Realistic Drawing & Painting with AI-Supported Geometrical and Computational Method (𝔉un-𝔍oy)

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1 Introduction

Research studies have shown that drawing is a key to help students' engagement in STEM disciplines, because many concepts in science, technology, engineering and math are so often visual and spatial in nature. Drawing is a key activity, alongside modelling, role-play and digital simulation to focus collaborative reasoning and

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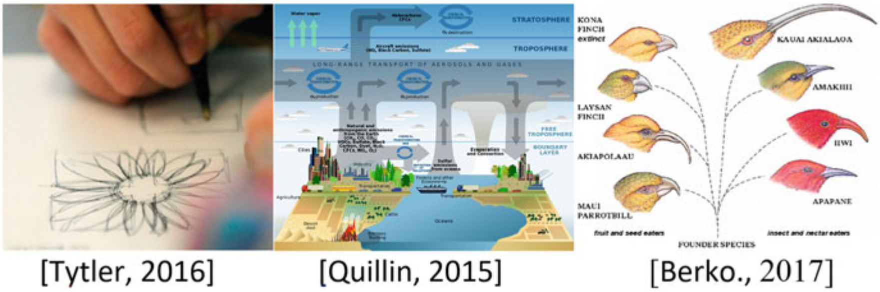

Fig. 1 Research studies show that drawing is a critical skill in STEAM learning

generation of meaning [1, 2]. A research study published in *Life Science Education Journal* [3] shows that:

- Drawing of visual representations is important for learners and scientists alike, such as the drawing of models to enable visual model-based reasoning.
- It is the core competency skill of *Vision and Change* report's modelling and simulation capability [4].
- The power of visual drawing has been used by scientists from the representational anatomical and engineering design works of Leonardo da Vinci to the theoretical phylogenetic work of Charles Darwin.

In the "Spatial Skills: A Neglected Dimension of Early STEAM Education," published at *Education Weeks*, February 2017 [5], the following points on STEM were made:

- Spatial skills predict success in STEM fields out to adulthood.
- The importance of spatial skills is often overlooked as a key feature of STEM education.
- Frequent neglect of spatial development creates an additional barrier to children's STEM learning (Fig. 1).

2 Insufficient Public-School Visual Art Education for STEM

In nationwide public K-12 education, visual art focused on drawing and painting has been significantly downplayed with an average of one 50-minute lesson every 2 weeks. A common misconception of the visual arts is that an individual needs to be gifted to master it – a perfect excuse to deprive visual art education for public

K-12 grade students. Recent studies show that drawing skill development for young learners has been intentionally and systematically neglected [5].

Theory of action 1 Certain key skills, such as drawing for STEM learning, have been purposefully overlooked and systematically neglected with a severe lack of education resources.

3 𝔉un-𝔍oy Visual Art Education for STEM

Built upon literature, prior practice, and research, our **𝔉un-𝔍oy** project applies computational thinking (CT), computing methods, technology and CT-enriched curriculum to promote desire and competency in the areas of visual arts development for K-12th grade learners. The National Research Council has documented the nature of young leaners' intrinsic desire to discover, explore and solve problems [6]. However, research on students using computational thinking with intriguing nature computing phenomena towards visual art, math and science learning, among the pre-kindergarten to 8th grade demographic, in a multi-year, formal and informal learning environment is relatively unexplored. As Wing pointed out, computational thinking benefits society in a much broader perspective, especially in early education [7]. A growing number of researches on integrating CT into early STEM learning has shown that new perspectives for studying and assessing the effectiveness of applying computational thinking in K-12 education is urgent [8–12].

𝔉un-𝔍oy project is built upon above solid research base [13, 14], increasing the probability that we will much better understand how to combine visual art, computational thinking and nature computing phenomena into an effective early STEM education practice, and increase STEM literacy.

4 Research Questions

- *RQ-1:* What pedagogical environments and learning strategies are needed for integrating computational thinking skills into drawing and painting learning from an early age (K-8th grade)?
- *RQ-2:* What are the learning progressions in computational thinking that can be identified from the early ages of kindergarten (5 years old) through middle school (6th–8th grades, 12–14-year-old)?
- *RQ-3:* How does computational thinking significantly improve drawing skill development, and how does drawing skill development greatly affect students' learning performance in STEM learning from the early grade pre-K to 12 grades?

- *RQ-4:* Under what conditions does the integration of computing into drawing and painting increase student interest, motivation, content acquisition and performance in STEM learning?

5 Design and Development Efforts

Theory of action 2 Certain vital habits and skills are best learned at a young age between kindergarten to 8th grade; past 8th grade, those skills take longer to learn, and teaching those skills becomes less effective.

