PolyPlay Eco STEAM Early Age Experiments, Lifelong Consciousness: Bringing STEAM's Whimsy to Market

Rémi Leclerc

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Early age experiments, lifelong consciousness: bringing STEAM's whimsy to market

Rémi Leclerc
PolyPlay Lab, Hong Kong

Abstract

A university design research unit, the PolyPlay Lab, was commissioned by a Hong Kong (HK) educational science, arts, and crafts kit company to investigate practices of environmental education (EE) early primary school stakeholder, market, technology, and symbolic elements. Weaving design, play, and STEAM (Science, Technology, Engineering, Art, Maths) education principles, the project determined tactics to stimulate children's environmental consciousness. Findings informed the design of EE product-service systems (PSS). Deliverables were tested in school with 150 children (ages 6 to 7) and 11 teachers. This paper describes the research process and its findings, which suggest there is value in leveraging: 1) experimental research through design and play; and 2) art's playful (or play's artful) whimsicality as effective strategies to design innovative EE PSSs to foster inner-city children's environmental sensitivity.

Keywords: STEAM, Early age environmental education, Experiential learning, Pro-environmental consciousness, Toy design, Science kits, Product-service system, Social design, Research through design

1. Design now? Social product-service system (PSS) design

Garland's 1964 1st Things 1st Manifesto declared designers' skills would be called on "for worthwhile purposes" to produce "a new kind of meaning". Where are we now?

Over the years the design practice has shifted its focus from form-giving to industrial design, from production to a product, from product- to human-centeredness, and from user- to social- and sustainability-centeredness (Diehl and

Christiaans, 2015). This empowers designers to: 1) establish design strategies to define desirable, feasible, and viable long-term future human-centred value propositions; 2) to harmonize tensions latent in complex stakeholder groups, including users, manufacturers, marketers, NGOs, or government organizations, to facilitate co-creation experiences; while 3) articulating coherent communication, and visualize culturally transformative problem-solving processes and outcomes; that 4) address broader social concerns, including education, sustainability, and social service (Manzini and Vezzoli, 2002).

Koskinen and Hush (2016) distinguish three forms of social design, underlying its aim, strategic, and knowledge dynamics. *Utopian social design* is derived from convictions that give meaning to design outcomes (e.g. the ideals of sustainable politics). Highlighting projects' scale of ambitions, *molecular social design* addresses incremental changes rationalised by the specifics of focused issues (e.g. designing early primary classroom EE STEAM PSSs for a HK company). *Sociological social design*, informed by theory, gives "insight into the social structures that produce and maintain the situations they try to change" (e.g. referring to education theory to construct pro-environment educational product-service systems).

As they propose better futures, designers *shape* culture (Leclerc, 2017). What of toy designers? Should playthings fulfil worthwhile purposes? Can play's developmental agency promote civic issues? Can the different forms of play, including its whimsical and subversive nature, appropriately facilitate STEAM EE beyond its utilitarian agenda?

STEM

STEM (Science, Technology, Engineering, and Maths) is an interdisciplinary approach aimed at enhancing acquisition of scientific and technological skills, proposing that learning improves when subjects are taught together, as in the real-world subjects are not isolated. Its social agenda was progressive on the onset: introduced in 1992 by City College of New York's STEM Institute, its aim is to ensure "minority students achieve academic excellence" and pursue careers in these fields. The US National Science Foundation promoted STEM from 2003 on as the government saw the need to train a workforce capable of meeting '21st century development imperatives', which mainstream economists see driven by technological innovation. They predict the growth of jobs requiring STEM competences will boost global demand for workers possessing problem-solving, project development, and systems management skills.

STEAM

While the integrative intent of STEM's multidisciplinary approach is conducive to fostering scientific literacy, it fails to connect science to the broader realities of human existence. The approach may train labour to support mainstream economists' technological innovation drive, but this leaves the feeling that something is amiss. A more holistic understanding of STEM education has emerged in recent years, STEAM, which leverages the creative and critical medium of Art to enhance STEM education. STEAM's potential lies beyond problem-solving as a philosophical approach to mindful knowing. While the A celebrates STEM, STEM elucidates A. This 'mostrare/dimostrare' positive feedback loop invites students to engage in epistemological, aesthetic, ethical, political, and metaphysical perspectives, in an ontological approach to education.

Environmental STEAM Education

This vision of STEAM is neither quaint nor innocent. A growing concern for sustainability – the most important challenge in humanity's history – has raised demand for better informed awareness of 'Eco' issues. 2005-2014 was the United Nations' Decade on Education for Sustainable Development (ESD), during which schools around the world embedded EE as a fundamental curricular component.

Hacking et al. (2007) see children as environmental stakeholders who "are affected by environmental decision-making and have a right to be involved in it". Liefländer et al. (2013) assert "strengthening connectedness to nature is more sustainable before the age of 11." 7 to 11, known as the Concrete Operation stage, (Piaget, 1971) is when children start using logical thinking and inductive reasoning, both essential for integrating abstract constructs and scientific concepts such as sustainability.

Yet development of EE innovation faces multiple challenges. Kollmuss and Agyeman (2002) "see environmental knowledge, values, and attitudes; together with emotional involvement as making up a complex we call 'pro-environmental consciousness'. This complex in turn is embedded in broader personal values and shaped by personality traits and other internal as well as external factors." For Chawla (1998), there is no single experience that sensitizes people's awareness but a combination of factors. She defines environmental sensitivity as "a predisposition to take an interest in learning about the environment, feeling concern for it, and acting to conserve it, on the basis of formative experiences."

Significant factors include (in order of efficacy):

- Childhood experiences in nature
- Experiences of pro-environmental destruction
- Pro-environmental values held by the family
- Pro-environmental organizations
- Role models
- Education

Education is least effective in forging children's pro-environmental consciousness and sensitivity, while 'childhood experiences in nature' works best. To truly meet the world's EE challenges, curricula need to be holistic, integrating education about, in, and for the environment (Palmer, 1998). This points to common misperceptions regarding attitudes to EE pedagogy. How is EE currently deployed? The passive, unquestioning exam-focused pedagogy dominating most schools does not nurture acquisition of discrimination, or mindful creativity. Also, while students may appreciate the value of practical EE activities, they do not always connect with environmental problems. Most teachers express an eagerness to deploy engaging EE, but too often due to structural constraints, they cannot create an atmosphere of positive appraisal let alone take their students outdoors. This hampers development of the self-esteem needed to connect problem-solving skills with the ability to empathize with broader community issues such as sustainability.

