Making Inspired by Nature: Engaging Preservice Elementary Teachers and Children in Maker-centered Learning and Biomimicry

Douglas Williams
University of Louisiana at Lafayette, USA
dwilliams@louisiana.edu

Aimee Barber
University of Louisiana at Lafayette, USA
abarber@louisiana.edu

Peter Sheppard
University of Louisiana at Lafayette, USA
psheppard@louisiana.edu

Abstract[75-150 words]: This exploratory project, *Making Inspired by Nature*, brings together the art of making and the creative practices of biomimicry to engage preservice teachers and children in building innovative solutions to real-world problems. To achieve this, this project is (a) building and evaluating digital resources and hands-on activities for engaging elementary children in innovation through the application of biomimicry and design thinking in a maker context and (b) evaluating models for deepening preservice teachers' pedagogical knowledge for supporting student learning in maker-centered classrooms.

Introduction

This exploratory project, *Making Inspired by Nature*, brings together the act of "making" with the innovative practices of biomimicry to engage preservice teachers and children in building innovative solutions to real world problems. To achieve this, this project is (a) building and evaluating digital resources and hands-on activities for engaging elementary children in innovation through the application of biomimicry in a maker context and (b) evaluating models for deepening preservice teachers' pedagogical knowledge for supporting student learning in maker-centered classrooms.

Maker-centered learning brings many of the practices and habits of mind employed in the maker movement into the educational setting (Clapp, Ross, Ryan, Tishman, 2016). Makerspaces are exciting collaborative spaces where learning is collaborative, interdisciplinary, shared, and driven by choice and interest.

Biomimicry, innovation inspired by nature, was popularized by Janine Benyus in 1997, though humans have always looked to nature for inspiration. Two common examples are how both Leonardo da Vinci and the Wright Brothers studied bird flight and body in their pursuit of human flight. More recently, innovations inspired by nature include gecko-inspired adhesives, antibacterial material inspired by shark skin, moisture collecting devices inspired by beatles, and wind turbines inspired by whale fins. Engaging children in biomimicry is an innovative way to engage children in learning about the natural world as they apply their own thinking and ingenuity in making solutions.

Preservice Teacher Experiences

Preservice teachers, participating in a junior-level technology integration course, were immersed in a progression of maker and biomimicry experiences.

Maker-centered Learning Experiences

Preservice teachers began by engaging in several tinkering activities such as Wind Tubes (Tinkering Project: Wind Tubes, 2019) and Marble Machines (Tinkering Project: Marble Machines, 2019) from the Exploratorium and learned a simple design process: Think - Make - Improve (Martinez,& Stager, 2013).

Building upon these experiences preservice teachers employed maker-centered learning thinking routines (Clapp et.

al) to develop a level of proficiency in using them with a variety of objects and systems. For example, they began with exploring the Parts, Purposes, Complexities (2019) of a screw, asking, what are it parts and their purposes. These were documented through sketches, describing words, and lists. Other thinking routines employed include:

- Parts, People Interactions (2019): Who are the people connected to the system?,
- Think, Feel, Care (2019): Explore the point of view of different people that interact with the system, and
- Imagine if… (2019): Explore the ways a system might be improved.

At the conclusion of these experiences, preservice teachers learned how these strategies can be employed in a classroom setting and how these strategies benefit the development of key "habits of mind" in children. In this project, experiences and activities are design to meet science standards and selected maker dispositions.

Problem Solving Challenges

To deepen experience with exploring systems thinking and skills in cooperation, communication, and creativity, preservice teachers experienced a series of team problem solving challenges such as:

- Building the tallest tower using 5 sheets of paper (Bordessa, 2005),
- Stacking cup challenge (Thompson, 2017),
- Team talk challenge (Fraser, Fraser, Lum, & Fraser, 2009), and
- Draw How To Making Toast (2019).

Making Inspired by Nature Experiences

To begin an introduction to biomimicry, preservice teachers completed a twist on the traditional design hunt activity (i.e. identify elements of the designed world). Preservice teachers were tasked with exploring an outdoor space to identify specific organisms that performed functions including: grip, protect, create color (Hunting and Gathering for Ideas, Biomimicry Institute, 2019).

