Designing Wearable Technologies, and the Experiences Around Them, for Children's Body Learning

Leyla Norooz
PhD Candidate
Information Studies, UMD

UMBC
April 24, 2017
Bachelors: Computer Science, UMD '11

Masters: Human-computer Interaction, UMD '14

Currently: PhD Candidate, Information Studies

www.LeylaNorooz.com
@lnorooz
leylan@umd.edu
Research Interests

Wearable Technology

Children’s Education Technology
Research Interests

Wearable Technology

Children’s Education Technology
Understanding abstract information is hard for children because they cannot:

See the information

Abrahamson, D., Lindgren, R. *Embodiment and embodied design*, 2014
Understanding abstract information is hard for children because they cannot:

- **See the information**
- **Connect abstract concepts to everyday life experiences**

---

Abrahamson, D., Lindgren, R. *Embodiment and embodied design*, 2014
Many Science, Technology, Engineering, and Math (STEM) topics are abstract.
Many Science, Technology, Engineering, and Math (STEM) topics are abstract. Children find them boring, irrelevant, and disconnected from their lives.
Óskarsdóttir, G. PhD Dissertation, 2006
Performance of U.S. 15-Year-Old Students in Mathematics, Science, and Reading Literacy in an International Context

First Look at PISA 2012
Students in the United States are falling behind in STEM achievements, resulting in a need for new methods of learning STEM topics.

Program for International Student Assessment (PISA), 2012
“...Help students build a cohesive understanding of science over time” by thinking and acting like professional scientists and engineers.

www.NextGenScience.org
Our Approach

**MEDIUM:**
Wearable Technology

**FRAMING:**
Anatomy & Physiology
Our Approach

**MEDIUM:**
Wearable Technology

Technology is integrating into the school environment

**FRAMING:**
Anatomy & Physiology
Our Approach

**MEDIUM:** Wearable Technology

Technology is integrating into the school environment

On-body sensor-based learning, via wearable interfaces, help children explore, analyze, and visualize phenomena in STEM

**FRAMING:** Anatomy & Physiology
## Our Approach

<table>
<thead>
<tr>
<th>MEDIUM: Wearable Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology is integrating into the school environment</td>
</tr>
<tr>
<td>On-body sensor-based learning, via wearable interfaces, help children explore, analyze, and visualize phenomena in STEM</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>FRAMING: Anatomy &amp; Physiology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract Information</td>
</tr>
</tbody>
</table>
## Our Approach

<table>
<thead>
<tr>
<th><strong>MEDIUM:</strong></th>
<th><strong>Framing:</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Wearable Technology</td>
<td>Anatomy &amp; Physiology</td>
</tr>
</tbody>
</table>

- Technology is integrating into the school environment
- On-body sensor-based learning, via wearable interfaces, help children explore, analyze, and visualize phenomena in STEM

- Abstract Information
- Can play a critical role in teaching other science topics (biology, math nutrition, systems, and matter and energy)
Our Approach

**MEDIUM:** Wearable Technology

Technology is integrating into the school environment

On-body sensor-based learning, via wearable interfaces, help children explore, analyze, and visualize phenomena in STEM

**FRAMING:** Anatomy & Physiology

Abstract Information

Can play a critical role in teaching other science topics (biology, math nutrition, systems, and matter and energy)
How should designers create wearable technologies, and the experiences around them, to help elementary-aged children understand abstract concepts?
How should designers create wearable technologies, and the experiences around them, to help elementary-aged children understand abstract concepts?
How should designers create **wearable technologies**, and the **experiences around them**, to help elementary-aged children understand abstract concepts?

1. **Design considerations for wearables**

2. Help children make **life-relevant connections** with the information
How should designers create wearable technologies, and the experiences around them, to help elementary-aged children understand abstract concepts?

1. **Design considerations for wearables**
2. **Help children make life-relevant connections with the information**
3. **Encourage children to think in new ways**
How should designers create wearable technologies, and the experiences around them, to help elementary-aged children understand abstract concepts?
How should designers create wearable technologies, and the experiences around them, to help elementary-aged children understand abstract concepts?
How should designers create **wearable technologies**, and the **experiences around them**, to help elementary-aged children understand abstract concepts?

- **BodyVis**
- **SharedPhys**
- **LPSV + Personal Relevance**
How should designers create wearable technologies, and the experiences around them, to help elementary-aged children understand abstract concepts?

BodyVis  SharedPhys  LPSV + Personal Relevance  Multi-day Workshop
How should designers create wearable technologies, and the experiences around them, to help elementary-aged children understand abstract concepts?
How should designers create **wearable technologies**, and the **experiences around them**, to help elementary-aged children understand abstract concepts?
BodyVis: A New Approach to Body Learning Through Wearable Sensing and Visualization

Leyla Norooz1, Matthew L. Mauriello2, Anita Jorgensen2, Brenna McNally1, Jon E. Froehlich2
Makeability Lab | Human-Computer Interaction Lab (HIL)
College of Information Studies1, Department of Computer Science2,
University of Maryland, College Park
{leylan, matthm-401, bmcnally, jofe}@umd.edu

ABSTRACT
Internal organs are hidden and untouchable, making it difficult for children to learn their size, position, and function. Traditionally, human anatomy (body form) and physiology (body function) are taught using techniques ranging from worksheets to three-dimensional models. We present a new approach called BodyVis, an e-textile shirt that combines biometric sensing and wearable visualizations to reveal otherwise invisible body parts and functions. We describe our 15-month iterative design process including lessons learned through the development of three prototypes using participatory design and two evaluations of the final prototype: a design probe interview with seven elementary school teachers and three single-session deployments in after-school programs. Our findings have implications for the growing area of wearable and tangible learning.

