire the development of future educational material alike.



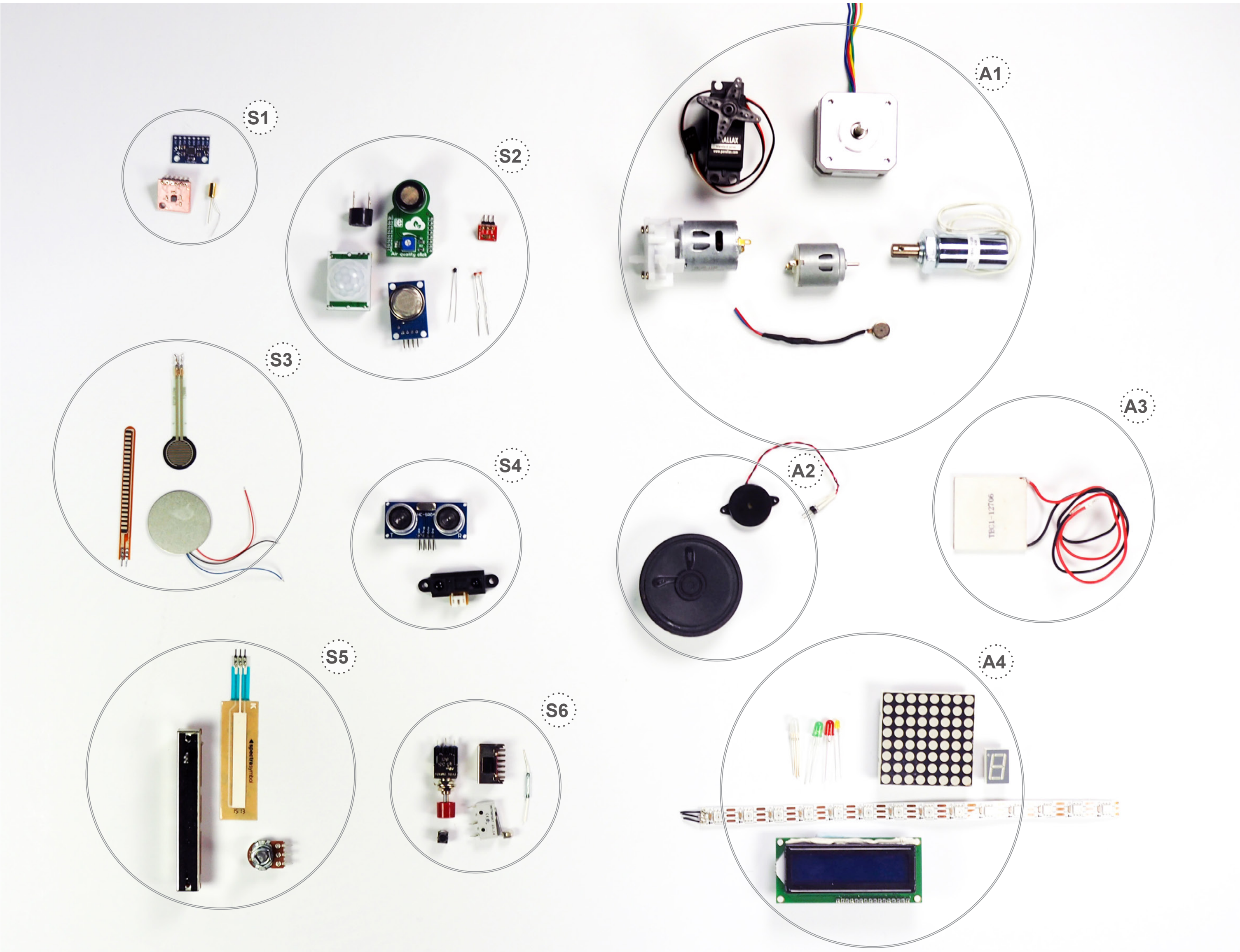
FIRST ENCOUNTERS WITH PHYSICAL COMPUTING

In our learning environment, students develop their physical computing skills in-class, through organized exercises, and through self-directed or project based learning. In particular for the latter, the following four materials typically shape the first encounters students have with physical computing: (**A**) electronic kits that contain a selection of basic components, (**B**) drawer storage units in electronics labs (**C**) textbooks and online resources alike that provide background, tutorials, instructions, and exercises, and (**D**) local or online outcomes of physical computing projects, where physical computing components are often embedded in rapid prototyped designs.

As a collection of learning material, they offer an awareness of available components and their appearance (**A**,**B**), stimulate hands-on experiential learning (**A**), invite for step-by-step learning (**C**), and inspire reflection on the potential of physical computing (**C**,**D**). However, they also hide components (**D**), while as a collection of material they can be overwhelming (**B**,**C**), or their application can be intimidating (**D**) for students. Further, none of these materials provides an immediate experience of what individual physical computing components can do (**A**,**B**,**C**,**D**).

There are various solutions available outside our learning environment that can overcome these or some of these issues. Examples are IdemoBits [10], Duinokit [11], Littlebits [12], MakerWear [13] or Wearable Bits [14] that afford an immediate experience with individual components. However, these learning materials tend to include components that are not available or supportable in-house, and can also be relatively expensive. This observation opened up a space for complementary educational material that offers a direct, graspable and meaningful experience of available in-house physical computing components. Such material would follow the dogma from the canonical textbook on physical computing, Making Things Talk: “It starts with the stuff you touch. [...] Physical objects will move, light up, or make noise. The first question to ask about any of them is: what does it do?” [2, p18].

