

POP-UP

# Sensory Design Lab

## A Prototype for Experimental Research in Real-Life Settings

STUDY 1:

How do personalization of space and environmental quality impact student response?

ASID Foundation Transform Grant



HKS

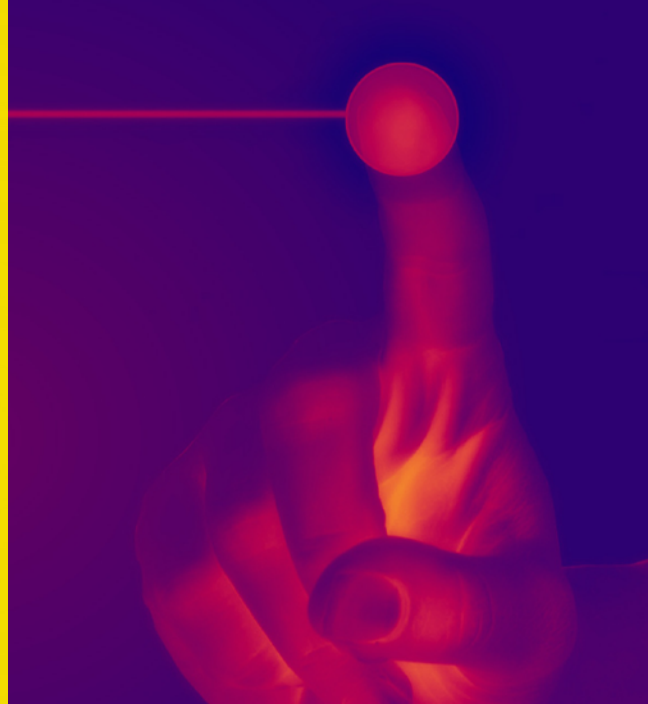
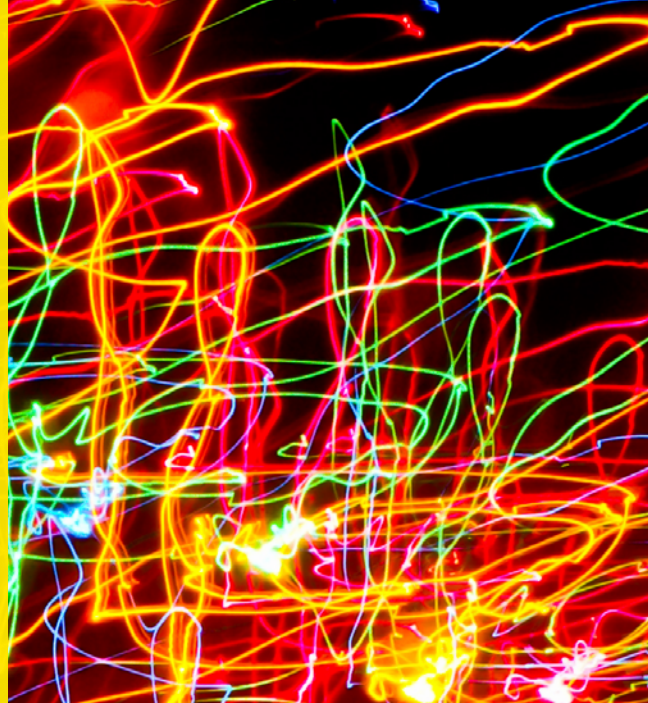


