EXISTEMOLOGY (EXISTENTIAL EPISTEMOLOGY): FROM DIY MAKER CULTURE TO BIY (BE-IT-YOURSELF) AND LBB (LEARN-BY-BEING)

Prof. Steve Mann, Ph.D., P.Eng.
University of Toronto, Faculties of Engineering, Art.Sci., and Forestry

ABSTRACT

This paper presents a new way of teaching that can be applied to any age group from preschool to university, university graduate studies, and even in retirement homes.

The method goes beyond problem-based learning, PBL (project-based learning), constructionism ("learn by doing"), and DIY maker culture, to encourage the students to not only solve problems but also become inventophers (inventor philosophers) using themselves as the learning medium. Basically it marks a transition from "do" to "be".

The new method has been referred to as LBB, existemology, ExistEd, or the "Mann method" (akin to the Suzuki method of teaching music, but for Design, Art, Science, Technology, Engineering, and Mathematics – putting a "heart-and-soul" into STEM to create DASTEM).

We are developing LBB-based curricula at and for universities, as well as K-12, beginning with an emphasis on local high schools. LBB is based on: (1) Open Source (existential self-determination and mastery over one's own destiny), BIY (Be-It-Yourself), and self-maker culture; and (2) embodied intelligence, e.g. Wearable Computing, (learning about computers by "being" a computer), fluid mechanics (e.g. hydraulophone, musical instruments in which the water in our bodies becomes part of the musical instrument —- "being water"), and, in the case of teaching younger children, anthropomorphic units (e.g. "being a ruler" by learning inches, feet, hands, handspans, cubits, yards, and other units that use the human body itself as the ruler, and thus re-enforce this embodied intelligence); and (3) personal involvement, e.g. teachers AND students who live the life they teach and learn. It gives students (and teachers) a much deeper sense of meaning and purpose in life.

1. PUTTING A "HEART-AND-SOUL" ON THE STEM

STEM is an acronym for Science, Technology, Engineering, and Mathematics, and an agenda of public education is integrating these disciplines.

Other interdisciplinary efforts like MIT's Media Laboratory, MIT's Lifeling Kindergarten, and the MITES, RSI, and WTP high school programs hosted by MIT, focus on AST (Art + Science + Technology).

Design is also an important discipline, so we might consider DAST = Design + Art + Science + Technology.

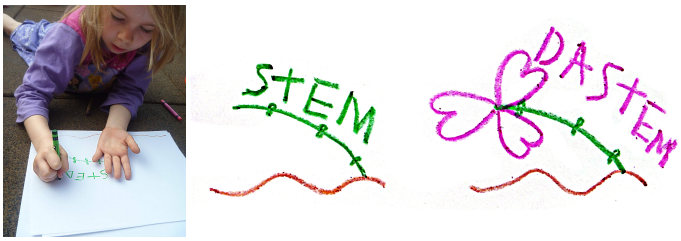

Figure 1: Science, Technology, Engineering, and Mathematics (STEM). Here Stephanie (age 5) draws a heart-shaped flower on the otherwise incomplete STEM, to represent DASTEM as the complete picture.

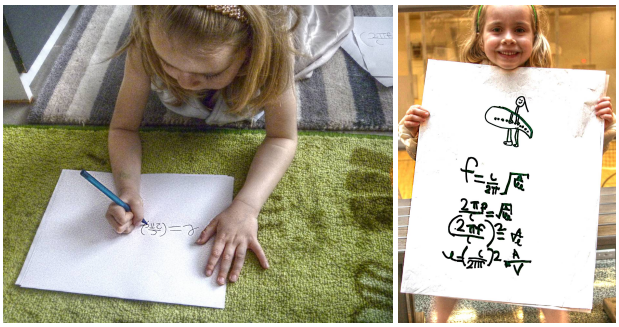

Figure 2: Stephanie (age 5) working out a simple mathematical derivation for the lengths of pipes in a musical instrument to be installed in her wading pool. Presenting her work at Artful Waters, Waterlution 2012, YMCA of Greater Toronto, 20 Grosvenor St., Toronto, Ontario, 2012 June 4, 6-9pm.

DAST could put a "heart and soul" into STEM, e.g. going beyond "multidisciplinary" to something we call "multipassionary" or "interpassionary" or "transpassionary", i.e. passion is a better master than discipline (Albert Einstein said similarly that "love is a better master than duty").

Consider, for example, DASTEM = Design + Art + Science + Technology + Engineering + Mathematics (dastemology), or perhaps DASI = Design + Art + Science + In(ter)vention or Innovation.

