It Lives! Promoting Creative and Innovation Thinking in Education

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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[1, 2, 3, 4, 5]. 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[6]. Sir Ken Robinson, 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[8]. 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[9]. In response to this need, *It Lives!* developed and piloted models for promoting these important innovative thinking skills in students.

In the midst of global competitiveness to innovate, there is also a call for international cooperation, which requires these creative and innovative thinking skills. International collaborations that use these creative thinking skills can develop valuable and innovative products and solutions. Additionally, Friedman points out that the advantage will go to the nations and groups that collaborate internationally. He also calls for today's students to be trained in global thinking and collaboration skills[10]. *It Lives!* addresses this need by developing a preliminary model for international conversations between students around science and inventing. For example, *It Lives!* connected middle school students in Texas, USA, and Ontario, Canada via Skype to share their experiences at the intersections of science, innovative thinking and their inventions.

As this global need for innovation in many fields increases, so does the importance of creative and innovative thinking. Noted creativity expert R. Keith

1 Friedman, T. and M. Mandelbaum. (2011). That used to be us: *How America fell behind in the world it invented and how we can come back*. NY, NY: Farrar, Straus and Giroux.

2 Robinson, K. (2009). *The element*. NY, NY: Viking Penguin Group.

3 Florida, Richard. (2003). *The rise of the creative class: …and how it's transforming work, leisure, community, & everyday life*. NY, NY: Basic Books.

4 The President's Council of Advisors on Science and Technology. (2010). Prepare and inspire: K-12 science, technology, engineering, and math (STEM) education for America's future. Washington, DC.

5 National Academies of Science, National Academy Of Engineering, Institute Of Medicine. (2010). *Rising above the gathering storm, revisited: Rapidly approaching category 5*. Members of the 2005 rising above the gathering storm committee. Washington, DC: National Academies Press.

6 Friedman, T. and M. Mandelbaum. (2011). That used to be us: *How America fell behind in the world it invented and how we can come back*. NY, NY: Farrar, Straus and Giroux.

facing page

7 Vibrating whisker from a breathing pore, Sibyl, Venice, 2012

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" where a focus is on producing ideas[11].

What are creative and innovative thinking? 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[12]. Since, as Sawyer points out, 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. Since our work with students and teachers involves both individual and group processing, we have focused on Sawyer's sociocultural approach to creativity. In this approach, creativity is seen in a group context, where it leads to a useful new product or innovation. *It Lives!*, promotes content-specific creative and innovative thinking individually and as a group to create an innovative solution that reflects the creative thinking. It also models for teachers ways in which to integrate these thinking strategies into classroom application.

Furthermore, Sawyer points out that the emerging field of cognitive neuroscience has developed a greater understanding of these important thinking skills[13]. Experts in this field, Sandra Chapman, Ph.D., 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[14].

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 USA, 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 USA have been on the decline

8 Robinson, K. (2009). *The element.* NY, NY: Viking Penguin Group.

9 General Electric. (2012). *GE global innovation barometer: Global research report.* Retrieved from http://files.gecompany.com/gecom/innovationbarometer/GE_Global_Innovation_Barometer_Report_January_2012.pdf

10 Friedman, T. (2007). *The world is flat: A brief history of the 21st century.* NY, NY: Picador/Farrar, Straus and Giroux.

11 Sawyer, R. K. (2012). *Explaining creativity: The science of human innovation.* NY, NY: Oxford University Press.

12 Ibid.

13 Ibid.

14 Chapman, S., J. Gamino, and R. Anand. *Higher order strategic gist reasoning in adolescence. In The adolescent brain: Learning, reasoning, and decision making.* Washington, DC: American Psychological Association, 2012.

since the 1990s, they point out, especially in kindergarten through sixth grade[15]. These concerns are borne out by US teachers we work 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.

In Canada, 2012 science scores on the international PISA exam[16] that tests the application as opposed to memorization of science facts, the Canadian students ranked very highly in comparison with other countries[17]. However, it is reported that these scores are declining, that Canada lags in its innovation, and that it must continue to improve students' learning and the outcomes capacity[18].

IT LIVES!: A PROJECT TO ADDRESS 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 US, *It Lives!* investigated the integration of these skills with specific science content learning in two schools in the US and one school in Canada. It collaborated with the education department at The Leonardo and local school districts and educators. It also hired a professional evaluator to assess students' attitudes, their growth in content knowledge, and the effect of their innovation/inventing experiences on content learning.