Author Keywords
Wearable, interactive body learning; physiological sensing

INTRODUCTION
Learning the position, structure, and function of internal body parts is challenging for children [29,30,35]. Unlike fingers, arms, toes, and other external parts, internal organs remain hidden beneath layers of skin, muscle, and tissue and operate without conscious thought, making it difficult for children—and even adults [3]—to understand the internal workings of their bodies. This body knowledge is important. For pre-school and primary school children, higher body literacy corresponds to greater compliance with health care regimens, better self-care practices, and increased self-understanding [30,33]. For example, young children with asthma are more likely to take inhaled medications if they understand how their lungs function [30]. Other researchers emphasize the critical role of anatomy and physiology in teaching and understanding basic science (e.g., biology) [11].

In pre-school and primary school education, human anatomy (body form) and physiology (body function) are traditionally taught using a mixture of techniques including 3D models and dolls, coloring and activity books, stories, audio-visuals, and video games [35]. With the advent of low-cost physiological sensing, ubiquitous computation, and electronic textiles (e-textiles), new approaches for body learning are now possible.

In this paper, we present BodyVis, a custom-designed wearable e-textile shirt that combines biometric sensing and interactive visualization to reveal otherwise invisible parts and functions of the human body (Figure 1). The wearer’s physiological phenomena are visualized on externalized fabric anatomy, allowing the wearer and viewers to gain a unique view of the internal body. While past research has investigated wearables [22,23,24] and augmented reality [2,4,26] for body learning, BodyVis is the first exploration of a physical/digital manifestation that actively responds to the physiology of the wearer.

To investigate our approach, we iteratively designed and evaluated three BodyVis prototypes over a 15-month design cycle. While our long-term aim is to assess how a BodyVis approach may impact learning, as an initial investigation, our research questions were exploratory: e.g., identifying key design considerations, exploring the understandability, aesthetics, and approachability of our prototypes, and examining how BodyVis engages children in body learning topics. Our design iterations were informed by two participatory design sessions with children, a MakerFaire exhibit, an early demonstration at a children and technology design conference (IDEX’15) [27], and relevant prior work (e.g., importance of 3D models in learning [31], idea of bio-responsive e-textiles [21]).
How should designers create wearable technologies, and the experiences around them, to help elementary-aged children understand abstract concepts?

1. Design considerations for wearables
2. Help children make life-relevant connections with the information
3. Encourage children to think in new ways
What if our clothes revealed how our body functions?

How could this change the way children learn about and understand their bodies?

Could a t-shirt be a platform for experimentation and inquiry?

LIVE PHYSIOLOGICAL SENSING & VISUALIZATION

LPSV
DESIGN/ARCHITECTURE

SharedPhys
Current Research
Future Work

BodyVis
LPSV + Personal Relevance
Multi-day Workshop
Current Research
Future Work
Heart Rate: 60 bpm
Breathing Rate: 15 bpm

See Norooz et al., 2015 for more
Detachable Organs

Prototype 3

Detachable Organs
His heart started beating faster.
Did you build that?
Is his heart connected to that belt?
What's under the heart?
His heart is "beeping" really slow.
Do those things come off?

BodyVis Usability Study

BodyVis
SharedPhys
LPSV + Personal Relevance
Multi-day Workshop
Current Research
Future Work
Wearers and non-wearers worked together to explore and play.

Removable organs allowed for exploration.

Promoted inquiry questions and observations.
Limitations

- Does not support comparison across learners
- Need more support for quantitative analysis
- Hard to see data over time
BodyVis: A New Approach to Body Learning Through Wearable Sensing and Visualization

Leyla Norooz1, Matthew L. Mauriello2, Anita Jorgensen3, Brenna McNally1, Jon E. Froehlich2
Makeability Lab | Human-Computer Interaction Lab (HCIL)
College of Information Studies3, Department of Computer Science2
University of Maryland, College Park
{leylan, matrim-001, bcmcnally, jonf}@umd.edu

ABSTRACT
Internal organs are hidden and untouchable, making it difficult for children to learn their size, position, and function. Traditionally, human anatomy (body form) and physiology (body function) are taught using techniques ranging from worksheets to three-dimensional models. We present a new approach called BodyVis, an e-textile shirt that combines biometric sensing and wearable visualizations to reveal otherwise invisible body parts and functions. We describe our 15-month iterative design process including lessons learned through the development of three prototypes using participatory design and two evaluations of the final prototype: a design probe interview with seven elementary school teachers and three single-session deployments in after-school programs. Our findings have implications for the growing area of wearables and tangibles for learning.

Author Keywords
Wearables, interactive body learning, physiological sensing.

INTRODUCTION
Learning the position, structure, and function of internal body parts is challenging for children [29,30,35]. Unlike fingers, arms, toes, and other external parts, internal organs remain hidden beneath layers of skin, muscle, and tissue and operate without conscious thought, making it difficult for children—and even adults [3]—to understand the internal workings of their bodies. This body knowledge is important. For pre-school and primary school children, higher body literacy corresponds to greater compliance with health care regimens, better self-care practices, and increased self-understanding [30,33]. For example, young children with asthma are more likely to take inhaled medications if they understand how their lungs function [30]. Other researchers emphasize the critical role of anatomy and physiology in teaching and understanding basic science (e.g., biology) [11].

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for components of this work owned by others than ACM must be honored. Abstracting with credit is permitted. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee. Request permissions from permissions@acm.org. 

CHI 2015, April 18 - 22 2015, Seoul, Republic of Korea
Copyright is held by the owner/author(s). Publication rights licensed to ACM.
ACM 978-1-4503-3145-6/15/04...$15.00
http://dx.doi.org/10.1145/2702123.2702259

In pre-school and primary school education, human anatomy (body form) and physiology (body function) are traditionally taught using a mixture of techniques including 3D models and dolls, coloring and activity books, stories, audio-visuals, and video games [35]. With the advent of low-cost physiological sensing, ubiquitous computation, and electronic textiles (e-textiles), new approaches for body learning are now possible.