To get an overview of physical computing components that are available in our current learning environment, we organized them according to sensing and actuating possibilities. Sensors and actuators often inspire interaction design projects and invite interaction designers to think in temporal relations between them. We organized them spatially to get a visual sense for their variety, and clustered them into appropriate categories for interaction design. We deliberately focussed on available and supportable components, because student design projects tend to be an in-situ structuring of design materials that are at hand [c.f. 4]. That is, imagination and acting upon imagination is constrained by local boundary conditions. Even though ‘out of reach’ components can and should inspire design projects, we prioritize the possibility to act upon inspiration and stimulate hands-on continuation of first encounters with physical computing.



ORGANIZING COMPONENTS

In-house electronic components that are used for physical computing can be organized into sensors and actuators, and grouped into meaningful categories for interaction design. Sensors can be grouped according to changes in the environment. Actuators can be grouped according to output modality.

Sensors

S1/ Movement: acceleration, tilt, direction

S2/ Environment: light, temperature, gas, motion

S3/ Flex & Force: bend, pressure, vibration

S4/ Distance

S5/ Passives: rotation, linear disposition

S6/ Switches: push, press, toggle, magnetic

Actuators

A1/ Tactition: motors, solenoid, air pump

A2/ Audition: speaker, buzzer

A3/ Thermoception: thermoelectric cooler

A4/ Vision: screen, dot-matrix, lightstrip, point lights

ELECTRONIC SMÖRGÅSBORDS

Visually organizing the physical computing components reminded us of a Swedish smörgåsbord - a collection of celebratory dishes of various foods served buffet-style on a table, where guests serve themselves from the possibilities laid out for their choice.

Inspired by the offering of a variety of possibilities that can be physically explored and experienced independently, we initiated the design of 'boards' to display our collection of physical computing components. One board would offer a 'buffet' of sensors (a SensorBoard), and another would offer a 'buffet' of actuators (an ActuatorBoard). To give prominence to a component's form factors and related components, we explored how we could stage the them using the previously identified groupings.

Based on our analysis and organization of components, four design principles for presenting the components emerged.

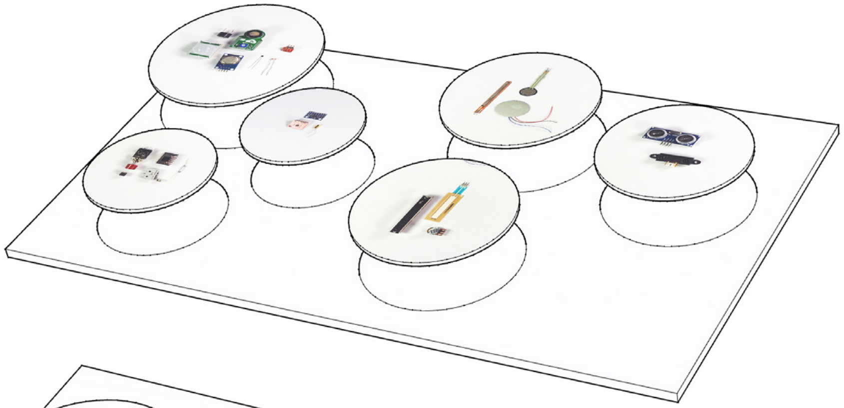
DESIGN PRINCIPLES

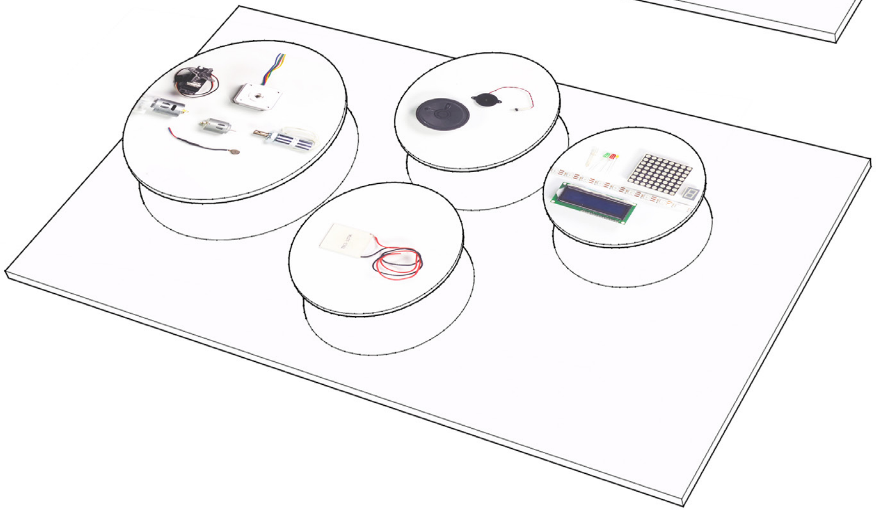
Principle 1: Demystify Function, Form and Feel
Instantly experience basic form-factors of components to demystify what they are, how they look and feel, and what they can do.

Principle 2: Facilitate I/O Explorations
Offer simple I/O variations to explore the potential for interaction of components.

Principle 3: Group, Label and Stage
Create an overview of related components by grouping and labeling them into meaningful categories. Stage components to give prominence to their form factors, robustly while acknowledging their fragility.

Principle 4: Accessibility
Constrain the presented components to those that are supportable and available in-house.





The act of making the SensorBoard and ActuatorBoard enabled us to explore the utility of the design principles, which inspired the design of two additional 'Boards', a PiezoBoard and a LightBoard.

/SensorBoard (p.5-6) **/ActuatorBoard (p.7-8)** **/PiezoBoard (p.9)** **/LightBoard (p.10)**

THE SENSORBOARD

A/ Clickable Scroll Wheel
Select a sensor by scrolling the wheel. Selected sensor is indicated by a lit LED underneath it. Click wheel to change output mode.

B/ 2*16 Character LCD Display
First line displays the name of the selected sensor. Second line displays numerical value or simple bar graph, depending on output mode.