2. Experientiality, design, play, and whimsy for STEAM EE PSSs

EE's efficacy is subject to first-hand experiences of nature. Most of the world's population now lives in large cities. How to foster inner-city children's pro-environmental sensitivity when they are disconnected from the reality of nature? Little reporting exists on projects exploring an integration of EE, STEAM and experiential learning that simulate experiences in nature. There lies an opportunity to research and design compelling learning aids that nurture inner-city children's pro-environmental consciousness.

STEAM's cross-disciplinary harmonization of natural and social knowledge connecting students to the real world echoes the integrative dynamics and principles of balance underlying ecology. An integration of experientiality, design, play, and humour principles – say, learning by whimsical doing – informed this project's design research processes and its outcomes.

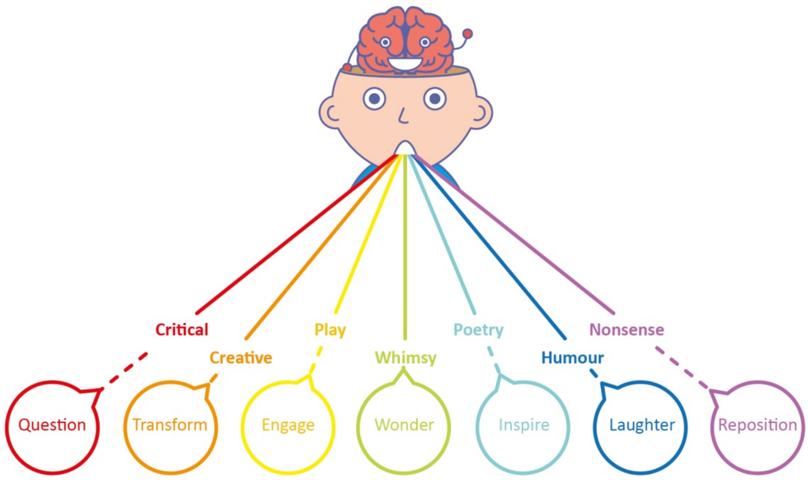


Figure 1. PolyPlay STEAM chart

Redefining STEAM's experientiality, Figure 1 converts STEAM values into action terms: Critical > Question; Creative > Transform; Play > Engage; Whimsy > Wonder; Poetry > Inspire; Humour > Laugh; Nonsense > Reposition.

Experiential learning, emphasizing awareness of one's relationship with phenomena, has in its different forms proved to produce better researchers, problem solvers, creators, and higher-order thinkers, mindful of the world and their peers. Kolb and Fry (1975) identified four parts to the experiential learning cycle: Experience, Reflect, Conceptualise, and Experiment. Schön (1983) situated reflexion 'in action' (whereby practitioners think as they do), and 'on action' (after the act). The approach encompasses:

- *Phenomenon-based*, where learners engage with the reality of our world;
- *Constructive*, where building, making, and manipulating provides hands on, tangible access to phenomena;
- *Action*, where small groups actively engage and experiment with real issues, supporting individual learning;
- *Problem-solving*, where a process of discovery and critical analysis leads to a solution;
- *Project-based*, where a process is articulated to offer a proposal in response to a brief;
- *Experiential*, where the doing only makes sense through reflecting.

Design harnesses experiential learning: research through design (Frayling, 1993) is constructive (Koskinen et al., 2011), taking designers through concrete experiences manipulating constructed objects; and reflective, whereas designers reflect *in* and *on* action, to generate knowledge and solutions. Design also naturally embraces STEAM principles. While designerly ways of knowing bridge the humanities to science (Archer, 1981, Cross, 1982), STEAM's holistic approach integrates A into STEM. Designers, like artists, appreciate in training and practice A's value in extolling S, T, E, or M. Artists' representation techniques familiarizes them with the science of materials and processes, while a concern with interpreting and re-presenting the world empowers them to give meaning to STEAM. Designers harmonize epistemological approaches borrowed from science and humanities. Consciously integrating play in their practice (Leclerc, 2017) enables them to conceive STEAM programmes nurturing children's mindful world awareness.

In modern mass-education, play has slowly emerged as a positive agent of physio-psychological and sociocultural transformation. Inspired by Rousseau and Schiller, Frœbel (1826) and Montessori (1912) advocated manipulative object play in children's education. One developed 'Gifts' for use in 'activities' in 'Kindergartens', the other 'Sensory Materials' in the 'Casa dei Bambini'. Both facilitate acquisition of fundamental abilities required to creatively perform in STEAM approaches. Artists, designers, architects Kandinsky, Gropius, Klee, Lloyd Wright, and Fuller acknowledged benefiting from Frœbel's approaches. Tom Tit's 300 Scientific Amusements (Good 1889), initially for children and family, contributed to the foundations of modern approaches to science education through its 'kitchen science'. Bruno Munari's Method (1977), based on Montessori's, advocated in *Giocare con l'Arte* (*Playing with Art* 1979)', "non dire cosa fare ma come" ('not to say what to do, but how') and "observing, making, and reflecting on the making". Arvind Gupta's Toys from Trash, upcycling found objects, whimsically demonstrate STEAM principles. His compelling online resource is referred to in schools worldwide to disseminate STEAM concepts and environmental citizenship.

"Professionals in many scientific, mathematical, and engineering fields articulate the need for creative and innovative thinkers in their professions and advocate for the use of playful learning methods to assist students in developing the intellectual abilities required for excellence in these fields" (Bergen, 2009). Play promotes experiential, naturally self-motivated exploration, discovery, creativity, and invention, and sustains children's engagement with different environmental concepts, helping them connect to these and appreciate cause and effect in sustainability (Persson, 2010, Honey and Kanter, 2013). Cutter McKenzie (2013) suggests "purposefully framed play, (…) a way of thinking about play in which open-ended play, modelled play, and teacher-child interactions about content knowledge associated with environmental education (…) connects with the importance of experience, content knowledge, and values in terms of environmental education, while also valuing the role of play and experience in teaching and learning from an early childhood perspective."