Research partners

CADRE | Center for Advanced Design Research and Evaluation

HermanMiller

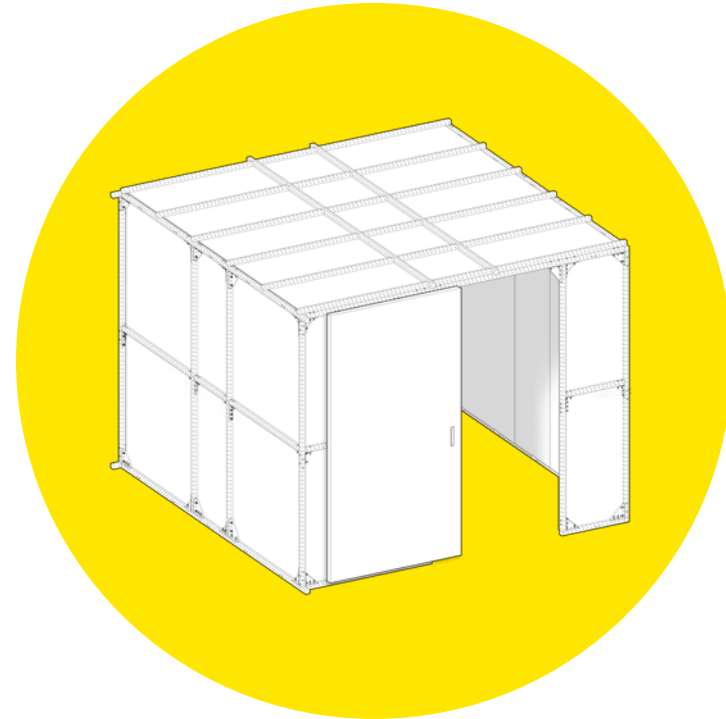
Research sponsor



#### THE CHALLENGE

The built environment can affect human outcomes. A systematic study of human-environmental relationships in a controlled environment can differ from real-life environments.

What if we could create pop-up experiment spaces to test how design can affect humans?



#### OBJECTIVE

The SDL prototype aims to explore the relationships among environmental conditions and human responses. This pilot study focused on furniture selection, room layout, and environmental conditions (sound, illumination, temperature and humidity) as independent variables. Human responses, such as behaviors, self-reported learning achievement, subjective anxiety levels, and heart rate were dependent variables.

#### LITERATURE REVIEW

The role of the physical environment can be critical in students' learning and may be more so when implementing approaches that increase students' autonomy, such as personalized learning. Strategies that have been recommended and implemented for such approaches include: (1) reconfigurable, multipurpose rooms that can facilitate a range of learning modalities (e.g., project-based learning, teacher-led small-group instruction, inquiry-based instruction, blended learning) (2) collaborative student and staff spaces (3) movable, multipurpose furniture (4) infrastructure to support anytime, anywhere learning. However, none of the previous studies isolated a single design variable within a controlled setting to assess its potential impact.

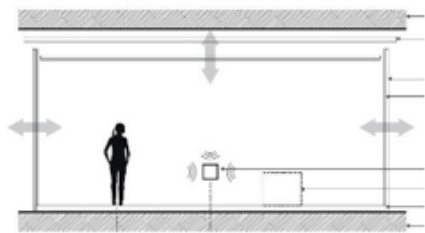
#### RESEARCH QUESTIONS

- 01:** How can we create a rapidly deployable space for environmental testing?
- 02:** Can we test relationships between environmental attributes and the response of high school students within a pop-up space?
- 03:** How do personalization of space and environmental quality impact student response?



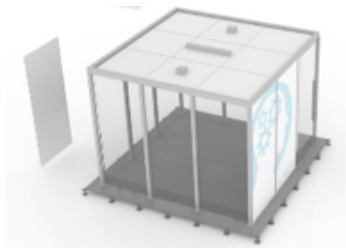
## METHODS PROTOTYPE DEVELOPMENT

The design team developed a manufacturer-agnostic prototype for a portable, flexible and trackable lab: The Sensory Design Lab (SDL). This prototype is 10' wide, 10' long, and 8' tall and built out of wood grid beam and 3-D printed connections (designed and created in-house). In addition, environmental sensors were developed to capture sound, light, temperature and relative humidity. The timeline below illustrates how we developed the SDL.



### CONCEPT DEVELOPMENT

A flexible and portable room where variables affecting spatial conditions and room configurations could be made while environmental and biometric data captured was proposed.

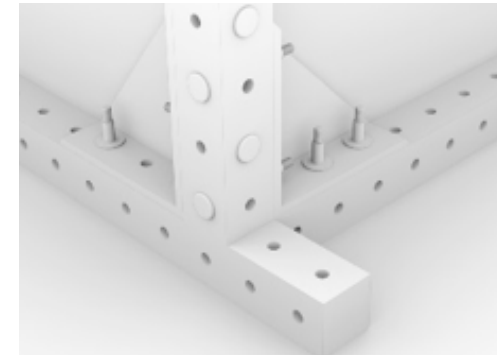


### ROOM FRAMING DESIGN

The room framing design proposal was based on an aluminum room-in-room system made of modular components on a floor plenum.

