Learning from Living Architecture

Philip Beesley, Becky Carroll, Rob Gorbet,
Lucinda Presley & Karen Zwart Hielema
Living Architecture Systems Group

This publication explores how the Living Architecture Systems Group uses its testbeds to support integrative education that combines the arts with science, technology, engineering and mathematics learning experiences. It provides background on the STEAM movement as a response to economic conditions and insights into learning and cognition. These education models can guide our understanding of sources of integrative knowledge. Three case studies of STEAM projects for different audiences are documented, demonstrating how LASG testbeds can support STEAM curriculum.

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LIVING ARCHITECTURE SYSTEMS GROUP

LASG

UNIVERSITY OF WATERLOO

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Introduction

The Living Architecture Systems Group's (LASG's) living architecture testbeds are designed as learning environments as well as being evolving prototypes of the group's components, systems, and behaviours. Installed in museums, universities, and public venues, the testbeds anchor curricula that explore engineering, physics, and living systems through an art-based lens. Beginning with programs developed for the Hylozoic Ground series of sculptures, the LASG has worked with educators to develop learning experiences for elementary, middle grade, and high school students as well as adult audiences. In addition, faculty at universities that host testbeds have incorporated them into courses and research projects for undergraduates in design, technology, and engineering.

Members of the LASG come from specialized disciplines, including architecture, engineering, fashion, synthetic biology, artificial intelligence, mechanics, sound composition and light. The concepts they used to create living architecture environments, including testbeds, are also being applied within schools, creating Science, Technology, Engineering, the Arts and Math (STEAM) experiences where young students can develop important thinking skills, exploring our rapidly changing world. STEAM uses the combination of art and science and technology learning to foster innovation and creativity alongside instruction in the skills and concepts students will need to succeed in the global economy. It also makes space for wonder and play within an academic curriculum, encouraging students to experiment and preparing them to tackle complex problems.

This publication will explore how the LASG uses its testbeds to support STEAM learning. It will provide background on the STEAM movement as a response to both economic conditions and insights into learning and cognition that have shifted our understanding of where innovative thinking comes from and how it might be fostered. Through three case studies of STEAM projects for different audiences it will introduce the LASG's approach to this type of learning and show how testbeds support STEAM curricula. Finally, it will offer a brief overview of ongoing STEAM efforts and how they intersect with the LASG's work more broadly.

The first two chapters of this folio are excerpts from "*It Lives!* Promoting Creative and Innovation Thinking in Education" by Lucinda Presley, Becky Carroll, and Rob Gorbet. The full essay appeared in the 2014 publication *Near Living Architecture: Work in Progress from the Hylozoic Ground Collaboration,* and appeared in the *2016 IEEE Integrated STEM Education Conference (ISEC).*[1]

The chapter "*Meander*: Learning about Living Systems" was written by Karen Zwart Hielema, Lucinda Presley and Rob Gorbet as part of a preliminary report on the core curriculum developed for the *Meander* sculpture at HIP Development's Tapestry Hall, Cambridge ON developed for Grades 5 and 8 students.

Applied case studies of STEAM workshops documented in the folio also include three workshop in collaboration with Domaine de Boisbuchet and a workshop with Riverview Highschool in New Brunswick, Canada led by Ian Fogarty and LASG members Rob Gorbet, Matt Gorbet and Philip Beesley.

1 Lucinda Presley, Becky Carroll, and Rob Gorbet, "It Lives! A Steam-Based in-Class Workshop for Promotion of Creative and Innovation Thinking," *2016 IEEE Integrated STEM Education Conference (ISEC)*, 2016, https://doi.org/10.1109/isecon.2016.7457546.

Background: Living Architecture and STEAM Education

A growing number of researchers, experts, and governmental agencies emphasize that a nation's success in today's global economy will be affected by its ability to innovate.[2] Economics authors Thomas Friedman and Michael Mandelbaum point out that, with information as close as our smartphones, the most important skill is now the ability to process information.[3] Sir Ken Robinson, an internationally recognized author and advisor to Fortune 500 companies, governments, and education, adds that the nations that most effectively train their students to process information innovatively will be the global leaders.[4] These statements are supported by a 2011 General Electric survey of 1,000 business executives in 12 countries, which found that 92% of the executives believed that innovation is the main driver of a competitive national economy.[5] In response to this need, the LASG has developed and piloted models for promoting these important innovative thinking skills in students of all ages.

As this global need for innovation in many fields increases, so does the importance of creative and innovative thinking. Noted creativity expert R. Keith Sawyer points out that, in response to the need for innovative thinking, countries such as the U.S., China, and the European Union are transforming their economies from industrial economies to "creative knowledge economies" focused on producing ideas.[6] Sawyer says that we must move beyond associating creativity only with the fine arts, for creativity is important in a wide variety of applications, including mathematical theory, experimental laboratory science, and computer software.[7] Since these thinking skills are increasingly used and studied in a variety of applications, there are a resulting variety of definitions and approaches to these skills.

Furthermore, Sawyer points out that the emerging field of cognitive neuroscience has developed a greater understanding of these important thinking skills.[8] Experts in this field, Sandra Chapman, Ph.D., Founder and Chief Director of the University of Texas at Dallas Center for Brain Health, and Jacquelyn Gamino, Ph.D., Director of the Center's Adolescent Reasoning initiative, have successfully studied important aspects of innovative thinking. Through rigorous studies, they have discovered strategies for promoting these thinking skills in students, especially adolescents. They recommend that students blend these interactive strategies: selecting the most important information, synthesizing this information to form abstracted meanings, and applying this synthesis to a creative and novel application.[9]

While experts are calling for integrating innovative and global thinking into education systems, and strategies exist to foster these skills, we found that there are advancements needed in both countries. In the U.S., Po Bronson and Ashley Merryman, in their famous *Newsweek* article, "The Creativity Crisis", point out that children's high scores on the Torrance Test of Creativity were three times more likely to predict that child's future lifetime creative accomplishment than IQ scores. In other words, these creative thinking skills help drive innovation. However, these scores in the U.S. have been on the decline since the 1990s, they point out, especially in kindergarten through sixth grade.[10] These concerns are borne out by U.S. teachers the LASG has worked with. They report that students often are afraid to take risks for fear of failure or because the challenge seems too great. They also point out that students have trouble synthesizing information to solve problems innovatively. This is due, they add, to standardized tests' emphasis on fact recall.

Canadian students ranked very highly in comparison with other countries in science scores on the 2012 international PISA exam,[11] which tests the application as opposed to memorization of science facts. However, these scores are reportedly declining, with Canada lagging in its innovation. If it is to maintain its place in the global rankings, it must continue to improve students' learning and outcomes capacity.[12]

The LASG's STEAM programming for testbeds has evolved in response to these conditions. Indeed, living architecture environments—which are conceived and built by interdisciplinary teams with expertise across the arts, sciences, and humanities—are ideally suited to develop the kind of innovative thinking Chapman and Gamino describe.

2 Thomas L. Friedman, and Michael Mandelbaum, *That Used to Be Us: How America Fell Behind in the World It Invented and How We Can Come Back*. (New York, New York: Farrar, Straus and Giroux, 2011).

Ken Robinson, *The Element*. (New York, New York: Viking Penguin Group, 2009).

Richard Florida, *The Rise of the Creative Class: …And How It's Transforming Work, Leisure, Community, & Everyday Life*. (New York, New York: Basic Books, 2003).

The President's Council of Advisors on Science and Technology, *Prepare and Inspire: K-12 Science, Technology, Engineering, and Math (STEM) Education for America's Future*. (Washington, DC. 2010).