Art and science kits demonstrate the whimsy of natural phenomena – the tangible dream stuff all toys are made of. Recognizing A's underlying playful whimsicality, we define whimsy as a fantasy play of poetry, humour, and nonsense, and in a pataphysical sense, expressing its full value when it is acted in the moment, bringing the 'general' of science to the 'particular' of individuals. Humour is a natural part of children's development (McGhee, 1979) and promotes recall and retention of material (Vance, 1987). By the age of 7, children have integrated skills to appreciate humour. The non-threatening framework of play entails fun and laughter. Laughter, while understood as a response to humour, may also be a physical reaction to the build-up of anxiety, releasing tension, easing student's bewilderment in their acquisition of complex knowledge.

3. PolyPlay Eco STEAM collaborative university-industry design project framework

Project framework and stakeholder map

For Baudelaire (1853), toys initiate children to art. And so to science. The best way to design an art or science kit is to play with their principles. Steps involved in designing art or science kits naturally foreshadow those players will follow. As one manipulates tools, materials, and components, one appreciates play as the 'highest form of research'.

With a view to integrate play and research through design, PolyPlay adapted the UK Design Council's Double Diamond to articulate a 5-stage Delineate > Discover > Define > Design > Deliver project framework. Facilitating the company's apprehension of design processes, the framework offered a comprehensive yet simple overview of the project for the small team to design, produce, test, refine, and communicate 3 curricula and 12 PSSs within 6 months. Its sequence consciously referred to experiential learning principles: Delineate (collaborative groundwork, scope wish lists and themes, plan, scaffold, return brief) > Discover (read, explore, observe, empathize, interpret) > Define (abstract, conceptualize, synthesize, map, specify) > Design (iterate, act, experiment, test, integrate) > Deliver (harmonize, communicate, share, implement, apply, value). Each stage concluded with a presentation to the company to define iterative scopes and align objectives.

Stakeholders were mapped (Figure 2) to contextualize EE curricula co-creation dynamics. This includes student end-users, probed for abilities and preferences and design experience for; teachers, who process teaching and uphold curricula standards; experts, guiding content selection; parents, motivating students; company managers, framing market requirements; and designers, harmonizing needs to consolidate appropriate EE PSSs.

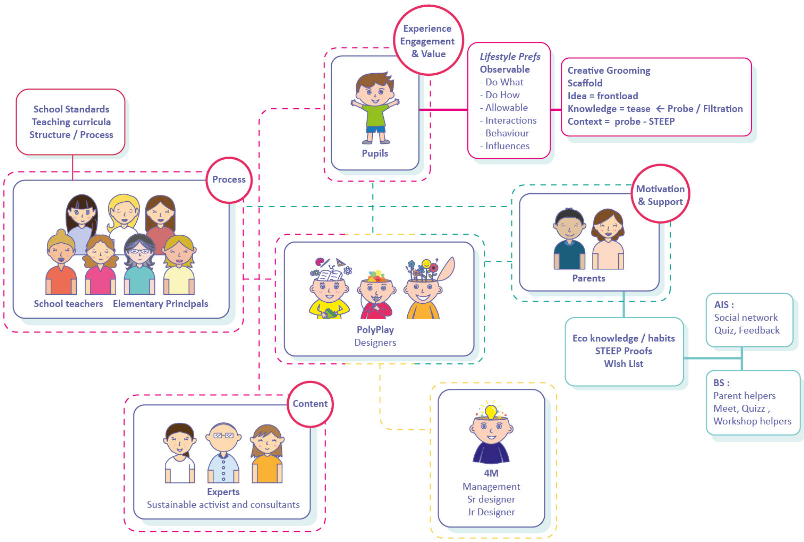


Figure 2. Project stakeholder map

Project research approaches

Return brief

Approach

- Dialog with company stakeholders through presentation of relevant past projects, and company and university visits

Objectives

- Ensure company's appreciation of experimental design processes
- Establish common design development language
- Articulate appropriate project research scope and stages
- Sign off project aims, objectives, and framework

Criteria

- Appropriateness of project scope

Environmental activists and STEAM educational expert interviews

Approach

- Semi-structured interview/work sessions with educators, EE experts, and NGO activists

Objectives

- Ascertain children's STEAM EE awareness, preferences, and play patterns
- Identify appropriate topics to design PSSs for

Criteria

- Appropriateness of EE topics and tactics to foster environmental consciousness

Findings

- Curriculum content, eco priorities, educational approaches

Children science literature and curriculum review

Approach

- Off/online desk research, and public/university library and book fair visits
- Children science and EE publications and (all age) satirical environmental cartoon review
- Benchmarking of primary school science curricula against experts' preferences

Objectives

- Identify cross-curricular teaching patterns
- Map educational topics
- Identify EE visual humour tactics
- Structure age-appropriate curricula
- Imbue STEAM EE PSS concepts with whimsy

Criteria

- Intended learning outcomes
- Relevance to environmental science and economic facts, issues, and sustainable lifestyles
- Humour themes, tactics, illustration techniques

Findings

- STEAM EE illustrated children literature covers all styles
- Little combine poetry, humour, and whimsy
- International Baccalaureate (EU): matches experts' preference. Science is linked to Issue & Lifestyle, and Cultural Representation. 'Sharing the planet' (resources), 'How the world works', and 'How we organize ourselves'.
- Next Generation Science Standards (US) somewhat matches experts' preference: Focus on Science & Issue. Although main learning outcome focus is Science, Earth & Human Activity dominates.
- General Support Programme (HK) does not match experts' preference: Focus on Science & Lifestyle. Issue is absent. Although all Science topics, most Socioeconomic facts, and all Livelihood aspects are covered, no Issue or Cultural Representation feature.

STEAM toy, quirky product, and artwork artefact benchmarking

Approach

- Critical review of educational arts and crafts and science kits, DIY 'kitchen science' experiments, toys, quirky objects, and artworks

Objectives

- Gain playful appreciation of technology and interaction
- Appreciate scientific principles from an artistic perspective
- Identify market opportunity gaps for design
- Define rich, hands-on EE PSSs imbued with whimsy

Criteria

- Humour: 4 levels of absurdity: 1) Experimentation; 2) Metaphor; 3) Whimsy; and 4) Nonsense
- Artistic: Relevance of eco issue, Metaphorical tactics, Communication effectiveness, Interaction with fixture, and Feasibility
- Sensory interaction/perception: Sight, Hearing, Smell, Taste, Touch, and Mindfulness
- Design: representation, materials, play types

Findings

- Most DIY 'kitchen science kits' channel basic concepts through simple production processes, and creative and manipulative play. All generate magic and wonderment. Upcycling materials *is* EE. Rule-based, skill-required, group game and character/narrative play (sharing similar principles) enrich kits with social play.