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

15 Bronson, P. and A. Merryman. (2010, July 10). The creativity crisis. *Newsweek*. Retrieved from www.thedailybeast.com/newsweek/2010/07/10/the-creativity-crisis.html

16 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.

17 Literacy Newfoundland and Labrador (2013). *Measuring up … and down: PISA 2012 reports on math, science, and reading scores for Canadian students*. Retrieved from http://www.literacynl.com/content/measuring-and-down-pisa-2012-reports-math-science-and-reading-scores-canadian-students

18 MaRS Market Insights (2011). *K-12 education: Opportunities and strategies for Ontario entrepreneurs*. Retrieved from http://www.marsdd.com/wp-content/uploads/2011/11/MaRSReport_Education.pdf

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?

25 Student worksheet with questions for each station

26 Students interacting with components

It Lives! found the use of brain-based strategies formulated by the Center for Brain Health very important in helping students create their inventions and in explaining the growth that we observed. These valuable brain-based strategies derive from recent discoveries in cognitive neuroscience. *It Lives!* discovered the importance of integrating these skills with classroom learning. *It Lives!* also used research-based education strategies. These education strategies included: hands-on inquiry, knowledge transfer, arts/design thinking, visual thinking, problem-finding/problem-solving based on real-world problems, collaboration, communication, persistence, flexible thinking, inventing, science literacy, and emotional engagement[20, 21, 22, 23, 24].

The *It Lives!* 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 designed the *It Lives!* workshop as a way 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

20 Costa, A.L. and B. Kallick. (2008). *Learning and leading with habits of mind: 16 essential characteristics for success.* Alexandria, VA: Association for Supervision and Curriculum Development.

21 Cropley. A.J.. (2003). *Creativity in education and learning: A guide for teachers and educators*. NY, NY: Routledge Farmer.

22 Gardner, H. (2008). *5 minds for the future*. Boston, MA: Harvard University Press.

23 Starko, A. (2004). *Creativity in the classroom: Schools of curious delight*. Mahwah, NY: Erlbaum.

24 Wiggins, G. and J. McTighe. (2006). *Understanding by design.* 2nd ed. Upper Saddle River, NJ: Pearson.

used exhibit-inspired shape memory alloy (SMA), found objects, and craft supplies to create a kinetic device that can demonstrate the interrelationship between synthesized science concepts, design, and art.

The workshop is comprised of four sequential sessions: an introduction to the sculpture and its components that makes 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 connect science concepts and use design principles to invent a solution to a real-world problem; and a 'making' session in which students fabricate their inventions using shape memory alloy and then present and promote 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. These concepts implicitly informed the questions that the project team poses to the students and the hands-on activities that it designed. Students have to explicitly choose among these concepts in the creativity session and explain how they see the concepts connecting to create their invention. Throughout the sessions, in presentation and facilitation, the project team also uses *Hylozoic Veil's* artistic aspects to further reinforce the connections between art and science.

In Session #1, Exploration, students are briefly introduced to the *Hylozoic Veil* exhibit in a seminar format by Rob Gorbet, one of the creators of the exhibit. Gorbet uses anecdotal narrative and rich images and video to engage the students at a level appropriate to their grade. Following this short introduction, students rotate in small groups between exploration stations where they interact with and observe components of the sculpture[25]. At each station, students are 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?)[26].

In Session #2, *Hands-On*, students connect their experience from Session #1 to their mandated grade-specific core science and art curriculum. Activities are carefully developed with the teachers to ensure relevance to

27 Grade 5 students use their curriculum on electricity to understand the scuplture

28 A student with plants and drawings of cells

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[27]. They can 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[28]. Students are 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.

