# Hungry Birds – a STEAM Experience

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## Abstract

Transdisciplinary STEAM experiences often produce enhanced breakthrough moments where learning thresholds are crossed and so-called curriculum boundaries broken. But what is STEAM? Why would we combine four knowledge areas: science, engineering, technology and math (STEM) into one acronym and add the 'A' to acknowledge interconnectivity with the Arts? We do this to reinforce connectedness in all its learning forms. Effective STEAM desegregates conceptual learning experiences and encourages a new form of 3R's vocabulary to emerge as foundation for 21st *and* 22nd century knowledge and skills. Hungry Birds provides a splash of playful creativity in the vast sea of transdisciplinary learning potential. Hungry Birds is essentially a math-making experience, never losing sight of the complexity, beauty and elegance of its mathematical foundation.

## Introduction

There are shifting views of how we learn and understand in the current trans-disciplinary education zeitgeist. Such perception suggests a greater need now for discussion on how science, technology, engineering and math concepts (STEM) integrate with the arts across a range of learning settings (A). Thus creating STEAM. The acronym provides a neat catchall title for creative learning ecology, where cultures of thinking, creative programming, inventive teachers and ways of teaching rely on passion, fearlessness and curiosity to incite memorable learning experiences [13][15]. Curiosity drives STEAM learning. Curiosity also lies at the core of mathematician and 1965 Physics Nobel Prize winner Richard Feynman's work, and in *The Pleasure of Finding Things Out* [7], Feynman acknowledges the balanced aesthetic input from both artist and scientist, while simultaneously promoting the humor and joy in curiosity and discovery. Hungry Birds is a making experience akin to the balanced aesthetic Feynman relishes. It provides a new twist on the hyperbolic paraboloid. Hungry Birds introduces whimsy to STEM explorations, inviting participants to indulge in math, metaphor and material manipulation.

## Background

Developmental iterations of this project were presented in Australia in 2017 at Queensland University of Technology's Robotronica Festival, and 2018, at Vivid Ideas in Sydney, where Hungry Birds contributed a unique sense of play to the largest festival of its kind in the Southern Hemisphere. More formally, our trans-disciplinary incentive draws on the perspective of Dr. Albert C. Barnes, creator of Barnes Foundation Education (Philadelphia) as the embodiment of STEAM connections. Barnes educators, influenced by the philosophy of John Dewey [5] shifted from a focus on integration of math and science content, to "a foregrounding of math and science *practices*" [8]. Similarly, transdisciplinary strategies applied to foregrounding math learning may be greatly enhanced by physically engaging in making such learning visible [10]. This interactivity of knowledge and skill underpins the Hungry Birds project. We use our hands to engage with the mathematics. Juhani Pallasmaa, Finnish architect and leading international figure in contemporary architecture, design and art culture, suggests the sensory realm exists as enabler for a full understanding of our capabilities as physical and mental beings [11]. Psychologist Csikszentmihalyi [4] and eminent creativity educator Sir Ken Robinson [14], consider non-rational elements of consciousness to also be significant contributors to the acquisition of knowledge. Dweck [6], in research on 'mindsets', believes that abilities can be cultivated. Making, or "the essence of the hand" as Pallasmaa [11] suggests, is not only a constant, passive executor of the intentions of the brain, but the embodiment of human existence, seminal to the evolution of skills, intelligence, conceptual and creative capacities. And so, we must consider the cultivation of a STEAM learning environment to be an exemplary model of a community of truth [12]. Within this community, collective learning incorporates the best features of all learners, of all ages, with the core of the subject matter. Perhaps also in this community, all participants in the activity concede that "the hand has its own intentionality, knowledge and skills" See Pallasmaa [11], p. 21, and by engaging in the current global renaissance of tinkering and making, we demonstrate the readiness of learning environments to embrace the intelligence and skills of both hand and mind.