- Toys' science facts are not contextualized to raise environmental awareness. Eco STEAM is a novelty and STEM dominates market. Technology does not necessarily enhance interaction. Activities are usually self-directed. Multi-player game play promotes discrimination and discussion of issues. Green designs are scarce. Aesthetic delight is not a priority.
- Artworks should not be 'easy': knowledge is a reward worth the challenge of mindful wonder. Metaphors break communication rules to mindfully engage audience in experience. Evocating natural elements' aesthetic and symbolic qualities connect the audience to issues.

Field visits

Approach

- On-site spatial assessment, interviews, artefact collection, photographic documentation

Objectives

- Ascertain current functions of relevant contexts:
- School: pedagogical usage and workshops
- Factory: production capabilities
- Book fair: promotional environments
- Store: company and competitor retail environments
- Museum: institutional/public account of topics' principles and applications

Criteria

- Relevance to innovative Eco STEAM EE PSS knowledge and pedagogy design

Findings

- International IB context is well prepared (equipment, pedagogy) to integrate innovative EE PSSs.
- Production supply chain offers plenty hardware solutions to integrate in designs, with print elements enabling flexible product adaptability, also allowing inclusion of found materials in learning aids.
- Book fairs rival with toy fairs in showcasing quality toys. Off-and-online

trans-media educational PSSs combine learning-by-playing narratives with quality interactive materials (digital, print, objects).

- Retail environments articulate multiple in-store functions (information, promotion, purchase, reading, recreation, education, making) to stimulate consumer experience and support business. Spaces integrate store, workshop, forum, playroom, library, auditorium, and restaurant.
- Science museum exhibits prioritize science and socioeconomic facts. Lack of socio-cultural contextualization abstracts knowledge and disconnects contents from reality. Young visitors prefer tangible over digital fixtures.

Research through design

Approach: constructive design

- Iterative curricula/learning aid/workshop design (ideate/make/test concept/prototype)
- Integration of sustainability, product affordability, art, and whimsy and humour in designs
- Outcome tests
- Elicitation of experiment feedback from stakeholders in interviews and surveys
- Value measurement

Objectives

- Produce engaging EE STEAM PSSs
- Link personal experiences (art) to universal truths (science)
- Verify value of design through research approaches for EE STEAM PSSs
- Structure trans-media narratives resonating with children's imagination
- Validate play, whimsy, and humour as effective EE tactics
- Promote the company's EE ambitions and respond to global green imperatives

Criteria

- Integration of formative environment experiences, experiential learning approaches, multiple play types, and whimsical interaction and narratives in the design of STEAM EE PSSs

Findings

- (Discussed in section 5)

Approach: Children context probes and culture mapping

- User-(as-player)-centred context probes engaging children in individual or group settings
- Creative take-home child/parent assignments
- Semi-structured interviews with teachers
- Verbal and visual poetic interpretation of environment

Objectives

- Ascertain children's environmental consciousness (awareness) and sensitivity (empathy)
- Situate EE STEAM EE PSS design opportunity
- Map domestic and broader social contexts, and lifestyle, play pattern, and EE

Criteria

- Awareness of environmental science and economic facts
- Levels of Energy, Air, Water environmental consciousness and sensitivity

Findings

(Discussed in section 4)

Approach: Children co-creative sessions

- Creative workshops integrating multiple imaginative, creative, language, narrative, role, social play forms
- Figurative and symbolic drawing, poetry, storytelling, characterization, and presentation

Objectives

- Tease out creative input from end-users
- Inspire creative processes and inform designs
- Verbal and visual poetic interpretation of natural elements

Criteria

- Innovation in pedagogy, communication play, and production

Findings

(Discussed in section 4)

4. Context probes, cultural maps, and creative sessions

The project team designed context and creative probes as playthings to elicit children's tacit and latent Eco STEAM awareness, abilities, and preferences to inform EE STEAM PSS design. Probe activities were tabled (Table 1) in a mini curriculum informed by the Topic Pyramid hierarchy (i.e. Facts > Awareness > Actions), and aligned in-class briefing, take home self-generating assignments, and classroom workshops.

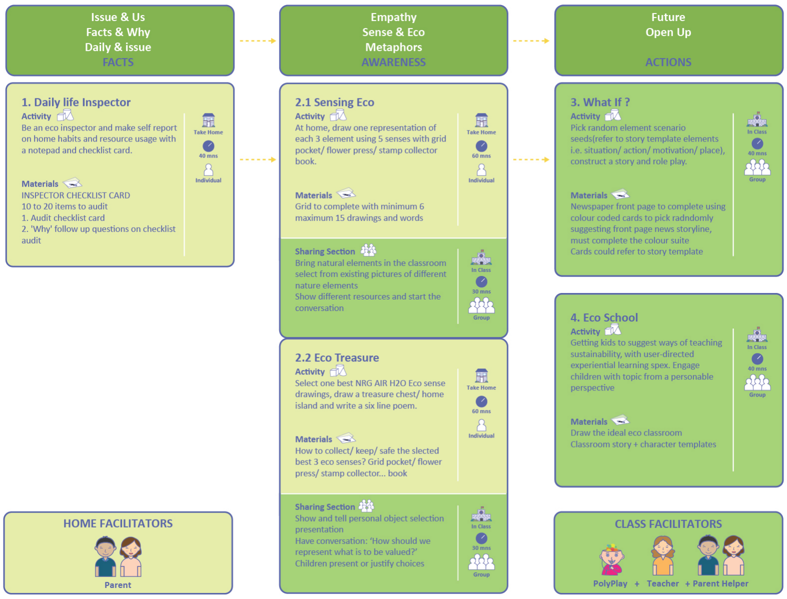


Table 1: PolyPlay EE STEAM context and creative probe activity table

Students were given take-home folders containing self-generating pen-and-paper probe materials to complete, inviting parents to learn of and contribute to the project. Students pondered on 'daily issues & us – facts & why' playing *Daily Life Inspector*. Donned with an Eco Inspector Badge (Figure 3) and Report File (Figure 4), they measured domestic resource consumption patterns. The badge elicits creative Eco STEAM character and toy design ideas such as nature codename, nature superpower, or nature toy.

Figure 3: Eco Inspector Badge

Once Reports were completed, students completed a Knowledge Quiz Card to ascertain Eco awareness.

