# Kinaesthetic and Collaborative Activities to Enhance Experience and Engagement among Secondary Mathematics Students

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## 1. INTRODUCTION

The use of kinaesthetic modes of learning is unquestioned in primary education, yet these are largely underused in secondary education despite considerable evidence of their importance for conceptual understanding for mathematics. There are rich realms of geometry to be learned in three-dimensional Euclidean space, and various "non-Euclidean" spaces, such as the surface of a sphere. It is also an area rich in potential for physical exploration with our bodies, based on kinesthetic thinking, by which we mean thinking that is mediated by real or imagined bodily motion and manipulation of objects. A core problem is that as the abstract conceptual content of education increases, the intellectual distance from physical activity increases, and it becomes a significant challenge to maintain the connections for learners.

Inspiration for our approach is drawn from the 2-dimensional "Turtle Geometry" microworld that was developed in the 1970s-80s as part of the Logo programming environment. A turtle is a physical or virtual device that has a definite position in the 2-D plane, and a heading, and it carries a "pen" to mark the trace of its movement. One of the great insights in the design of Turtle Geometry was the recognition of "body syntonic" learning (Papert, 1980): that young children learn through the use of their bodies, and therefore a computational learning environment could simultaneously allow children to use body syntonicity to negotiate with the learning environment and promote them towards thinking about and through systematic, symbolic (programmed) structures. The interface device of the turtle provides the basic body syntonic interaction, and there are systematic geometrical principles "embedded" in the microworld which children discover/encounter through play and exploration (Noss & Hoyles, 1996).

## 2. CONTENTIONS

Both kinaesthetic and collaborative activities have been shown to enhance learning experience. There is a common assumption that physical activity in learning is a necessity for primary-age students but that secondary students have progressed beyond this to "symbolic" stages of learning. We are conducting an exploratory research project to investigate the possibilities for using "physical computing" technology to support kinaesthetic learning in mathematics for late secondary (14+ year old) students. We created several collaborative learning activities using sharable interfaces, based on commonly-used programmable hardware/software (Arduino microcontrollers, robot platforms, "Processing" programming environment, etc).The mathematical topic has focused on 3-D geometry, which is little addressed at the secondary level. Our preliminary findings are that students are eager to use new tools to enhance their learning activities and see them as a way to supplement their traditional textbooks and classroom materials. Students shared the tangibles among themselves to work toward common goals. This increased dialogue and debate about the concepts in 2-D and 3-D geometry around which the activities were centered. Because they worked together, explorations could be performed in union, or when a particular student obtained a valuable insight, that could be shared with the group. These shared benefits were typical of the observed effects of using tangibles among our participants.

Our work suggests that these shared and embodied learning activities offer several advantages over textbooks or solely desktop computer-based activities. We believe that tangible/physical computing has significant benefits for education and are exploring four key questions in this area:

1. In what ways do co-located and collaborative activities foster sharing and exploration?

2. How does the use of tangibles lead to students having enhanced learning experiences?

3. What kind of benefits do shared tangibles offer benefits over single-user activities?

4. How can physical computing tools be made accessible (i.e., ease of use, cost) to teachers and learners?

We believe that one benefit of addressing these topics will be that clear frameworks can be identified which will help to better situate tangibles within learning environments.

## 3. RAPID PROTOTYPING OF LEARNING DEVICES

Our aim in this work was to investigate bodily interaction with mathematical ideas, and we chose "non-Euclidean" geometry as the subject area, specifically geometry on the surface of a sphere. We tried to problematise concepts that students would consider obvious and beyond question: are there "straight lines" and "angles" on the surface of a sphere? If so, what do these have to do with the familiar straight lines and angles of the 2-D plane? The idea was that such questions would create the stimulus for working with physical devices on the sphere and the plane. The common objective for all the activities was to explore shared, physical interactions with inexpensive or easy-to-make tangibles. We created several hardware and software devices to explore these topics and recruited four groups of secondary age students to use them in exploratory activities. We employed consumer products such as the Nintendo Wii, and created two bespoke tangible computing devices. The devices were all hand-held and sharable among the participants.

**DODO on the Sphere:** A straight line is formed when a Turtle is moving its left and right legs (or wheels) at the same rate. This applies to planar 2-D geometry and also to spherical geometry. We mounted a microcontroller to a pair of wheels to create a "Double ODOmeter" (DODO). The cumulative rotation of the wheels was mapped to a graphical display on-screen. Students moved the DODO around the surface of a 1-metre diameter sphere. The on-screen representation of the movement of the wheels allowed students to collaboratively identify the relationship of the rotation of the wheels and the nature of a "straight line" on the sphere.

**Virtual Angles:** To explore the concept of angle we devised a way to use an inexpensive webcam to draw angles on-screen, by fitting the webcam with an infrared filter, which limits vision to infrared light sources. Using readily available blob-detection software, infrared light sources could be identified and plotted. We mounted infrared LEDs to battery packs so that each student would have a hand-held emitter. Each emitter was used as the vertex of a "virtual angle" and lines between them and angle values were displayed on-screen. Each student was able to create and manipulate angles in collaboration with others. This required students to work together in the real-world to effect a desired outcome in the screen-based representation. In a related activity, students used this system to explore the angle properties of polygons, where the software automatically drew a polygon through as many light spots as the camera detected.

**Great Circles and Spherical Triangles**: The most complex activity was to explore lines and angles on a sphere. We used a Nintendo Wiimote and a transparent acrylic hemisphere with a diameter of 1 metre. The infrared camera in the Wiimote was used to track infrared LEDs held against the hemisphere surface by up to three participants. The positions of the points of light were plotted upon the surface of a virtual hemisphere on-screen, and lines plotted between them. By moving the light positions in relation to one another, students could: (1) experience the "straight" paths on the sphere (the great circles), and (2) identify the relationships among the angles of spherical triangles that were plotted on-screen. The surprising nature of the spherical triangle – that it may contain more than 180 degrees – was experienced physical and virtually by the participants' interactions with each other and with the representation.

## 4. REFERENCES

Noss, R., and Hoyles, C. (1996). *Windows on Mathematical Meanings*. Dordrecht: Kluwer Academic Publishers.

Papert, S. (1980). *Mindstorms: Children, computers and powerful ideas*. New York: Basic Books.