STEADYING A BALLOON'S FLIGHT

One of the first things I noticed on entering the Grade IV classroom at Poorna Learning Centre for a science activity session was the balloons on the students' desks. The students shared that they had just discussed things related to air with their class teacher. One of them demonstrated how he could get his balloon to make weird sounds by compressing its mouth while the air went out of it. All of us laughed with him.

Many of the students expressed fascination with what they had observed happening when they inflated a balloon and let it go without tying up its mouth. When I asked them to describe how these balloons moved, the children used words like "squiggle", "wiggle", and "flutter". When asked for ideas about what made these balloons move, a student suggested that the air rushing out of the mouth of the balloon pushed it forward.

A few children volunteered to demonstrate how the balloon moved. We observed the paths of 7-8 balloons in flight. I drew these on the blackboard one after the other, to help the students observe their paths more carefully (see **Fig. 1**). We noticed how the balloons seemed to go in unpredictable directions, changing speed and direction rather quickly and randomly. I wondered out loud, *"Can we make the balloon go in a straight line?"*

A student spontaneously inserted a pencil into the mouth of a balloon, blew air into it, and let it go, perhaps to see if the pencil would guide it to move in a straight line. As the rest of the students had also jumped out of their seats to try out their own ideas, I found myself in the usual position of a grown-up caught amidst spirited and creative children.

Within minutes, the students had spontaneously assembled into groups, each with about 3-4 children who generally hung out together. A few students filled sand in a balloon before blowing air into it. But on releasing this, it fell straight down to the ground. So they tried seeing how much sand they could scoop out for the balloon to still be able to fly up, but take a straighter path. Another group tried a similar experiment with tiny pebbles.

Yet another group of students filled a balloon partly with tap water, and then blew air into it. On letting it go, they observed that the balloon did not take its usual zigzag path. Instead, its mouth moved in a circle, squirting water like a garden sprinkler. Amidst squeals and peals of surprise and delight, the students started flinging it higher to make it stay in the air longer.

The student who had inserted the pencil into the balloon had been trying out other things with his group. I noticed that his group had now moved on to using adhesive tape to stick one end of a string to the surface of a balloon. They tied a pencil to the other end of the thread, but it still weighed down the balloon and it could not take flight. Then, they tried replacing the pencil with an eraser, which they had to progressively cut into smaller pieces. It was by trying out these variations that they were able to arrive at one that could steady the balloon's flight without causing it to sink to the ground.

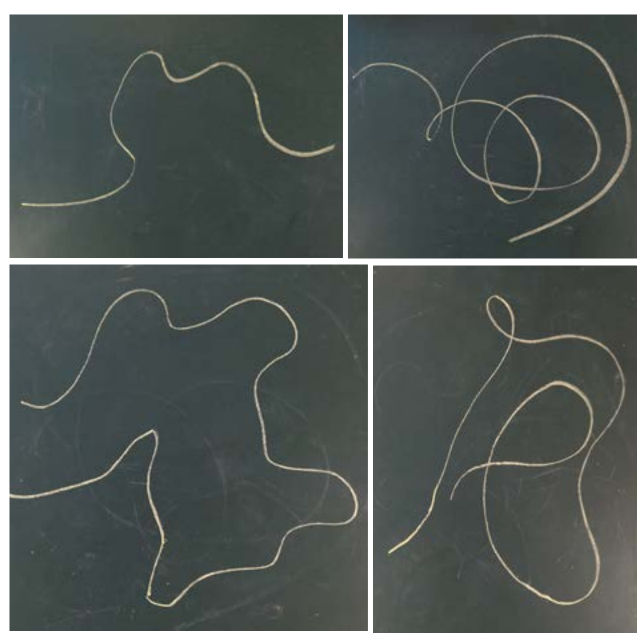

Fig. 1. Tracing balloon paths.

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I used my phone to take slow-motion videos of these attempts to steady the balloon's flight. When I replayed these videos towards the end of the class, the children shared some of their thoughts and observations (not all of them were science-related). I tried to collate these ideas on the blackboard, mostly in the children's own words.

My reflections

I found it interesting that the children designed their experiments using whatever materials they could find in their surroundings, and that they were familiar with. It was also quite apparent that the children had their own ideas about the factors that affect motion. It is likely that they arrived at these ideas from their earlier experiences with the movement of objects in the physical and natural world. Although these ideas and conceptions did sometimes appear in the class conversations, they were mostly implicit in the decisions and directions the children took in their explorations with the balloon's motion. Incidentally, these ideas happened to be just adequate for most of their iterative efforts to be moderately successful. In their attempts to steady the balloon's flight, it is possible that the students picked up and formed more such ideas and conceptions about motion.

