An Ecosystem: Computational Thinking, Project-Based Learning & Logo

Nancy Otero Ornelas
nancy@portfolio-school.com
Founding Director of Research and Learning Design, Portfolio School, New York, NY
www.portfolio-school.com

ABSTRACT

This paper describes an ecosystem of project-based learning formed around Logo-based tools and computational thinking. At Portfolio School - a mixed-age, project-based learning, maker centered micro-school in NYC with ten children between the ages of 6-10 year old, learners used GoGo Board, Netlogo, TurtleArt, and LightLogo to design personal projects using robotics, create laser cut bookmarks designed with functions, construct and program a LED bonfire, and code agent-based simulations. Observations throughout the school-year suggested that this ecosystem immersed learners into the computational thinking world and supported the development of agency by providing an environment where learners could: 1) create things that were meaningful to them and 2) give learners the opportunity to take ownership over the process of making.

Keywords:

Project-based learning; Logo; Computational thinking; Physical Computing; STEM; Hands-on learning; Maker centered learning, FabLab.

1. INTRODUCTION

Computational thinking (CT) is a defining competence to master in today's world, and a powerful mediator of agency for children. The importance of CT is reflected also in the estimate that by 2020 one of every two jobs in STEM will be in computing [1]. The latest Next Generation Science Standards and Common Core [16, 17] also acknowledge the fundamental role of CT in other subject domains, such as the STEM fields. Integrating CT into other subject domains gives learners a more realistic perspective of those fields, deepens their learning and understanding, prepares them for future careers in those disciplines, and provides a meaningful context in which computational thinking can be used [2, 10, 18, 19, 20, 13, 15, 23, 24]. For this reason, Portfolio School (PS) has been developing CT activities for its learners starting from kindergarten based on the framework described by Weintrop et al [23]. We chose that framework because it was designed for being embedded into the STEM learning experience. This contextualization of CT practices resonates with the multidisciplinary characteristics of the projects at PS.

Paper to be presented at the FabLearn Conference at Stanford University Oct 2017.

Project-based learning (PBL) plus digital fabrication is a natural framework for integrating multiple disciplines in the context of meaningful questions and projects, giving the sense of authenticity and real-world applications [3, 4, 5, 13] and it is the main teaching methodology at PS. PBL has gained popularity in recent years and research supports that learning occurs better in hands-on experiences [7]. As we looked to extend CT practices to digital fabrication, design and personal expression we included Blikstein [3] suggestions. His design principles are important for us because they present a link between PBL, CT and maker-centered learning and suggest a multidisciplinary approach.

Logo-based technology tools allowed learners to interact with CT ideas in a way previously inaccessible for them. Research has cautioned us about the use of technology for its own sake [9, 14] and advises that when technology is not designed for children or for learning it can result in frustration, adverse feelings towards programing and science, and misconceptions or non-transferable learning [8]. The wrong choice of technological tools can also increase gender and achievement gaps and perpetuate biases around the concepts of science and math, design, art, computer science and engineering. Logo-based tools have been used to overcome those possible pitfalls [3, 4] and because they share some design principles, key platform knowledge is transferable between tools.

We next describe our efforts in designing and implementing activities: 1) where learners genuinely engage in the process of making their projects, 2) that can be used to create something meaningful for each learner, 3) support the development of CT, and 4) keeps the learner motivated to learn more about CT. We hope that the lessons we learned can be used in other formal and informal learning settings.

2. DESCRIPTION

The learning experiences at PS are structured as a sequence of units consisting of two parts: 1) a network of multidisciplinary, smaller "learning-projects" linked through a topic, and 2) a bigger multidisciplinary final project that answers a driving question or solves a specific problem related to the same topic. This year's topics were ice, color, and the neolithic revolution. Concurrently with the units, children do personal projects that can be on different topics. The goal of every learning experience is to produce a shareable artifact and demonstrate the understanding of the activity's learning goals. Learning is measured through: quality of the project (finished, functional, aesthetics, has bugs, etc), written responses to questions (explain why zebras couldn't be domesticated), challenges (fix a piece of code, discover if there is sugar dissolved in a glass of water without tasting it), creative expression (writing their own rainbow myth), and drawing diagrams explaining a mechanism (role of pollination in the reproductive cycle of plants).

Every unit had a CT component. CT components have three parts: explorations, challenge questions, and large projects. In the exploration phase children interact freely with the technology. Next, the teacher asks some questions or posts a challenge and by overcoming the challenge students are introduced to formal concepts such as range, variable, initial-conditions. Finally, after the resolution of several increasingly sophisticated challenges or questions that demonstrate the understanding of the technology and CT concepts, children indepently create a longer project that will be shared.