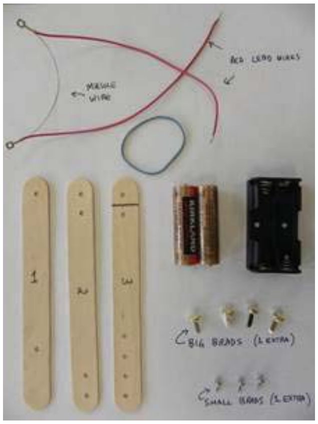
In Session #3, Creative Problem Solving, students are assigned to three-person design teams and are given a challenge framed as "you have been hired by the Discovery Channel to use a novel kinetic device to demonstrate the intersection of three science concepts." A demonstration lever device is assembled at the front of the classroom from a kit we've designed, using the same Flexinol® shape memory alloy wire[29] that is used to generate motion in the *Hylozoic Veil* exhibit components. Students follow along in teams to assemble identical lever devices from their own kits. In 5th grade, they also draw and label their understanding of how muscle wire uses electricity to make a physical change in their device, using required science concepts. They then discuss and reflect on the motions generated and how those motions remind them of concepts from their science curriculum

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

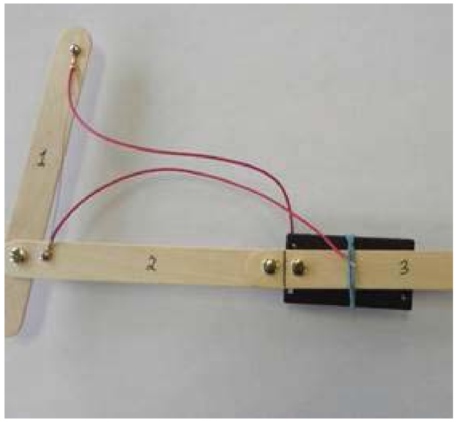
30 Labelled diagram of a student's kinetic device

(e.g., does it remind you of a flagellum, a lever, a volcano erupting, tectonic plate movement, etc.). Students then select the key concepts from their science core concept list that they feel could best be illustrated using their kinetic device. In teams, they draw and label their device, integrating their chosen science and art concepts in their work[30]. This phase of the project uses the brain-based strategies developed by the UT Dallas researchers. Students select from the variety of science information that they had learned in Sessions #1 and #2. They also choose from a list of selected Earth, life, and physical science concepts. They synthesize at least four of these selected concepts to come up with a "big idea", and then apply that synthesis to solve a problem.

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



31 Components for a student's kinetic device



32 Assembled kinetic device

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, we conducted a pilot study in three schools: two classes of 7th grade students at Palestine Junior High, Palestine, Texas; four classes of fifth grade students at Woodrow Wilson Elementary School in Salt Lake City, Utah; and one class of 7th grade students and one class of 8th grade 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 of the program, and the degree to which it promoted science learning, youth engagement in science process skills, and problem-based learning. In addition, we 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, and opportunities for students to develop critical thinking, innovation and problem solving skills.

top

33 Students working on their kinetic device

below

34 Students planning how to design their kinetic device

35 Englehardt and Beichner, (2004). *Students' Understanding of Direct Current Resistive Electrical Circuits*. American Journal of Physics, 72, 98-115.

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[33, 34]. 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."

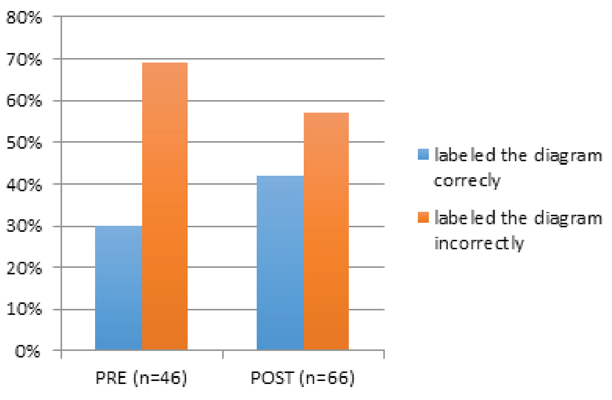
The *It Lives!* workshop helped students understand important core science concepts and to make connections between science concepts. As Salt Lake City teachers reported in post assessments:

> "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!"

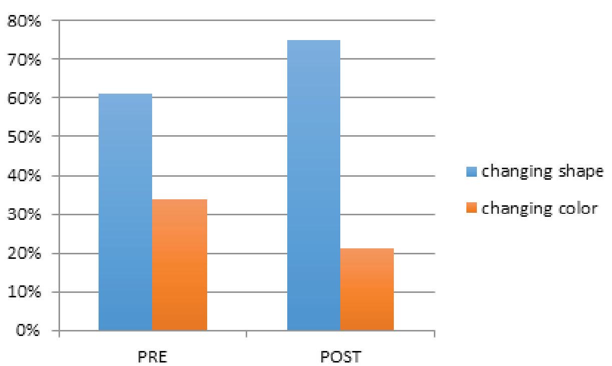
For example, two 8th grade students we interviewed in Texas were able to articulate the connections between science concepts they were making through the building activity with the muscle wire:

> "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."