One such student preconception about motion that was most evident during this exercise was the belief that the lighter an object is, the more easily it changes its path. If this were true, adding extra mass to the balloon in some form or the other would make it less susceptible to whatever was causing its path to change (such as random changes in the direction of air being released from its mouth, anisotropic air resistance due to irregularities in its shape, and stray air drafts in the room). This is what seems to have led to attempts to steady a balloon's flight by filling it with sand, water, and stones; or using thread to suspend a pencil or eraser pieces from the balloon. Interestingly, this idea is identical to the age-old idea of using a ballast or a weight to steady the motion of a ship. This idea is also related to an aspect of inertia that is embedded in Newton's Second Law, which states that for a given force (here, the reaction force on the balloon due to the air rushing out of its mouth), the acceleration of an object (which is the rate at which the magnitude and/or direction of the balloon's velocity changes) is inversely proportional to its mass (see **Box 1**). While children of this age may not have a conceptual grasp of the exact mathematical meaning of acceleration, the nature of their explorations suggest that they do seem to hold some related ideas about inertia and motion. These ideas need to be acknowledged and addressed with care while introducing Newton's laws in higher classes (see **Box 2**).

In the process of testing out their ideas, the students sometimes also stumbled upon and explored other

Box 1. The changing momentum of these rocket-like balloons:

The mass of these balloons decreases as they deflate, which is like the classic case of the motion of a rocket that is simultaneously using up fuel and losing mass. The form that Newton's Second Law takes for describing such a situation is slightly different from that given in most high school textbooks. In this more general form, we account for the fact that the momentum of an object can change both as a result of a change in its mass and/or its velocity.[1]

Box 2. Introducing Newton's Laws of Motion:

Extensive research in the field of science education has shown that Aristotelian notions of inertia of motion are held even by people who have formally studied Newton's laws of motion at both high school and undergraduate levels. These include, for example, the belief that 'a force is needed to keep an object in motion', or 'in order to make an object go at a higher speed, one needs to apply a stronger force'. Since these notions happen to emerge quite naturally from our everyday experiences with physical phenomena, they are quite difficult to correct.

Aristotle believed that all objects seek to go to their natural place. A stone falls because it is made of the earth element and so belongs to the earth. Similarly, a bubble is made of air, so it rises. Galileo questioned this notion, disproved it, and instead argued that inertia was the natural tendency of all material objects.[2] This is Newton's first law. Systematic and persistent efforts are needed to introduce students to the idea of inertia in the way Galileo corrected and replaced Aristotle's idea of 'natural motion'. These are also needed to help them see the effects of forces such as friction and air resistance along with the effects of other forces that are applied on an object.

Research has also shown that merely watching demonstrations or doing experiments does not guarantee that students develop an accurate understanding of such concepts that are often counterintuitive. Rather, a combination of experimental work, articulation of students' ideas, argumentation, and snippets from the history of science is needed. Also needed is more back-and-forth between all of these based on students' responses. Such processes may enable teachers to create the right pedagogical brew for meaningful sense-making.

Perhaps, posing this (and similar) challenges of steadying a balloon's flight could be an effective way to start a unit on 'Motion' for high school students. In addition to eliciting student ideas about motion, it could help teachers connect such concrete experiences to the somewhat abstract, cryptic, and finished form in which Newton's laws of motion appear in most textbooks.

unexpected phenomena. This included, for example, the balloon that spun around squirting water due to the pressurized air inside, or the fact that a ballast that is too heavy makes the balloon fall to the ground before the air coming out can set it into any noticeable horizontal motion. These explorations also provoked some conversations before, during, and after their experiments in which they shared and developed some thoughts and ideas about such phenomena.[3]

Another interesting thing to note is how the social aspects of learning emerged organically in these explorations. Some of these took the form of an immediate peer group to work with as well as to compare and learn from. Every time someone had an idea, they tried to explain it to the other children in their group while showing the object or accessory (like sticking tape) that they intended to use. The others would then express their opinions and suggestions. The way students took charge of their learning was something that made me glad as a teacher. Also, the way the students moved around for the entire 40-minute class while being intellectually active and engaged, pointed me to the pitfalls of treating teaching-learning as a solely cerebral activity that Rabindranath Tagore has cautioned against.[4] In retrospect, I find it exciting to see how such experiences seem to echo ideas of Constructionism by Seymour Papert, which suggest that the construction of knowledge is facilitated by tactile and tangible manipulation of material.[5]

Around the world, there have been innovations in teaching science that have supported the idea of involving students in working on an engineering design challenge such as the one discussed here. In India as well, there have been efforts to help children learn through makerspaces or tinkering labs (a space that has resources such as tools and materials to build and create objects and contraptions).[6] This experience with primary students at Poorna points to the potential of such exercises even within a classroom setting. They help create space for students to take ownership of their learning rather than simply being passive listeners. They also offer teachers the opportunity to listen to student ideas and document their work. This, in turn, can expand the range of approaches and examples that a teacher can use to connect students' 'feel for phenomena' to school science in a more immediate and embodied sense.

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