Indeed, when describing STEM to a five-year-old girl, she seemed to feel the STEM alone was missing something, and drew a heart-shaped flower to represent DA (Design and the Arts). See Fig 1. Expanding our minds into the broader intellectual landscape does not mean being shallower. We do not advocate a tradeoff of breadth for depth. We propose, instead, existemology as a means to attain a simultaneous increase in both depth and breadth, e.g. "serious fun and frolic" where mathematics meets

aquatic play. For example, Stephanie (age 5) is installing some hydraulic resonators in her wading pool to make a fun and playful underwater musical instrument (a hydraulophone) that physicists and engineers would tell her is impossible to make "because water is not compressible". She begins by writing $f = \frac{c}{2\pi}\sqrt{\frac{A}{Vl}}$, putting the 2π together with the f, dividing by c, and squaring both sides, then solving for the length, l, as shown in Fig 2 and the corresponding video. As we will see in this paper, water is a very existential element for fun and frolic, and "learn by being" philosophy.

Perhaps what we want to nurture is the "inventopher" (inventor+philosopher), through existemology (existential epistemology), i.e. "learn-by-being". In particular, aim to go beyond merely putting technology into classrooms, or churning out design technicians. Instead we want students to also think about the philosophical and humanistic elements of technology, in a way more traditionally associated with philosophy, the humanities, and the fine arts.

This goes beyond the "learn by doing" (the constructionist education of Minsky and Pappert at MIT).

2. THE EXISTENTIAL RULER

A simple example of putting existemology into practice is when we teach our children how to measure something, using anthropomorphic units (measurements based on the human body) (wikipedia.org/wiki/Anthropic_units) like inches (width of the thumb) or feet. The human body itself becomes the ruler. We learn about rulers, and measurement in general, by becoming the measurement instrument.

2.1. Rule of thumb

In many languages, the word for "inch" is the same as (or similar to) the word for "thumb"; in:

- French: the word pouce also means inch;
- Italian: pollice = inch or thumb;
- Dutch, duim = inch or thumb;
- Czech and Slovene: palec = inch or thumb.
- Spanish: pulgada = inch; pulgar = thumb;
- Portuguese: polegada = inch; polegar = thumb;
- Swedish: tum = inch; tumme = thumb;

and thus we have the idiomatic expression "rule of thumb": "a principle with broad application that is not intended to be strictly accurate or reliable for every situation. It is an easily learned and easily applied procedure for approximately calculating..."
[http://en.wikipedia.org/wiki/Rule_of_thumb]

It is easier to teach a 4-year old to measure in inches (thumb widths) than in a unit that was once defined as hundredths of one ten-millionth of the distance from the Earth's equator to the North Pole (hundredths of a metre, i.e. centimetres), and is now defined as hundredths of "the length of the path travelled by light in vacuum during a time interval of 1299,792,458 of a second"
http://en.wikipedia.org/wiki/Metre

Each of us has a different width of thumb, and will thus get different answers when measuring the same thing, but if we're measuring the space between seeds while planting flowers in a garden (i.e. not building a nuclear reactor or aerospace rocket) maybe it is better to have the intuitive and existential understanding of measurement that corporeal units like inches and feet give us.

Let's measure the height of horses in "hands" (defined as exactly 10.16 centimetres) rather than centimetres, and worry more about intuition and common sense than accuracy.

2.2. From counting on fingers to division-by-hand

The human hand is rich with measurement units:

- the "hand", i.e. the width of the fingers AND the thumb, as used to measure horses, standardized to be 4 inches (one third foot);
- the "palm", i.e. the width of the finguers (not including the thumb) is standardized to be 3 inches (a quarter foot). Recall that the thumb is 1 inch, so we have a simple equation: hand – palm = thumb.
- the "shaftment" is the width of the fist and outstretched thumb. It is standardized to be six inches (half a foot);
- the "handspan" is the width of a human hand, from the tip of the thumb to the tip of the pinky finger. It is standardized to be 9 inches (3/4 of a foot).

It is interesting to note that there are 12 inches in a foot. The number 12 is very special because it has a large number of integer divisors, e.g. half a foot is 6 inches (a shaftment), a third of a foot is 4 inches (one hand), and a quarter of a foot is 3 inches (one palm).

A number like 10 does not divide up a nicely, e.g. a third of 10 is 3.3333333333333333333...