### MODULAR WOOD FRAMING

After an exhaustive search for framing products already on the market, none quite met the initial criteria. The team decided to work with a modular wood grid beam product that could easily be customized and transported. The grid holes on each beam allowed for easy modification of the framing system.



### FRAME DETAILS + CONNECTIONS

To ensure that the room system had a flush interior wall panel condition, similar to how rooms are typically constructed, the wood framing system required a custom corner bracket and wall panel clip. The team used in-house 3-D printers to develop several iterations of wall panel clips and corner brackets.

### FUTURE DEVELOPMENT

While the wood framing systems met the criteria of being lightweight, modular and easily customized, issues of long-term durability and overall structural [in]ability to support heavier wall panels remains a limitation of the system. Future development of the lab will look to utilize a lightweight extruded aluminum framing system with a more robust wall clipping system.

The team will use commercially available EEG headsets and other physiological monitoring capabilities to conduct further research of the sensor network.

00

01

02

03

04

05

06

07

08

### LAB PRECEDENT RESEARCH

The initial search looked for precedents within the industry related to similar lab typologies and existing modular frame products, also known as room-in-room systems.



### FRAME PRODUCT RESEARCH

In lieu of creating a fully customized room solution, the team initially searched for room-in-room products already on the market.

#### Product Criteria:

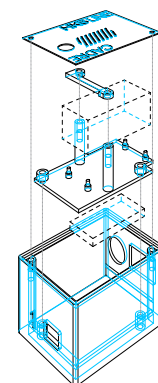
- Brand Agnostic
- Modular Frame
- Lightweight
- Within Budget

#### Framing Options:

- Room-in-Room System
- Extruded Aluminum Shapes
- Steel Framing systems
- Wood Framing systems
- Plastic Wall systems
- Expanded Polystyrene Blocks

### SENSOR DEVELOPMENT

Using an Arduino board, designers created custom sensors that allowed for control of on-board sensors, as well as access to the data. The sensors were roughly half the cost of market sensors.



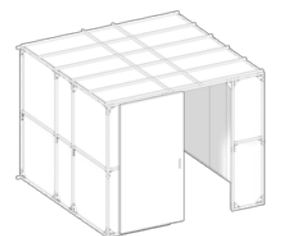
- ◀ Acrylic Cover
- ◀ Custom Arduino
- ◀ Mounting Bracket
- ◀ LiPo Battery
- ◀ 3D Printed Case

### VALIDATION/CALIBRATION

The team used commercial sensors to validate the data from the custom sensors and calibrated the custom sensors when necessary.

### DISD INSTALLATION

The team installed the Sensory Design Lab in January 2017 in IDEA. Installation took a team of three around two hours to transport and fully assemble.



## ON-SITE EXPERIMENT

The team conducted a pilot test at a high school—Innovation, Design, Entrepreneurship Academy (IDEA, from now on)—in Dallas, TX. Dallas Independent School District recently implemented personalized learning programs in five schools, including IDEA. It was a new school with only ninth- and 10th-graders at the time of the pilot study.

The team installed two thermal cameras to capture participant behavior while maintaining privacy. Wristband devices measured the participants' heart rates. Herman Miller provided ten pieces of furniture—four chairs, four stools, a table and a mobile white board that were located outside the SDL before the experiment.

A total of thirty students, up to three at a time, participated in the experiment. Researchers told consenting participants to bring study materials to their session. When the students arrived, researchers informed them about the study, asked for their consent, and gave each

student a wristband device. The students filled out a short pre-experiment survey about current anxiety levels and their achievement goals. The participants set up the space using the provided furniture and worked on their own study materials. Once their session was over, they completed a post-experiment survey about their current level of anxiety, what they accomplished during their 30 minutes in the SDL, and what they wished to have in their learning environments.

Researchers documented the space after each session and manually coded the final layout into multiple variables, such as which direction each participant faced and which furniture pieces they selected. They also coded thermal video recordings into behavior variables, including fidgeting and conversation. Lastly, we developed a personalization index to assess the degrees of personalizing the space and an interface change index to measure how frequently the participants changed work interface (e.g. laptop, prints, white board etc.).