Next, they experienced a series K-5 lessons (Making Inspired by Nature, 2019) that bring together making and bio-inspired design including: Shape and Function (Scallop Shell), Keeping Cool (Termite Mound Architecture), Aerodynamics (Gliding Seeds), and Strong Towers. Each lesson addressed Next Generation Science Standards (NGSS) and several of the maker habits of innovation. For example, the Shape and Function (Scallop Shell) Lesson address the following:

> *K-2 Engineering Design*
> ETS1-2. Create a physical model to show how shape of an object helps it function as needed to solve a problem.
> 1-LS1 From Molecules to Organisms: Structures and Processes
>
> *Habits of Innovation*
> Curiosity, Creativity, Communication

As a capstone experience, preservice teachers used 2 of these lessons with a small group of children in K-5.

Methodology

Data collection includes qualitative and quantitative data to provide information on the quality of the materials, the design iterations, perceived impacts on preservice teachers and students, and strengths and challenges associated with implementation of the newly developed materials. Data sources include preservice teacher pre and post surveys (N = 42 at baseline; N = 31 at follow up), preservice teacher interviews (N=20). All preservice teachers taking the project course participated in the baseline survey (N = 40) and 78% (N = 31) completed the follow-up survey; just over half (55%) of students completed both a baseline and follow-up survey (N = 22).

Survey data was collected for pre/post analyses on demographic information and a range of outcome variables: (1) emphasis, value, and utility of core foundational experience topics, (2) teaching efficacy and beliefs related to mathematics problem-solving and biomimicry in science (Tschannen- Moran & Hoy, 2001), (3) connectedness to nature (Mayer & Frantz, 2004) and (4) resources necessary to support their work as a maker educator in the future.

Preservice teacher focus group participants were randomly selected. They were asked about: their experience with

project materials, curricula, and the website; participation in Science and Innovation Saturday Program student camps; participation in the summer Innovation, Design, and Robotics camp; perceived outcomes for themselves and their potential students; and strengths and challenges of the project.

Reliability analyses were conducted on the preservice teacher baseline data to identify clusters of similar items to form composite scales, which are more robust and reliable than single survey items. As shown in Table 1, composite scales at baseline had acceptable internal reliability (alpha coefficient greater than .700).

Scale	Number of Survey Items	Cronbach's Alpha (N =42)
Preparedness on Topics of Maker-Centered Learning, Design Thinking, and Biomimicry	16	.976
Value of Maker-Centered Learning, Design Thinking, and Biomimicry	15	.939
Utility of Maker-Centered Learning, Design Thinking, and Biomimicry	15	.931
STEM Teacher Efficacy and Beliefs (PSTEBS): Problem-Solving for Mathematics	11	.856
STEM Teacher Efficacy and Beliefs (PSTEBS): Biomimicry in Science	11	.872
Connectedness to Nature	14	.739

Table 1. Preservice Teacher Survey Composite Scales Internal Reliability

Analysis

Qualitative data collected through interviews and focus groups were analyzed using an approach that closely follows methods explicated by Miles, Huberman, and Saldaña [21]. This approach emphasizes well defined study variables to ensure the comparability of data and reduction of data using data displays and matrices so that the common themes can be identified. The qualitative data was analyzed for trends, and were used to validate and extend understanding of survey data, probing complex issues in greater depth.

Quantitative data collected from participant surveys were analyzed and presented using descriptive statistics (e.g., frequencies, means, and standard deviations). Frequencies of response categories were calculated for three scales at post-test: Emphasis on, value of, and utility of maker-centered learning, design thinking, and biomimicry. Means and standard deviations were calculated for all preservice teachers who completed both a baseline and follow-up survey to assess change in outcomes during participation in camp.

Mean differences were examined between sample of students who took both the baseline and follow-up surveys and those who took just one survey, using an independent samples t-test with a Bonferroni adjustment for multiple comparisons. No differences between outcomes were found, suggesting preservice teachers who took only one survey (either baseline or follow-up) did not differ from those who took both surveys. Change over time was documented using paired-sample t-tests and a Bonferroni adjustment.

Findings and Discussion

Preparedness On Topics Related to Core Foundational Experiences: Maker-Centered Learning, Design Thinking, and Biomimicry.

Preservice teachers indicated that the Making Inspired by Nature Core Foundational Experiences emphasized all intended topics to at least a moderate amount. Most respondents indicated that their experiences placed much emphasis or complete emphasis on each topic. Overall, the combined score indicated that the core foundational experiences placed much to complete emphasis on maker-centered learning, design thinking, and biomimicry topics ($M = 4.67$, $SD = .45$). This finding seems to indicate that participants feel they were engaged in maker-centered learning, design thinking, and biomimicry.