## Workshop Aim

The Hungry Birds workshop is tailored to a general audience, as well as targeted towards pre and in-service teachers, interested academics, and tertiary students. Typically, these are audiences who enjoy collaborative creating and meaningful making. Hungry Birds provides a playful metaphorical experience not only for the math-minded and creative but those drawn from different disciplines such as Engineering, IT, Design, Fine Arts and Crafts and Education. There is no pre-requisite skill needed to participate. Enthusiasts will engage with paper engineering to construct a mathematical model representing a hyperbolic paraboloid (HP), as shown in Figure 1. The HP is a shape that, amongst a myriad of applications, also remarkably resembles the beak of a bird! The beaks represent a small concessional link with biomimicry, another of STEAM's potent learning concepts. The session includes exploration of mathematics, experimental making and introductory mechatronics and coding. Embedding design and artmaking in STEM provides tangible experiences that encourage investigations of the relationship between logical functions and abstract concepts and processes. What appears as complex is not a new concept; artists and polymaths like Leonardo Da Vinci have already experienced and shown us the importance of integration to achieve higher-order thinking skills. Yet in Hungry Birds, we aim to place humour at the front and centre of embodied learning. The workshop focuses on innovative and cohesive integration of art and design with STEM theory and concepts. In particular, Hungry Birds is directed towards physically visualising mathematics in an accessible and achievable contextual format.

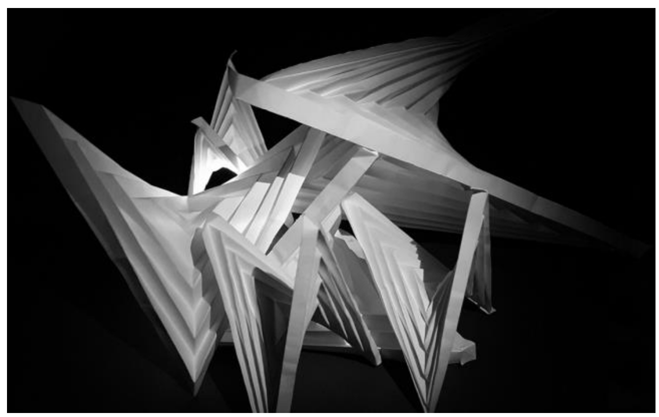

**Figure 1**: *Hyperbolic Paraboloids, randomly arranged.*

## Workshop Outline – the audience experience

In Hungry Birds, we briefly explore curves through Cartesian plotting and graphing, conic sections and terminology related to art and design principles (Figure 2). Participants then fold a paper *hyperbolic paraboloid* (HP), visualising this sophisticated mathematical shape in 3D. We call this a whimsical "flat to form" experience. We explore the concept of biomimcry in folded mechanisms by experimenting with articulated movement of the 3D forms (Figures 3, 4 and 5).

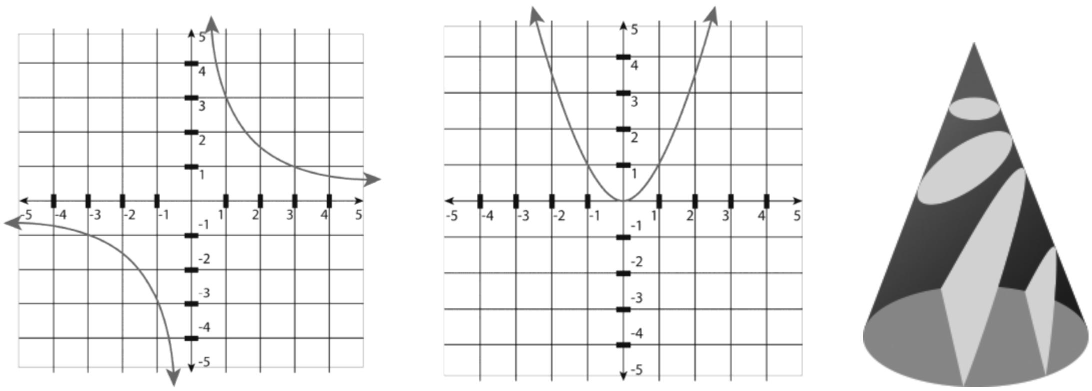

**Figure 2**: *Cartesian plotting and graphing, and conic sections.*

Folding the HP paper structures is similar to folding a paper fan. Figure 3 indicates the alternating fold lines embedded into the paper templates used in the workshop. Instructions are as follows:

