A Study of the Element "Water"

by

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translated by Ted Warren

In middle school physics, it is fruitful to bring well-known phenomena into more clear and conscious light. Such an everyday topic is water. Because we take water for granted and we assume we know so much about it, we rarely reflect upon the element's being and meaning. Every child enjoys splashing in it. No one outgrows the fun of water. But they may be surprised to discover the nature of this element.

We studied water in a three-week block, using our imagination, curiosity and flexible thinking. We practiced sculpting thoughts and concepts in order to follow the winding stream on which water led us.

The water cycle as the basis for life

This theme was taught in the fifth grade biology lessons, so we began our study with review: The warmth of sunlight draws water from the seas, oceans, moist earth and vegetation up to the atmosphere. There the water forms a layer of wet air around the earth, which condenses into rain, snow and hail that wander back to the earth, seas and oceans. We recalled that water movements in fresh water begin in the different levels in rivers, waterfalls and rapids, while movements in salt water begin with temperature differences, wind pressure, the rotation of the earth and tides.

We admired the miraculous balance between evaporation and the discharge of rivers into the oceans during this pulsating cycle. We looked for other ways in which water or any fluid moves through a cycle. Our attention fell upon the great ocean currents, and we made drawings of the Gulf Stream before focusing on the circulation of blood in our bodies. We agreed that the movement of fluids provides a unique foundation for life.

Thunderstorm rolling onto land from the ocean

We took a trip to the sea floor and the various underwater formations. On the edge of every ocean there are common formations: the continental depression—the egg that falls down, the enormous deep ocean with relatively few deep-sea cavities.

To follow the water cycle children need to think in a way that does not lock them into finite details, but rater enables them to flow with the descriptions of the development of related phenomena.

Water's tendency to the globular form

Our next step was to study a forming tendency of water; the one that is most readily apparent is the water drop. All solid bodies have the ability to maintain their structure outwardly. This structure can occur through accident (breakage), or it can be defined geometrically by internal forces that are expressed in crystallization. Solid bodies have countless shapes, but water demonstrates only one common form, namely the globe. All liquid materials have one common dimension; they can build only one surface form, namely the globular form.

Water droplets on a rose bush, Note the reversed reflective image within the drop.

In beautiful water drops that shine while falling, we see the globular tendency. Yet we also see the potential for water to collect in a round globe in the huge formations of the oceans of the world. Also solid materials do as water—they join in the globular form. All erosion and disintegration tend to create globes. The fact that materials pack together from every direction and build a globe appears as primeval phenomena in the shape of a water drop. These observations result in what we normally call gravitation. Phenomenally we find all of the parts of physical materials trying to collect in a common globular form.

When we look at hail, we find the globular tendency, which can be further seen in layers of globular rinds one on top of the other. It is easy to experience every lake, pond and puddle as parts of global surfaces which in their totality would cover the earth in concentric layers. This is convincingly demonstrated in communication pipes. Water seeks the same level in every pipe that means the global surface is parallel to the ocean surface. It does not matter how thick or thin the pipes may be. The amount of water in the differently shaped pipes will hold each other in balance because, as coherent amounts of water, they will tend to a common globular form.

At this point the pupils were asked to describe the relationship between floating liquids and the tendency to form globes. An eighth grader described our experiences in these words: "Water's tendency to form globes appears in drops, which you will see, if you pour water on a warm plate, or water on impregnated clothes, and so forth. If the water is not allowed to take its own globular form, it will collect parallel to the surface of the earth, which is itself an enormous globe.

A water level is also a globe, or more correctly defined as a part of a globe. If you build a house anywhere on the surface of the earth, the level will follow the surface of the earth. Gravity causes this effect. It collects everything into a middle point. But fluids have the ability to pull back into themselves. Because of gravity they can form globes, within and of themselves.

Conclusion: globular tendency = gravity.