### ENVIRONMENTAL SENSORS

Lighting, Temperature, Sound, Humidity



### SELF-REPORTED

Anxiety and Achievement



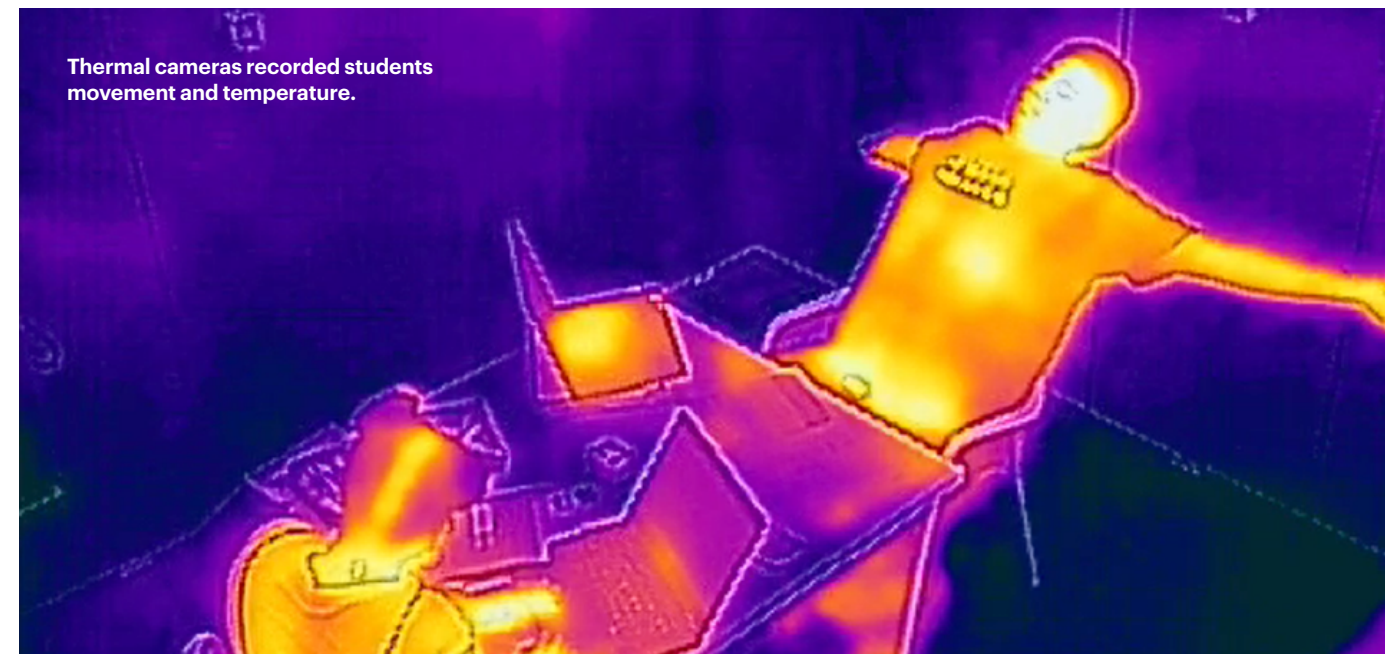
### WRISTBAND

Heart Rate and Movement



### VIDEO/THERMAL

Movement Behavior

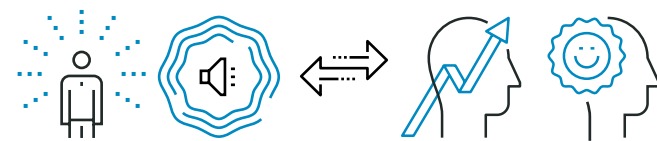


Thermal cameras recorded students movement and temperature.

## WHAT WE LEARNED

- + Students who could see outside the SDL reported higher achievement than those with no or limited visual access. Yet, some students indicated visual distractions could interfere with their learning.
- + Larger groups personalized the space more than smaller groups, implying personalization may be desired more in collaborative settings.
- + Fidgeting was most likely when baseline sound levels were lower. Fidgeting may help to relieve anxiety but may not help academic performance.
- + Anxiety levels decreased during the 30-minute experiment; however, the reduction was smaller when sound levels were high. Higher anxiety levels at the beginning of the experiment were related to lower degrees of personalization.
- + Students find comfort in a variety of positions, including leaning back while seated. They preferred chairs to stools, with stools being used as an additional surface for belongings.