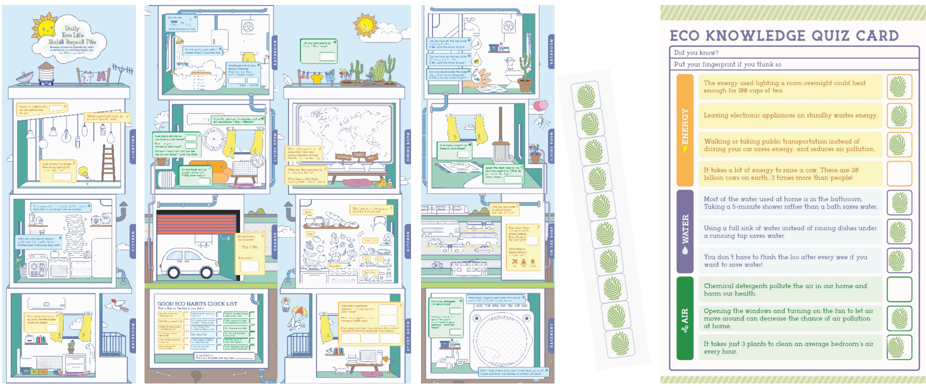


Figure 4: Eco Inspector Report File front and back, and Eco Knowledge Quiz Card with fingerprint stickers

To emotionally connect with the environment, students then completed the *Sensing Eco* card set, drawing visual metaphors for Energy, Air, and Water inspired by one of 6 senses and write an adjective qualifying their interpretation (Figure 5).

Figure 5: Sensing Eco cards. Students pick a blank card, select an element, a sense, and an adjective to create visual nature Metaphors.

Students then chose their favourite 'Metaphor' for each element as an *Eco Treasure* to insert in a space Rocket (Figure 6) as gifts to inhabitants of an extra-terrestrial planet with depleting resources, as a token of 'Empathy'. They arranged cards in order of preference and completed a poem template using the three Metaphors' qualifiers. Back in school, students placed their rocket on a space poster, sending their gift to the alien featured atop.

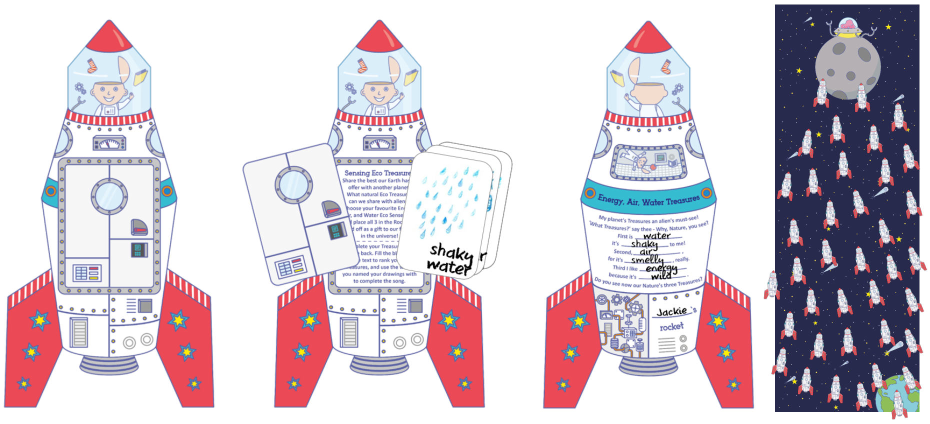


Figure 6: Eco Treasure Rocket. From left: front view with rocket door/pocket cover shut; front view with door/cover and Energy/Air/Water Metaphor cards; back view with completed poem; poster with class's rockets sent to alien planet.

In-class activities generated perspectives for future actions. Groups of students in *What if?* referred to a 'headline from the future' to create the "Daily So So"'s newspaper front page story. Context, Time, Characters, Hero, Twist, and Resolution story elements are allocated to each student, who spins a top dial (Figure 7) to obtain random story threads.

Figure 7: What if? Daily So So story element spinning dial top

The group discussed the story with a facilitator before segments were individually drawn. Segment scripts and pictures were added on the newspaper front page template (Figure 8). Then the Group Speaker read it to the class.

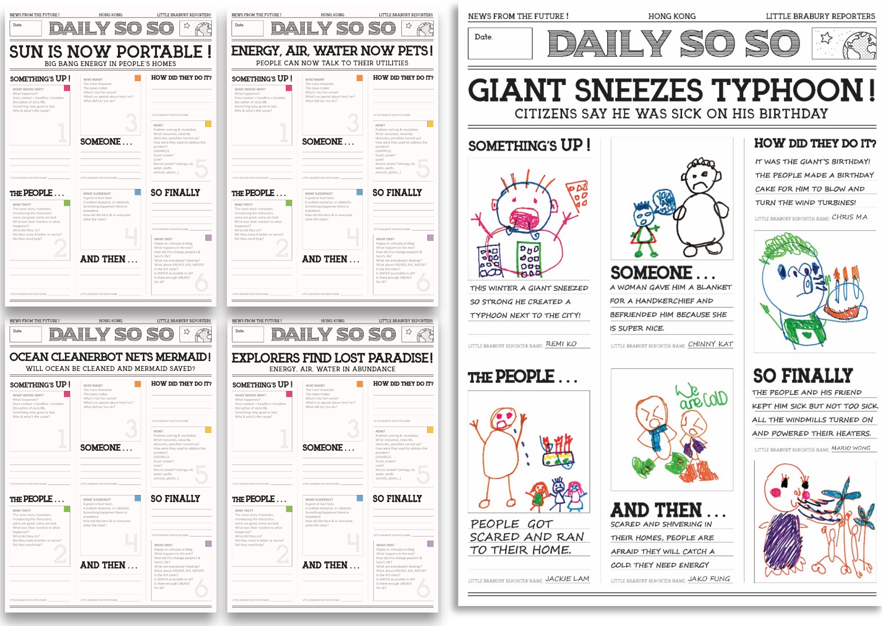


Figure 8: What if? Daily So So front page templates and completed.

The final activity teased out students' ideas for their dream *Eco School*. As they drew on an A3 format drafting sheet they were given (Figure 9), a facilitator noted down their oral descriptions to complement visual content analysis.

Figure 9: Eco School design drawing sheet and facilitator's note pad.