In this paper, we present BodyVis, a custom-designed wearable e-textile shirt that combines biometric sensing and interactive visualization to reveal otherwise invisible parts and functions of the human body (Figure 1). The wearer’s physiological phenomena are visualized on externalized fabric anatomy, allowing the wearer and viewers to gain a unique view of the internal body. While past research has investigated wearables [22,23,24] and augmented reality [2,4,26] for body learning, BodyVis is the first exploration of a physical/digital manifestation that actively responds to the physiology of the wearer.

To investigate our approach, we iteratively designed and evaluated three BodyVis prototypes over a 15-month design cycle. While our long-term aim is to assess how a BodyVis approach may impact learning, as an initial investigation, our research questions were exploratory: e.g., identifying key design considerations, exploring the understandability, aesthetics, and approachability of our prototypes, and examining how BodyVis engages children in body learning topics. Our design iterations were informed by two participatory design sessions with children, a MakerFaire exhibit, an early demonstration at a children and technology design conference (IDC ’15) [27], and relevant prior work (e.g., importance of 3D models in learning [31], idea of bio-responsive e-textiles [21]).
SharedPhys: Live Physiological Sensing, Whole-Body Interaction, and Large-Screen Visualizations to Support Shared Inquiry Experiences

Seokbin Kang, Leyla Norouz, Vanessa Oguamanam, Angela C. Plane, Tamara L. Clegg, Jon E. Froehlich

ABSTRACT

We present and evaluate a new mixed-reality tool called SharedPhys, which tightly integrates real-time physiological sensing, whole-body interaction, and responsive large-screen visualizations to support new forms of embodied interaction and collaborative learning. While our primary content area is the human body, we use the body and physical activity as a pathway to other STEM areas such as biology, health, and mathematics. We describe our participatory design process with 20 elementary school teachers, the development of three contrasting SharedPhys prototypes, and results from six exploratory evaluations in two after-school programs. Our findings suggest that the tight coupling between physical interaction, sensing, and visualization in a multi-user environment helps promote engagement, allows children to easily explore cause-and-effect relationships, supports and shapes social interactions, and promotes playful experiences.

Author Keywords

Physiological sensing; large-screen displays; mixed-reality; scientific inquiry; collaborative learning; STEM; wearables

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI)

INTRODUCTION

With the emergence of body-tracking technologies such as Fitbit and the Microsoft Kinect, there has been increased interest in exploring how embodied interaction [14] can enable and support new learning experiences [34]. Recent work by Lee et al., for example, helps demonstrate the potential of wearable activity trackers and interactive visualizations to engage children in scientific inquiry that is authentic and life-relevant [36, 37]. Often citing the role of embodiment in cognition [56], others have explored utilizing the entire body through movement or gesture to support new forms of computer-mediated learning [31, 34]. Though a nascent area, research suggests that these whole-body interactions can help increase engagement [1, 62] and immersion [1, 69], support and shape social interaction [59, 69], and aid learning [31]

Building on the above work, this paper introduces and evaluates SharedPhys, which integrates live-streaming physiological sensors, whole-body interaction, and real-time large-screen visualizations to create a novel mixed-reality learning environment. With SharedPhys, children interact physically—both explicitly via body movement, gesture, and position as well as implicitly via their changing physiology. While prior work has explored body-centric inquiry (e.g., [32, 36, 37]), the data collection and subsequent analyses are often disjoint and performed on a traditional computer setup. In contrast, our work simultaneously involves the body in data collection, interaction, and analysis creating new opportunities for feedback loops and playful experimentation. Similarly, while recent work has explored mixed-reality environments for collaborative learning, most have utilized simulations (e.g., [12, 42, 47]) or artificial data (e.g., [58]). Our work combines live streams of real body-data in a shared environment. We believe this tight coupling between physical action, physiological sensing, and live visualization offers new, rich possibilities for user interaction and learning experiences.
How can we compare and analyze bio-data over time?
large display

physiological sensors

kinect camera
SharedPhys: Three Designs
SharedPhys: Three Designs

Magic Mirror
Basic human **physiology & anatomy**

Animal Avatar
Structures and processes across animals

Moving Graphs
Relating **health and human activity**
SharedPhys: Three Designs

Magic Mirror
Basic human physiology & anatomy

Animal Avatar
Structures and processes across animals

Moving Graphs
Relating health and human activity

See Kang et al., 2016 for more
Moving Graphs
Findings

Tight **coupling** between actions and visualizations

The shared environment afforded **social interactions**

**Interplay** between wearers and non-wearers
**SharedPhys: Live Physiological Sensing, Whole-Body Interaction, and Large-Screen Visualizations to Support Shared Inquiry Experiences**

Seokbin Kang, Leyla Norouzi, Vanessa Oguamanam, Angelisa C. Plane, Tamara L. Clegg, Jon E. Froehlich

Makeability Lab | Human-Computer Interaction Lab
Department of Computer Science, College of Information Studies, College of Education
University of Maryland, College Park

{skang, leylan, vano, angelisa, tlclegg, jonf}@umd.edu

ABSTRACT

We present and evaluate a new mixed-reality tool called SharedPhys, which tightly integrates real-time physiological sensing, whole-body interaction, and responsive large-screen visualizations to support new forms of embodied interaction and collaborative learning. While our primary content area is the human body, we use the body and physical activity as a pathway to other STEM areas such as biology, health, and mathematics. We describe our participatory design process with 20 elementary school teachers, the development of three contrasting SharedPhys prototypes, and results from six exploratory evaluations in two after-school programs. Our findings suggest that the tight coupling between physical interaction, sensing, and visualization supports collaborative learning, allows children to explore cause-and-effect relationships, and promotes playful experiences.