C/ Switches
Microswitch, Miniswitch, Toggleswitch, Reedswitch

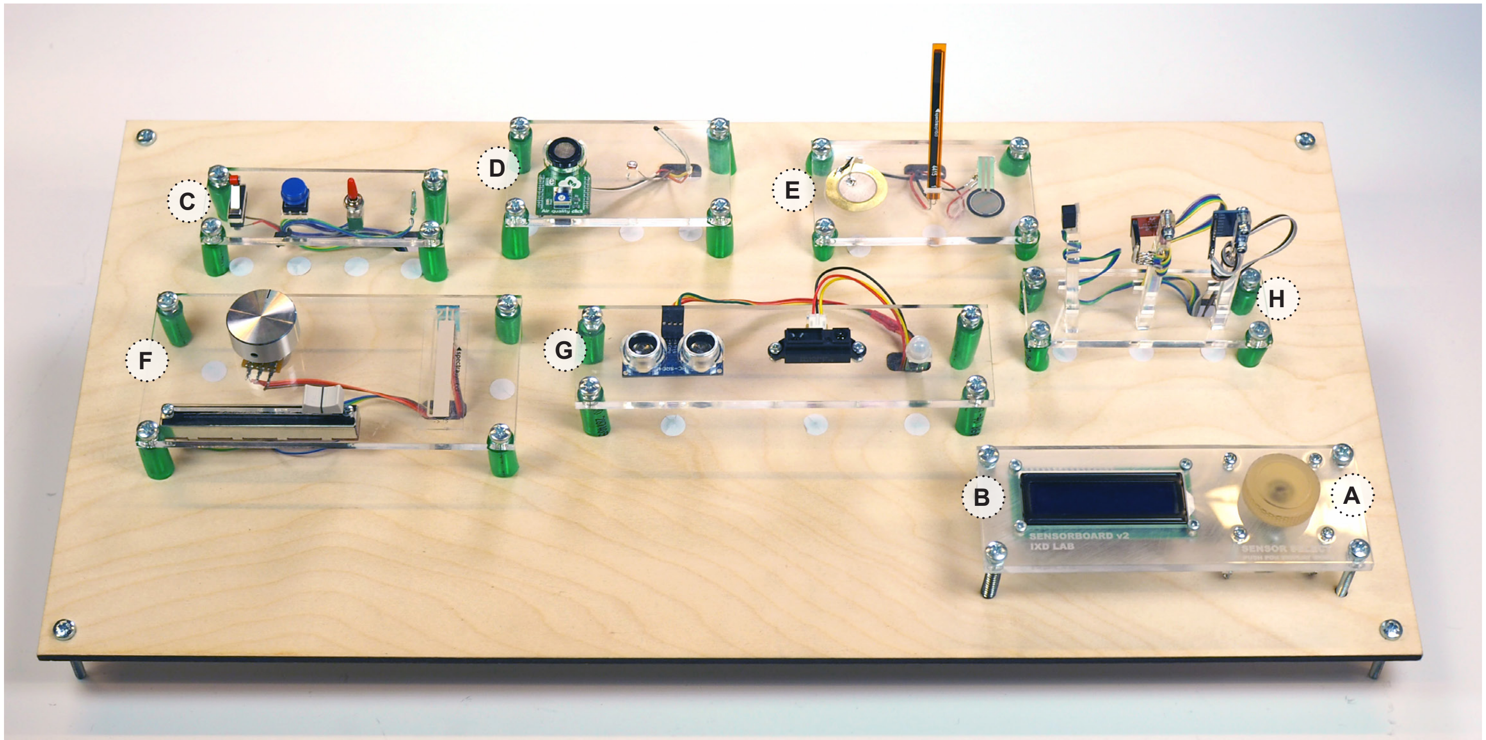
D/ Environment
Air Quality sensor, Light-dependent resistor, Thermistor

E/ Force & Flex.
Piezo element, Flex sensor, Force sensor

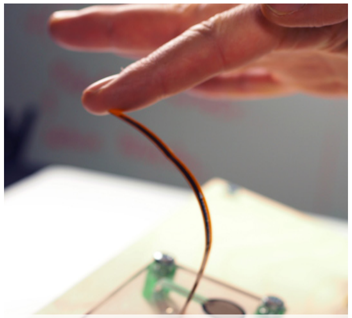
F/ Passives
Rotary Pot, Slide Pot, Soft Pot

G/ Distance
PIR Motion, Ultrasonic Proximity, Infrared Proximity sensor

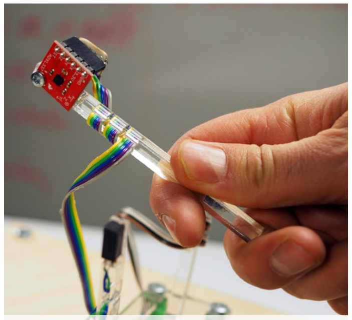
H/ Motion
Accelerometer, Magnetometer, Tiltsensor




Reed Switch. Hold a magnet up close to change displayed output


Flex Sensor. Bend flex sensor to change displayed output

Soft Pot. Slide finger over soft pot to change displayed output


Accelerometer. Shake in one direction to change displayed output

Design Considerations

The four design principles inspired reflection and aided decision making in designing interactions with the SensorBoard.

P1 How to demystify function, form and feel of components?

Some sensors provide rather stable output that can be easily displayed and sensibly be interpreted (e.g. passives and switches), yet other sensors provide rather unstable output which require a relatively large amount of filtering (e.g. distance and motion). This posed a dilemma regarding the amount of noise filtering. How much filtering would be needed to appropriately illustrate the workings of a sensor, while at the same time provide a sensible output? A filtered sensor output reflects to a lesser extent the actual output of a sensor, yet results in a clean and interpretable signal display. An unfiltered sensor output realistically reflects the actual output of a sensor, which students will encounter in working with the component, yet risks being unstable and less inviting for exploration. P2 aided decision making.