National Academies of Science, National Academy Of Engineering, Institute Of Medicine, *Rising Above the Gathering Storm, Revisited: Rapidly Approaching Category 5*. (Washington, DC: National Academies Press, 2010). https://doi.org/10.17226/12999.

3 Friedman, and Mandelbaum, *That Used to Be Us*.

4 Robinson, *The Element*.

5 General Electric, *GE Global Innovation Barometer: Global Research Report*. Jan 2012, http://files.gecompany.com/gecom/innovationbarometer/GE_Global_Innovation_Barometer_Report_January_2012.pdf

6 R. Keith Sawyer, *Explaining Creativity: The Science of Human Innovation*. (New York, New York: Oxford University Press, 2012).

7 Sawyer, *Explaining Creativity*.

8 Sawyer, *Explaining Creativity*.

9 Sandra B. Chapman, Jacquelyn F. Gamino, and Raksha Anand Mudar. "Higher Order Strategic Gist Reasoning in Adolescence," *The Adolescent Brain: Learning, Reasoning, And Decision Making*. (Washington, DC: American Psychological Association, 2012), pp. 123-151, https://doi.org/10.1037/13493-005.

10 Po Bronson, and Ashley Merryman. "The Creativity Crisis." *Newsweek*, July 10, 2010, http://www.thedailybeast.com/ newsweek/2010/07/10/thecreativity-crisis.html

11 PISA is the Program for International Student Assessment, first launched in 2000 by the OECD in response to member countries' demands for regular and reliable data on the knowledge and skills of their students and the performance of their education systems. PISA surveys take place every three years.

Literacy Newfoundland and Labrador. "Measuring Up … and Down: PISA 2012 Reports on Math, Science, and Reading Scores for Canadian Students." 2013, http://www.literacynl.com/content/measuring-and-down-pisa-2012-reports-math-science-andreading-scores-canadian-students

12 MaRS Market Insights. *K-12 Education: Opportunities and Strategies for Ontario Entrepreneurs*. November, 2011, http://www.marsdd.com/wp-content/uploads/2011/11/MaRSReport_Education.pdf

Above

The *Hylozoic Veil* installation established the conceptual framework for the *It Lives!* Project, Salt Lake City, 2011

It Lives!: A Project to Enhance Creative and Innovation Thinking in Education

Taking into account the need for creative and innovation thinking, the strategies that promote these skills, and the realities of the education systems in Canada and the U.S., the LASG's *It Lives!* program investigated the integration of these skills with specific science content learning in two schools in the U.S. and one school in Canada. The project process began during the commissioning of *Hylozoic Veil* in 2011 for The Leonardo art+science museum in Salt Lake City. The *It Lives!* project team identified an opportunity to bring the multidisciplinary nature and ideas of the sculpture into classrooms, helping to connect students' core art and science curricula and providing a context in which to explore creative and innovative thinking and invention. They collaborated with the education department at The Leonardo and local school districts and educators to develop the curriculum, and hired a professional evaluator to assess students' attitudes, their growth in content knowledge, and the effect of their innovation/inventing experiences on content learning.

Right

Student worksheet with questions for each station

Further Right

Students interacting with components

It Lives! – Exploration

Our Investigation

Station #1:
1) What we noticed happening:
2) What were the most important science concepts used? (list the numbers from your Science Concepts sheet)
3) Which other stations use similar ideas and concepts?

Station #2:
1) What we noticed happening:
2) What were the most important science concepts used? (list the numbers from your Science Concepts sheet)
3) Which other stations use similar ideas and concepts?

Station #3:
1) What we noticed happening:
2) What were the most important science concepts used? (list the numbers from your Science Concepts sheet)
3) Which other stations use similar ideas and concepts?

The resulting *It Lives!* workshop aimed to immerse students in the intersection of hands-on science, engineering, design, and art thinking to help them solve a real-world problem innovatively as a team. The student teams used exhibit-inspired shape memory alloy (SMA), found objects, and craft supplies to create a kinetic device that demonstrated the interrelationship between synthesized science concepts, design, and art.

The workshop was comprised of four sequential sessions: an introduction to the sculpture and its components that made explicit connections between aspects of the sculpture and the core curriculum, a hands-on exploration of science concepts that relate to the sculpture, a creative problem-solving session in which students connected science concepts and used design principles to invent a solution to a real-world problem, and a "making" session in which students fabricated their inventions using shape memory alloy and then presented and promoted their inventions to the class.

At each site, the classroom material was tailored to the grade- and board-specific core curriculum. The project team worked closely with teachers to identify core concepts from science and art that they wanted to emphasize for their students. This list of core concepts formed an implicit and explicit basis for the entire workshop, informing the questions that the project team posed to the students and the hands-on activities that it designed. Students had to explicitly choose among these concepts in the creativity session and explain how they saw the concepts connecting to create their invention. Throughout the sessions, in presentation and facilitation, the project team used *Hylozoic Veil*'s artistic aspects to further reinforce the connections between art and science.

In Session #1, Exploration, students were briefly introduced to the *Hylozoic Veil* exhibit in a seminar format by Rob Gorbet, one of the creators of the exhibit. Gorbet used anecdotal narrative and rich images and video to engage the students at a level appropriate to their grade. Following this short introduction, students rotated in small groups between exploration stations where they interacted with and observed components of the sculpture (images previous page). At each station, students were prompted by worksheets to apply the methods of scientific inquiry and their grade-specific science concepts to their exploration of the sculpture's pieces (e.g., What am I seeing? Why is it happening? What science concepts are involved?) (image previous page).

Further Left

Grade 5 students use their curriculum on electricity to understand the sculpture

Left

A student with plants and drawings of cells

In Session #2, Hands-On, students connected their experience from Session #1 to their mandated grade-specific core science and art curriculum. Activities were carefully developed with the teachers to ensure relevance to the specific students in the workshop, guided by the core concepts list. For example, students in Grade 5 studying electricity might work in a small group to explore what happens when closing a switch connecting a battery to an active exhibit component (image above). They could then rewire the circuit using alligator clips, and choose from various conductors and insulators to compare the conductivity and resulting functioning of the circuit. Students in Grade 7 studying plant cells might be asked to draw parallels between the elements in the exhibit components in front of them to plant life, or to the functioning of a cell, supported by visuals depicting cellular structure (image above). Students were explicitly asked to consider

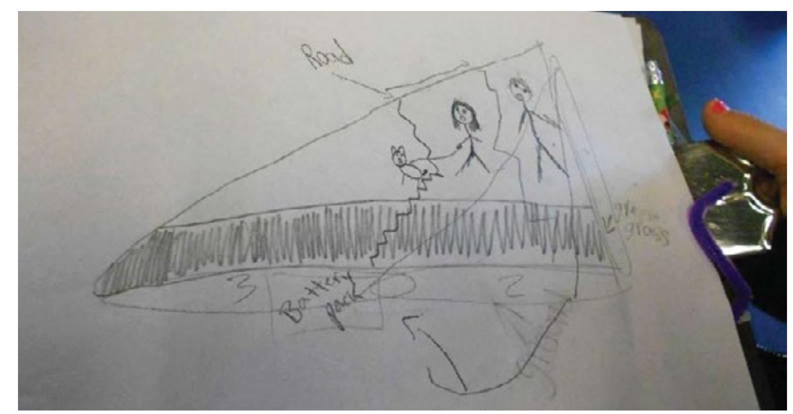
the cross-over of terms such as balance, form, shape, and line from science (e.g., in structures) and art to emphasize the similarity in design thinking and the creative process.