Author Keywords

Physiological sensing; large-screen displays; mixed-reality; scientific inquiry; collaborative learning; STEAM; wearables

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI)

INTRODUCTION

With the emergence of body-tracking technologies such as Fitbit and the Microsoft Kinect, there has been increased interest in exploring how embodied interaction [14] can enable and support new learning experiences [34]. Recent work by Lee et al., for example, helps demonstrate the potential of wearable activity trackers and interactive visualizations to engage children in scientific inquiry that is authentic and life-relevant [36, 37]. Often citing the role of embodiment in cognition [56], others have explored utilizing the entire body through movement or gesture to support new forms of computer-mediated learning [31, 34]. Though a nascent area, research suggests that these whole-body interactions can help increase engagement [1, 62] and immersion [1, 69], support and shape social interaction [59, 69], and aid learning [31].

Building on the above work, this paper introduces and evaluates SharedPhys, which integrates live-streaming physiological sensors, whole-body interaction, and real-time large-screen visualizations to create a novel mixed-reality learning environment. With SharedPhys, children interact physically—both explicitly via body movement, gesture, and position as well as implicitly through changing physiology. While prior work has explored body-centric inquiry (e.g., [32, 36, 37]), the data collection and subsequent analyses are often disjoint and performed on a traditional computer setup. In contrast, our work simultaneously involves the body in data collection, interaction, and analysis creating new opportunities for feedback loops and playful experimentation. Similarly, while recent work has explored mixed-reality environments for collaborative learning, most have utilized simulations (e.g., [12, 42, 47]) or artificial data (e.g., [58]). Our work combines live streams of real body-data in a shared environment. We believe this tight coupling between physical action, physiological sensing, and live visualization offers new, rich possibilities for user interaction and learning experiences.
"That’s your heart!": Live Physiological Sensing & Visualization Tools for Life- Relevant & Collaborative STEM Learning

Leyla Norooz, Tamara L. Clegg, Seokbin Kang, Angelisa C. Plane, Vanessa Oguamanam, Jon E. Froehlich
University of Maryland, College Park, Maryland, USA
{leylan, tclegg, sbkang, appleace, vanouga, jonf}@umd.edu

Abstract: Wearable technology and large-screen display systems show potential for helping learners engage in STEM in ways relevant to their daily lives, but it is important to understand how learning activities coupled with these tools can promote rich learning experiences. To advance these goals, our work utilizes a new genre of embodied technology tools for STEM learning—live physiological sensing and visualization (LPSV) tools, called BodyVis and SharedPhys—that display learners’ physiological functions in real-time on a wearable, e-textile shirt and a large-screen display, respectively. We iteratively developed a set of learning activities to evaluate how these tools can support STEM engagement. Our findings show potential for LPSV tools to enable new forms of life-relevant and collaborative scientific learning experiences.

Keywords: embodied learning, STEM, physiological sensing, LPSV tools

Introduction
Recent advances in wearable technologies (e.g., fitness trackers) enable new opportunities to make STEM learning less abstract and more relevant to learners’ lives. However, to fully realize the potential of wearables for STEM learning, we must understand how learning activities coupled with these tools can promote meaningful learning experiences. We advance this understanding in the context of live (i.e., real-time) physiological sensing and visualization (LPSV) tools that support embodied learning to promote life-relevant, collaborative STEM learning. LPSV tools integrate real-time physiological sensing and visual displays to promote learning about organ function, physical activity, and scientific inquiry.

Our prior work has focused on the design of two LPSV tools, BodyVis and SharedPhys (Figure 1a and c, respectively), to support body learning and engagement in scientific inquiry by visualizing wearers’ live body-data (i.e., heart and breathing rate) on an electronic textile (e-textile) shirt (BodyVis) and a large-screen display (SharedPhys). We have two high-level goals with our LPSV tools: (1) to help children understand and learn about the body and its connection to the physical world (e.g., eating, exercise), and (2) to use the body as a life-relevant platform to help children build general scientific inquiry skills (e.g., Why does my heart rate increase before a test or during soccer practice?). In this paper, we analyze data from several deployments with a common analytical lens aimed specifically at better understanding how LPSV tools can support life-relevant and collaborative STEM learning experiences for elementary-aged youth.

Our findings show that LPSV tools were relevant to our participants’ daily lives as they connected their own organ functions (e.g., heart and breathing rate) to their everyday physical activities, emotions, and social experiences. Additionally, learners engaged in collective observation, experimentation, and hypothesis generation as they interacted with our LPSV tools. Our contributions include (i) characterizing learning experiences children have with LPSV tools, and (ii) design implications for LPSV learning activities.

Life- Relevant and Collaborative Learning Technologies
Our goal is to leverage wearables to deepen learners’ STEM engagement through supporting life-relevant, collaborative inquiry experiences. In life-relevant learning experiences, learners derive meaning relevant to their lives from acting and thinking like scientists (Clegg, Gardner, & Kolodner, 2010). Such experiences enable learners to connect science inquiry and learning to their own interests, passions, and lived experiences (Clegg et al., 2016). Two recent approaches to wearable learning tools illustrate the potential of wearables to support life-relevant experiences by investigating one’s own physical and physiological data: (i) using fitness trackers for math analysis—e.g., comparing sports, validating accuracy of fitness trackers, strategizing workouts based on statistical data analysis (Lee, 2015, Chapter 9) and (ii) experimenting for STEM learning and health knowledge (e.g., Carter Chung & Schaefer, 2015). These approaches offer opportunities for learners to create and engage in new inquiries with data from activities in their everyday lives (e.g., games, sports).
Live Physiological Sensing and Visualization (LPSV) Tools

BodyVis

SharedPhys

LPSV + Personal Relevance

Multi-day Workshop

Current Research

Future Work
How should designers create wearable technologies, and the experiences around them, to help elementary-aged children understand abstract concepts?