We can say that solid bodies are individualized in their ability to pull together—they individualize gravity—while liquids collect in a unified gravitational form. In other words, liquids, when they are as small as a drop, can break free from the power of gravity and create their own world. This moved our study on to surface tensions, but before we worked with that phenomenon we observed how water moves and forms itself in rivers, rapids, waterfalls and waves.

Meandering stream

Water tends to move in zigzags and whirlpools. We all know that rivers form zigzags on their way to the sea. We see it most clearly when rivers slow down in flatlands. The winding zigzags can be so strong that they form small lakes adjacent to the river. As the river water flows through the zigzags, it makes spiral movements in both the outer banks and the inner banks of the river.

We easily demonstrated the spiral movement of the water by pouring a flat, broad stream of water from a milk carton. A beautiful spiral forms. Water wants to wind around itself. We have seen this many times before and the pupils enjoy this familiar phenomenon in a new, existential context.

We used a simple apparatus to demonstrate the water spiral in a glass container with a hole in the bottom where a rubber tube is attached so that the speed of water emission is controlled. When the water is released it forms the same spiral as we see in the bathtub. Only now we can view the spiral from the side. The tip of the spiral "hangs" at the spout, while the whirlpool forms an upward funnel while swinging from side to side. If the water flow is stopped, the tip of the spiral is lifted up from the vessel; when the water is released again, the spiral tip sinks down to the hole. The whole process reminds us of a miniature tornado. It is a fascinating and beautiful play!

We reflected upon the fact that water never moves in a straight line, but in a spiral form. Once again our thoughts have softened up and allow us to feel with our senses. If it is allowed to play on its own terms, water cannot be held to straight lines and formations. This enlivens our observation and thinking.

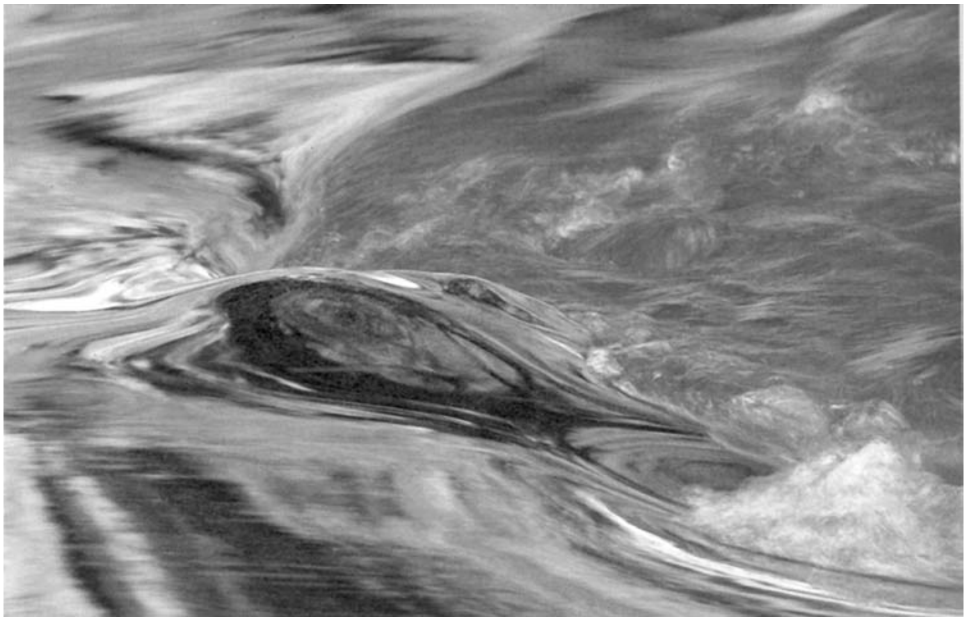
Form springs from movement

The next day we try to remember, as well as possible, any waterfalls we have seen. Water streams off the rock formations and with a majestic expression thunders down towards cliffs and stones. The spray rises and white, splashing formations fill the landscape in foaming water at the bottom of the falls. What is going on?