Value and Utility of Topics Related to Core Foundational Experiences: Maker-Centered Learning, Design Thinking, and Biomimicry

Participant responses for the value scale were recorded on a Likert scale from 1 (no value) to 5 (complete value). Preservice teachers initiated core foundational experiences with a relatively high level of value in teaching K-12

children maker-centered learning, design thinking, and biomimicry, with ratings of topics related to these falling between much value and complete value. They increased slightly over the course of their engagement with Making Inspired by Nature activities, though the change was not significant after correcting for multiple comparisons, t (21) = - .12, p = .0468 Ceiling effects due to high baseline scores may conceal significant changes. It appears that, at least for this group of participants, preservice teachers entered the project already valuing the importance of engaging children in these innovative practices.

Participant responses for the Utility scale were recorded on a Likert scale from 1 (extremely unlikely) to 5 (extremely likely). Preservice teachers initiated core foundational experiences with a relatively high level of belief that they are likely to use maker-centered learning, design thinking, and biomimicry in their future classrooms, with ratings of topics falling between somewhat likely and extremely likely. They were fairly stable over the course of their engagement with Making Inspired by Nature activities, with a very slight increase that did not reach significance, t (21) = -0.97, p=.341. Ceiling effects due to high baseline scores may conceal significant changes. This finding indicates that participants entered the program with high value for these types of activities and and belief that they would likely use these activities in their future classrooms.

Preservice STEM Teacher Efficacy and Beliefs: Mathematics and Science.
Respondents rated their confidence in their teaching skills based on a series of statements on a Likert scale from 1 (strongly disagree) to 5 (strongly agree). Preservice teacher efficacy and beliefs grew over the course of their experience with Making Inspired by Nature. They rated most statements about agreement with items related to efficacy and beliefs for problem-solving for mathematics as between neither agree nor disagree and agree at baseline, and at follow-up increased slightly, closer to agree for the same statements, on average. This change was not significant, t (20) = -2.06, p =.053. Preservice teachers increased their efficacy and beliefs for biomimicry for science, rating statements at follow-up, on average, as neither agree nor disagree at baseline and agree at follow-up. This change was significant, t (19) = -3.68, p = .002.

Preservice Teacher Connectedness to Nature.
Respondents indicated their agreement with statements about connectedness to nature on a scale from 1 (strongly disagree) to 5 (strongly agree). Preservice teacher connectedness to nature grew slightly over the course of their experience with Making Inspired by Nature, though this change was not significant. They rated most statements about agreement with items related to efficacy and beliefs for problem-solving for mathematics as between neither agree nor disagree and agree at baseline, and at follow-up increased slightly. This change was not significant, t (20) = -1.49, p =.153.

Preservice Teacher Focus Group Responses Related To Impact
All respondents agreed that the Making Inspired by Nature project increased their understanding of biomimicry and design thinking in a maker context and enlarged their pedagogical knowledge for supporting student learning in maker-centered classrooms. They believed that had acquired skills for translating concepts into classroom practice and utilizing more experiential approaches in their instruction.

In terms of pedagogical knowledge for supporting learning in maker-centered classrooms, teachers expressed the vital importance of helping students believe they could be makers and thought that if students perceived of themselves as makers in one class, they could then carry that understanding with them to other classes. Teachers reiterated that their pedagogy would be informed by greater creativity and stated that the teaching strategies they learned would help them make class content more developmentally appropriate. They said they planned to use more hands-on activities to increase student engagement and foster resiliency and persistence.

The Making Inspired by Nature project clearly impacted teachers' interest in biomimicry and ability to help students apply biomimicry to solving real-world problems. One teacher said that the project encouraged students to think about problems in their community and build prototypes to decrease river pollution. Several teachers described using the knowledge of biomimicry to help students recognize the extensive use of this concept in engineering and design applications. Others said they planned to make biomimicry a fundamental way to teach problem-solving skills by turning to nature for solutions.

There was strong agreement among most teachers that involvement in the Making Inspired by Nature project would foster changes in their classroom curriculum instruction, and/or assessment practices. The majority of teachers

indicated that they would use more hands-on activities, forge connections between making and being inspired by nature, and integrate biomimicry concepts into lesson plans. Some teachers said they recognized the importance of letting students struggle with a problem and find their own solutions rather than telling them how to solve it. Other teachers said they wanted to create a maker center in their classroom in which students could examine different objects and create whatever they wanted.