1. Design considerations for wearables
2. Help children make life-relevant connections with the information
3. Encourage children to think in new ways
How do **LPSV tools** support **life-relevant** STEM learning experiences for youth?
How do LPSV tools support life-relevant STEM learning experiences for youth?
Learning Activities for LPSV Tools
Learning Activities for LPSV Tools

Participatory Design
Learning Activities for LPSV Tools

Participatory Design

Goal
To collaboratively design learning activities that utilized our LPSV tools
Learning Activities for LPSV Tools

Participatory Design

Children
Learning Activities for LPSV Tools

Participatory Design

Children

Teachers

BodyVis  SharedPhys  LPSV + Personal Relevance  Multi-day Workshop  Current Research  Future Work
Learning Activities for LPSV Tools

Participatory Design

Competitions
Games

BodyVis
SharedPhys
LPSV + Personal Relevance
Multi-day Workshop
Current Research
Future Work
Learning Activities for LPSV Tools

Participatory Design

Competitions
Games

Experimenting high- and low-impact physical activities

BodyVis  SharedPhys  LPSV + Personal Relevance  Multi-day Workshop  Current Research  Future Work
The Resulting Learning Activities

- Small groups or pairs brainstorm activities
- Make predictions
- Test with BodyVis or SharedPhys
- Discuss results

BodyVis  |  SharedPhys  |  LPSV + Personal Relevance  |  Multi-day Workshop  |  Current Research  |  Future Work
Sessions

BodyVis

<table>
<thead>
<tr>
<th>BodyVis</th>
<th>LPSV + Personal Relevance</th>
<th>SharedPhys</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Research</td>
<td>Multi-day Workshop</td>
<td>Future Work</td>
</tr>
</tbody>
</table>

SharedPhys
Sessions

BodyVis

LPSV + Personal Relevance

Multi-day Workshop

Current Research

Future Work

SharedPhys
Sessions

BodyVis

SharedPhys

LPSV + Personal Relevance

Multi-day Workshop

Current Research

Future Work
Sessions

Joint 2\textsuperscript{nd} and 3\textsuperscript{rd} grade private school classroom

Out of school programs (Boys & Girls Club)
Participants (Total)

- 5-13 Ages
- 130 Participants
- 54 Female
- 76 Male

BodyVis  SharedPhys  LPSV + Personal Relevance  Multi-day Workshop  Current Research  Future Work
Analysis

**Life-relevant Experiences**
Indicators of linking experiences to everyday life, demonstrations of excitement and curiosity

**Collaboration**
Ways wearers and non-wearers interacted
Analysis

Life-relevant Experiences
Indicators of linking experiences to everyday life, demonstrations of excitement and curiosity

Collaboration
Ways wearers and non-wearers interacted
Findings: Life-Relevance

Both Tools
Children utilized everyday activities to form questions and hypotheses
Findings: Life-Relevance

BodyVis

LPSV + Personal Relevance

Multi-day Workshop

Current Research

Future Work

SharedPhys
Findings: Life-Relevance

BodyVis

Emotion $\rightarrow$ Physiology

SharedPhys

LPSV + Personal Relevance
I kind of felt embarrassed because all these people were staring at me. So it kind of went up.
Findings: Life-Relevance

BodyVis

Emotion → Physiology

SharedPhys

Connection between bodies & visualization

LPSV + Personal Relevance

Multi-day Workshop

Current Research

Future Work
LPSV + Personal Relevance
Findings: Life-Relevance

BodyVis

Emotion → Physiology

SharedPhys

Connection between bodies & visualization

Games and competition

LPSV + Personal Relevance
Implications

Learners need **formal and informal** learning time with LPSV tools
Implications

Learners need **formal and informal** learning time with LPSV tools

Need opportunities to **wear & observe**
Implications

Learners need **formal and informal** learning time with LPSV tools.

Need opportunities to **wear & observe**

Learning contexts should be **flexible**
“That’s your heart!”: Live Physiological Sensing & Visualization Tools for Life-Relevant & Collaborative STEM Learning

Leyla Norooz, Tamara L. Clegg, Seokbin Kang, Angelisa C. Plane, Vanessa Ogwumike, Jon E. Froehlich
University of Maryland, College Park, Maryland, USA
{leylan, tclegg, skbkg, aplane, vanogu, jorf}@umd.edu

Abstract: Wearable technology and large-screen display systems show potential for helping learners engage in STEM in ways relevant to their daily lives, but it is important to understand how learning activities coupled with these tools can promote rich learning experiences. To advance these goals, our work utilizes a new genre of embodied technology tools for STEM learning—live physiological sensing and visualization (LPSV) tools, called BodyVis and SharedPhys—that display learners’ physiological functions in real-time on a wearable, e-textile shirt and a large-screen display, respectively. We iteratively developed a set of learning activities to evaluate how these tools can support STEM engagement. Our findings show potential for LPSV tools to enable new forms of life-relevant and collaborative scientific learning experiences.

Keywords: embodied learning, STEM, physiological sensing, LPSV tools

Introduction
Recent advances in wearable technologies (e.g., fitness trackers) enable new opportunities to make STEM learning less abstract and more relevant to learners’ lives. However, to fully realize the potential of wearables for STEM learning, we must understand how learning activities coupled with these tools can promote meaningful learning experiences. We advance this understanding in the context of live (i.e., real-time) physiological sensing and visualization (LPSV) tools that support embodied learning to promote life-relevant, collaborative STEM learning. LPSV tools integrate real-time physiological sensing and visual displays to promote learning about organ function, physical activity, and scientific inquiry.

Our prior work has focused on the design of two LPSV tools, BodyVis and SharedPhys (Figure 1a and c, respectively), to support body learning and engagement in scientific inquiry by visualizing wearers’ live body data (i.e., heart and breathing rate) on an electronic textile (e-textile) shirt (BodyVis) and a large-screen display (SharedPhys). We have two high-level goals with our LPSV tools: (i) to help children understand and learn about the body and its connection to the physical world (e.g., eating, exercise), and (ii) to use the body as a life-relevant platform to help children build general scientific inquiry skills (e.g., Why does my heart rate increase before a test or during soccer practice?). In this paper, we analyze data from several deployments with a common analytical lens aimed specifically at better understanding how LPSV tools can support life-relevant and collaborative STEM learning experiences for elementary-aged youth.