That is why we tell time with 12 hours to the day, etc., and why all attempts to make a metric clock (10 hours per day, 10 minutes per hour, etc.) have failed in the court of popular opinion.

2.3. "Kill a pascal"

Consider a four-year-old learning about water pressure:

Daddy: this gauge is in kilopascals.
Christina (age 4): why "kill a pascal"?
Daddy: kilo means 1000, so its 1000 pascals.
Christina: What's pascal?
Daddy: A French physicist, also one newtwon per square meter.
Christina: What's newton?
Daddy: Another physicist....

The same child had no problem understanding water pressure in pounds per square inch or Christinas (her own body weight) per square Stephanie (her sister's area). The very inacuracy of anthropomorphic units, especially when used across various age groups, is why the concept is so powerful as a teaching tool: it is OK to make mistakes, to take guesses, and to get a rough imprecise understanding of the world around us.

3. WEARABLE COMPUTING

Another example of existemology is wearable computing: we learn about computers by "becoming" the technology [Mann, 2006] (perhaps in the "cyborg" sense).

We can learn alot about the world around us, such as public spaces, by bringing computation into our own personal space. For example, we learn about surveillance by engaging in its reciprocal (sousveillance), i.e. simply taking pictures of the world around us, often uncovers inconsistencies (e.g. cameras are often prohibited in places where there are a lot of surveillance cameras). This concept deals with public spaces and subversion [Cunningham, 2009].

Another example, the EyeTap electric eyeglasses, cause the eye itself to, in effect, become both the camera and display, giving rise to augmediated reality, i.e. mediated reality (not merely augmented reality with adding new matter, but actually being able to more broadly mediate the visual perception of reality). See for example, Chapter 23 of http://www.interaction-design.org

In this context, the wearer even has the apperance of having a glass eye (camera eye), so the appratus has been referred to as the "glass eye" and is referred to as the "glass eye effect"[Mann, 2002], or "MannGlass".

Google has recently been working on a similar project. A recent article begins:

> The first surprising thing about Google Glasses is that anybody thinks this is a new idea (just have a look at this history of mobile augmented reality). Steve Mann, a Canadian known as the father of wearable computing, has been developing systems since the 1980s with obvious industrial, medical and military applications.

Google Project Glass: will we really wear digital goggles? by Jack Schofield, The Guardian, 2012 April 5th. http://www.guardian.co.uk/technology/2012/apr/05/google-project-glass-digital-goggles

Thus the "existential camera" and "existential computer" [Eye am a Camera: Mediated Reality, WearComp, and the EyeTap Camera, Dinner Banquet Speech, Wednesday, August 18, 1999, 7:00 - 9.30 p.m., Sig Mobile, [http://www.sigmobile.org/mobicom/1999/speakers.html] are entering the mainstream. See Fig 3.

It has been said that wearable computing represents a $241 billion industry.

Much like the Suzuki method for teaching music, the "Mann method" (author S. Mann) of teaching is based on existemology. The human body itself becomes a measuring instrument like a ruler or a camera. Or the human body becomes a computer or a musical instrument that teaches physics, states-of-matter, mathematics, and the like.

3.1. Pipe Dreams

An example around this idea is Pipe Dreams, a series of performances and demonstrations in 2011, in which author S. Mann played instruments while sleeping. A skull cap with 64 brainwave electrodes was connected to a computer that played four instruments, one in each state-of-matter: chimes made from pipes (solid matter); a hydraulophone (liquid matter); a pipe organ (gaseous matter); and a plasmaphone (sound from the fourth state-of-matter).

When the solid, liquid, and gas pipes are arrayed together around the sleeping subject, they form an interesting sculptural form as well. The tubular glockenspiel has pipes that vary in length inversely as the square root of the frequency, whereas the pipe organ has pipes that vary inversely with linear frequency, and the hydraulophone pipes vary inversely with the square of the frequency:

Xylophone or glockenspiel	Pipe organ	Hydraulophone
length $\propto \sqrt{f}$	length $\propto f$	length $\propto f^2$

Moreover, the chimes (glockenspiel) are velocity-sensing, whereas the pipe organ is displacement sensing, and the hydraulophone is absement sensing. Absement is the time-integral of displacement. More generally, hydraulophones give rise to a new kinematics that includes negative derivates-of-displacement:

... absounce, abserk, abseleration, absity, absement, displacement, velocity, acceleration, jerk, jounce, ...

See Fig 4.

3.2. Serious frolic

I recall the advice given to me back when I was still a non-tenured professor: "Don't have fun, or at least don't appear to be having fun. You need to be serious, or at least appear to be serious. You need to be doing research out of a sense of duty, and not be enjoying it, or at least not seem to be enjoying it.".