### KEY TAKEAWAY:



**VIEW & ACOUSTICS IMPACTS ACHIEVEMENT & ANXIETY**

## DESIGN IMPLICATIONS

- + Visual connection to other areas can help learning but may distract students depending on the student and the context. Researchers recommend providing as much visual information as possible from a given spot to provide students choices to optimize their view.
- + Sufficient space can support personalization, such as adjusting seating orientation and choosing a view.
- + More options for personalization may be desired in larger spaces that can accommodate different sizes of groups and independently working students.
- + Careful acoustic considerations are needed to control sound levels in school environments. Researchers recommend sound-absorbing materials. Some background noise—e.g. white noise, sounds of nature—may also be beneficial.
- + Providing choices of moveable and ergonomic furniture can aid students' personalization of their space by allowing for different body postures, as well as uses.
- + Casters not only allow students to easily move when needed but can also reduce associated noises.
- + Storage space in the learning environment can reduce unnecessary trips to retrieve items, which can also reduce distractions to other students.



## SENSORY DESIGN LAB DEVELOPMENT

The success of the pilot study shows the potential of systematically controlling light and temperature, finishes and colors, views and openings, proportions and many other features in future studies to assess the impact of interior design on the human response.

Since the pilot study, the SDL has been used to understand room layout for healthcare and hospitality. Further development of the SDL focuses on expanding its capability to measure neurological responses by incorporating supplemental sensors and technology.

The additional equipment includes VR/AR headsets, monitoring equipment that senses space and motion, sensors for measuring galvanic skin response (GSR), as well as an EEG.

Scheduled studies using the added technology include investigating tactile VR/AR immersive environments. The popularity of using VR/AR in the architectural industry is rapidly growing, especially in replacement of physical full-scale mockup. The SDL will be used to develop a physical environment, overlaid with a digital environment, that can be used for spatial testing.



**VR/AR EQUIPMENT**

Digitally Immersive Environments



**VIDEO**

Movement and Depth



**GSR SENSOR**

Physical Response to Emotion



**EEG SENSOR**

Neurological Response



## FRACTAL SCALING IN ARCHITECTURE

---

The next key study to take place in the SDL will focus on the effects of form and pattern, primarily on the use of fractal scaling in architecture. This study is based on theories suggesting humans have developed innate neural connections that only activate in response to specific geometric occurrences and spatial parameters. Synthetic 2-D and 3-D geometric fractal scaling patterns will be tested against patterns found in nature to see if the neurological effect is comparable.





### WHAT'S NEXT

The initial sensory design lab prototype concept has been implemented into two other studies. The first is a series of living labs in HKS offices that are equipped with environmental sensors and collect human responses. The second is a Sensory Wellbeing Hub installed in a Chicago public high school. This hub provides an ideal environment for students with developmental disabilities who may experience abnormal sensory processing and need a personalized sensory environment. The hub is also equipped with environmental and motion detection sensors. Both studies are currently in data collection.



### ADDITIONAL INFORMATION

---

#### FUNDING

This study was funded by an ASID Foundation Transform Grant, with additional support provided by Herman Miller and USG.

#### TEAM MEMBERS

Upali Nanda, PhD  
Giyong Park, PhD, AIA  
Angela Ramer  
Jon Bailey  
Tim Logan  
Jonathan Essary  
Melissa Hoelting

#### ADVISORS

Leonardo Gonzalez, HKS  
Aaron Hollis, HKS  
Ashley Flores, Dallas Independent School District  
Courtney Egelston, DISD, IDEA  
Sarah Ritsema, DISD, IDEA  
Susan Whitmer, Herman Miller