We observe a fairly constant form in the waterfall and in the water below. What is taking place? The movement of the water creates a constant form while the materials stream more or less unnoticed through the form. It is a majestic performance of a law of life. The material that is formed through movement is subordinate and exchangeable. We discuss this observation and then look at our own bodies as examples. After seven years practically all of the materials in our bodies have been exchanged for new materials, but the form remains.

In the waterfall the water funnel is exchanged in a short period of time; in our body's waterfall, the process takes much longer. The form of our body is not determined by a collection of static parts, but it is a movement that is filled with material in rhythmical exchange.

Let us observe the waves of the ocean. This brings us to a new phenomenon. The forward moving wave travels through water that stands almost still in its place. A water particle in a wave moves in a circle at the surface. The movement is more elliptic under the water and approaches a back and forward movement farther down. A stormy ocean is a complicated combination of unlimited rows of movement that grasp the same materials at the same place. There may be only one body in each place on land but in water there can be different movements in the same place that culminate in a final sensible expression in a certain form only to be exchanged in the next moment for a new one. Flexible thinking is required to follow the game. A good exercise is to exchange the experiences. First review the observation of a waterfall, where the movement creates a constant form that is continually streaming with new material. Next consider waves in the ocean, where the form moves in a forward motion while the material remains in the same place. These are opposite systems that both express the moving element: water.



Running brook showing surface tension

Surface tension

We return to detailed observations of the shape of water, the surface of the globe. Water takes the shape of the vessel it is in. The surface of water is even with the earth as a parallel surface. A certain amount of isolated water can create a globe from its own power, for example a water drop that falls. Any fluid will contract to a globe if it is able to form freely. This tendency is clearly demonstrated in the case of mercury that approaches the shape of a globe even when in its most solid form.

What are the special geometric qualities of a globe? Of all of the platonic bodies, the globe has the least surface in relation to its volume. This means that any liquid can approach the globe shape by making its surface as little as possible. The inner necessity for a liquid to make its surface as little as possible can be demonstrated through a number of experiments and thereby enlighten our study of the concept of surface tension.

A glass vessel filled with water is set before the class. A beautiful squirrel tail with bushy hair is swung in the air a couple of times before it is dipped into water. When we pull it up, that hair has naturally cling together and the tail looks small and miserable. I ask the pupils, "Why has the squirrel tail hair stuck together?"

The answer is usually, "Because the tail is wet." To demonstrate that this answer is not enough, I dip the tail once again in the water and hold it there. What do we see? The hair flows back and forth in a bushy formation under the water. The tail is wet, but the hair does not stick together. Once again we pull the tail out of the water and the hairs stick together again. A membrane, a "layer of skin" of water is created around the tail hair. Before our eyes a contraction along the surface takes place. We experience the concept of surface tension.

Another experiment is to carefully place a razor blade in the water. It floats. We weight it down with half a match and add six more. We notice that the blade has made an indentation in the surface of the water. Another visible experiment can be carried out with a finely netted wire basket filled with wax. The wires are coated in wax but the holes are open. A sizeable wire net can float on water but if you touch it, it quickly sinks to the bottom.

Water's tendency to make as small a surface as possible can be demonstrated in other ways as well. Each pupil makes a ring of thin steel thread. In their ring they loosely tie together some thin threads to make a mask. When this steel-thread ring together with the thin threads is dipped into soapy water, a membrane will form over the entire form, and the threads will float in the soapy membrane. When we put a hole in one of the masks, it will immediately take the shape of a circle. Stick a hole in the neighboring mask and it will immediately make a circle, but where the two circles connect, a straight line will be formed. The hole grows as much as possible because the soapy membrane around it tries to contract together to the smallest surface. The circle expands geometrically into the largest surface in relation to the periphery. The remaining masks that are still covered by the water membrane will have reached their absolute minimum. We observe the surface tension pull all membranes into a minimum. This same "compression tendency" drives free-flowing water and all other liquids to create the smallest spatial form, the globe.