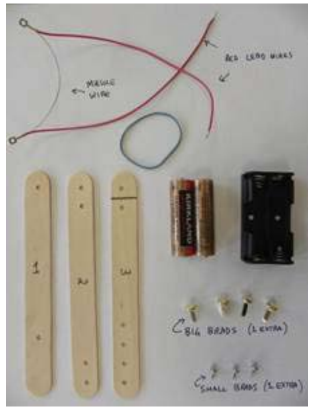
In Session #3, Creative Problem Solving, students were assigned to three-person design teams and are given a challenge framed as "you have been hired by the Discovery Channel to use a novel kinetic device to demonstrate the intersection of three science concepts." A demonstration lever device was assembled at the front of the classroom from a kit designed by the LASG, using the same Flexinol® shape memory alloy wire[13] used to generate motion in the *Hylozoic Veil* exhibit components. Students followed along in teams to assemble identical lever devices from their own kits. In Grade 5, they also drew and labelled their understanding of how muscle wire uses electricity to make a physical change in their device, using required science concepts. They then discussed and reflected on the motions generated and how those motions reminded them of concepts from their science curriculum (e.g., does it remind you of a flagellum, a lever, a volcano erupting, tectonic plate movement, etc.). Students then selected the key concepts from their science core concept list that they felt could best be illustrated using their kinetic device. In teams, they drew and labelled their device, integrating their chosen science and art concepts in their work (image below). This phase of the project used the brain-based strategies developed by the UT Dallas researchers. Students selected from the variety of science information that they had learned in Sessions #1 and #2. They also chose from a list of selected Earth, life, and physical science concepts. They synthesized at least four of these selected concepts to come up with a "big idea", and then applied that synthesis to solve a problem.

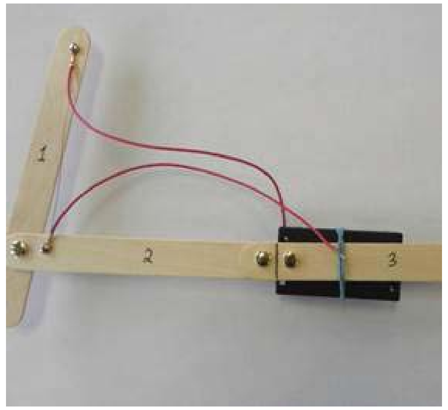
13 Manufactured by Dynalloy Inc., www.dynalloy.com

Right

Labelled diagram of a student's kinetic device







Further Left

Components for a student's kinetic device

Left

Assembled kinetic device

In Session #4, Making, students used found objects and craft supplies to bring their 2D solutions demonstrating their science concepts into 3D, built around their SMA devices. The resulting solution had to be visually understandable and represent the integration of at least three science concepts across science disciplines. When complete, each group presented to the class how their invention illustrated their key concepts and why they had made the design choices they did. In this session, students solidified and demonstrated their science knowledge. Taking their 2D images into 3D design often involved adjustment in design and materials. They also wrote an explanation of their inventions, using the science concepts to demonstrate how their invention solved their problem.

It Lives! Results

To study the impact of the *It Lives!* workshop on students' interests and attitudes toward science and engineering, their content knowledge of key concepts, and their assessment of how visual thinking, strategizing, and experience affect their learning, the LASG researchers leading the project conducted a pilot study in three schools: two classes of Grade 7 students at Palestine Junior High, Palestine, Texas; four classes of Grade 5 students at Woodrow Wilson Elementary School in Salt Lake City, Utah; and one class of Grade 7 students and one class of Grade 8 students at MacGregor Public School in Waterloo, Ontario, Canada, totaling 213 students. In all three locations, students were given two pre and two post assessments, one focusing on attitudes/interests and another on content. In addition, teachers were also given a post assessment to collect data about their perceptions

Top

Students working on their kinetic device

Bottom

Students planning how to design their kinetic device

of the program and the degree to which it promoted science learning, youth engagement in science process skills, and problem-based learning. In addition, the researchers conducted in-person observations of the *It Lives!* Program in Palestine and interviewed students about their experiences in the program.

Preliminary data collected from the pilot observations of the program by evaluators, teachers and program implementers, pre-post attitude and content assessments, and from teacher post assessments, indicate that *It Lives!* provided engaging experiences for youth that combined art and rigorous and appropriate science content, as well as opportunities for students to develop critical thinking, innovation, and problem-solving skills.

First and foremost, the *It Lives!* workshop activities were engaging to students. All of the teachers reported that their students were active participants and highly engaged throughout the course of the project (images left). As Salt Lake City teachers reported in post self-assessments:

> "All students were on task all of the time. Our discussion when we returned to the classroom had a lot of energy and was most positive!"
>
> "They were all on task and enthralled with the project!"
>
> "Students were engaged, learning and excited. I didn't see one student that was not engaged."

The *It Lives!* workshop helped students understand important core science concepts and to make connections between science concepts. As Salt Lake City teachers reported in post assessments:

> "It really helped my students understand that a physical change occurred; there was no new substance formed with the muscle wire contracted."
>
> "The chart reading was great, and I loved how it connected electricity with animal adaptations. So creative!"

For example, two Grade 8 students interviewed in Texas were able to articulate the connections between science concepts they were making through the building activity with the muscle wire:

> "We are making an arm out of popsicle sticks. We wanted to do something with the muscular system and structure. It seemed like force and motion and muscles made sense to combine."

Data from pre-post content assessments in Salt Lake City indicated that students had made progress in understanding how circuits work, a notoriously difficult concept for students to grasp.[14] One question on the pre-post assessment asked students to label the power source, switch, conducting wires, and muscle wire in a diagram of a circuit. On the pre-assessment of the Woodrow Wilson grade 5 students, of the 46 students who labelled the diagram, 30% labelled the diagram correctly, while 69% labelled it incorrectly. On the post assessment, of the 66 students who labelled the diagram, 42% labelled it correctly, while 57% labelled it incorrectly. Thus, as Table 1 (following page) highlights, not only did the number of students who actually labelled the diagram increase by 20 students, the gap pre-post narrowed from +39% incorrect to +15% incorrect.

14 Paula Vetter Engelhardt and Robert J. Beichner, "Students' Understanding of Direct Current Resistive Electrical Circuits," *American Journal of Physics*, 72, no. 1 (2004): pp. 98-115, https://doi.org/10.1119/1.1614813.

Another example of the grade 5 pre-post content assessment data highlighting content knowledge gains is shown on Table 2 (following page), where students demonstrate their understanding of the physical change in the shape memory alloy (muscle wire).

Students also articulated their appreciation for the inquiry-based methods of exploration the project provided, and how those methods helped further develop their understanding of key concepts. Students were encouraged to embark on their own inquiries, pursue their own questions, and were supported in working through a design challenge. As two teachers noted:

> "Students were given the opportunity to explore their own questions."
>
> "It's the way learning should look."

Students appreciated the ways in which the *It Lives!* Making activity allowed them to better understand the science concepts they had been working with in their classroom throughout the year. As one student noted:

> "We've been studying muscles in science class. For most people, if you work hands-on, you can understand it better. If you build it, and you see an arm moving up and down, it makes more sense."