Figure 10: To reward their 'playbour', students were awarded an Eco Guardian Certificate.

Context probes, cultural maps, and creative sessions findings

150 children and 11 teachers at an international IB-track primary school participated in the probes. Both statistical and anecdotal relevance of answers were considered for interpretative content analysis to inform design.

Eco Inspector Card

Students *identified* as plants, elements, or animals + colour + powers. *Secret base* is mostly home in hidden corners. *Animals to talk to* are familiar pets (dogs and cats). *Nature superpower* nurture nature. *Best nature toy* is inspired by plants, element, character features. *Nature play* is active, wonderful, magic, active, and *Best outdoor activity* is sports. *Family biggest nature lover* is themselves, then parents.

Eco Inspector File

At 7, most children have a good conceptual knowledge of sustainability: running taps waste water, transportation and chemicals pollutes water and energy; outdoor pollution gets indoor, and remedial solutions like plants cleaning air exist. Connecting personally to issues and developing practice will happen as students grow. Energy and Air are challenging EE science data to visualize; Water, tangible, is easier.

Eco Sense

Energy is the element most represented by participants for visual interpretations, with strongest emotions. *Air*, most abstract element to represent, is poetically represented through emotions, not objects. *Water*, most tangible and favourite element, is represented through widest range of sensory experiences.

What if?

Students felt empowered by the opportunity to express themselves and contribute individual story segments to a group project on equal terms. Narratives were familiar: monsters and fairies, caring and daring heroes, twists were ominous, and ending were happy returns to normalcy, underlying conservation.

Eco School

Content analysis revealed children see this 'Best school of all', where fantasies of nature come true, allows engagement in play with friends, family, animals, much of it active, but also experiential; nurturing nature, and being nurtured. A world of amazement, where children are free and safe to express themselves, find solace, and grow on their own terms.

5. PolyPlay Eco STEAM EE PSS project outcomes

The project delivered:

1. A design through research STEAM EE framework, taxonomies, assessment models, curricula, and workshop scripts.

2. 12 indoor 'propshops' organised along 3 Energy, Air, and Water curricula (say 4 per topic), deploying 50 different learning aids including toys and games, downloadable booklets, worksheets, cards, and stickers, and onscreen presentations and scripts

3. Workshop facilitator booklets including:

- Topics, aims, and learning outcomes
- Rundown and activity outline
- Participant group size, workshop duration, and venue specifications
- Onscreen briefing and discussion slides
- Scripts and discussion points

- Learning aid description and operation instructions

4. Project design research and development process report with objective and interpretive database on children's knowledge of, attitude to, and representation of environment issues

5. A framework supporting the formation of new brand communication strategies for a leading science kits company

Eco STEAM EE framework

Childhood experiences in nature best nurture pro-environmental consciousness, but few enjoy these in cities like HK. The Eco STEAM EE PSS framework combines formative experiences with simulations of experiences in nature to engage inner-city children and foster pro-environmental consciousness:

- Ensuring early age child-appropriate, learner-centred experiences combining open-ended and modelled play patterns facilitated by teachers
- Harmonizing multiple play types, such as gross motor, manipulative, constructive, imaginative, creative, narrative, role, social, and cognitive play
- Enhancing play with whimsy and humour as engaging strategy to palliate for remoteness from nature, entice interest, sustain attention, and promote retention
- Bringing role models such as friends, teachers, and parents in the play to connect learning experiences with the broader social picture
- Promoting pro-environmental values held by the family by referring workshop contents to home habits
- Simulating experiences of environmental destruction, such as waste, floods, and pollution, to dramatize real-life consequences of environmental neglect.

Eco STEAM EE Topic Pyramids

Desktop research and expert interviews were synthesized into a pyramid of topics (Figure 11) to identify suitable issues for each topic curriculum. Three ascending levels structure educational narrative flow and advocacy for pro-environment consciousness, highlighting Premise for, Purpose in, and Process of discovery.

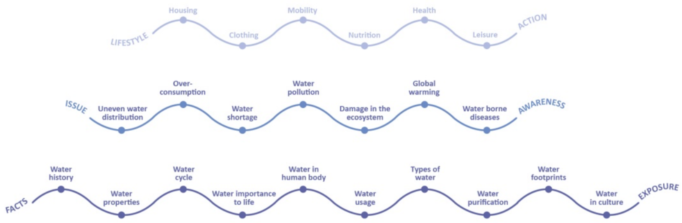


Figure 11: Water topic Pyramid

At each level topics are prioritized left to right. Level 1: Exposure to 10 Facts, introduces science facts and resource economics; Level 2: Awareness of 7 Issues, concerns consequences of resource exploitation; Level 3: Six Actions to change Lifestyles connects water issues to daily lives to promote sustainability. Its thematic framework is informed by Sun Yat Sen's and Chiang Kai Shek's modern China's principles of livelihood: Clothing, Food, Dwelling, Travel, Leisure, and Health. The hierarchy helped organize the workshops' thematic sequence into four steps (Science Facts, Economics Facts, Issues, Lifestyle), from exposing bigger picture issues (macro, global, community, social) to promoting sustainable lifestyles at home (micro, local, domestic, personal).

Eco STEAM EE Wheel

The pyramids were incorporated into an EE Wheel (Figure 12) to illustrate its experiential and ecological circular values, and structure PolyPlay Eco STEAM PSSs.

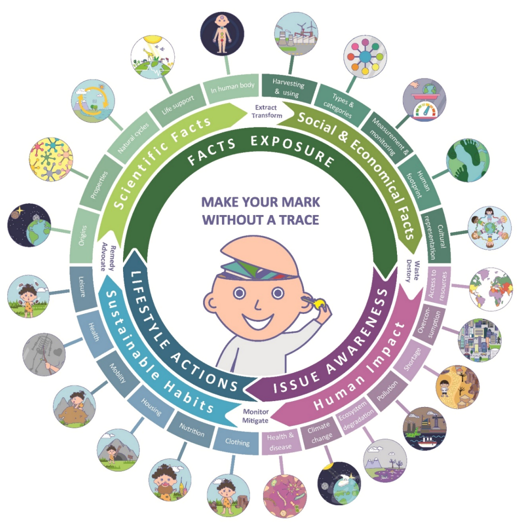


Figure 12: PolyPlay STEAM EE Wheel

The cyclical narrative strategy intended to foster children's pro-environment consciousness, adopt future sustainable lifestyle choices, develop environmental citizenship, and empower them to advocate conservation. It takes learners from Exposure to Scientific Facts (to) Extract & Transform (giving rise to) Social & Economical Facts (which leads to) Waste & Destroy (which needs) Issue awareness (of) Human impact (to) Monitor & Mitigate (and take) Actions to change lifestyle (and foster) Sustainable habits (to) Remedy & Advocate (to conserve the reality of) Scientific Facts.