Our findings show that LPSV tools were relevant to our participants’ daily lives as they connected their own organ functions (e.g., heart and breathing rate) to their everyday physical activities, emotions, and social experiences. Additionally, learners engaged in collective observation, experimentation, and hypothesis generation as they interacted with our LPSV tools. Our contributions include (i) characterizing learning experiences children have with LPSV tools, and (ii) design implications for LPSV learning activities.

Life-Relevant and Collaborative Learning Technologies
Our goal is to leverage wearables to deepen learners’ STEM engagement through supporting life-relevant, collaborative inquiry experiences. In life-relevant learning experiences, learners derive meaning relevant to their lives from acting and thinking like scientists (Clegg, Gardner, & Kolodner, 2010). Such experiences enable learners to connect science inquiry and learning to their own interests, passions, and lived experiences (Clegg et al., 2010). Two recent approaches to wearable learning tools illustrate the potential of wearables to support life-relevant experiences by investigating one’s own physical and physiological data: (i) using fitness trackers for math analysis—e.g., comparing sports, validating accuracy of fitness trackers, strategizing workouts based on statistical data analysis (Lee, 2015, Chapter 9) and (ii) exergaming for STEM learning and health knowledge (e.g., Carter Chung & Schaefer, 2015). These approaches offer opportunities for learners to create and engage in new inquiries with data from activities in their everyday lives (e.g., games, sports).
Live Physiological Sensing and Visualization Ecosystems: An Activity Theory Analysis

Tamara Clegg, Leyla Nurouz, Sokhin Kang, Virginia Byrne, Monica Katzen, Rafael Velez, Angelisa Plane, Vanessa Oguamanam, Thomas Outing, Jason Yip, Elizabeth Bonsignore, Jon Froehlich

University of Maryland, College Park
(tclegg, leyla, byrne, rvelez, vanoga, ebonsign)@umd.edu

Computer Science, Mathematics
University of Maryland, College Park
(sbkang, mkatzen, aplane, jouting, jyip)@umd.edu

The Information School
University of Washington
jyip@uw.edu

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for components of this work owned by others than ACM must be honored. Abstracting with credit is permitted. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee. Request permissions from Permissions@acm.org.

Figure 1. In this paper, we present a four-day deployment study of LPSV tools in a formal classroom environment where (a) children brainstorm questions, test hypotheses with a model-based tool called (b) BodyVis and with an analytic-based tool called (c) SharedPhys, and (d) present their experiment results.

ABSTRACT
Wearable sensing poses new opportunities to enhance personal connections to learning and authentic scientific inquiry experiences. In our work, we leverage the body and physical action as an engaging platform for learning through live physiological sensing and visualization (LPSV). Prior research suggests the potential of this approach, but was limited to single-session evaluations in informal environments. In this paper, we examine LPSV tools in a classroom environment during a four-day deployment. To highlight the complex interconnections between space, teachers, curriculum, and tool use, we analyze our data through the lens of Activity Theory. Our findings show the importance of integrating model-based representations for supporting exploration and analytic representations for scaffolding scientific inquiry. Activity Theory highlights leveraging life-relevant connections available within a physical space and considering policies and norms related to learners' physical bodies.

INTRODUCTION
With the emergence of cheap and reliable wearable activity trackers, there has been renewed interest in the role of sensors for learning and education [4,26,27,29]. Indeed, wearable sensing capabilities pose new opportunities to significantly enhance personal connections to learning and authentic scientific inquiry experiences (e.g., asking questions, collecting and analyzing data, making claims) [7]. For example, trackers that learners wear on their wrists or clothes can seamlessly collect data about one’s physical activity (e.g., steps taken) and vitals (e.g., heart rate) throughout the day that can be analyzed later on mobile or desktop devices [4,28]. These new capabilities also significantly increase learners’ opportunities to apply scientific inquiry to their daily life experiences—to scientize everyday life [8,9].

We are particularly interested in leveraging the body and physical action as a platform for learning through live physiological sensing and visualization (LPSV) [22,42]. LPSV tools sense and visualize learners’ physiological functioning (e.g., heart rate, breathing rate) in real-time, projecting analytic (i.e., graph-based) and model-based representations of the data. For example, BodyVis [44] and SharedPhys [22] are two LPSV tools that visualize wearers’ live body-data on an electronic textile (e-textile) shirt and a large-screen display respectively (Figure 1).

While research on applying wearable sensing to educational technology is still in its infancy, it builds on a long history of prior research on sensor-based learning (SBL) (e.g., [19,31,53,55]). These studies have shown the effectiveness of real-time analytic data (e.g., real-time graphs of changes in one’s motion) (e.g., [4,33]) and model-based representations [13,31] for supporting authentic scientific
How should designers create **wearable technologies**, and the **experiences around them**, to help elementary-aged children **understand abstract concepts**?

1. **Design considerations** for wearables

2. Help children make **life-relevant connections** with the information

3. Encourage children to **think in new ways**
Single session deployments for each tool
Single session deployments for each tool
Limited amount of time for lots of activities
The use of microcomputer based laboratories in chemistry secondary education: Present state of the art and ideas for research-based practice

Montserrat Tortosa

Received 11th December 2011, Accepted 15th May 2012
DOI: 10.1039/c2rp00009a

In microcomputer based laboratories (MBL) and data loggers, one or more sensors are connected to an interface and this to a computer. This equipment allows visualization in real time of the variables of an experiment and provides the possibility of measuring magnitudes which are difficult to measure with traditional equipment. Research shows that the advantages of using this technology go further than simply motivating students as they can improve other abilities, such as interpretation of graphs, and it can help to develop several competencies and higher order learning skills in students. The aims of this study are to learn about the potential of MBL in chemistry classrooms and to present a framework for research based lab sheets. In this work, research reporting significant learning in secondary school chemistry laboratory using an inquiry approach related to microcomputer based laboratory experiences is reviewed. Instructional effectiveness of the technology, research based materials for students, ideas for practice and opinions of teachers and students when using this technology are reviewed.