P2 How to facilitate I/O explorations?

We decided that there is pedagogic merit in offering both filtered and unfiltered output modes to demystify form, feel and function. It would show the potential of a component, while it at the same time would invite for prolonged I/O explorations of an individual component.

A/ We choose to work with a clickable scroll wheel to enable a different output mode on the LCD screen upon a click.

B1/ The first output mode displayed a visual and filtered signal, in the form of a horizontal bar graph.

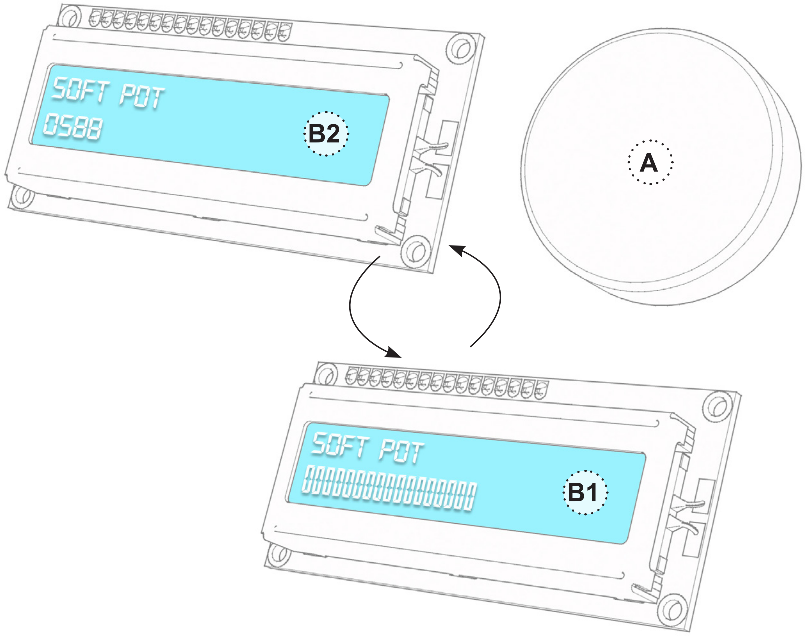
B2/ The second output mode displayed the unfiltered signal, as a numerical value (ranging from 0-1023).

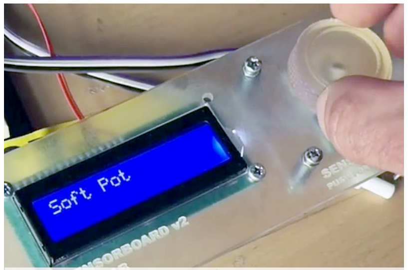
P3 How to group, label, and stage components?

The sensors were grouped into categories according to what they can sense in the environment. The categories were labeled using terms that are commonly used in online webshops and the local learning environment. The components are categorically displayed in order to encourage the making of an informed differentiation between similar sensors. The scroll wheel for sensor selection is spatially close to the sensor display.

P4 Are all components accessible?

All of the presented components are available for students and supportable by staff. A basic programming code for each sensor is available for students on the webpage of our learning environment.