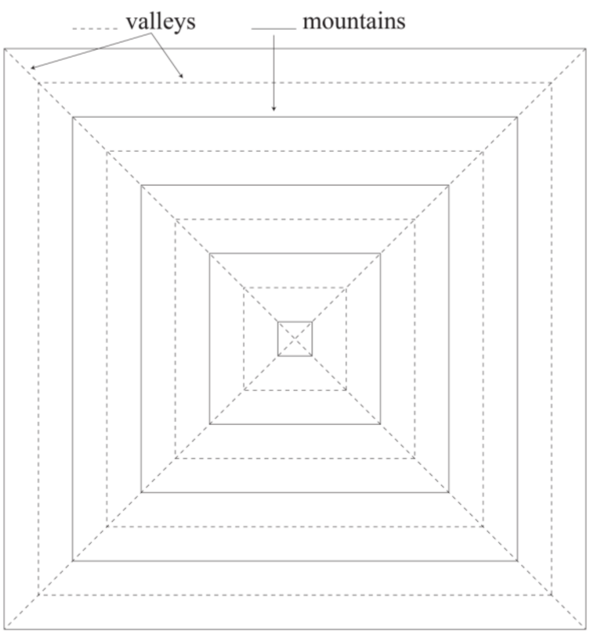


**Figure 3**: *HP guides for folding.*

Step 1 Fold the diagonal lines into valleys

Step 2 Fold the first concentric square into a valley (down), keeping the corners pointing out like spears.

Step 3 Fold the next line into a mountain (up).

Step 4 Continue to fold, alternating mountains and valleys until every square is creased.
Try not to keep your structure “flat” because the paper will naturally want to curve. See Figure 4.

Step 5 Spread the structure out again to reveal the hyperbolic paraboloid shape.