Introduction

Significant learning in the chemistry laboratory

The idea that meaningful learning is possible in the laboratory if students are given opportunities to manipulate equipment and materials in a suitable environment (Tobin, 1990) is widely accepted, but research in didactics has not found simple relationships between laboratory experiences and the learning outcomes of students (Hofstein and Lunetta, 1982, 2003). The science laboratory is a unique learning environment as it has the potential to provide science teachers with opportunities to vary their instructional techniques and to avoid a monotonous classroom learning environment. Although it has been demonstrated that traditional teaching methods do not solve students’ learning difficulties, even for those who wish to become scientists, there are various opinions on how to teach or how to apply the results of the research on science education into school laboratories. It is generally accepted that meaningful learning takes place when students not only remember but also make sense of and are able to apply what they have learned (Anderson and Krathwohl, 2001), and that there is a considerable amount of evidence collected by researchers of science teaching that traditional instructional methods, largely lectures and undertaking exercises, are not effective methods for all learners. Sufficient data do exist to suggest that laboratory instruction is an effective and efficient teaching medium to attain some of the goals for teaching and learning science and that appropriate laboratory activities have a great potential in promoting positive attitudes and in providing students with opportunities to develop skills regarding cooperation and communication (Hofstein, 2003; Hofstein and Mamlok-Naaman, 2007).

To improve science competencies in citizenship, inquiry-based science education (IBSE) has been proposed by many science researchers and educators. IBSE has proven its efficacy at both primary and secondary level increasing students’ interest and attainment level while motivating the teacher at the same time (Hofstein et al., 2003; Fortus et al., 2006; Rocard et al., 2007; Barnes et al., 2010). There is agreement (Rocard et al., 2007) that inquiry is a good way of presenting laboratory work, and that to improve scientific literacy (PISA OECD, 2003) learners must have opportunities to practice selected skills. The analysis regarding the students’ perceptions clearly demonstrates (Hofstein, 2003) that students who were involved in inquiry-type investigations found the laboratory learning environment to be more open-ended and more integrated with a conceptual framework than those students in a control group. They also found that the gap between the actual and the preferred learning environment on various levels was significantly smaller in the inquiry group than in the control group. Students perceived that they were more involved in the learning process and found the procedures more open-ended. The integration of laboratory experience with other pedagogical interventions and classroom instructional techniques was associated with a significant reduction in the magnitude of the differences

Of the studies that have taken place in formal classrooms...

Often focus on a narrow set of components in the ecosystem (e.g., teacher preparation, tool maintenance and management, curriculum)
How does the **LPSV ecosystem** influence children’s **life-relevant connections** to **scientific inquiry**?
How does the LPSV ecosystem influence children’s life-relevant connections to scientific inquiry?

Asking questions, collecting and analyzing data, making claims
Designing the Workshop

Previous Study → Implementation

- BodyVis
- SharedPhys
- LPSV + Personal Relevance
- Multi-day Workshop
- Current Research
- Future Work
Learners need **formal and informal** learning time with LPSV tools. **Play** time and **mediated learning** time.
Learners need **formal and informal** learning time with LPSV tools.

need opportunities to wear & observe

A **different children wears** a tool each day.

**Designing the Workshop**

**Previous Study**

Learners need **formal and informal** learning time with LPSV tools

**Implementation**

Play time and **mediated learning** time

Need opportunities to **wear & observe**
Learners need **formal and informal** learning time with LPSV tools.

Need opportunities to **wear & observe**

Learning contexts should be **flexible**

**Play time and mediated learning time**

A **different children wears a tool each day**

Children design **science experiments**

**Learners need formal and informal learning time with LPSV tools**

**Designing the Workshop**

**Previous Study**

**Implementation**

---

BodyVis

SharedPhys

LPSV + Personal Relevance

Multi-day Workshop

Current Research

Future Work
Day 1: Play and Discovery

Children discussed questions and engaged in free-form exploration with the tools in a scavenger hunt.
Day 2: Exploring Physical Activities

Children brainstormed physical activities with BodyVis. They then tested their hypotheses with SharedPhys.
Day 3: Science Experiments

Children planned scientific investigations of their choosing with BodyVis or SharedPhys.
Day 4: Presentations

Children presented their choice-based investigations.
4-Day Workshops

1st Grade  2nd Grade  4th Grade

1. PLAY  2. EXPLORE  3. EXPERIMENT  4. PRESENT

BodyVis  SharedPhys  LPSV + Personal Relevance  Multi-day Workshop  Current Research  Future Work
4-Day Workshops

1st Grade

2nd Grade

4th Grade

12 Days Total

1. PLAY

2. EXPLORE

3. EXPERIMENT

4. PRESENT

BodyVis

SharedPhys

LPSV + Personal Relevance

Multi-day Workshop

Current Research

Future Work
Participants (Total)

65 Participants

27 Female

24 Male

Undisclosed 11
Activity Theory Analysis

Activity Theory places an emphasis on analyzing the interaction between people, artifacts, and social groups.

Artifact:
LPSV tools & Non-technical artifacts (e.g., food, scaffolding charts)

Subject:
Learners

Object:
Motivation for learning about scientific thinking

Outcome:
Life-relevant scientific inquiry

Rules:
Classroom Governance (norms & conventions)

Community:
Social context in which learners collaborate with one another or with teachers & researchers

Division of Labor:
Learners divvied tasks Teacher & facilitator roles
Findings

4th Graders were better at engaging in scientific inquiry
Findings

4th Graders were better at engaging in scientific inquiry

Need for objectives and more direct instruction
Findings

4th Graders were better at engaging in scientific inquiry

Need for objectives and more direct instruction

BodyVis promoted personalization; SharedPhys promoted socialization
Findings

4th Graders were better at engaging in scientific inquiry.