A. Select sensor and output mode with clickable scroll wheel

B2. Numerical output value

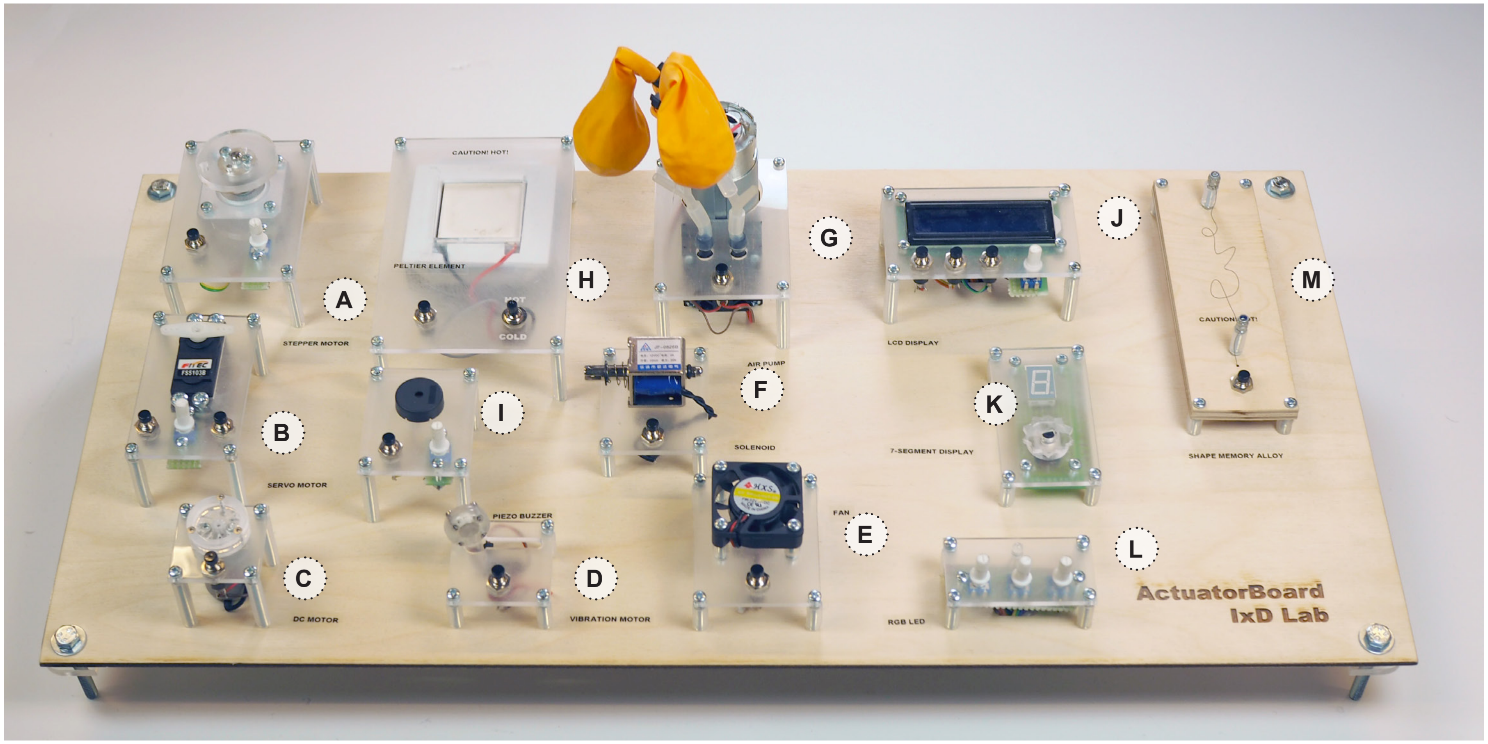
THE ACTUATORBOARD

Tactition
A/ Stepper Motor
B/ Servo Motor
C/ DC Motor
D/ Vibration Motor
E/ Fan
F/ Solenoid
G/ Air Pump

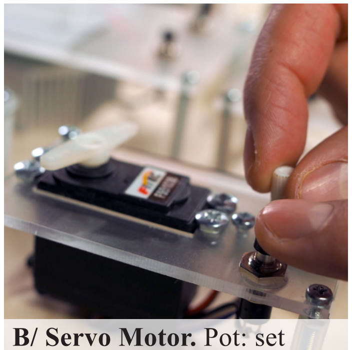
Thermoception
H/ Thermoelectric Cooler module

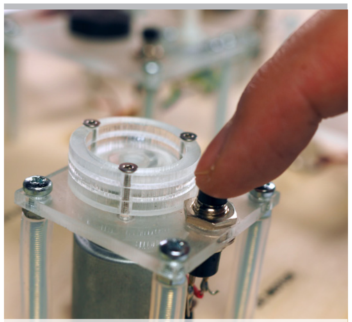
Audition
I/ Piezo Buzzer

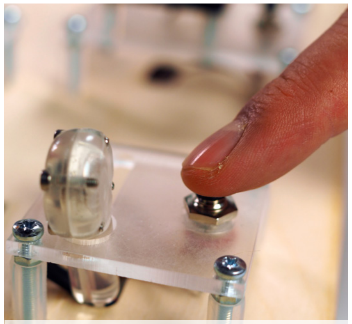
Vision
J/ 2*16 Character LCD Display
K/ 7-Segment Display
L/ RGB LED
M/ Shape Memory Alloy

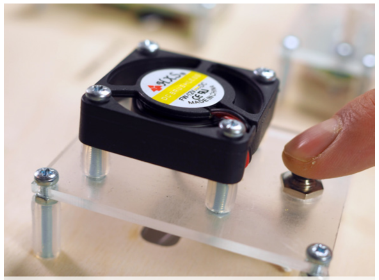


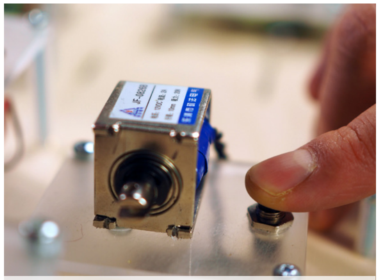

A/ Stepper Motor. Pot: set speed and direction. Button: activate motor.


B/ Servo Motor. Pot: set angle. Buttons: turn left or right.

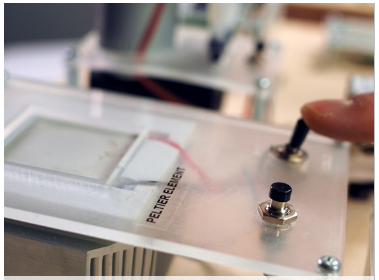

C/ DC Motor. Button: Activate motor.

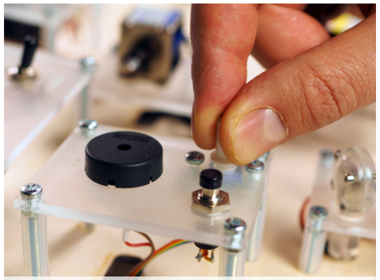

D/ Vibration Motor. Button: Activate motor.

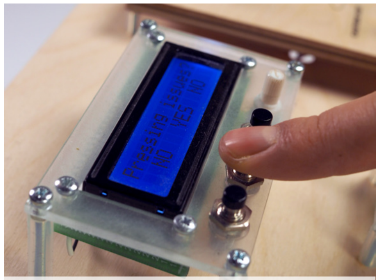

E/ Fan. Button: Produce current air.

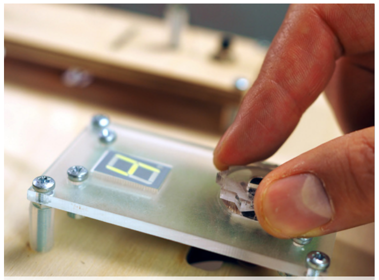

F/ Solenoid. Button: move inner cylinder.