The careful design and implementation of activities helped students to engage in productive problem-solving and to develop critical and innovative thinking skills. Students explored components of the exhibit, chose to combine concepts they had been studying in school that connected to the

Table 1

Number of students who labelled circuit diagram correctly before and after the excercises

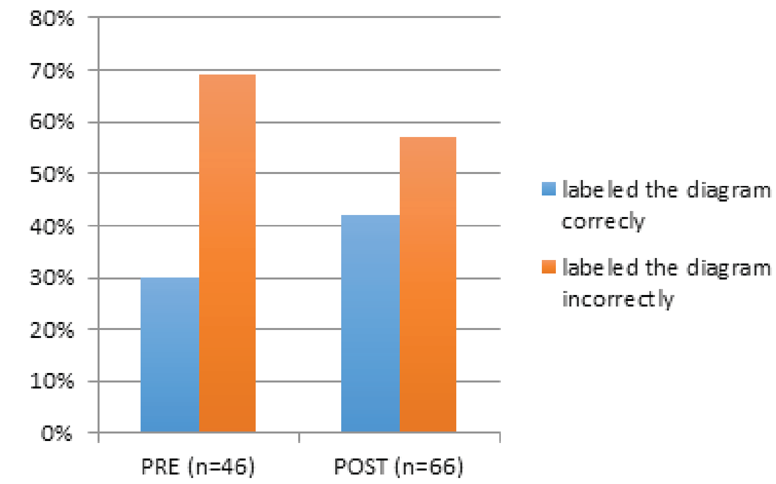


Table 2

Number of students who demonstrated an understanding of the physical change in the shape memory alloy. N=97

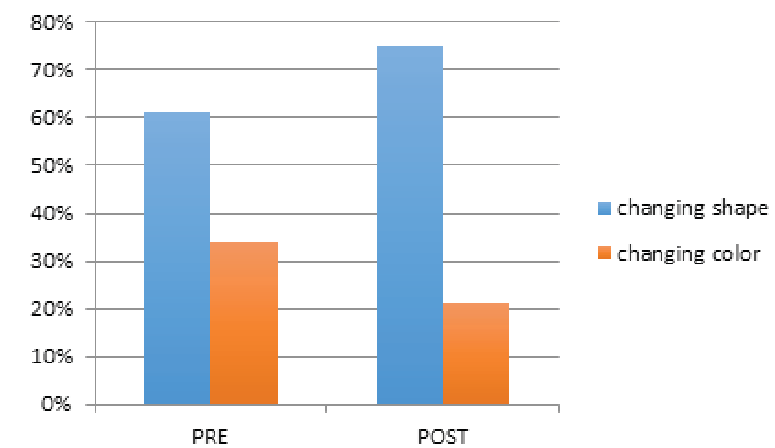
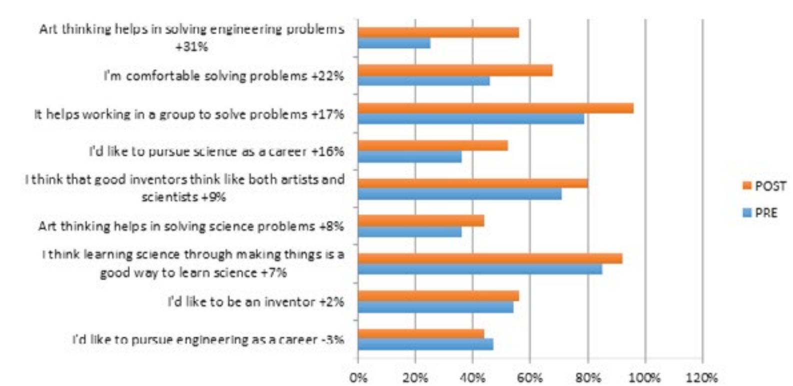


Table 3

Pre and post student attitude assessment from a grade 5 class. N=25; percentage of students choosing 4 or 5 on a rating scale, where 5 = strongly agree and 1 = disagree



explorations they had done in the first session, assembled a kinetic design from a kit to better understand how the shape memory alloy wire works, and then were asked to respond to a design challenge to create something that would demonstrate their concepts to younger students. At every step along the way, students had to conceptualize the design challenge and explain their means for addressing that design challenge. As teachers noted in post assessments:

> "I loved how the students were given the responsibility to create their own circuit."
>
> "It was clear that the presentation was designed in such a way that it encouraged investigation and problem solving, culminating in an activity that required invention and creativity."

Table 3 (previous page) highlights pre-post attitude assessment data from one grade 5 class of students. The results are ordered from highest percentage of increase to lowest. The graph shows the increases in students' attitudes toward the importance of art thinking in solving problems, their own comfort level in solving problems, their attitudes toward working in groups, and their interest in pursuing science. All but one increased as a result of their participation in the program.

Teachers and students alike found value in the *It Lives!* workshop in developing student conceptual understanding and in enhancing students' creativity, innovation skills, critical thinking, and problem solving.

Facing

Child interacting with the *Hylozoic Veil* installation

Facing

Interactive components on the *Meander* installation at Tapestry Hall, Cambridge, Ontario serves as a medium for experiential learning

Meander: Learning about Living Systems

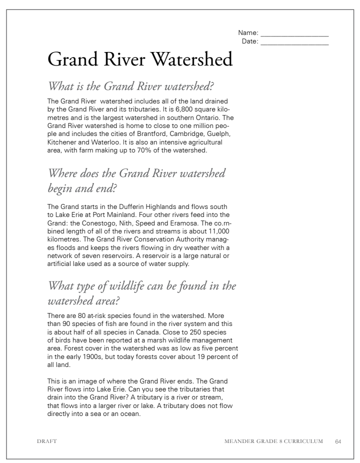
Meander is an LASG testbed mounted within Tapestry Hall, a historic warehouse building in Cambridge, Ontario, that has been converted into an event space. It is organized as a series of species within an artificial ecosystem. Dense patterns of vibrating and curling fronds and chains of pulsing lights lining its mesh surfaces can gently flex and move in response to visitors' presence. Like natural environments such as forests and rivers, large networks of parts within this sculpture pass physical impulses and information back and forth. The entire *Meander* environment works as an interconnected whole that takes inspiration from the Grand River, a complex ecosystem weaving its way through the centre of Cambridge, spanning geological time scale periods in its gradual formation. To give local students and educators access to *Meander* that will complement and enrich existing STEAM programs.

The *Meander* STEAM experience provides an Ontario curriculum standards–based educational experience where students engage, learn, and solve real-world problems using important critical, creative, and innovative thinking skills. As with *It Lives!*, this curriculum is designed to support today's students in their development of important workforce-related cognitive skills alongside mandated content learning. The LASG has developed a *Meander*-based curriculum for Grades 5 and 8, with material that can be adjusted to meet curricular needs and that is intended for delivery both within the immersive environment of *Meander* and within remote classroom locations.

Both versions of the *Meander* experience promote student engagement and learning of standards-based content and vital higher-level thinking skills. They are based on how systems such as the Grand River and *Meander* constantly change and reorganize. In the Grade 5 version of the curriculum, students work to solve the problem of how to minimize heavy flooding on the Grand River using an aesthetically pleasing sculpture. The Grade 8 version adds the issue of water quality, creating a more complex problem for students to solve. Both versions integrate science, visual art, and language with important thinking skills such as problem-solving, changing perspectives, synthesizing, and envisioning.

Below

Grade 8 Curriculum handout with content relating the Grand River. These handouts introduce key concepts of ecology and hydrology in a digestible manner to a younger audience.



Name: ____________
Date: ____________

Grand River Watershed

What is the Grand River watershed?

The Grand River watershed includes all of the land drained by the Grand River and its tributaries. It is 6,800 square kilometres and is the largest watershed in southern Ontario. The Grand River watershed is home to close to one million people and includes the cities of Brantford, Cambridge, Guelph, Kitchener and Waterloo. It is also an intensive agricultural area, with farm making up to 70% of the watershed.

Where does the Grand River watershed begin and end?