Conclusion

Both survey and interview data suggest that the experiences provided to preservice teachers left them feeling well prepared and likely to use maker-centered learning and biomimicry in future classrooms.

References

An Introduction to Design Thinking Process Guide (2013) . Retrieved January 17th, 2015 from, https://dschool.stanford.edu/groups/designresources/wiki/36873/attachments/74b3d/ModeGuideBOOTCAMP2010L.pdf

Benyus, J. (2019). Biomimicry in action. [online] Ted.com. Available at: https://www.ted.com/talks/janine_benyus_biomimicry_in_action?language=en [Accessed 4 Jan. 2019].

Biomimicry Institute (2019). Hunting & Gathering For Ideas - AskNature. [online] AskNature. Available at: https://asknature.org/resource/hunting-gathering-for-ideas/#.XC9snM9KjUI [Accessed 4 Jan. 2019].

Bordessa, K, (2005). Team Challenges: 170+ Group Activities to Build Cooperation, Communication, and Creativity. Chicago Review Press.

Chatterji, M. (2005). Evidence on "what works": An argument for extended-term mixed-method (ETMM) evaluation design. Educational Researcher, 34(5), 14-24.

Chen, X. (2013). STEM Attrition: College Students' Paths Into and Out of STEM Fields (NCES 2014-001). National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education. Washington, DC.

Clapp, E. P., Ross, J., Ryan, J. O., Tishman, S. (2016). Maker-centered learning: Empowering young people to shape their worlds. John Wiley & Sons.

Creative Problem Solving: Students' skills in tackling real-life problems (2014). Retrieved January 17th, 2015 from http://www.oecd.org/pisa/keyfindings/pisa-2012-results-volume-v.htm

Cross, N. (2007). Designerly Ways of Knowing, Birkhauser, Basel, Switzerland.

Cross, N. (2007). Creative thinking in design: an introduction. In '07 Proceedings of the 2007 Symposium on Science of Design (pp. 2-3). Arcata, California: ACM.

Cross, D. (2011). Design thinking. New York: Berg.

Draw How To Make Toast (2019). Retrieved January 4, 2019, https://www.drawtoast.com/

Fraser, K., Fraser, L., Lum, B., & Fraser, M. (2009). The 175 Best Camp Games.

Fu, K., Moreno, D., Yang, M., & Wood, K. L. (2014). Bio-inspired design: An overview investigating open questions form the broader field of design-by-analogy. Jounral of Mechanical Design, 136 (11).

Imagine if… Thinking Routine (2019). Retrieved January 4, 2019 from, http://agencybydesign.org.s219538.gridserver.com/wp-content/uploads/2014/10/AbD_Imagine-If.pdf

Making Inspired by Nature (2019). Retrieved January 4, 2010 from, https://www.makinginspiredbynature.org.

Martinez, S., & Stager, G. (2013). Invent to learn: Making, tinkering, and engineering in the classroom. Constructing Modern Knowledge Press.

Mayer, F. S. and Frantz, C. M. (2004). The Connectedness to Nature Scale: A measure of individuals' feeling in community with nature. Journal of Environmental Psychology, 24, 503-515.

Nelson, H. G., & Stolterman, E. (2002). The design way. Englewood Cliffs, New Jersey: Educational Technology Publications.

Nelson, H. G., & Stolterman, E. (2003). The design way: Intentional change in an unpredictable world: Foundations and fundamentals of design competence. Englewood Cliffs, NJ: Educational Technology Publications.

Parts, Purposes, Complexities Thinking Routine (2019). Retrieved January 4, 2019 from, http://www.pz.harvard.edu/sites/default/files/AbD_PPC.pdf

Parts, People Interactions Thinking Routine (2019). Retrieved January 4, 2019 from, http://www.pz.harvard.edu/sites/default/files/AbD_PPI.pdf

PBS.org. (2019). Making Stuff Wilder | NOVA. [online] Available at: https://www.pbs.org/video/2365105192/ [Accessed 4 Jan. 2019].

Thompson, B. (2017). Cup It Up!. Barry W Thompson.

Tinkering Projects: Marble Machines (2019). Retrieved January 4, 2019 from, https://www.exploratorium.edu/tinkering/projects/marble-machines
Tinkering Projects: Wind Tubes(2019). Retrieved January 4, 2019 from, https://www.exploratorium.edu/tinkering/projects/wind-tubes
Think, Feel, Care Thinking Routine (2019). Retrieved January 4, 2019 from, http://www.pz.harvard.edu/sites/default/files/AbD_TFC.pdf