The traditional "old school" approach to STEM is that if you want to be taken seriously, you need to be serious, and that there is no room for play and unstructured learning.

Inverse kinematics was discovered from frolicking in fountains and splashing around with hydraulophones.

Originally this important contribution was not taken seriously, and a good deal of effort was expended to make fun of it, and to have the Wikipedia entry on absement deleted:

> Re: What is the integral of displacement?
> by You, sir, name? Sun Mar 01, 2009 1:26 pm UTC
>
> "Absement" seems very artificial. Not every integral corresponds to a meaningful quantity. To make my point clear, let's define an utterly non-sequitur integral.

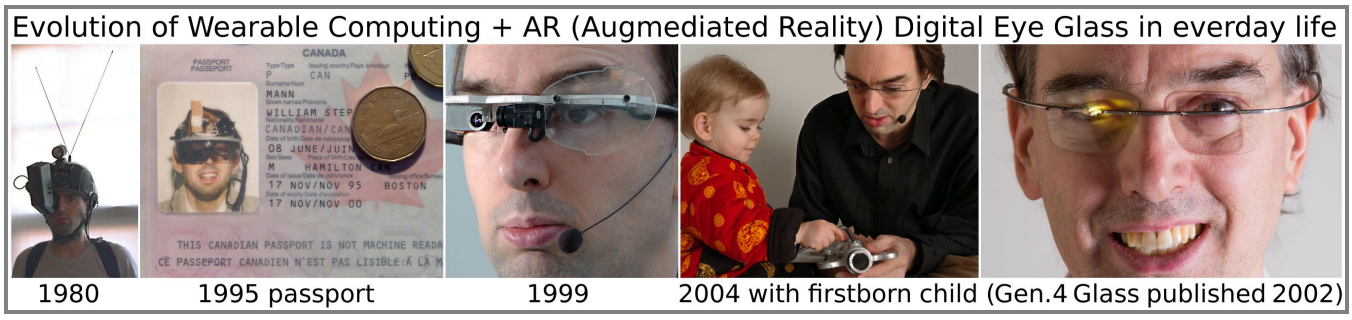

Figure 3: Augmediated Reality: The existenial camera and computer.