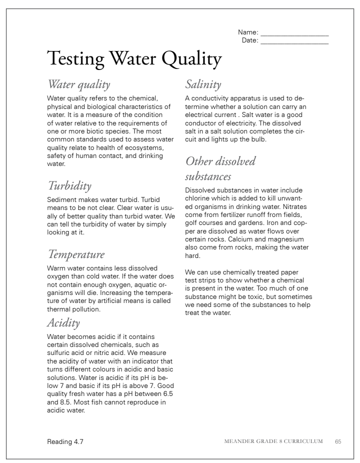
The Grand starts in the Dufferin Highlands and flows south to Lake Erie at Port Mainland. Four other rivers feed into the Grand: the Conestogo, Nith, Speed and Eramosa. The co.rnbined length of all of the rivers and streams is about 11,000 kilometres. The Grand River Conservation Authority manages floods and keeps the rivers flowing in dry weather with a network of seven reservoirs. A reservoir is a large natural or artificial lake used as a source of water supply.

What type of wildlife can be found in the watershed area?

There are 80 at-risk species found in the watershed. More than 90 species of fish are found in the river system and this is about half of all species in Canada. Close to 250 species of birds have been reported at a marsh wildlife management area. Forest cover in the watershed was as low as five percent in the early 1900s, but today forests cover about 19 percent of all land.

This is an image of where the Grand River ends. The Grand River flows into Lake Erie. Can you see the tributaries that drain into the Grand River? A tributary is a river or stream, that flows into a larger river or lake. A tributary does not flow directly into a sea or an ocean.

DRAFT MEANDER GRADE 8 CURRICULUM 64



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Testing Water Quality

Water quality

Water quality refers to the chemical, physical and biological characteristics of water. It is a measure of the condition of water relative to the requirements of one or more biotic species. The most common standards used to assess water quality relate to health of ecosystems, safety of human contact, and drinking water.

Turbidity

Sediment makes water turbid. Turbid means to be not clear. Clear water is usually of better quality than turbid water. We can tell the turbidity of water by simply looking at it.

Temperature

Warm water contains less dissolved oxygen than cold water. If the water does not contain enough oxygen, aquatic organisms will die. Increasing the temperature of water by artificial means is called thermal pollution.

Acidity

Water becomes acidic if it contains certain dissolved chemicals, such as sulfuric acid or nitric acid. We measure the acidity of water with an indicator that turns different colours in acidic and basic solutions. Water is acidic if its pH is below 7 and basic if its pH is above 7. Good quality fresh water has a pH between 6.5 and 8.5. Most fish cannot reproduce in acidic water.

Salinity

A conductivity apparatus is used to determine whether a solution can carry an electrical current . Salt water is a good conductor of electricity. The dissolved salt in a salt solution completes the circuit and lights up the bulb.

Other dissolved substances

Dissolved substances in water include chlorine which is added to kill unwanted organisms in drinking water. Nitrates come from fertilizer runoff from fields, golf courses and gardens. Iron and copper are dissolved as water flows over certain rocks. Calcium and magnesium also come from rocks, making the water hard.

We can use chemically treated paper test strips to show whether a chemical is present in the water. Too much of one substance might be toxic, but sometimes we need some of the substances to help treat the water.

Reading 4.7 MEANDER GRADE 8 CURRICULUM 65

Name: ____________
Date: ____________

Watersheds

What is a watershed?

A watershed is the area of land where all of the water that falls in it and drains off of it goes into a common outlet. Watersheds can be as small as a footprint or large enough to encompass all of the land that drains water into rivers that drain into bays that drain into the ocean. A watershed is an area of land that drains all of the streams and rainfall to a common outlet. Think about a local river or creek. Where does it start? Where does it pass through and where does it end up? All of the area covered is a watershed.

Where can watersheds be found?

Homes, farms, cottages, forests, small towns, big cities and more can make up watersheds. Everything is connected in a watershed and what happens upstream impacts the conditions downstream. Watersheds can be urban, rural, wild and anywhere in between. Toronto contains seven river watersheds. Each of these watersheds drain into Lake Ontario. This, in itself, is part of the Great Lakes Basin watershed.

What features can be found In watersheds?

Watersheds are populated with freshwater features such as lakes, ponds, reservoirs, groundwater aquifers, snowpacks, glaciers and icefields.

Watersheds include all the land, plants, air, and animals within its borders. Landforms such as hills or heights of land determine the boundaries of watersheds and direct the speed and path of its rivers.

Each watershed has a unique mixture of land and water habitats.

What is the purpose of a watershed?

A watershed fulfills three primary functions. The first is to capture water. The second is to filter and store the water in the soil. The third function is to release the water into a water body.
As precipitation falls, it is stored in the watershed's land and waterbodies. This water is slowly released through shallow water discharge into the river.

Open and closed watersheds

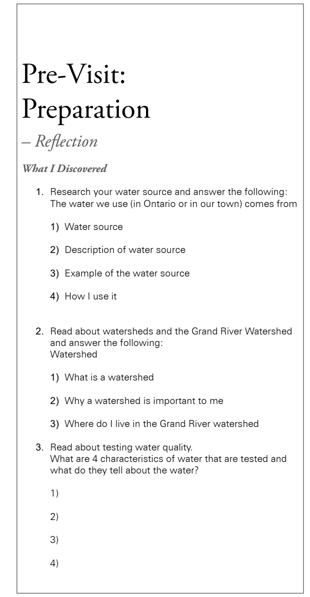
There are two major types of watershed: open and closed. An open watershed eventually drains into the ocean. A closed watershed can escape only by evaporating or seeping into the earth. Most watersheds in Canada are open. For example, the rain that falls in the St. Lawrence River watershed, winds up in the St. Lawrence, which flows into the Atlantic Ocean.

Downstream Issues

All of the water in o watershed shares the same fate and flows to the some place. As a result, watersheds are sensitive to

Reading 4.3 MEANDER GRADE 8 CURRICULUM 66

The Student Experience with *Meander*



Pre-Visit: Preparation

– Reflection

What I Discovered

1. Research your water source and answer the following:
   The water we use (in Ontario or in our town) comes from
   1) Water source
   2) Description of water source
   3) Example of the water source
   4) How I use it
2. Read about watersheds and the Grand River Watershed and answer the following:
   Watershed
   1) What is a watershed
   2) Why a watershed is important to me
   3) Where do I live in the Grand River watershed
3. Read about testing water quality.
   What are 4 characteristics of water that are tested and what do they tell about the water?
   1)
   2)
   3)
   4)

Above

Pre Visit worksheet to students

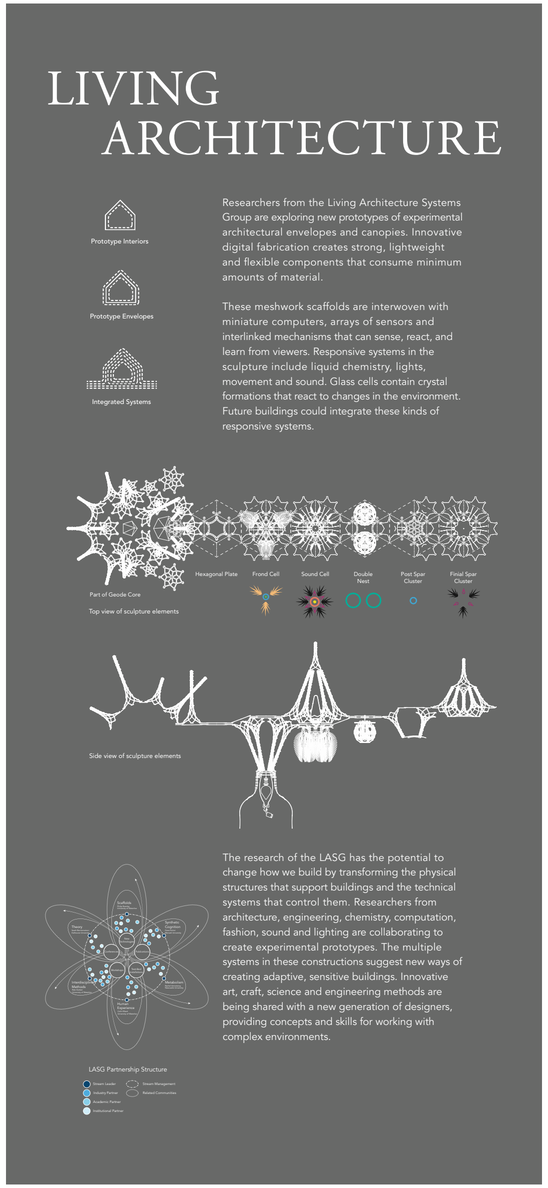
The *Meander* experience is comprehensive and adjustable. It includes the following stages (times and extent of the experiences are adjustable):