Based upon the theory of action 1 and 2, we have conducted the first major design and development module and built our successful pilot project titled "Drawing & Painting with AI-supported Geometrical and Computational Methods ***Fun-Joy***." It heavily uses the four key components in computational thinking [7]:

1. *Decomposition* – breaking down a complex drawing object into smaller, more manageable parts
2. *Abstraction* – level by level, focusing on the important geometrical shapes only, ignoring irrelevant drawing details
3. *Pattern recognition* – looking for similarities among and within drawing objects, and apply patterns in drawing
4. *Algorithms* – developing a step-by-step solution/rules to follow to solve the drawing challenge

Computational thinking conquers a complex problem by breaking it down into a series of smaller, more manageable problems (*decomposition*); each of these smaller problems can then be looked at individually and compared to previously solved problems (*pattern recognition).* By focusing only on the important details, while ignoring irrelevant information (*abstraction*), eventually, simple steps or rules to solve each of the smaller problems can be designed (*algorithms*). The cornerstone of our theory of action is: the most effective teaching and learning happens when teacher deeply inspires students' curiosity, and motivates their desire with guidance to explore, depict, replicate and interact with the amazing external world using the leaner's own hands. New education approaches should capture this human nature of learning and correct the flaws inherited from traditional public education practices [15–17] (Fig. 2).

Our major research methods include:

- Integrating computational thinking approaches into STEM disciplines, including visual arts education
- Applying modelling-centred inquiry and project-based learning into the study
- Applying the fascinating phenomena in nature computing, including biological and physical computing, to stimulate young learners' desire to learn and discover
- Applying the project-based online interactive cyber-learning communities, to promote students to spontaneously develop an in-depth understanding of com-

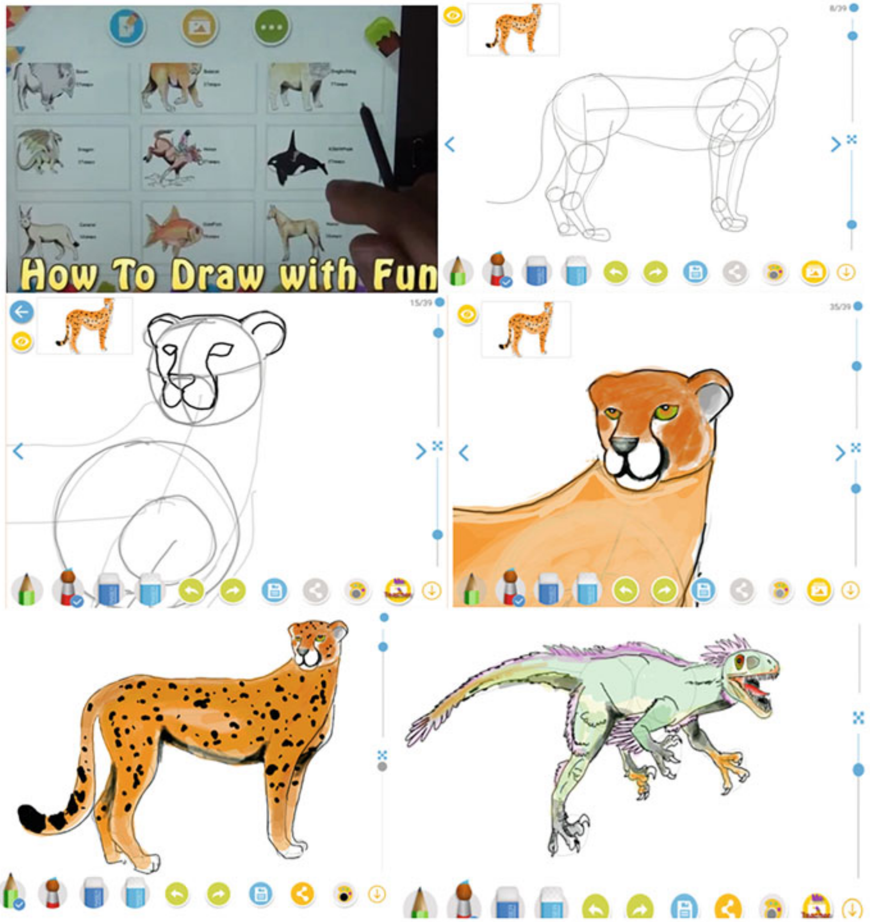

Fig. 2 Teaching software developed in our pilot project "Realistic Drawing & Painting with Geometrical and Computational Methods (**𝔉un-𝔍oy**)"

putational thinking as a way of creative approach towards learning in STEM fields