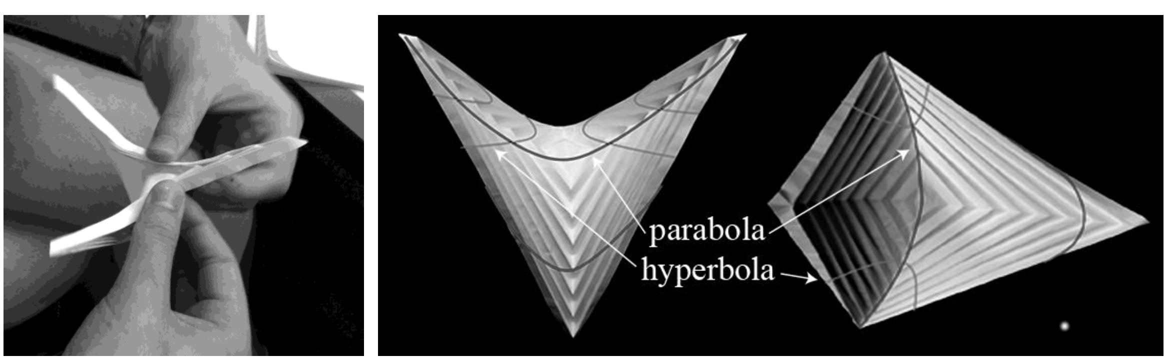


**Figure 4**: *Constructing the HPs and revealing the curves.*

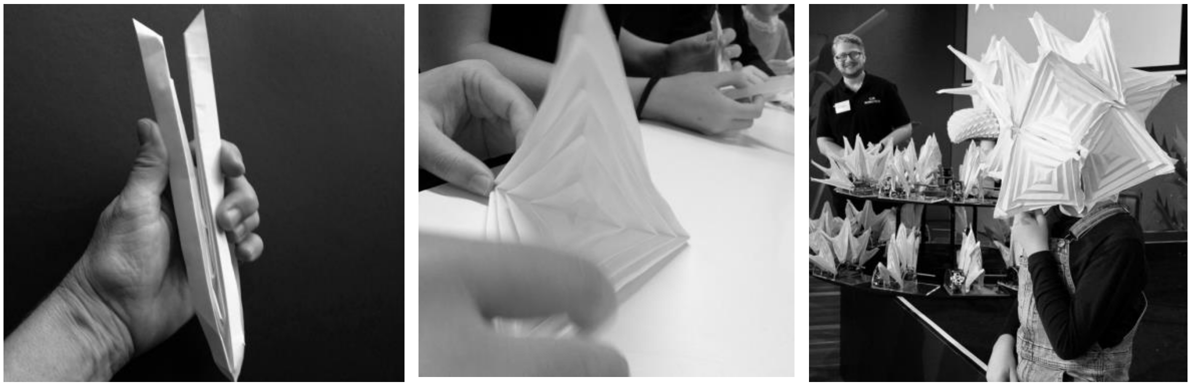

**Figure 5**: *Folding and manipulating the HPs into playful polyhedral constructions.*

Participants make as many HP structures as possible, one of which is contributed to the collective construction of the "nest". During this phase, the HPs are attached to specific pre-made mechanical components inherent in the nest structure, the "mini-nests" (Figure 6). Once attached, the motion sensors built into the mini-nests are activated and tested. At this stage, opportunities exist in manipulating aspects of the Hungry Birds movement via participant programming/coding. There are several scalable outcomes relatable to the Hungry Birds experience. The collective structures can be simply realised as a min-nest, more literally described by Stewart as "an electronic, arduino controlled, ultrasonic object detecting, stepper motor driven expanding and retracting LED lit screw mechanism"; or combined to form a colony of nests, appropriately protected by a watchful "motherbird" – a pre-made structure incorporating many HPs of varying sizes and other paper engineered materials. (Figure 16). The following URL address demonstrating how group of eighty participants contributing to the formation of a giant nest surrounding and watched over by the illuminated motherbird:
https://www.youtube.com/watch?v=jXQeph-tHI0.

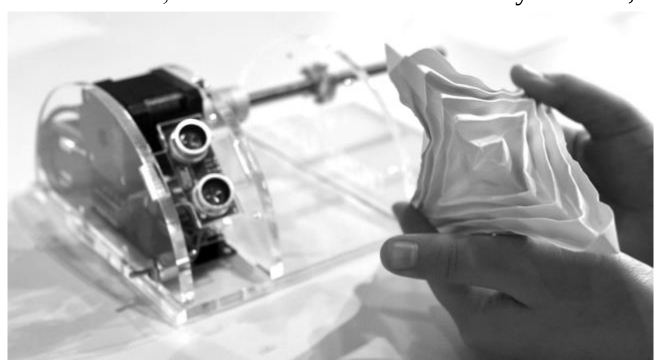

**Figure 6**: *Hungry Birds "mini-nest" incorporating motion sensors.*

Remaining HPs are utilised in problem solving activities requiring the construction of an assortment of polyhedra such as dodecahedron and icosahedron as seen in Figure 5. For Bridges 2019, Stage 3 of the Hungry Birds experience requires participants to adorn themselves with a custom designed luminescent HP provided in the paper materials for folding. This performative embodiment aspect of the workshop aims to augment the playful approach to cementing mathematical knowledge by enhancing the memorability of the experience (Figures 7 and 8). Lights will be dimmed to transform the space into a metaphorical manifestation of a family of warm bodied hungry birds.

**Figure 7**: *Wearing the HP beak.* **Figure 8**: *Embodiment of the HP structures.*

## Learning Opportunities

When you investigate STEM concepts through an Arts context, the connections between knowledge and learning demonstrates content interrelationships more explicitly, and is often a lot of fun. Art and Science have been interrelated since humans started thinking conceptually but more broadly, the Arts in STEAM represent Humanities, Language Arts, Dance & Physical Movement, Drama, Music, Visual Arts, Design and New Media. The following knowledge areas provide possible opportunities for increased STEAM content, either self-experienced, or potential. HP making has been or can be applied to:

- Literacy activities in the context of narrative building. For example, students used the HP folding experience as analogous to grit and persistence stories, where patience and perseverance proved triumphant. This was used in the context of personal or family stories within a group of first and second generation migrants and refugees living in Australia (Figure 9).
- Inter-cultural studies related to the significance of stars in cultural narratives. For example, the following link will provide access to a large STEAM workshop related to the Japanese cultural festival of Tanabata. [17] The STEAM experience involving vertical student participation where older students explained science and math concepts to younger students in order to collectively construct a giant artwork based on the shapes of stars (Figure 10).
- Design thinking sessions conducted within University of Technology's Bachelor of Creative Intelligence and Innovation courses as a visual metaphor for divergent and convergent thinking (Figure 12).
- Learning geometry.
- Exploring the concept of linear motion.
- Science studies related to space and the universe.
- Architecture as a STEAM discipline, where ancient engineering techniques combine with contemporary technology – for example:
  In Santiago Calatrava's *Milwuakee Art Museum* the 'Bris Soleil' (or permanent sun shading), bridge and galleria are inspired by nature, featuring a combination of organic forms and technological innovation, blurring the boundaries between engineering, sculpture and architecture (Figure 11) [2]. Among the many elements in Calatrava's design are:
  - movable steel louvres inspired by the wings of a bird
  - a cabled pedestrian bridge with a soaring mast inspired by the form of a sailboat;
  - a curving single-storey galleria reminiscent of a wave.
- HPs in engineering employ straight lines to create of curves in explorations in materials technology, plus functional and aesthetic relationships with space, structure, strength and serviceability.
- Human- technology interaction

**Figure 9**: *HP inspired stories.*

**Figure 10**: *Tanabata [17]*

**Figure 11**: *Milwuakee Art Museum [2].*

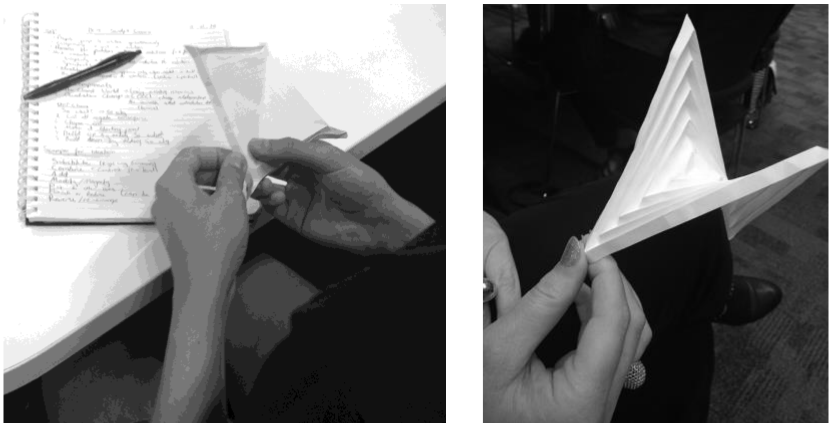

**Figure 12**: *Student HP making, Bachelor of Creative Intelligence and Innovation at UTS.*

Manipulating the code that services the moving components of the Hungry Birds mini-nests advances the learning experience into the digital processing environment, affording investigations into human-technology interaction (Figure 13). Specific technology used in the Hungry Bird mini-nest mechanisms directly relates to various industrial hardware and software implementations used throughout the engineering, manufacturing, automation and robotic fields. Participants can draw from the many concepts presented in mechatronic aspect of the workshop and see how each part of the hungry bird nest applies to other real world systems on a larger scale. The mini-nest consists of 3 core segments that work together to for a cohesive system, each of which can stem a wide range of educational focus areas. These are as follows:

**Figure 13**: *Manipulating the Arduino code.*

| | |
|---|---|
| **Hardware** | Laser cut structural supports, mechanical fasteners and a linear gear system. Giving insight to manufacturing processes, common assembly techniques, mechanical systems and material selection considerations. |
| **Electronics** | Printed circuit boards (PCBs), switches, wires, motors, LED's, microcontrollers, batteries and sensors. Allowing discussion of circuits, electrical components, electro-mechanical devices, common electronic principles & laws, and safety precautions. |
| **Software** | Arduino integrated development environment (IDE), variables, line based code and embedded systems. Teaching concepts of loops, logical thinking, mathematics, logic operators, binary, and different computer languages. |

The coupling of the HP folding experience along with the robotic-like nature of the mini-nest system gives rise to discussion of many emerging technologies such as soft robotics, robotic end-effectors & manipulators, social robotics, ethical use of automation, and the sustainability of ongoing technological advancement. Figure 14 displays the 3D digital modelling for the design of the Hungry Birds mini-nests and Figure 15 illustrates the prototype realisation of the design in the Hungry Birds workshop.