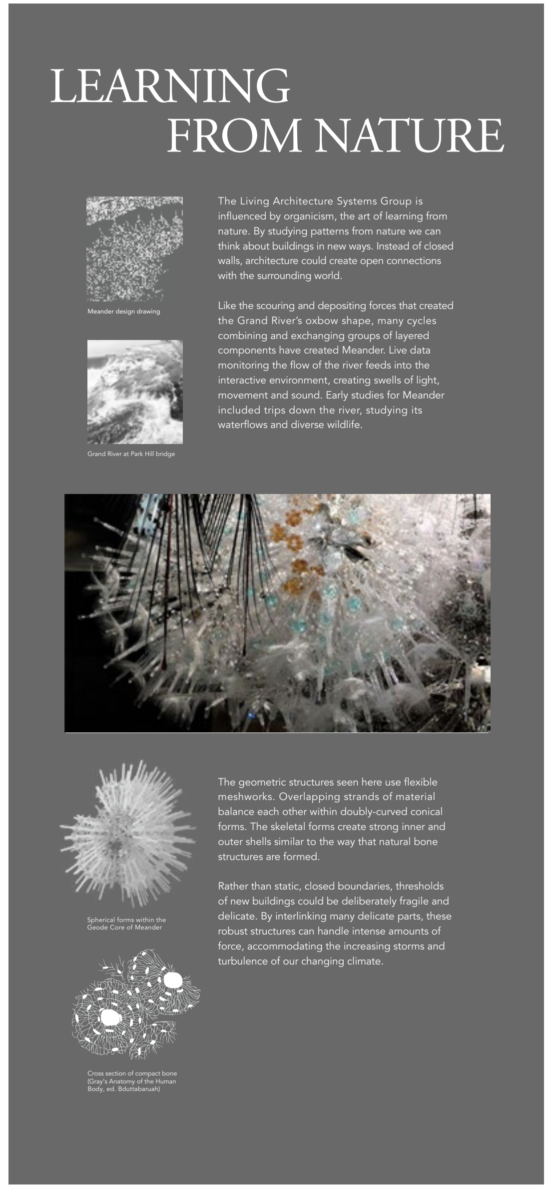
Overview
Includes the topic, essential question, objectives, expectations/goals, success criteria, learning context (skills and vocabulary), and learning environment.

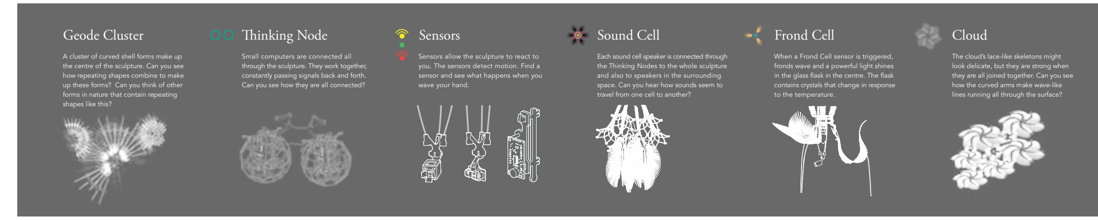
Pre-visit Introduction (~1-1.5 hrs.)
Includes list of materials for these pre-visit activities, the problem for the students to solve during the entire *Meander* experience, the exhibit experience introduction, a virtual exhibit scavenger hunt, hands-on investigations, virtual investigations of the Grand River, possible use of *Meander* kits, and a writing reflection on these pre-visit experiences.

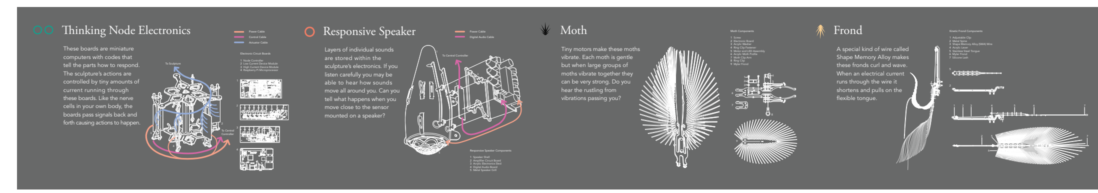
Exhibit Visit (~2 hrs.)
Includes introduction, where the students are reminded of the problem they will be solving; guided facilitation of viewing the exhibit; a scavenger hunt of the interpretive display; hands-on activities focused on grade-level objectives; Making activities where the students work collaboratively to solve their problem, creating their own working prototype; and a reflection on their experience and their learning at the exhibit.

Post-visit: Presenting, Defending, and Promoting their Solution, then Reflecting (~2 hrs.)
Includes students' preparation of their invention's presentation, defense, and promotion; student assessment; extensions into other disciplines such as life systems; and student reflections.









Making Testbeds Accessible: The Public *Meander* Exhibit

Above and Facing

Meander Interpretive display showing various components of the sculpture

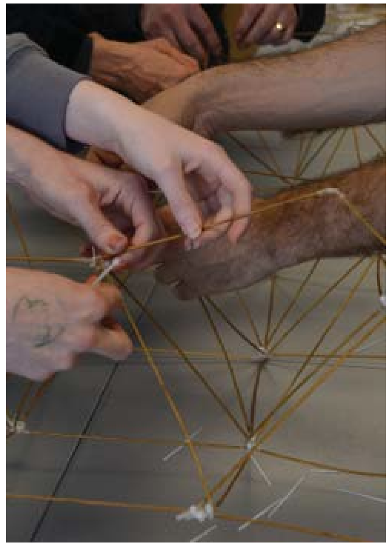
An interpretive display area positioned adjacent to the physical *Meander* sculpture within Tapestry Hall includes STEAM-oriented exhibition graphics and physical artifacts. The physical exhibit area includes animations and short film segments presented on digital displays. These physical and digital media are intended to complement the curriculum described in the previous chapter and to make the testbed accessible to wider audiences.

Conclusion

LASG's STEAM material and curricula support the use of testbeds as learning environments. They also help LASG researchers expand their understanding of creative thinking and explore how audiences connect with living architecture. The *It Lives!* curriculum, for example, seeks to foster the group creativity needed to develop products and innovations. *Meander* connects students with the natural environment they live alongside as well as with the mechanical principles that govern the testbed's behviour and construction. Elsewhere, STEAM programs have led LASG team members to think differently about testbeds' capabilities. For instance, input from students in a program with Riverview High School in Moncton, New Brunswick, prompted changes to LASG software that have improved the group's interfaces for working with testbeds. More than outreach, STEAM is an integral part of the LASG's working methods and plays a crucial role in the development of future living architecture.