The topics, activities, and projects are derived whenever possible from children's interest or curiosity. At the end of this experience (unit) that lasts three months the final project is presented to parents at exhibition night together with other selected projects. The smaller learning projects typically last 4-6 hours and are done individually or in small groups. All children work together on the final project which lasts 20-30 hours. Time for personal projects is 2 hours per week throughout the year.

The activities were designed, implemented, and documented by the PS staff. The collected data consists of observations during their process, learners' drafts and iterations, results of their challenges, a final project per activity, and learners' reflection. Activities include reflection time during which children were asked about their experiences, design choices, and sentiment towards CT. We used this data to extend the current activity or design the CT activities for the next units and to understand how the learning experiences impact the children. We next present the CT activities with the motivation for the activity, why the technological tool was chosen, an example of how CT was explored, and a case study that summarizes their impact on the children.

3. Invention and GoGo Board

Given complete free choice two of our children (six and seven year olds) chose to learn robotics during their personal project time and use the learning to design a project: 1) A horse that walks and eats like a biological horse and 2) A ninja turtle car. As this was the first CT activity the children did, we choose a technology that is hands-on, concrete, has a low-floor entry, and is complex enough to be used to create sophisticated artifacts. A variety of CT concepts and practices were explored throughout their projects including input-output, range, pseudo code, control statements, decomposing the project into sub-problems and reframing new problems into known problems for which computational tools already exist. We choose the GoGo Board (open-source hardware device for educational robotics, scientific experiments, and environmental sensing) because of its plug-and-play capacity. Sensors, motors and LEDs do not need a breadboard or

Case Study

Children completed the challenges and finished a first version of their project mostly by themselves though some help was needed on the physical part of the their projects (e.g. aligning the wheels of their car). Three months after the introduction of the GoGo Board, part of the final project of the last unit of the school year was to build a four-floor castle for two new guinea pig pets. Our 1st grade student decided that her contribution to the castle would be to design a device that would tell us how dirty the castle was using the GoGo Board. She remembered how the humidity sensors worked and wanted to use them to trigger LEDs of different colors that will represent the level of dirtiness in the castle. She programmed the GoGo Board, created extensions for the sensors, laser cut an interface for the LEDs, and presented her working prototype at exhibition night. We believe that the fact that our 1st grade learner wanted to develop something with the GoGo Board again and was able to do most of it independently suggests that she learned important CT concepts that can be transferred into her own inventions, and that she developed her sense of agency, realizing that there are technologies she can use to create objects meaningful to her, and worthy of sharing with others. These changes were shown also outside the school when, a few months later her parent told us that his daughter was aggravated that her father was leaving to go to the gym. She told him that he did not need to go--she could build him a treadmill! "It's just a motor, a belt and a switch," she confidently explained.

any driver to be installed or for the sensing data to be seen. All of the sensor activity can be seen in a bar-graph in which the range of all the sensors is normalized. Children can use blockly, a block web-based environment to program the GoGo Board.

Example of how CT concepts were presented

After the sensors were introduced (light, temperature, infrared, etc) and children learned how to connect them and visualize the sensing, the teacher asked them to see if they could find out how they work and notice differences between them. Children noticed that even though all the sensors had the same range (0-1023), the speed and ease by which each sensor can reach the highest and lowest boundary was very different. The teacher then talked about what range means, how range is important when designing their projects, and how sensors measure the physical environment. Later, one of the challenges was to discover the range of at least three different sensors, and use that information to code an instruction to trigger an output.

4. Self-Expression with TurtleArt and LightLogo

During a previous activity on laser cutting, children used Corel Draw as the vector graphic environment to create their designs. This experience made us realize that manipulating a mouse can be challenging for our five and six year old learners when precision is required in their graphic design. Still, these young learners wanted to use the laser cutter to create beautiful and intricate shapes rather than just reuse images from the internet. Given their motivation we decided to create an activity in the color unit that would merge geometry, laser cutting and CT. We chose TurtleArt (a block-based micro world in which the sequence of blocks are a program that draws an image) for this activity because of its focus on design, modular orientation, documentation, ease

Case Study

After children finished their first design using My-Block we gave learners the choice of continuing their project on TurtleArt or by using CorelDraw. All learners chose TurtleArt and after the learning-project was over, two of them used their designs in a self-selected project–engraving the designs on laser cut boxes they created as Christmas presents for relatives. During the next unit, part of the final project for exhibition night was to transform the reading nook of the school into a cave. Students wanted to have a bonfire inside the cave. For obvious reasons that was not possible but we told them that maybe they could use LEDs to do it. Because of their project idea complexity we introduced to them LightLogo, a micro world that can be loaded on Arduino and has the ability to program a neopixel ring through the Logo language using the same idea of a “walking turtle” (the method that was introduced with TurtleArt). Given their previous experience with TurtleArt, three children choose to delve into LightLogo: two students (6 and 9 years old) paired to create the bonfire with pieces from acrylic and another student (10 years old) wanted to create a stalagmite with a neopixel ring inside. This was the first project in which children needed to program in textual code rather than with visual blocks. They learned about syntax, uploading code, the process of connecting the Arduino to the neopixel, and they coded their first functions and variables. Both the bonfire and the stalagmite were inside the cave for exhibition night.

of use, and natural integration with geometry.