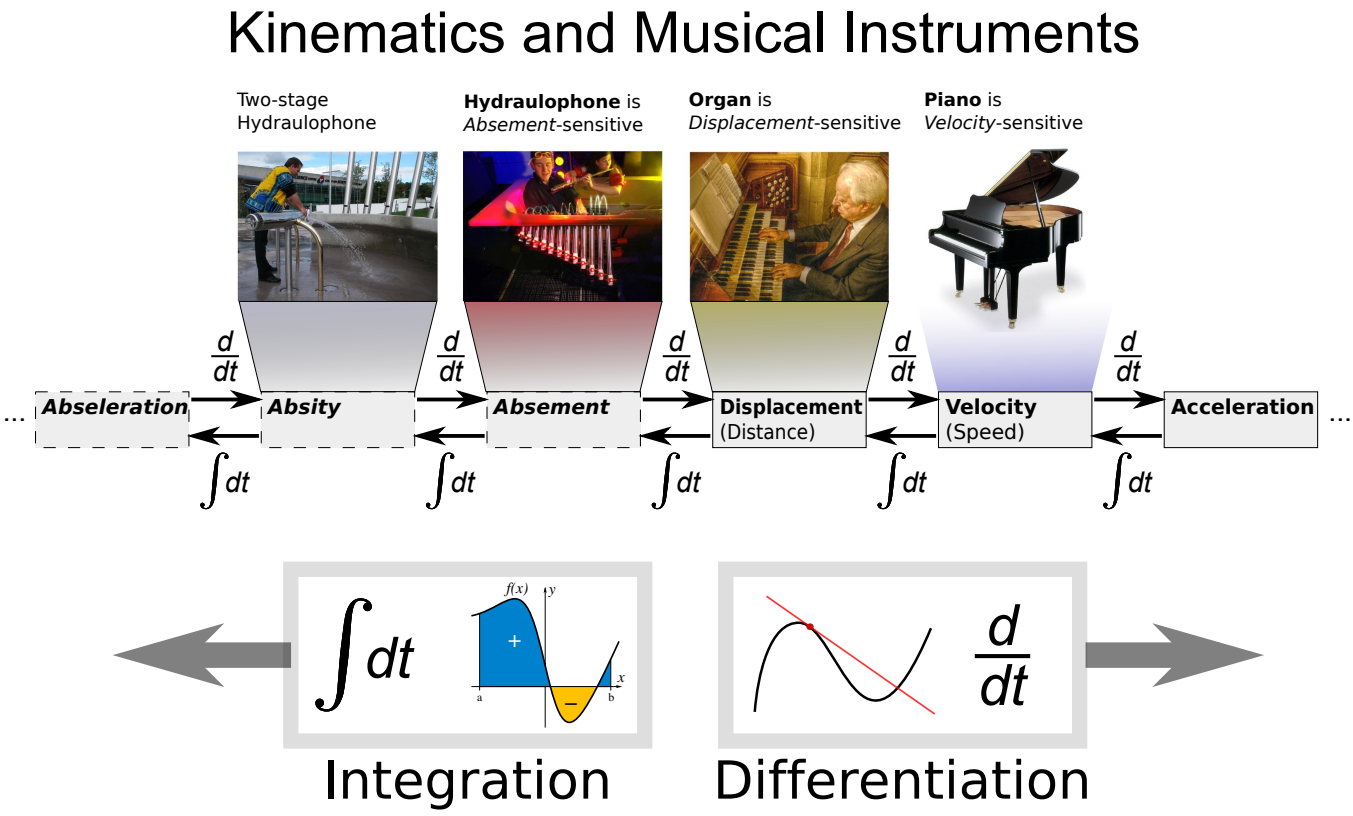

Figure 4: Hydraulophones reveal and exhibit a completely new way of understanding and thinking about kinematics: negative derivatives of displacement! Figure: concept by S. Mann; layout and design by S. Mann and R. Janzen

Let's first define the clown-nose field. At the center of every clown noise is a point "charge", so the clown-nose field

$$\vec{N} = \sum_{n \in \text{noses}} R_n \frac{1}{r_n^2} \hat{r}$$

where R_n is the radius of the clown nose, and $\vec{r}_n$ is the coordinates to the clown nose.

Let us next define burrito-giraffe space. Burrito-giraffe space is a pseudo-cylindrical coordinate system oriented after a given burrito, and which end of them points closest to a giraffe. The positive z-axis is defined as the direction in which the symmetry line comes closest to a giraffe. The radial axis is defined normal to the burrito surface, and the angular axis is defined as though burrito-giraffe space was a regular right handed coordinate system.

Finally, let's find a dog, say a Labrador, and integrate $\vec{N}.d\vec{A}$ over it's surface, and get the clown-nose flux of a labrador in burrito-giraffe space. (Actually, you could use it to determine if there are clown-noses in your Labrador)

Where was I? Oh, yeah, just because you can integrate it doesn't mean it corresponds to some meaningful quantity that deserves a wikipedia article.

But these simple and FUNdamental aspects like state-of-matter and kinematics allow us to see the world in new ways, beyond music. For example, others have recognized the didactic value of the inverse kinematics philosophy:

> Although time-integrated charge is a somewhat unusual quantity in circuit theory, it may be considered as the electrical analogue of a mechanical quantity called absement. Based on this analogy, simple mechanical devices are presented that can serve as didactic examples to explain memristive, meminductive, and memcapacitive behavior.[Jeltsema, 2012]

3.3. Water, Forestry, and First Nations

The water instruments allow a natural element —- water —- to itself become a musical instrument. We are working to combine water and forestry in a series of musical performances in various forests. One such performance contextualizes the forest canopy as a "cathedral" of sorts, where native flutes are played high in the forest canopy, along a canopy walkway. Additionally, various water instruments are played on and in natural bodies of water in the forest.

In one of the compositions there are three elemements:

- Earth: Native Drums, forest, and tree instruments, including the Xyolin. These instruments are played on the ground;
- Water: Hydraulophones, which are played on and in natural bodies of water in the forest. Some of these instruments are actually played underwater;
- Air: Native Flutes played high in a forest canopy walkway.

Thus we have Earth on the ground, Water on and in the water, and Air up in the air.

The use of the five Elements (Earth, Water, Air, Fire, Idea) is part of our work at the nexus of art, science, technology (engineering), and design to support "DAST" (Design, Art, Science, and Technology) outreach.

Lateral thinking within this new "states-of-matter" musical instrument ontology (physical organology) can lead to the invention and rapid prototyping of many new musical instruments in a DIY readymade context well-suited to existemological outreach.