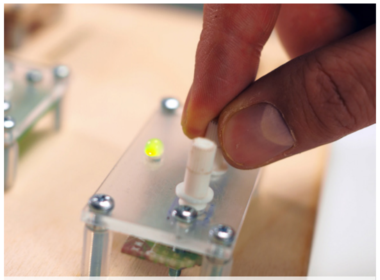

G/ Air Pump. Cover left or right tube + button: Pump air or suck air.

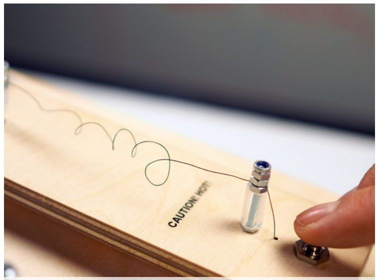

H/ Thermoelectric Cooler Module. Switch: set cold or hot. Button: activate.


I/ Piezo Buzzer. Button: produce tone. Pot: set tone.


J/ LCD Display. Button: change text. Pot: set screen brightness.


K/ 7-Segment Display. Dial: set number on display from 0-9.


L/ RGB LED. Pots (left to right): set red, green, and blue strength.


M/ Shape Memory Alloy. Button: Move alloy to original shape.

Design Considerations

P1 How to demystify function, form and feel of components?
The ActuatorBoard presents 13 actuators and offers simple mappings, in most cases a single button actuates the device momentarily (**C**,**D**,**E**,**F**,**G**,**H**,**J**,**M**).

P2 How to facilitate I/O explorations?
Four mappings invite for an interaction that goes beyond a button press. The servomotor (**B**) mapping was devised to reflect the basic software interface. It requires that the number of degrees are set using a potentiometer, and a press on the button left or right turns the servomotor in that direction. The RGB LED (**L**) mapping was devised to reflect the basic hardware interface. It has three potentiometers to set red, green, and blue, each corresponding to one leg of the RGB LED. The stepper motor (**A**) encourages I/O exploration through pushing the button to activate the motor, and simultaneously rotating the potentiometer, covering a range from fast counterclockwise rotation to standing still to a fast clockwise rotation. Similarly, the piezo buzzer (**I**) produces a tone depending on the position of the potentiometer.

P3 How to group, label, and stage components?
We grouped the components spatially and based on output modality. Taction was positioned towards the left side of the board, vision toward the right side of the board, and audition and thermoception in between.

P4 Are all components accessible?
Less commonly used components such as the shape memory alloy and peltier element are in limited supply at our institution, yet affordable at a local supplier. All components are supportable by staff.

THE PIEZOBOARD

The PiezoBoard was designed to illustrate that the piezo element can be combined with various materials to detect vibration. This shows that the application of a single sensor can afford and open up to a variety of interactions. The intensity of the red LED above the embedded piezo element corresponds to the amount of detected vibration in the material.

