Affordances and Insights for Teaching Simple Circuits to Blind and Sight Impaired Children

Dan MacIsaac[1], Kathleen Falconer[2], Manuela Welzel-Breuer[3] and Pamela Detrois[4] *macisadl@buffalostate.edu*

1. State University of New York (SUNY) Buffalo State College, 1300 Elmwood Avenue, Buffalo, NY 14226; 2. Institut für Physikdidaktik, Universität zu Köln, Cologne, Germany; 3. Physics Department, Pädagogische Hochule Heidelberg University of Education, Heidelberg, Germany; 4. Staatliche Schule für Blinde und Sehbehinderte in Ilvesheim, Germany

Abstract

We describe affordances – simple modifications to equipment and procedures, and interventions for an introductory activity examining the classic relative brightness of one bulb in a circuit, two bulbs in series, and two in parallel circuits. Affordances for partially sighted students are straightforward, with slight but important adaptations to apparatus, lesson flow and timing. Affordances for profoundly blind students include using circuit representations on raised paper (swell paper) with and without Braille, and rigidly concrete circuits created with commercial apparatus. Given a second or two for thermal stabilization, sightless students can discriminate by touch amongst dark, partially lit and brightly lit incandescent bulbs for the traditional comparisons. We also discuss the need to establish trust and safety for blind children in handling simple circuit elements.

Background

All people are uniquely able, and it has been claimed that *"good design for the blind and partially sighted is good design for everyone* (Ref: Euro Banknotes)." ***Affordances*** are *object properties* that help people use things. For example, on exit doors, push plates are a common affordance indicating to all users which side of a door should be pushed upon. Door handle levers are standard affordances that remove many of these steps and make it possible for people to use doors with much less difficulty. Differing sizes and shapes of coins are affordances that can make it possible to readily discriminate money denominations under poor lighting, stress or without looking. ***Accommodations*** are adjustments made to *systems* to make them fairer to all, like classroom seating and timing changes to improve opportunities for disabled students and instructors.

An Absolutely Awful Doorknob

Old fashioned spherical doorknob, plus modern lock require the user to grasp, hold and twist the knob while pushing, pulling and stepping through the door.

Push Plates

Lever Door Knob

Blind and visually impaired students come in a wide spectrum of abilities, from no light perception and complete vision loss (estimated at 15%), through partially sighted (20/500 vision with a field of view of < 20° is a US designation for legally blind; about 1.3 million Americans), to totally functional vision after correction to normal levels (about 14-19 million Americans report low or problematic vision). Students each have unique needs and often multiple disabilities (premature birth; learning disabilities; inherited diseases), and as an instructor you should hold a private meeting with blind students to be briefed upon their individual needs, accommodations and interventions.

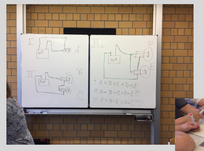
Specialty eyeglass kits (REF GLASSES) model various kinds and levels of vision impairment via stops, filters and masked out areas, these can be particularly helpful for educators testing activities and designing / modifying instruction.

Characterizing vision issues (from blind to impaired; can be combinations):

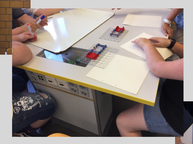
- blind **from birth: no experience of light perception at all** – sees no more than you see with your elbow; student can fill in some missing elements from discourse (seeing the back of your own head by description, palpation)
- partial light perception; can tell if a bulb is lit from holding it close to eye; might sense colors
- fuzzy, blurred, multiple images, out of focus – like looking through waxed paper or heavily frosted glass, or tape on glasses – can perceive some items from some limited visual angles
- grey or colored mist overlays all vision (tape or marker on glasses)
- tunnel vision – can perceive only a narrow field of view; can bring items into visual areas but might not be able to track multiple variables or instruments in an experiment across a wide field of view (stops and masks)
- obstructed vision / blind spots and regions -- like clear glass or waxed paper spattered with opaque paint
- partially blind after years of vision – many coping strategies and strong ability to fill in partially seen images due to sighted experience plus training

Affordances

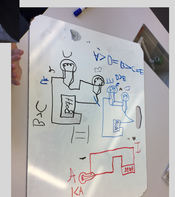
The most important and common affordance is to ***take more time,*** particularly during hands-on lessons and lessons involving reading directions. This is a profound accommodation, and often legally required for registered disabled students. A ***reduced-distraction environment*** is another common affordance. Finally, a ***large readily visible classroom whiteboard and projecting surface*** is another affordance that should be used with low vision students. *Modeling Physics*-style shared ***group whiteboards*** are also natural affordances for students with problematic vision to work in groups.



Large whiteboard at the front of classroom



Sample student whiteboard with their predictions



Students starting to make a prediction to the bulb problem using the whiteboards and swell paper diagrams.

Sighted and unsighted issues with real world circuits

It is well-reported that students building circuits encounter many practical concerns or "vagarities of breaking down" working with real world simple circuit batteries and bulbs: dead batteries, broken filaments, broken connecting wires, difficulties making solid, durable connections, avoiding short circuits and even deciding whether or not the color of insulation on wires means anything (Finklestein, Adams, Keller, Kohl, Perkins, Podolefsky, Reid, & LeMaster, 2005), beyond any physics content conceptual difficulties.

Broken Equipment

A Modified Connection
Using a larger, more robust clip attached to the smaller, fragile clip, improves handling.

More Robust Wires and Connectors

Vision impaired students also have trouble tracking small mobile items like batteries and bulbs that can roll around or be brushed off the table (can use low cafeteria-style trays), seeing small details like connection sites (poles, tips of bulbs), and tracking multiple items (meters) simultaneously across limited fields of view.