Facing

Workshops staged at The Leonardo, Salt Lake City in 2013 extended the *It Lives!* curriculum. Children and adults studied the geodesic structures and resilient mechanisms of the *Hylozoic Veil* sculpture system, and then worked with simple bamboo and flexible silicone tubing joints to make their own triangulated space frame structures.



Second Land: Ground Veiling

Lessac, France 2019 (Domaine de Boisbuchet)

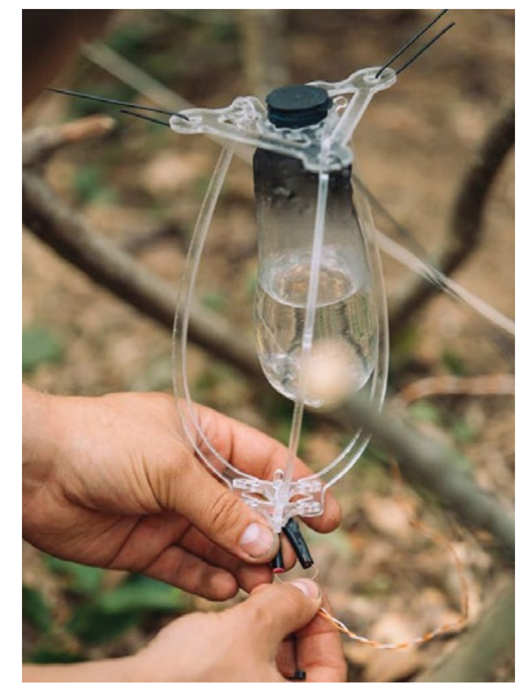
Could we imagine creating a new surface for the earth? *Second Land* makes use of simple natural materials like saplings and reeds, drawn locally from the riverside lands and agricultural fields of the Domaine and woven together with massed arrays of liquid-carrying vessels. Workshop participants at the Domaine worked together to construct an interwoven hybrid membrane which covers the land and creates shelter, hoping to discover renewed qualities of fertility. The workshop was preceded by the demonstration of pattern-books and open geometries from the Living Architecture Systems Group and the *Hylozoic Series*, setting the precedent for common form-languages to emerge. Domaine de Boisbuchet is a French country estate where Alexander von Vegesack, co-founder and director of the Vitra Design Museum from 1988 to 2011, established a non-profit center for design education. For the past twenty years, the Domaine de Boisbuchet has hosted workshops on design and related disciplines conducted by internationally acclaimed experts and organized design seminars and competitions.

Above

Activated *Second Land: Ground Veil* at dusk

Facing

Participants working on assembling the wood lattice and potato batteries. As part of the workshop, they learned key concepts relating to how batteries work in relation to the reactivity series.



Endless Connections

Lessac, France 2021 (Domaine de Boisbuchet)

Endless Connections was an installation created within a workshop about manmade and natural sound. Composite interactive systems were created that integrated simple custom microprocessors, motors, lights, and sound recorders. The program featured a new generation of custom 'smart actuator interface' microprocessors developed by the LASG engineering team. A new dynamic software interface provided primary controls and behaviour scripting for the physical devices.

Participants under the direction of workshop leaders Philip Beesley, Rob Gorbet and Anne Paxton engaged in a series of experiments with the aim of creating a hybrid soundscape, bridging nature's orchestra with artificially created sounds and tones. The installation was set within a high stone barn space, situated within Boisbuchet's unique environment of experimental architecture and nature. A performance extended the installation into adjacent landscape locations including a grove of trees surrounded by fields, and a terrace bordered with stone walls adjacent to the barn space.

Above

Sound and light performance of the Endless Connections workshop

Facing

Participants constructing interactive modules as part of the workshop

Shadows And Whispers

Lessac, France 2022 (Domaine de Boisbuchet)

Shadows and Whispers: Emerging Forms at the Edges of Nature was a workshop that produced an environment mounted within a stone barn in Lessac, France. The workshop brief asked evocative questions, speculating that within whispering sounds, new voices might be heard, and within glimmering shadows, dream-like worlds might be seen. Could nature and technology cross over and combine into new forms? What can we learn from the patterns of nature and, in reverse, what can we offer nature? The final environment consisted of a projection screen, sound and lighting devices, and numerous skeletal interaction systems making a theater of shadows and garden of forms. Four construction kits including introductory stations, scaffolds, geometry explorations, and electronics hardware and software were combined to support the exploration and creation of polyhedra, geotextiles, and truss systems, activated by electronics and sound. Under the leadership of Philip Beesley and Rob Gorbet, workshop participants created an interwoven new world, operated with the support of technical and digital devices and installed within Boisbuchet's unique architecture and nature.

Above

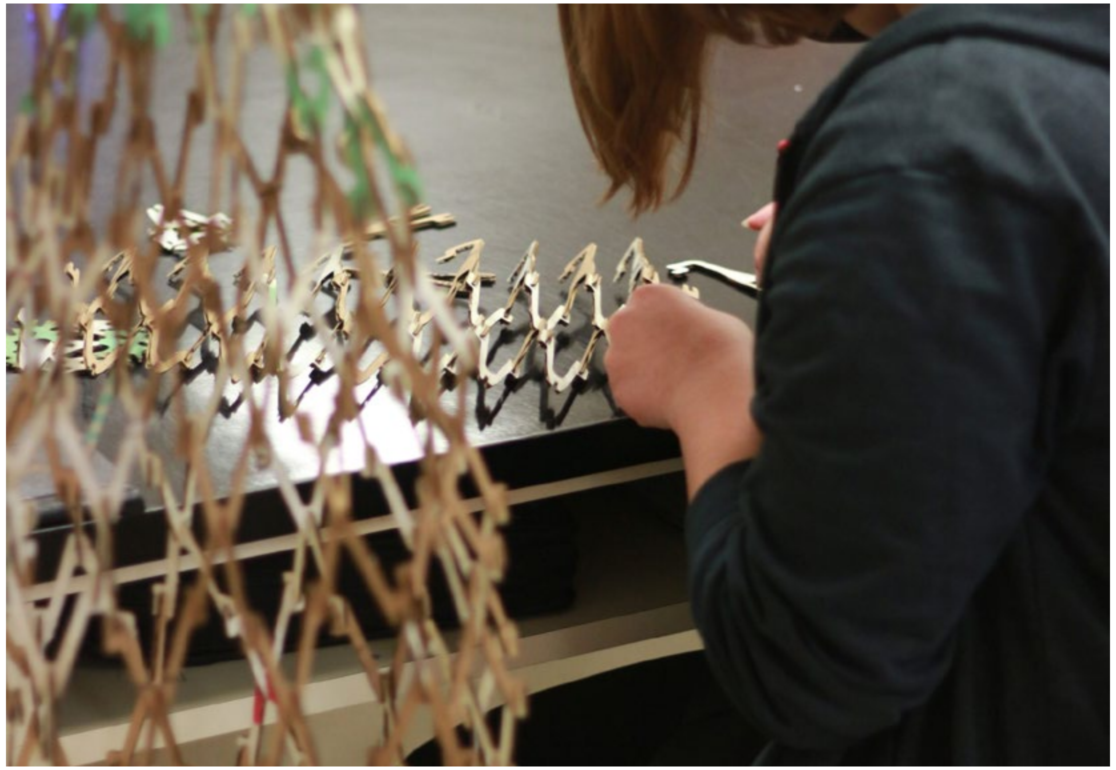
The final activity of the workshop was a sound and shadow performance generated from the interactive modules produced by the participants.