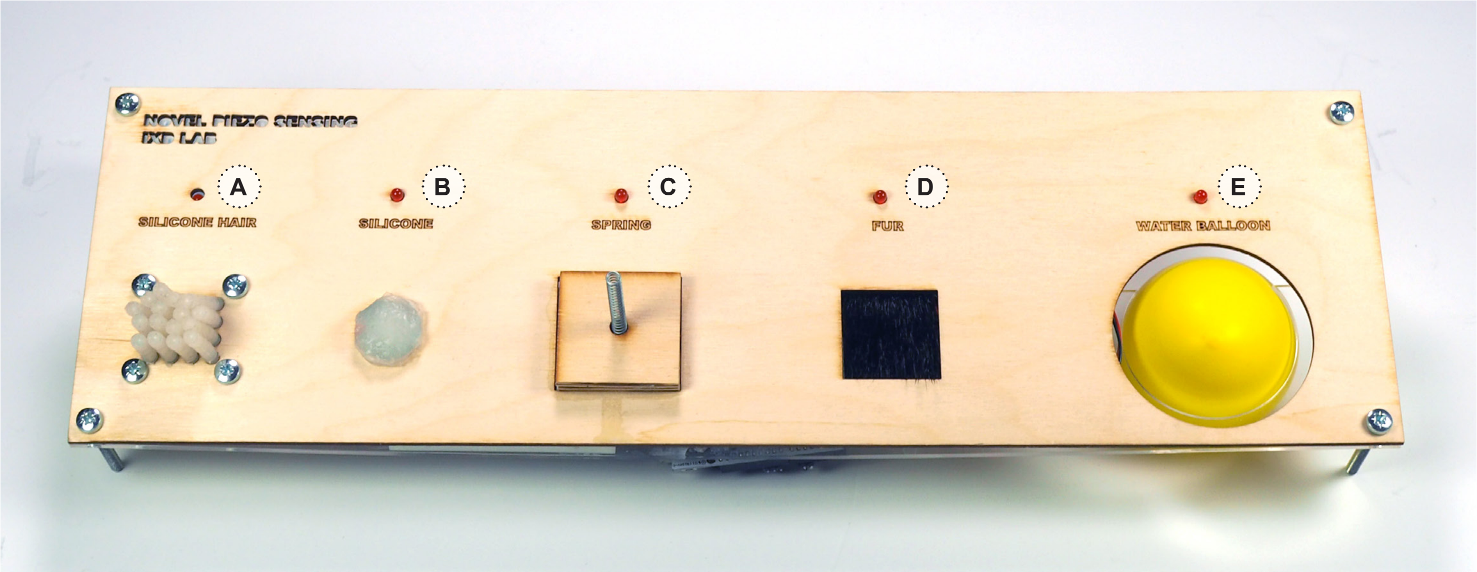
A/ Silicone hair

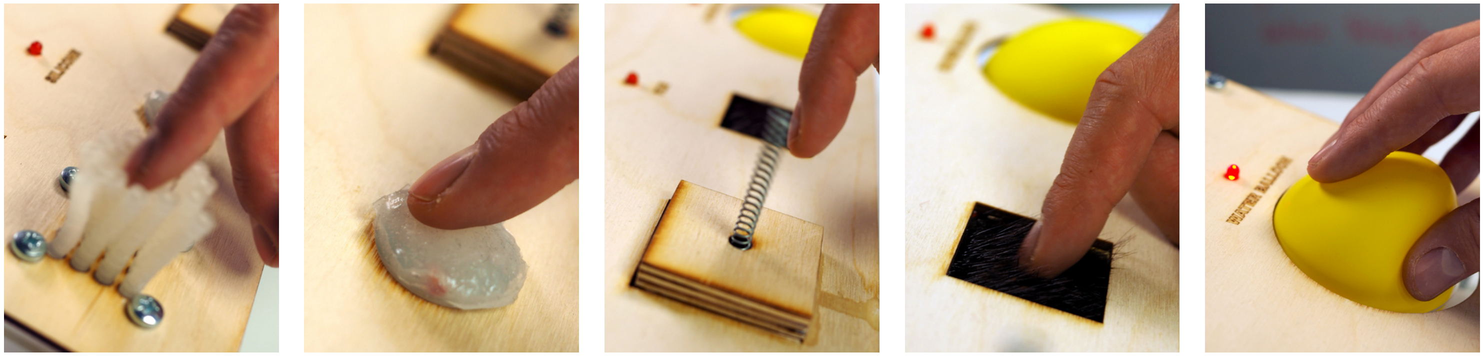
B/ Silicone

C/ Spring

D/ Fur

E/ Water balloon





Design Considerations

Noise filtering of the piezo output was a pedagogic consideration: no filtering would render the point light feedback incomprehensible, and as such hinder the material experience. Each material can be manipulated with various intensity, resulting in a corresponding intensity of light.

The PiezoBoard uses rather unconventional, yet available materials to inspire novel applications of a single physical computing component. This comes at a cost in terms of a robust staging - e.g. the water balloon is relatively fragile.

THE LIGHTBOARD

The LightBoard illustrates five output possibilities for light, yet also invites to explore temporal form possibilities of each light source.

A/ Six-Position knob to select a light source, or none in the off position

B/ [x,y] Light Control to control the light behaviour of the selected light source. The light control is made by physically connecting two rotary potentiometers, which allow precise positioning in the x-y space.

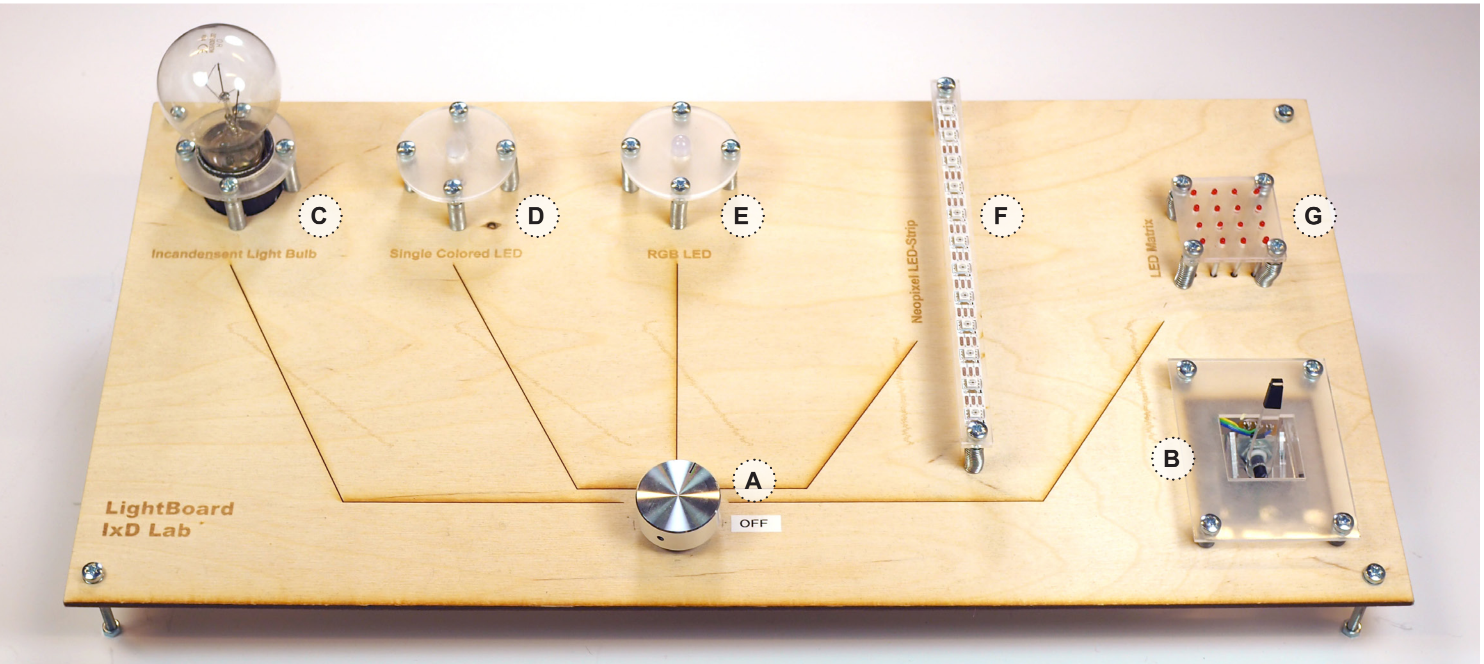
C/ Incandescent Light Bulb [x: set blink speed from fast to slow, y: set intensity from low to high]

D/ Single Colored LED [x: set blink speed from fast to slow, y: set intensity from low to high]