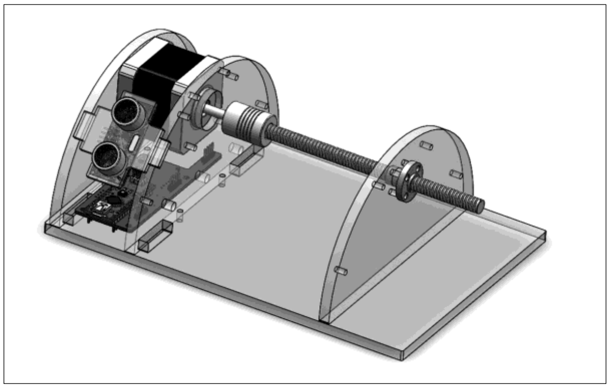

**Figure 14**: *Digital 3D model of mini-nest design.*

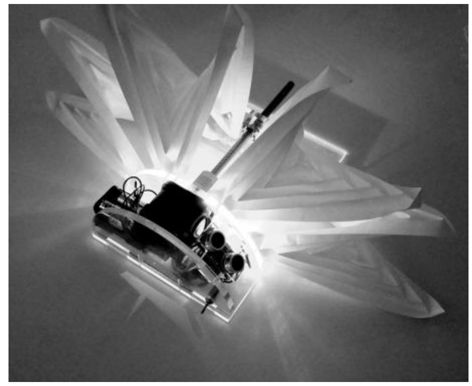

**Figure 15** *Realisation of mini-nest design.*

Melissa and Annette from STEAMpop [16] value the connection between the Arts and STEM and strive to provide unique hands-on STEAM experiences in education, community and corporate environments. The partnership with Corey Stewart from CJS Robotics [3] allows us to develop customised projects in the field of robotics, electronics and mechatronics. Figure 16 shows a completed Hungry Birds nest, replete with "motherbird" and functional hungry beaks that open and close on approach.

**Figure 16**: *Hungry Birds motherbird and mini-nests.*

## Sustainability / recommendations

By targeting key focus areas covered in many school curriculums, particularly in reference to coding and programming (Figure 13), participants of the Hungry Birds experience are able to further grow the knowledge and interest of STEAM related subjects such as Science, IPT, Industrial arts, Physics and Mathematics. Folding the HPs and constructing a mini nest or polyhedra provides enough degrees of difficulty for participants/learners to gain a satisfying sense of individual and collective agreement through manual and mechanical dexterity. Engaging in Hungry Birds affords the development of partnerships between local and global learning communities with the intention of developing exemplary STEAM practice. The transdisciplinary experience is a high quality contribution to current connected incentives in learning. It is thought provoking and informative.

## Conclusion

We consider transdisciplinary STEAM experiences to be "a form of learning on the "cerebral and cell layer", see Gulliksen [9] p. 10. Perhaps adding the A to STEM permits all of us to ask more "what if" questions and allow us to co-create in unfamiliar territory. What if we combined complex geometry with embodied interactive making activities? Gulliksen would term this a "rich experience" and rich experiences give us a vocabulary, drawn not only from a lingual context but also from multiple forms of representation, with a variety of functional concepts. Transition to STEAM shifts and expands our learning into rich inquiry-based and problem-based experiences, where we all learn how to represent and make ourselves through participation. This is how we might assist our young peers to prepare for future career settings, currently unknown. Previous participant comments express how Hungry Birds provides a fascinating and innovative way to engage with math. In our modesty, we say it is simply the encouragement of curiosity, experimentation, and willingness to take risks and further develop human creative capacities. In effect, just another chance to take on new challenges and explore possibilities.

**Figure 17**: *Hungry Birds participant holds the motherbird.*

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