Standing Battery in Cup Affords Easier Access to 'tippy' 4.5V Battery Terminals

Commercial circuit kits (Snap Circuits™; Cambridge BrainBox™) that support, confine and direct student assembly can profitably restrict and guide "students messing about" as well as holding things solidly in place for extended visual and tactile exploration and tracking, rather than flopping erratically across the table with intermittent connections. The kits also helps match circuit representations and reduce circuit troubleshooting.

Floppy Circuits

Circuit Kits

The Impact of Personal Electronic Devices

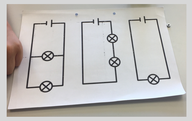
A generation ago expensive dedicated devices like talking calculators and clocks, talking water level indicators and magnifying text readers using large monitors and cameras were required for teaching blind students; since then the boom in personal device technology is revolutionizing support for the blind.

Old school talking Voltmeter- an expensive, specialty, single purpose piece of equipment

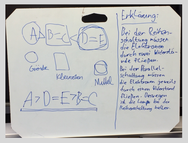
Student feeling a bulb in a circuit, while an instructor holds a light signaling device to hand to student if required. Also note hands-on-hands-on tactile guidance.

Smart watches with cell phones allow for tracking blind children, ready contact, talking maps direction finding and guiding, and apps can recognize changing light levels, read news and time, recognize money denominations, and act as talking calculators. Inexpensive tablets with cameras and WiFi or cellphones can do the above, and also act as enhanced portable readers for classroom text reading, reading .pdf files aloud, and magnifying figures and circuit diagrams. Convenient personal earbuds can help students read .pdf and websites aloud without distracting other students.

Curriculum Created Touch Diagrams that may or may not match the activities



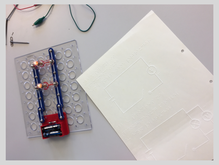
These affordances and accommodations can benefit many students.

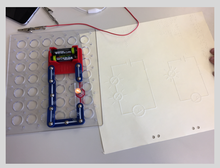


Students` whiteboard after experimenting with the different circuits.

Interventions (BOTH affordances and accommodations):

- more time to use limited vision, tactile exploration (hands-on-hands-on), to read Braille & swell paper and extended discussion / description
- not too much noise / distraction; help sharply focus attention
- making larger graphic and text representations via group & whole class whiteboards; both "sit closer to the board" and "bring the board to the student"
- enlargers (video devices, hand lenses, electronic pads and tablets)
- larger handling-friendly apparatus (larger bulbs, alligator clips, batteries)
- Improved apparatus (handling and reducing troubleshooting – better connectors reduce loose connections; burned out bulbs; exhausted batteries)
- trays and stands to keep apparatus in place; keep it from rolling away
- swell paper and braille circuit diagrams directly matching concrete circuit
- tactile circuits locked in position geometrically for comparisons, troubleshooting, bulb touching and touch temperature assessment
- comfortably touchable unshielded bulbs and motors for tactile and auditory sensing etc.





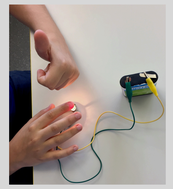
Circuits with Equivalent Braille Circuit Diagrams

Discussion & Lessons Learned

What "at-Risk" Children have taught us about learning physics:

From Refugee children:

- Equity is the / an explicit goal; Classroom culture as well
- Construct welcoming learning environment for welcome-ness
- Having fun is the / an explicit goal; Play
- Take risks / emotional safety
- Grab the apparatus; figure it out
- Be frustrated; Embrace failure; fail harder; fail better
- Support explicit student self-monitoring of learning (metacognition; Veritasium; attentiveness, frustration & delusion)
- Students are very mobile phone-centric / aware



Thumbs up
Determining the bulb is lit by feeling the temperature.

Student disconnecting clip to the battery.

Thumbs Down
Determining the bulb is not lit by feeling the temperature.

From Blind children:

- More time, even more time, and yet more time again (course content cuts; only have time for curricular important stuff and student interests)
- Design the learning envelope carefully; use simulation devices (glasses)
- Affordances and accommodations by individual student (differentiation)
- Whiteboards and big boards
- "Hands-on" concrete apparatus play and "hands-on-hands-on" exploration also takes one-one-one attention from instructors, tutors, LAs
- Risk taking and trust
- Limited perception / attention
- Strong use of analogy / description / discussion
- Multiple representations and variety of equipment
- Robust & enlarged equipment
- Tech helps tons! Phones and linked watches, as well as inexpensive tablets, texts chosen for audio file quality etc

References & Links

(Ref: Euro_Banknotes) "A good design for the blind and partially sighted is a good design for everybody" was the principle behind the cooperation of the European Central Bank and the European Blind Union during the design phase of the first series banknotes in the 1990s.[126] As a result, the design of the first euro banknotes include several characteristics which aid both the blind and partially sighted to confidently use the notes.[126] https://en.wikipedia.org/wiki/Euro_banknotes

Fixed circuits that stay in place but can be touch explored and traced, with bulbs and motors that can be touched: Snap Circuits™ <elenco.com/brand/snap-circuits> and Cambridge Brainbox™ <cambridgebrainbox.com/Primary2.html>

Swell Paper -- photocopier and laser printing paper that physically forms raised lines when ink is fused to it and supplementary heat applied so printing can be read by both sight and touch (moderate cost): <americanthermoform.com/product/swell-touch-paper/>

Light Level Detector <maxiaids.com/light-on-light-detector> these expensive custom devices for the blind are currently being replaced by off the shelf smart watch apps and tablets. http://li129-107.members.linode.com/research/statistics-on-vision-impairment/prevalence-of-vision-impairment/

REF GLASSES: Commercial (Impaired) Vision Simulation Glasses: <good-lite.com/Details.cfm?ProdID=766>; Free and homemade simulations: <perkinselearning.org/scout/blog/simulation-vision-conditions>

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