Example of how CT concepts were presented:

In the introduction to TurtleArt the concepts of flow-control and My-Block (a block option that allows users to create their own block, something similar to a function) were presented. We then explored the concept of angles and their relation with the different types of triangles with and without TurtleArt. Each learner chose a triangle with the challenge of using it to create some designs for a bookmark. As a constraint, learners were required to make at least one of their designs using My-Block. This restriction was made with the goal of guiding the learners to compare the process of creating the shape using a modular approach with My-Block or without it. Most learners started drawing and forgot about My-Block, but as soon as one of them remembered the square example (where My-Block was introduced) and created a My-Block for his triangle, he shared his discovery and everyone started using it.

Figure 1. From left to right: 1) Learner programing the GoGo Board for her personal project. 2) Learner installing her dirtiness detector prototype designed in GoGo Board 3) Laser cut designs made in TurtleArt.

5. Scientific Models and NetLogo

Given the importance of understanding the use of computational simulations and its power for experimentation and learning [23], during the first six months of the year our students used PhET (Interactive math and science simulations) and Netlogo (A multi-agent programmable modeling environment) to explore ideas such as temperature, states of matter, and how the leaves change color during autumn. When the older children (9 and 10 years old) learned that they could modify the code on the NetLogo simulations they started altering the model and soon after, expressed that they wanted to make their own simulations.

The final unit focused on domestication of animals and on natural and artificial selection. As part of the work for the final exhibition, the older learners created simulations of a simplified ecosystem in NetLogo. One of them was inspired by the ecological challenges cheetahs are suffering and wanted to do his simulation about them. The other one wanted to recreate the evolution of the black peppered moths during the industrial revolution. Throughout the next two and a half months students devoted around 30 learning hours in parallel about ecosystems, natural selections, agent-based simulations and coding in order to create their projects. We choose NetLogo because it is easy to integrate in a multidisciplinary PBL experience since it allows creating simulations of any type of complex system, it provides a low-floor environment for the CT categories of simulations, models systematic thinking, and the language used to code is Logo-based.

Example of how CT concepts were presented

Students explored two NetLogo simulations: wolf-sheep-predation and rabbits-grass-weeds. The teacher then asked them to identify the elements of the system, and explain how the elements interact, and how that relates to the system as a whole. During this investigation concepts such as initial-conditions and complex system were explained. Later children needed to define the elements of their simulation and their interactions accordingly to the ecosystem they wanted to create.

Students presented simulations at exhibition night. Both simulations had the base of a predator-prey system, presented energy levels of their agents by a plot and by a label, had parameters such as total population of their different agents, and energy gain from consumption and food growth for the primary consumers. The peppered moth simulation went a step further and created a slider to represent the camouflage of the black peppered moth. When the camouflage was low, birds will equally eat white and black pepper moths. But when it was high birds will eat more white pepper moths assuming that the black peppered moths were harder to find. By that mechanism the white moth population decreased and the student was able to recreate what happened to this population during the industrial revolution. His camouflage slider was a representation of a mechanism used by natural selection. After the older children finished the simulation they were so excited about CT that they next chose to begin a project on artificial intelligence. Both students trained a neural network to identify each other's faces and a wall.

6. CONCLUSION

If we want children to gain agency through CT they need to understand how to use it to create their own solutions to problems, support their self-expression, generate new forms to interact with one another, and gain access to powerful ideas (in the Papert sense [19]) in other domains. For PS the agency that children gain through CT is the real skill they will need in their future and so we believe these activities are the beginning of a learning trajectory in that direction. While deeper analysis needs to be done with the collected data, the ecosystem of PBL formed around CT and Logo-based tools enabled children as young as six to experience success and develop interest and confidence in their ability as programmers, inventors, scientist and artists.

The observations suggested that besides the chosen technology some of the key elements of the ecosystem were: 1) Multidisciplinarity, putting CT in a context that can motivate children and their curiosity, and helped them to experience the benefits of knowing CT concepts such a control statements or how to create a function that draws triangles. 2) Encountering of powerful ideas such as angels, complex systems or natural selection. 3) Open design projects that gave children the opportunity to make meaningful and personal choices.