Need for objectives and more direct instruction.

BodyVis promoted personalization; SharedPhys promoted socialization.

Non-technical artifacts (jump rope, games, pregnant teachers) promote inquiry.
Implications

Designing Artifacts to Support Life-Relevant Inquiry

Link model-based and analytic representations to help children make connections
Implications

Designing Artifacts to Support Life-Relevant Inquiry

- Link model-based and analytic representations to help children make connections
- Leverage non-technical artifacts to promote inquiry investigations and life-relevant connections
Implications

Integrating LPSV Tools into the Classroom Environment

Allow for **incremental integration** of new variables into inquiry experiences for younger learners
Implications

Integrating LPSV Tools into the Classroom Environment

Allow for **incremental integration** of new variables into inquiry experiences for younger learners.

Help educators **mitigate** the range of **sensitive discussions** that may arise in LPSV environments.
Live Physiological Sensing and Visualization Ecosystems: An Activity Theory Analysis

Tamara Clegg1,2, Leyla Norouzi2, Sonshin Kang1, Virginia Byrne2, Monica Katzen1, Rafael Velecz2, Angelisa Planc2, Vanessa Ogurmanan1, Thomas Outing2, Jason Yip2, Elizabeth Bonnigone3, Jon Frochlich4

1 Information Studies, 2 Education, 3 Computer Science, 4 Mathematics, and 5 The Information School
University of Maryland, College Park and University of Washington
{jccleg, leylan, vbyrne, rvelez, vanouga, ebonigone} @umd.edu

ABSTRACT

Wearable sensing poses new opportunities to enhance personal and communal connections to learning and authentic scientific inquiry experiences. In our work, we leverage the body and physical action as an engaging platform for learning through live physiological sensing and visualization (LPSV). Prior research has shown the potential of this approach, but was limited to single-session evaluations in informal environments. In this paper, we examine LPSV tools in a classroom environment during a four-day deployment. To highlight the complex interconnections between space, time, teachers, curriculum, and tool use, we analyze our data through the lens of Activity Theory. Our findings show the importance of integrating model-based representations for supporting exploration and analytic representations for scaffolding scientific inquiry. Activity Theory highlights leveraging life-relevant connections available within a physical space and considering policies and norms related to learners’ physical bodies.

Author Keywords

Scientific inquiry, SBL, LPSV, wearables for learning

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI)

INTRODUCTION

With the emergence of cheap and reliable wearable activity trackers, there has been renewed interest in the role of sensors for learning and education [4,26,27,29]. Indeed, wearable sensing capabilities pose new opportunities to significantly enhance personal connections to learning and authentic scientific inquiry experiences (i.e., asking questions, collecting and analyzing data, making claims) [7]. For example, trackers that learners wear on their wrists or clothes can seamlessly collect data about one’s physical activity (e.g., steps taken) and vital signs (e.g., heart rate) throughout the day that can be analyzed later on mobile or desktop devices [4,26]. These new capabilities also significantly increase learners’ opportunities to apply scientific inquiry to their daily life experiences—to scientize everyday life [8,9].

We are particularly interested in leveraging the body and physical action as a platform for learning through live physiological sensing and visualization (LPSV) [22,42]. LPSV tools sense and visualize learners’ physiological functioning (e.g., heart rate, breathing rate) in real-time, projecting analytic (i.e., graph-based) and model-based representations of the data. For example, BodyVis [44] and SharedPhys [22] are two LPSV tools that visualize wearers’ live body-data on an electronic textile (e-textile) shirt and a large-screen display respectively (Figure 1).

While research on applying wearable sensing to educational technology is still in its infancy, it builds on a long history of prior research on sensor-based learning (SBL) (e.g., [19,31,53,55]). These studies have shown the effectiveness of real-time analytic data (e.g., real-time graphs of changes in one’s motion) (e.g., [41,53]) and model-based representations [13,31] for supporting authentic scientific...
Current Research
Iterating on the Workshop

Participatory Design with Teachers

BodyVis  SharedPhys  LPSV + Personal Relevance  Multi-day Workshop  Current Research  Future Work
Iterating on the Workshop

Participatory Design with Teachers

Goal

Cognitively **scale activities** and assessments with respect to grade level

Develop additional **scaffolding** materials to guide learning

Identify **key points for teachers** to address sensitive topics and control physical activity
Changes Made to the Workshop

Daily Objectives

BodyVis  SharedPhys  LPSV + Personal Relevance  Multi-day Workshop  Current Research  Future Work
Changes Made to the Workshop

- Daily Objectives
- Structured Activities
Changes Made to the Workshop

- Daily Objectives
- Structured Activities
- Cognitively Scaled Activities and Assessments
Iterating on the Workshop
Current Research
Future Work
LPSV Tools are abstract in and of themselves
How should designers create wearable technologies, and the experiences around them, to help elementary-aged children understand abstract concepts?

1. Design considerations for wearables
2. Help children make life-relevant connections with the information
3. Encourage children to think in new ways
“Learn about how wearables work by building your own wearables”
Modeling Body Systems via Wearable Construction Kits

“Learn about how wearables work by building your own wearables”
Key Takeaways

When designing wearable technologies for school environments:

Involvem *all* stakeholders in every step of the design process
Key Takeaways

When designing wearable technologies for school environments:

- Involve *all* stakeholders in every step of the design process
- Consider pre-established dynamics of the environment
Key Takeaways

When designing wearable technologies for school environments:

- Involve all stakeholders in every step of the design process
- Consider pre-established dynamics of the environment
- Cognitively scale activities based on age and ability