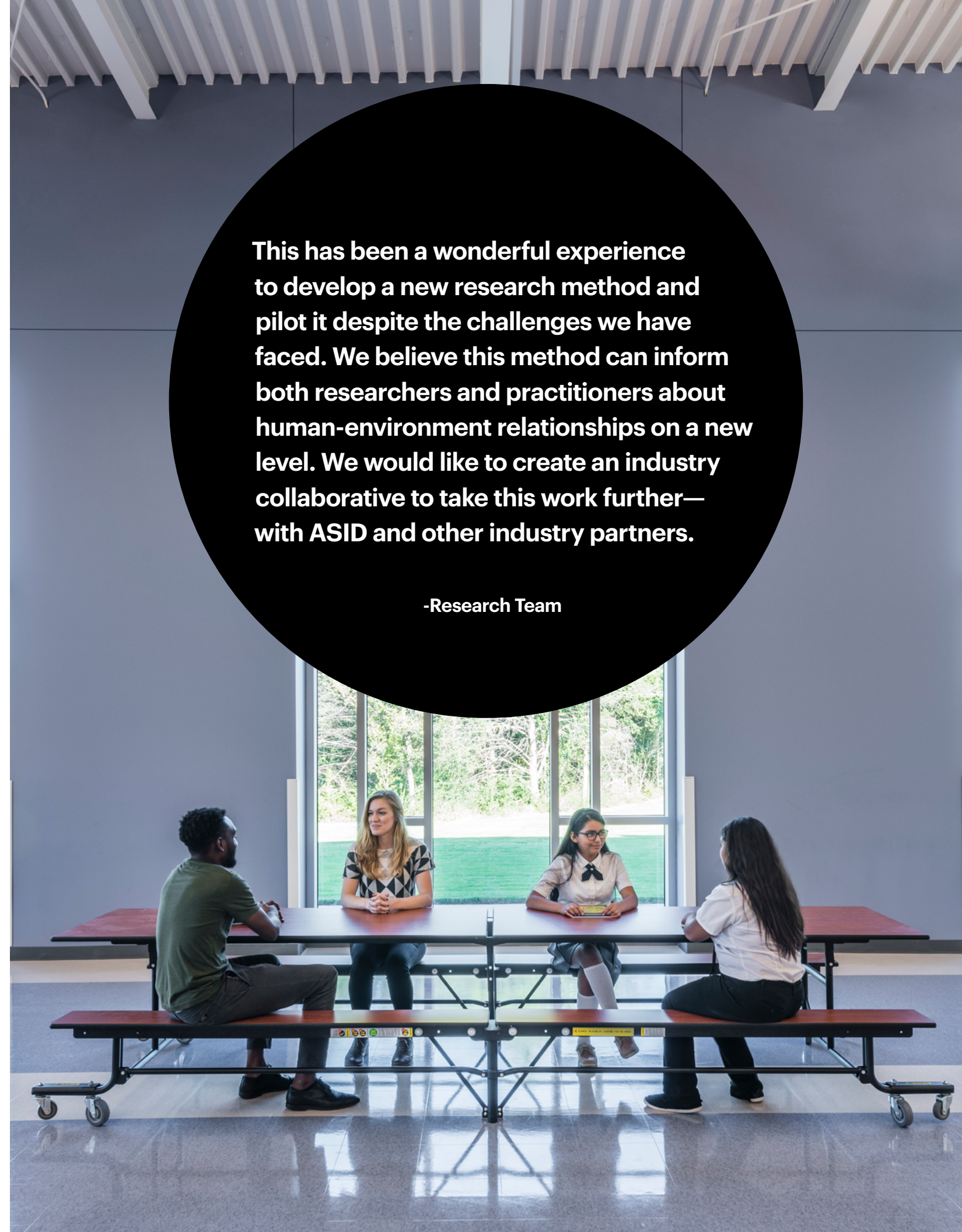
#### DATE COMPLETED

2017



**This has been a wonderful experience to develop a new research method and pilot it despite the challenges we have faced. We believe this method can inform both researchers and practitioners about human-environment relationships on a new level. We would like to create an industry collaborative to take this work further—with ASID and other industry partners.**

**-Research Team**







# HKS

## **ABOUT HKS**

HKS, Inc. is a team of more than 1,300 architects, interior designers, urban designers, scientists, artists, anthropologists and other professionals working together across industries and across the globe to create places that delight, heal and stimulate peak performance.

The firm has nurtured a culture of extraordinary people with curious and creative minds who are passionate about delivering elegant solutions. HKS has a dedicated research team that digs deep to discover processes and ideas that improve outcomes for everyone. In everything HKS does, it is mindful of the fragility of all life and of the planet.

[www.hksinc.com](http://www.hksinc.com)

## **ABOUT CADRE**

CADRE, the Center for Advancing Design through Research and Evaluation, is a 501(c)3 not-for-profit organization that aspires to make research a catalyst for architectural innovation. Founded by HKS in 2008, CADRE investigates the impact of design on people, organizations and eco-systems, via industry and academic partnerships.

[www.cadresearch.org](http://www.cadresearch.org)