Figure 2. From left to right: 1) Children exploring LigthLogo 2) Bonfire made with LightLogo and acrylic pieces. 3) Learns exploring states of matter with a PhET simulation 4) Learner presenting his simulation at exhibition night.

7. BIO

Nancy Otero is the Founding Director of Research and Learning Design at Portfolio School. She has a masters in Learning, Design and Technology from Stanford University and collaborated with Transformative Learning Technology Lab for four years. She co-founded FAB!, a non profit in Mexico that works with public schools.

8. REFERENCES

1. ACM Pathways report 2013
2. Augustine NR (2005) Rising above the gathering storm: energizing and employing America for a brighter economic future. National Academies Press, Washington, DC
3. Blikstein P (2013) Digital fabrication and ‘‘making’’ in education: the democratization of invention. In: Walter-Herrmann J, Buching C (eds) FabLabs: of machines, makers and inventors, Transcript Publishers, Bielefeld, pp 1–21
4. Blikstein, Paulo. “Travels in Troy with Freire.” Social justice for teachers: Paulo Freire and the possible dream (2008) (2008): 205-244.
5. Blikstein, Paulo, and Dennis Krannich. “The makers' movement and FabLabs in education: experiences, technologies, and research.” Proceedings of the 12th international conference on interaction design and children. ACM, 2013.
6. Blikstein, Paulo, et al. “An Assessment Instrument of Technological Literacies in Makerspaces and FabLabs.” Journal of Engineering Education 106: 1 (2017): 149-175.
7. Chinn CA, Malhotra BA (2002) Epistemolog-

ically authentic inquiry in schools: a theoretical framework for evaluating inquiry tasks. Sci Educ 86(2):175–218

8. Carter, M. P. (2013). WP2-Analysis of use of game based learning initiatives.
9. Cuban, L. (2001). Oversold and underused: Computers in the classroom. Cambridge, MA: Harvard University Press.
10. [3] Culp, K. M., H
11. Eisenberg M (2002) Output devices, computation, and the future of mathematical crafts. Int J Comput Math Learn 7(1):1–44
12. Eisenberg, M (2017) Pervasive fabrication: Making construction ubiquitous in education. Pervasive Computing and Communications Workshops, 2007. PerCom Workshops' 07. Fifth Annual IEEE International Conference on. IEEE, 2007
13. Hambrusch S, Hoffmann C, Korb JT, Haugan M, Hosking AL (2009) A multidisciplinary approach towards computational thinking for science majors. In: ACM SIGCSE bulletin, vol 41, pp 183–187
14. Holbert, N. (2016). The powerful ideas of making: Building beyond the curriculum. Journal of Innovation and Entrepreneurship, 5(1), 30.
15. Jona K, Wilensky U, Trouille L, Horn MS, Orton K, Weintrop D, Beheshti E (2014) Embedding computational thinking in science, technology, engineering, and math (CT-STEM). Pre- sented at the Future Directions in Computer Science Education Summit Meeting, Orlando
16. Khalil, M., Taraghi, B., & Ebner, M. (2016). Engaging Learning Analytics in MOOCS: the good, the bad, and the ugly. arXiv preprint arXiv:1606.03776.
17. Linn MC, Clark D, Slotta JD (2003) WISE design for knowledge integration. Sci Educ 87(4):517–538
18. National Governors Association Center for Best Practices, Council of Chief State School Officers (2010) Common core state standards for mathematics. National Governors Association Center for Best Practices, Council of Chief State School Officers, Washington, DC
19. NGSS Lead States 2013
20. Papert, Seymour. Mindstorms: Children, computers, and powerful ideas. Basic Books, Inc., 1980.
21. Repenning A, Webb D, Ioannidou A (2010) Scalable game design and the development of a checklist for getting computational thinking into public schools. In Proceedings of the 41st ACM technical symposium on computer science education. pp 265–269
22. Sengupta P, Kinnebrew JS, Basu S, Biswas G, Clark D (2013) Integrating computational thinking with K-12 science education using agent-based computation: a theoretical framework. Educ Inf Technol 18(2):351–380
23. Straumanis, J. (2015). Postsecondary play: the role of games and social media in higher education. Planning for Higher Education, 43(2), 95-100.
24. Weintrop, D., Beheshti, E., Horn, M., Orton, K., Jona, K., Trouille, L., & Wilensky, U. (2016). Defining computational thinking for mathematics and science classrooms. Journal of Science Education and Technology, 25(1), 127-147.
25. Wilkerson-Jerde MH (2014) Construction, categorization, and consensus: student generated computational artifacts as a context for disciplinary reflection. Educ Technol Res Dev 62(1):99–121
26. Wilensky U, Reisman K (2006) Thinking like a wolf, a sheep, or a firefly: learning biology through constructing and testing computational theories—an embodied modeling approach. Cogn Instr 24(2):171–209