4. DIY: DO IT YOURSELF, AND OPEN SOURCE

The following concepts fall very much inline with the existential epistemology of teaching students self-determination and mastery over their own destiny:

- the DIY (Do it your*self*) movement;
- the "maker" movement;
- the "Open Source", "Free Software", and GPL (GNU Public License) movement;
- the Wikipedia and free knowledge movement.

These are important cornerstones of existemology-based LBB.

aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa

more to come ...

5. REFERENCES

[Alonso and Keyson, 2005] Alonso, M. B. and Keyson, D. V. (2005). *MusicCube: making digital music tangible*. ACM CHI.

[Cunningham, 2009] Cunningham, F. (2009). Public spaces and subversion. In *Rites of Way: The Politics and Poetics of Public Space*, pages 85–99, Waterloo, On. Wilfred Laurie University Press.

[Geurts and Abeele, 2012] Geurts, L. and Abeele, V. V. (2012). Splash controllers: Game controllers involving the uncareful manipulation of water. In *Proceedings of the ACM Tangible Embedded and Embodied Interaction*, pages 183–186, Kingston, Ontario, Canada.

[Ishii and Ullmer, 1997] Ishii, H. and Ullmer, B. (1997). Tangible bits: Towards seamless interfaces between people, bits and atoms. *Proceedings of the ACM CHI 97 Human Factors in Computing Systems Conference*, pages March 22–27, 1997, Atlanta, Georgia, pp. 234–241.

[Jeltsema, 2012] Jeltsema, D. (February 15-17, 2012). Memory elements: A paradigm shift in lagrangian modeling of electrical circuits. Vienna, Austria. In proc. 7th Vienna Conference on Mathematical Modelling (MathMod), Nr. 448,.

[Kim-Cohen, 2009] Kim-Cohen, S. (2009). *In the Blink of an Ear: Toward a Non-Cochlear Sonic Art*. Continuum.

[Lapp, 2010] Lapp, D. R. (2010). In *THE PHYSICS OF MUSIC AND MUSICAL INSTRUMENTS*, pages 99–101, http://staff.tamhigh.org/lapp/book.pdf, WRIGHT CENTER FOR INNOVATIVE SCIENCE EDUCATION TUFTS UNIVERSITY MEDFORD, MASSACHUSETTS.

[Machover, 1991] Machover, T. (1991). Hyperinstruments: A composer's approach to the evolution of intelligent musical instruments. In Freeman, W., editor, *Cyberarts*. Spartan Books, San Francisco.

[Mann, 2001] Mann, S. (2001). *Intelligent Image Processing*. John Wiley and Sons. ISBN: 0-471-40637-6.

[Mann, 2002] Mann, S. (2002). Mediated reality with implementations for everyday life. *Presence Connect*. wearcam.org/presenceconnect.

[Mann, 2006] Mann, S. (2006). Learning by being: Thirty years of cyborg existemology. In Weiss, J., Nolan, J., Hunsinger, J., and Trifonas, P., editors, *The International Handbook of Virtual Learning Environments*, volume 14, pages 1571–1592. http://www.mendeley.com/research/learning-by-being-thirty-years-of-cyborg-existemology/.

[Mann, 2007] Mann, S. (2007). Physiphones... In *Proc. New Interfaces for Musical Expression*.

[Mann et al., 2007] Mann, S., Janzen, R., and Meier, J. (2007). The electric hydraulophone: A hyperacoustic instrument with acoustic feedback. In *Proc. International Computer Music Conference, ICMC '07, August 27-31, Copenhagen, Denmark*, volume 2, pages 260–7.

[Overholt et al., 2011] Overholt, D., Berdahl, E., and Hamilton, R. (2011). Advancements in actuated musical instruments. *Organized Sound*, 16(2):154–165.

[Silver et al., 2012] Silver, J., Rosenbaum, E., and Shaw, D. (2012). Makey makey: Improvising tangible and nature-based user interfaces. In *Proceedings of the ACM Tangible Embedded and Embodied Interaction*, pages 367–370, Kingston, Ontario, Canada.

[Vertegaal and Ungvary, 2001] Vertegaal, R. and Ungvary, T. (2001). Tangible bits and malleable atoms in the design of a computer music instrument. In *CHI '01: CHI '01 extended abstracts on Human factors in computing systems*, pages 311–312, New York, NY, USA. ACM Press.

[Yao and Odobez, 2007] Yao, J. and Odobez, J.-M. (2007). Multi-layer background subtraction based on color and texture. *CVPR*, pages 1–8.