PolyPlay Eco STEAM EE curriculum

The Wheel helped define a taxonomy of relevant topics (Figure 13) identified in interviews and literature review and inform PolyPlay Eco STEAM's curriculum (Figure 14).

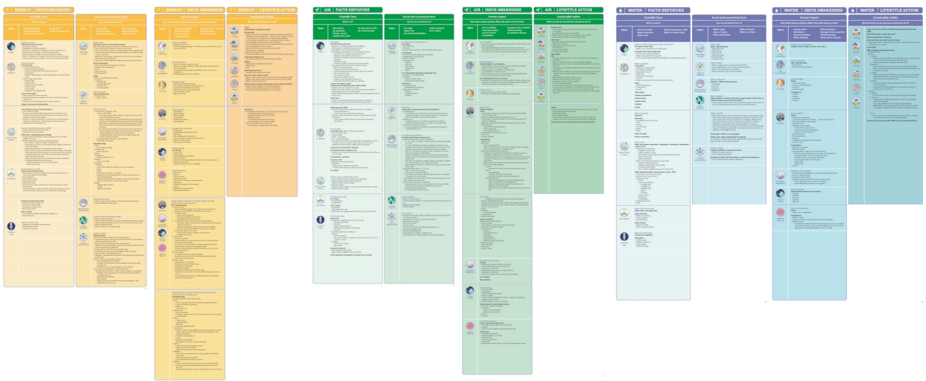


Figure 13: Energy, Air, and Water topic taxonomy

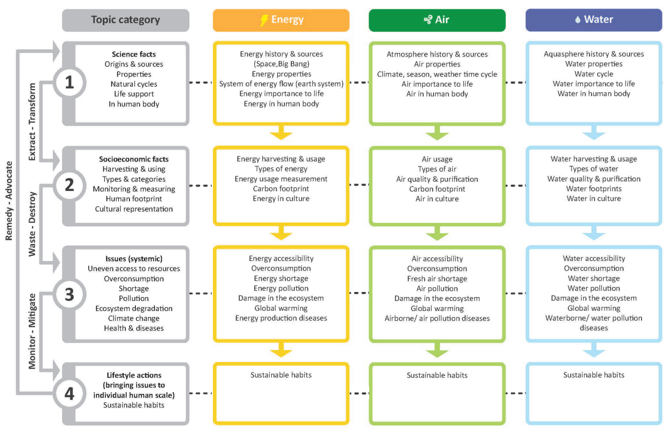


Figure 14: PolyPlay EE STEAM topic curriculum map

The curriculum determined topic theme choice (Figure 15) for the design of learning aids.

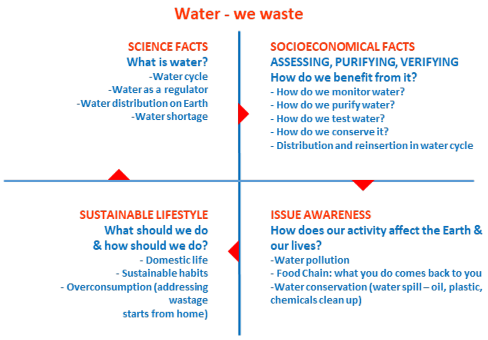


Figure 15: PolyPlay Water EE STEAM learning aid design theme Wheel.

Eco STEAM EE value assessment chart

An 8-criteria PSS concept measuring chart (Figure 16) was created to ascertain the pedagogical value of each PSS and pertinence of concepts to select for development. These were paired along 4 axes at opposite ends to signal complementary value.

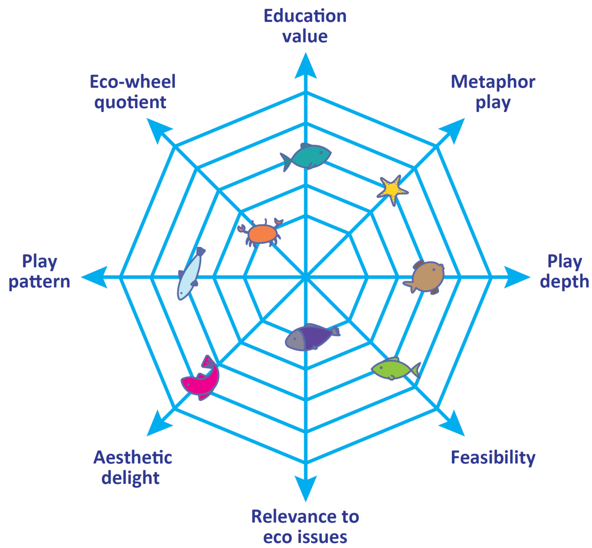
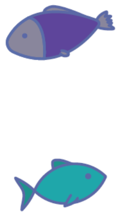


Figure 16: PSS concept measuring chart

Pedagogical axis (concept)



Relevance to eco issues (Content)

Strength of relationship between activities and environmental issues, and effectiveness in simulating experiences in nature.

Education value (Learning)

Effectiveness of the product-service system in facilitating teaching and attainment of expected learning outcomes.

Semantic axis (representation)

Metaphor play (Whimsy)

Potency of symbolic relationship between content and activities, and appropriateness of whimsy, humour, poetry, and nonsense in supporting education.

Aesthetic delight (Sensory enjoyment)

Ability of system to generate positive emotions, enthuse participants, and promote learning.

Play axis (interaction)

Play pattern (How to play)

Richness of interaction eliciting sensory engagement (sight, touch, hearing, smell, taste) and adequacy of affordances.

Play depth (Sustained appeal)

Value of system in stimulating interest, sustaining appeal, repeatability of play patterns, interpretive open-endedness motivating new learning experiences.

Production axis (object)

Feasibility (Fabrication)

Pertinence of design choices for development and Production, in terms of complexity, cost, safety, implementation.

Eco-wheel quotient (Environmental friendliness) Sustainability of system in terms of materials, making, usage, durability, lifecycle, and post-usage.