Water contracts on the outside into a "skin." Where this "skin" appears the water approaches a more solid form, creating something that resembles a solid border surface. The solid border surface is a permanent quality all solid substances have without effort. Water and all liquids recreate this "skin" continuously, and the "skin" dissolves as soon as the water returns to its own element. The "skin" appears only in relation to another element; it cannot appear in its own element.

Our experiment becomes even more complicated when go beyond working with a membrane in a flat circle on one plane to use wire-meshings in a three dimensional figure. I pass out thin wire thread to the pupils, who each make a spatial figure. We start with regular figures such as pyramids, cubes or cones. In every case the surface tension will create the minimum surface. A soapy water membrane will cling to the wire everywhere but also create surfaces that hang together in the holes. A cube made of wire thread will have eight slightly bent-over surfaces inside with a square that holds them together in the middle. With a little practice we can create an inner cube of water membrane materials that hangs elegantly in slightly bent-over membranes, held to the thread on its side. The inner water cube contains six membranes with air inside, held together merely by water membranes.

At this point we test the pupils' inventive capacity. Some make the most complicated, irregular forms in order to see what happens, while others experiment to observe the laws of freely moving water figures. The whole time they can be surprised by the forms created by the pure liquids. There was a lot of variation: symmetrical, asymmetrical, bowed-over, distorted shapes that were made of steel thread by the children.

Capillaries—water's tendency toward gas formations

We notice that water at the top of the thin tube does not arch upward but pulls upwards along the sides, creating an arched valley. "But that cannot be true!" cry out the excited pupils. "That goes against everything we learned about water pulling together to form a globe!" Now we are in the middle of an exciting problem and must expand our understanding of water.

We start new experiments by (1) dipping a piece of sugar in colored water, and (2) dripping ink on absorbing paper. We watch how the liquid in both cases spreads into the material. It is sucked over the surface. Every pupil is given a flame and a thin glass tube of 20–30 cm. The glass tube is warmed up in the middle until it is soft. Quickly and decisively we pull it out to a length of 60–80 cm, thus a capillary tube with minimal inner sections. We break off one side to the point where the capillary tube shows that water moves in thin canals, and with this experience we look again into water cycles in vegetation. Water can climb up 50–60 meter tall trees. And what happens on top? There the water evaporates into the atmosphere. Capillaries may be considered a stage in water's path to evaporation. In the earth, water collects in pools by the roots; through the trunk, branches, twigs, and leaves, it is thinned out by increased capillary movement until it escapes out into the air as water-steam in gas form.

This is the opposite phenomenon to the tendency to form globes as water tries to approach solid materials. In the capillary movements water tries to approach gases. "Where else do we find capillaries?" I ask the children. In bogs or other places water is sifted into more solid materials. A bog can also be found in the lymph system of our body. Our whole body is filtered by water, and without that hydrating of our body, we are not worth much. Once again we touch on water's life-bearing activities. The ability to spread out, climb up, thin out in all directions—these are tendencies in capillaries that are qualities of gases. Gases do this on their own, but water needs a partner to support it becoming more and more like gas with evaporation and centripetal spreading.

Here a further experiment can help to demonstrate capillary movement. In a vessel with colored water we place a rag that reaches from the water over the edge and down to another vessel alongside. The liquid will slowly penetrate the rag and travel over to the other vessel. This is also known as osmosis. Another demonstration can be created with two glass plates put together with a matchstick to keep them apart. A rubber band holds them together. These plates are placed in a colored liquid and the liquid will be pulled up in a beautiful bow along the side where the glass plates are placed together.