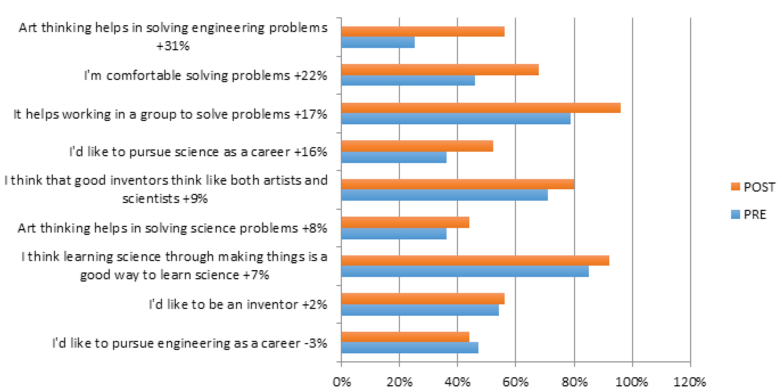
Data from pre-post content assessments in Salt Lake City indicated that students had made progress in understanding how circuits work, a notoriously difficult concept for students to grasp[35]. One question on the pre-post assessment asked students to label the power source, switch, conducting wires, and muscle wire in a diagram of a circuit. On the pre-assessment of the Woodrow Wilson 5th grade students, of the 46 students who labeled the diagram, 30% labeled the diagram correctly, while 69% labeled it incorrectly. On the post assessment, of the 66 students who labeled the diagram, 42% labeled it correctly, while 57% labeled it incorrectly. Thus, as the graph on the following page highlights, not only did the number of students who actually labeled the diagram increase by 20 students, the gap pre-post narrowed from +39% incorrect, to +15% incorrect[36].



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



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



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

Another example of the 5th grade pre-post content assessment data highlighting content knowledge gains is shown in the graph below, where students demonstrate their understanding of the physical change in the shape memory alloy (muscle wire)[37].

Students also articulated their appreciation for the inquiry-based methods of exploration the project provided, and how that helped further developed 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 we interviewed 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 concepts they had been studying in school to combine that connected to the 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, 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.

The graph below highlights pre-post attitude assessment data from one 5th grade 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[38].

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.

IT LIVES: SUMMARY AND FURTHER PLANS

Our experience with the pilot *It Lives!* sessions is incredibly encouraging and we look forward to being able to enlarge the reach of the program by seeking additional funding. In the next stage of the project we will be further refining the project to further integrate brain-based strategies and more fully address the engineering component. We also will be scaling the delivery to other grade levels and developing a train-the-trainer teacher professional development program. These strategies will help us improve the project, multiply the number of students exposed to the workshop, and enable broader delivery. We expect that this effort will be supported through partnerships with school boards in Canada and school districts in the US in which we've had successful pilots. In addition, we will be working with PBAI, creators of *Hylozoic Veil* and pioneers in near-living architecture, to develop a series of classroom kits that teachers may use for the hands-on portions of the workshop.

Another avenue we will be exploring, which was tested in the Canadian pilot, will be connecting students internationally through videoconferencing. In the pilot, grade 8 students from MacGregor Public School in Waterloo, Ontario had a 15-minute video conference with grade 7 students from Palestine Junior High in Palestine, Texas. A team of Palestine students presented the design they had completed earlier in the second iteration of the *It Lives!* workshop at that school, and both groups exchanged questions about the design problems they faced as well as about their cultures and environments. We would like to take this international collaboration further, possibly even introducing to the students the idea of remote design teams. These skills will be vital in these students' futures as the world continues, as Friedman says, to "flatten"[39], and global collaboration becomes even more prevalent. Combining these global collaborative skills with creative and innovative thinking and discipline-based knowledge will provide these students a firm foundation for their futures.

39 Friedman, T. (2007). *The world is flat: A brief history of the 21st century.* NY, NY: Picador/Farrar, Straus and Giroux

facing page

40 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.