- Imposing professional development experiences at the centre of this project to include school teachers, social and learning scientists, out-of-school practitioners, informal educators, education media and technology developers, into the research work
- Applying a participatory approach that engages teachers as partners in research, expanding their computational vision that leads to the success for all students
- Producing data on how integration of visual art, biological and physical computing in nature with computational modelling, simulation in algebra, geometry and

science can improve students' deeper understanding and interests in STEM and computing fields
- Developing strategic curricular design, transformative teacher training, and close monitoring of student learning outcomes in formal classroom and informal out-of-school settings

Theory of action 3 At a young age, especially from K-8th grades, one is:

I. Curious about the world
II. Eager to sense every element the world has
III. Keen to mimic, depict and replicate with one's own hands
IV. Ardent to draw, paint, evolve, innovate and invent one's own counterparts of the nature and human world

Theory of action 4 Humans have instinctual interest in nature phenomenon and their causes.

Theory of action 5 Unexplained phenomena will stimulate innate inquisitiveness and trigger one's intense desire to discover and understand.

Fun-Joy's approach is based upon the theory of action 3, 4 and 5, together with computational modelling and simulation. We have conducted the major design and development which applies the visual art skill knowledge with fascinating nature phenomena caused by biological computing and physical computing, to improve students' deeper understanding, interests and mastery in targeted STEM fields. It has profoundly stimulated young learners' intrinsic desire and deeply promoted the mastery of exploring, discovery and innovation.

6 Preliminary Results

Our pilot project **Fun-Joy** heavily applies AI-aided computational thinking with geometrical methods in visual art skill development for learners who lack inborn artistic talents in the visual art domain. Since its debut on Google Play, the software designed for this project has been downloaded by more than 5 million learners, and has been translated into 65 languages; more than 110,000 learners have given written review comments on Google Play; the average score is 4.6 out of 5.0 scale, topping the highest in its category (Fig. 3).

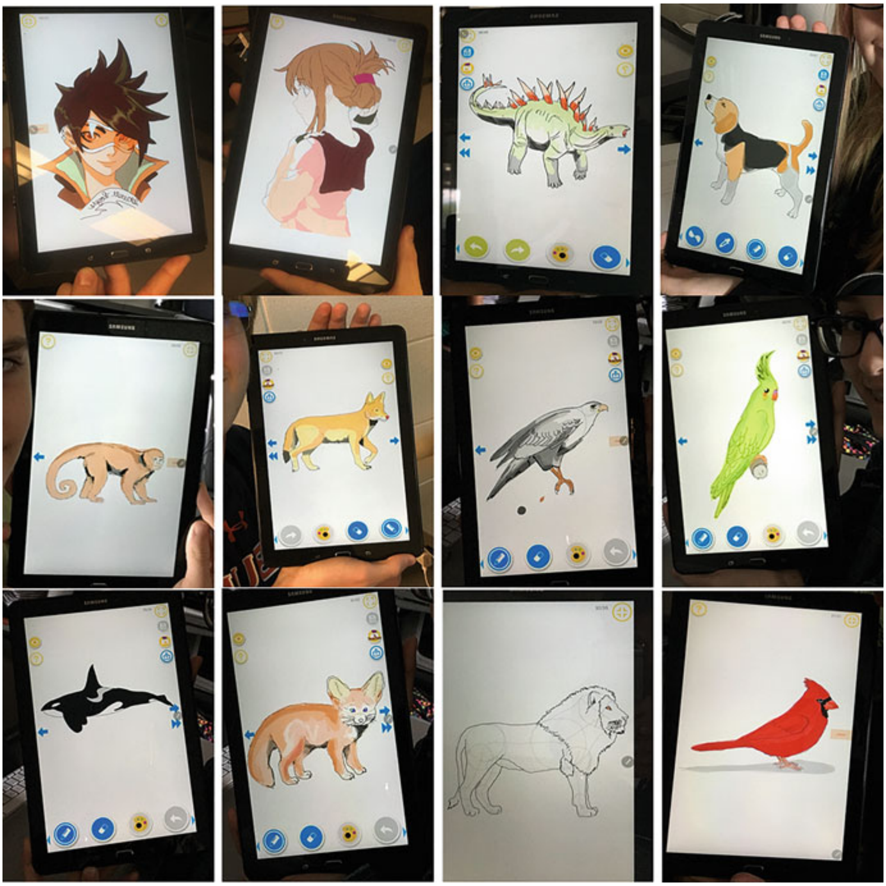

Fig. 3 Students' work after 1-week summer camp with **Fun-Joy**, the visual art skill knowledge teaching software in our pilot project "Realistic Drawing & Painting with Geometrical and Computational Methods"

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