Figure 16: PolyPlay STEAM EE PSS value assessment radial chart

Workshop Rundown

Facilitator-to-participant group ratio is 1 to 5-6 children. Each workshop starts with ground knowledge discussed and special vocabulary frontloaded ("What, Why?") to scaffold teaching and learning. Students are then briefed on rundown before engaging in activities under facilitators' supervision. Flow follows Transmission (briefing), Process (experimentation play), Discovery (through instrument manipulation), and Interaction (quiz to verify learning and discussion to enforce reflective experience) (Fleer 2007). Trial and error in some activities empowers participants to figure answers alone and construct knowledge on their own terms.

6. Discussion: marketing STEAM's whimsy: measuring and validating design through research

Design validation is qualitative. The challenge of measuring this project's value lies in whether whimsy and play enhances EE; and research through design is an effective approach for EE PSS innovation fostering environmental sensitivity. Factors to ascertain include learning, emotion, and experience. Whether the PSS effectively fosters pro-environment citizenship remains to be seen – children are years away from adulthood. Meanwhile, the project's hypothesis was validated in that the emotional connection children made with the issues through play's engaging framework stimulates motivation for, sustains interest in, and enhances EE experiences. They enjoyed play processes, sustained attention thanks to laughter, and acquired knowledge, and teachers found the experience conducive to learning. This was verified in immersive protocol observation of students in workshops, semi-structured teacher debriefing interviews, client presentation feedback, and expert presentation feedback (EE curriculum expert, environmental activist, design research professor). More formal protocols involved post-workshop online teacher questionnaires and student quizzes (Figure 17) a week after the workshops to allow assimilation of knowledge and ascertain learning experience.

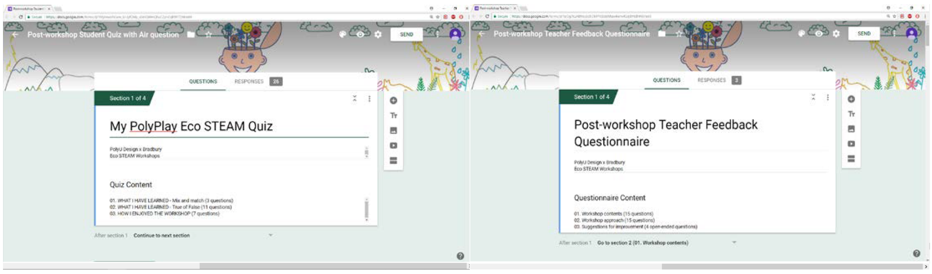


Figure 17: Post-workshop online student quiz and teacher questionnaire landing pages

Students

The Quiz combined multiple answers and true or false questions on learning, and yes or no questions on experience. An average 75%+ of students gave correct answers, dropping to 50% when knowledge was more abstract, counterintuitive, or used higher-level vocabulary, confirming the EE PSS's overall effectiveness. Feedback on workshop revealed they enjoyed the experience, endorsing deployment of play and poetry in EE. Humour, age-appropriate vocabulary, and pertinent examples emerged as sensitive areas needing contextualization EE PSS tactics to foster sustainable habits.

Teachers

Teachers provided feedback on content and approaches. Empowered as teaching experts, they were more aware of needs and progress than students. They embraced play and laughter to complement formal teaching while mindful of time length, information overload and materials' durability.

Overall, teachers were very positive about the project, finding the workshops great by making science education more meaningful, enforcing understanding of conservation. The workshops sparked children's interest for and learning science, and the format (opening discussion, experimentation, integration, wrap up discussion) and activities were well thought out. They observed that students wanted to explore environmental science and adopt sustainable habits, as they understood the impact of people's daily habits, and play helped connect to habits. Beginning each session with the 'why' gave children a purpose and context for each activity, and they thought the props were beautiful and offered a great visual way to teach, giving the children a nice experience to learn through play-based activities and allowing them to 'see' the abstract. Teachers found they could step in very easily and that play, including group play, was a good and better way to learn and enjoy science classes. The whimsy, laughter, poetry and creativity reinforced traditional scaffold and enhanced learning, as children needed time to make connections, find things for themselves without as much adult intervention, especially initially. The teachers had fun using characters and activities to teach, as humour enriched environmental education, and they welcomed more hands-on exploration play with aids, and more meaningful discussions and reflection time, as well as to allow for making mistakes and trial for first-time playing, such as holding one topic workshop at a time to 60 minutes optimum duration to allow 'inquiry' to happen.

7. Conclusion

Bridging a university design research laboratory with school, community, and industry, the project demonstrated the value of 1) research through design in the conception of EE STEAM product-service systems AND in generating research tools and artefacts valuable on their own merit; 2) deploying play to entice children's interest in STEAM concepts; 3) STEAM as a medium to foster early pro-environmental consciousness; and 4) leveraging play's whimsy, poetry, humour, and nonsense to enhance the 'A' in Eco STEAM.

Beyond generating knowledge to inform the project, research through design entails the construction of processes and materials of value in themselves. The project's Cultural Context & Creative Probes intended for users to create research data on their own, were recognized on hindsight for their intrinsic value as learning aids applicable to other EE contexts.

The project contributed to a leading educational arts, crafts, and science educational toy company's strategic brand value proposition development, integrating: 1) experimental design processes in its practice; 2) upcycled components in its environmental STEAM PSS production; and 3) trans-media workshops in its community outreach strategy, internally, in retail and education concept spaces, and externally, in community educational venues.

Knowledge engendered provided the company with a strategic design framework for development of innovative educational PSSs. The experiment furthers the regional toy industry's progression from Original Equipment/Design Manufacturing) OEM/ODM production-based development paradigms to value-focused Own Brand and Strategic Management (OBM/OSM) ones.

Acknowledgments

The author wishes to thank the following persons and organizations for their role in the project:

Project Team: Catherine Fung Shuk Ting, Design Project Manager; Jacqueline Ko, Design Assistant; Kammy Lam Pui Chu, Chinny Wong Chin Chin, Interns; and The Hong Kong Polytechnic University BA (Product Design) Student Helpers.

Consultants: Catherine Touzard, EE Expert; Christian Masset, Environmental Activist; and Ilpo Koskinen, Professor.

Education stakeholders: Bradbury School Year 3 Students and Teachers, Hong Kong.

Supporting organization: The Hong Kong Polytechnic University School of Design Institute for Enterprise.

Commissioner: 4M Industrial Development Ltd.

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