E/ RGB LED [based on chromatisity diagram. x: blue to red, y: blue to green]

F/ Neopixel LED-Strip [x: red to green to blue, y: set position]

G/ LED Matrix [x: set x-position, y: set y-position]

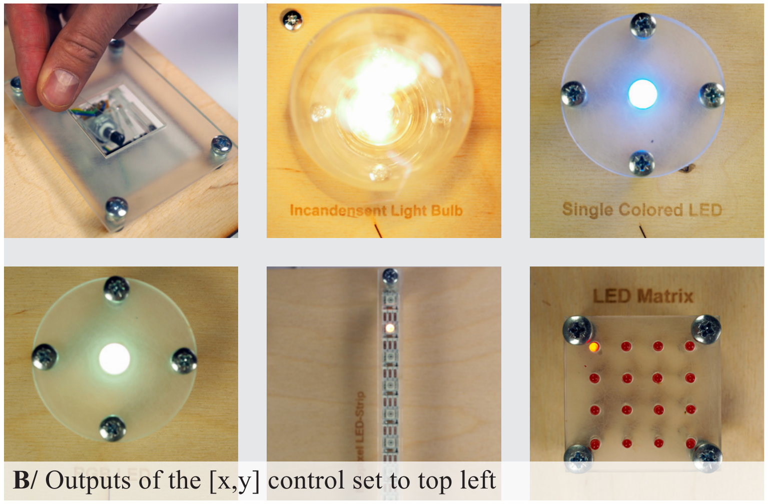


Design Considerations

In comparison with the other three boards, the x-y light control allowed us to put more emphasis on interaction design potential of the components, in terms of demonstrating temporal form giving possibilities. This invites for a feel and experience that, besides demystifying the 5 components, inspires students to think of light beyond the on-off switch. Manipulating the x,y control instantly changes the selected light output according to the corresponding light behaviour.

The lights are organized from left to right from relatively simple to more complex components. The six-position knob and x-y control both feel firm.

All components are available in-house, only the incandescent light bulb requires an affordable AC dimmer module.



B/ Outputs of the [x,y] control set to top left

As a collection, the boards are permanently staged in a main corridor of our university building. As such, they have shown to fulfill several purposes: give visibility to the practice of physical computing, trigger interaction with physical computing components, raise curiosity about physical computing, and invite and inspire to think in possibilities beyond the screen.

Scenario of Use

Two students are working on an interaction design project that concerns the transition of people between spaces. They have a rough idea of sensing someone's distance to a door, and to provide 'some kind of feedback' based on the dynamics of approaching.

The students remember the electronic boards as they have passed by them many times, sometimes playfully pushing switches or rotating knobs (**P2**). They now experiment more intentionally with different sensors on the SensorBoard, and through a process of explorative elimination figure out that their idea could be realized with proximity sensors, either an Infrared sensor or an Ultrasonic sensor (**P3**). The former has more range, yet seems to detect changes in distance a bit slower than the latter (**P1**). The ActuatorBoard and LightBoard inspire the students to think in different kinds of feedback. They never experienced a solenoid before (**P1**), and think that it could be welcoming to slightly open a door when someone approaches. When interacting with the buzzer they are reminded of the auditive parking assistance in cars. The length of the Neopixel LED strip would offer possibilities to visually indicate someone's distance to the door, for example on the other side of the door.

They decide to make a small-scale setup for each of the idea directions. When they ask for components and help, they already have a better-informed idea of the possibilities and limitations of some technologies, and won't be disappointed that they can't be supported materially or intellectually (**P4**). Their ideas are realistically constrained, and can be abandoned at an early stage without any real cost.

DISCUSSION

The different boards presented in this pictorial are essentially bespoke inspirational tools that offer direct first-hand experiences for interaction design students who are new to physical computing. We propose the smörgåsbords to be made by and within the institutions or communities that would want to work with them, to complement other resources in the learning environment. Natually, there are commercial alternatives available to introduce students to physical computing. However, with this work we wanted to emphasize that for newcomers who are doing interaction design projects with physical computing, it is often a matter of in-situ structuring of local and available design materials. This realistically constraints students projects to materials that can be supported, while also stimulates playful experiences of possibilities.

The emerged design principles intent to support the development of new boards that zoom in and show the potential of individual components (alike the PiezoBoard) or address a meaningful cluster of related components (alike the LightBoard).

Situating the Boards in the domain of interaction design allows us point to their qualities and future work. Following Löwgren and Stolterman's understanding of interaction design, 'design ability' refers to acting within existing resource constraints; to creating, shaping and deciding on structural, functional, ethical and aesthetic use-oriented qualities; and to 'coming prepared' to a design situation - having encountered a repertoire of examples that can be related to a design situation [3, p43]). These three elements offer a useful construct to point to related qualities of the smörgåsbords: they enable students to act within the local resource constraints, both materially and intellectually (see **P4**); they aid the creation of and decisions about functional use-oriented qualities, as they inspire and inform about technological possibilities through first-hand experience (see **P1** and **P2**); and they aid in coming prepared by offering an organized set of physical computing components in relevant interaction design categories (see **P3**).

We have observed that the electronic smörgåsbords stir student's curiosity about the look, feel and potentials of a physical computing component. In longer interactions, this curiosity turned towards the underlying workings, as some students lifted up the smörgåsbord to look 'under the hood'. With new learners in mind we deliberately left out elements of programming and electronic wiring, to give prominence to the function, form and feel of components. However, based on this observation we see potential in designing pedagogic instruments that do address programming and wiring in physical computing. Firstly, to use, reflect and iterate on the design principles, secondly to explore what it would mean for their presentation, but mostly, to support interaction design education and the interaction designers they produce.

ACKNOWLEDGEMENTS

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