Facing

Workshop participants programming and constructing interactive modules in preparation for the final performance.

LEO Riverview

Riverview, Canada 2022 (Riverview High School)



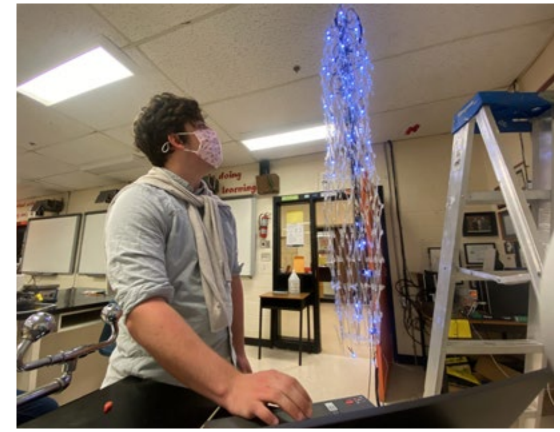
High school students at Riverview High School (Riverview, New Brunswick) led by Ian Fogarty have been working with LASG members Rob Gorbet, Matt Gorbet and Philip Beesley since 2020 to combine fabrication, physics, geometry, and STEAM to create embodied knowledge related to science disciplines. The initial explorations of the students have resulted in the installation of a permanent testbed column sculpture in the lobby of the school with ongoing experimental work continuing within the classroom. The installation emerged from a series of digitally fabricated, interactive prototypes supporting active electronics and microprocessors controlling vibrating mechanisms and lights, with possible applications within new kinds of smart buildings and furniture. Custom software configured by the students is being used to control the responsive behaviours within the column.

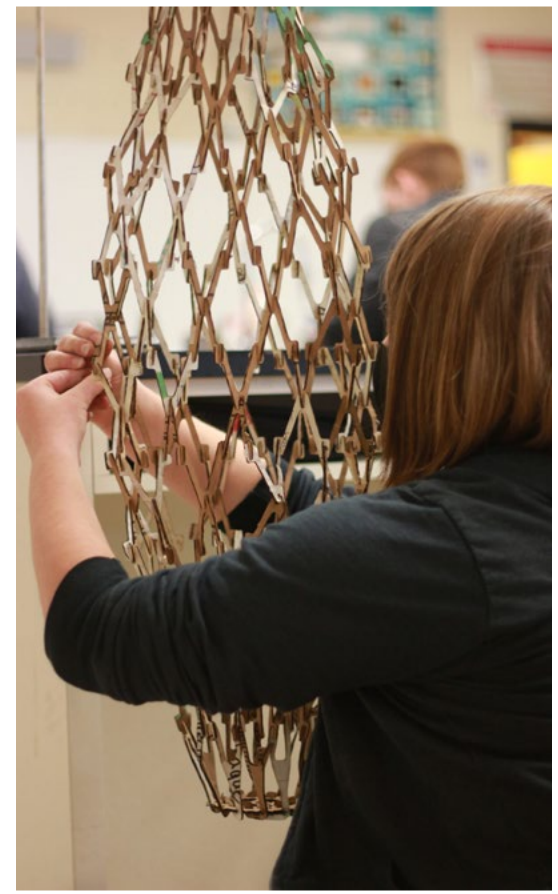
Above

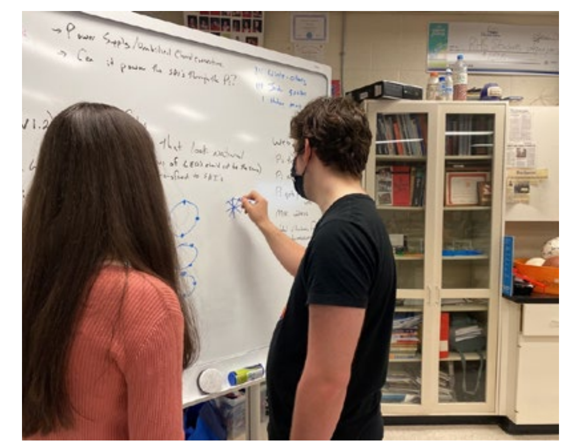
Assembly of prototype Chevron Column by students

Facing

Students in the process of assembly the final Chevron Column







About the Living Architecture Systems Group

The publication forms part of a series of work-in-progress reports and publications by Living Architecture researchers and contributors. The Living Architecture Systems Group is an international partnership of researchers, artists, and industrial collaborators studying how we can build living architectural systems— sustainable, adaptive environments that can move, respond, and learn, and that are inclusive and empathic toward their inhabitants. "Smart" responsive architecture is rapidly transforming our built environments, but it is fraught with problems including sustainability, data privacy, and privatized infrastructure. These concerns need conceptual and technical analysis so that designers, urban developers and architects can work positively within this deeply influential new field.[15] The Living Architecture Systems Group is developing tools and conceptual frameworks for examining materials, forms, and topologies, seeking sustainable, flexible, and durable working models of living architecture.

Living Architecture Systems Group research is anchored by a series of prototype *testbeds*: accessible, immersive architectural sites containing experiments and proof-of-concept models that support living architecture as a practical model for our future built environment. These testbeds act as *boundary objects*[16] that help researchers answer ethical, philosophical and practical questions about what living architecture means and who it is for within our societies and environments, creating sites of collaborative exchange that act both as research ventures and as public cultural expressions.

A series of far-reaching critical questions can be explored by using the tools and frameworks that are described within this specialized publication series: can the buildings that we live in come alive? Could living buildings create a sustainable future with adaptive structures while empathizing and inspiring us? These questions can help redefine architecture with new, lightweight physical structures, embedded sentient and responsive systems, and mutual relationships for occupant that provide tools and frameworks to support the emerging field of living architecture. The objective of this integrated work envisions embodied environments that can provide tangible examples in order to shift architecture away from static and inflexible forms towards spaces that can move, respond, learn, and exchange,[17] becoming adaptive and empathic toward their inhabitants.[18]

15 Kas Oosterhuis and Xin Xia, *iA #1, Interactive Architecture* (Rotterdam: Episode Publishers, 2007).

Nicholas Negroponte, *Soft Architecture Machines* (Cambridge, Mass.: MIT Press, 1975).

Lucy Bullivant, *4dsocial: Interactive Design Environments* (London: AD/ John Wiley & Sons, 2007).

Neil Spiller, *Digital Architecture Now: A Global Survey of Emerging Talent* (London: Thames & Hudson, 2009).

Michael Fox and Miles Kemp, *Interactive Architecture* (Princeton: Princeton Architectural Press, 2009).

16 LASG uses Bowker and Star's terms *boundary object* and *boundary concept* to frame the design and analysis of the multiple physical armatures and architectural constructions that make up LASG testbeds. In order to act effectively, a boundary object needs to be both concrete and abstract, both precisely defined and fluid, offering an "object that is part of multiple social worlds and facilitates communication between them; it has a different identity in each social world that it inhabits": Geoffrey C. Bowker and Susan Leigh Star, *Sorting Things Out: Classification and Its Consequences* (Cambridge, Mass: MIT Press, 1999): pp. 409.

17 For example the Living Architecture (LIAR) next-generation, selectively programmable bioreactor developed by LASG Metabolism Stream Lead Rachel Armstrong, Newcastle, uses microbial processes to generate electricity, oxygen, fertiliser, and other life-sustaining outputs from waste (carbon dioxide, grey water) that would otherwise be ejected from a building: "Living Architecture LIAR," accessed February 2, 2022, https://livingarchitecture-h2020.eu/.

18 Bullivant, *4dsocial*.

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