Pressure in water

We fill a vessel with water that is connected by a rubber hose at the bottom to a fountain. The higher we raise the vessel the higher the spout will flow out of the fountain. We realize that the difference in height will affect the speed with which the water leaves the fountain. Pressure increases with the difference in height. Then we connect the vessel with a little container that has holes from all of its corners. When we raise the vessel with water, the waterspout will stream from every corner. No matter how we hold the container the stream of water spread to very corner. We see that pressure in water moves to every side and is strongest where the distance up to the water surface in the vessel is largest.

To make it even clearer we place a messing pipe on the highest edge. Along the pipe are holes bored in a row. We fill the pipe with water and the waterspout is at the bottom, where the pressure is greatest, and continually shorter towards the top, where the pressure is least. We see that the water pressure increases with height.

Now we can speak about the relationship between weight and pressure. We can ask if water has any weight at all. Can it be weighed? Not without being placed in a container. You always have to fill water in a container to judge whether there is a weight increase in relation to the emptied container.

We use this experience to ask, ”What happens when we stick an empty container in water?” The container becomes lighter and it becomes buoyant. Weight and buoyancy are opposite symmetrical phenomena and may be explained: “Water in a body adds weight, water surrounding a body reduces weight.” We can take a step further and say: If you prevent a stone from falling, you realize its weight. If you prevent water from flowing freely, you notice its pressure.

The weight of solid bodies is analogous to a flowing medium’s horizontal surface. Just as weight can only appear within a confined surface, so must buoyancy have limited surface to appear. A natural conclusion is that amounts of water that are down in water and surrounded by water float in total balance. It has neither “weight” nor “ buoyancy,” nor does it have a surface where pressure may occur. We can say: water surrounded by water is weightless and not subject to gravity.

We try to avoid conclusions. The concepts our pupils build about water need to be based on experiences they have with water. This allows the children to remain open and flexible in their thinking. Their enthusiasm for the subject grows as their thoughts become more connected and enlivened. This is our educational goal with the lessons about water.

The hydrostatic paradox

We demonstrate the hydrostatic paradox, or Pascal's tube as it is also called. Three tubes of different form are mounted on a scale. All of the tubes have a round circular opening at the bottom that is covered by a thin rubber membrane. One tube is straight and is the same width along its whole length. Another tube expands as it moves towards the opening at the top, while the third tube becomes smaller and is more lopsided.

When the tubes are mounted by weight the indicator moves to the same point as soon as water in the tube reaches a certain height. This is the same for all three tubes. The result is dependent on the volume of the water in the pipe, on the pressure. The pupils can understand that the same result appears in the tube that expands towards the top and in the straight tube because they can imagine that the water rests on the lopsided edges. The fact that the result is the same for water in the tight, lopsided tube awakens second thoughts and excitement. The question arises: "How can there be almost no 'weight' of water in the small tube, and we still get the same result?"

Let us summarize our experiences with the three main phenomena of water:

1) The tendency to form a globe with a skin-like substance and surface tensions, and an approach to the solid, formation building
2) Capillary action, siphoning, hydrating, osmosis, evaporation, movement
3) Pressure that searches for balance and that takes the form of globe surface

We have experienced how necessary water is for life, how strongly it forms, but also how it continually removes the created forms if no solid substance enters and allows itself to be formed by the movement. The formative forces in water appear beautifully in streaming whirlpools. These may also be seen when an object moves through water, for example, when we row on a summer morning on a mirror-perfect lake. We can also create these conditions in the classroom. A vessel 30x60 cm and only a few centimeters deep will work well. Paint the vessel black inside; fill it with water that has glycerin added to it in order to make the water a little harder. Spread aluminum powder over the water surface and move a stick through the liquid. Beautiful whirlpools will appear and quickly disappear. This leads us to the philosophical statement, "All solid bodies are movement that has become still."

Water's life-bringing element is the basis for movement and formation, but not for the ability to let formation become solid. To become solid, another element is needed. This we will explore in the geology block. Solids are the remains of movement. The study of the element water leads us to new studies in nature.

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Vortice train created by drawing a feather through water on which has been sprinkled lycopodium powder from the spore cases of club mosses