Science Teaching – Part II
Methods and Approaches

Roberto Trostli

Editor's note: This article is taken from a lecture delivered to teachers in Hungary in June 2013. Some of the examples refer to the physical presence of the speaker in front of the audience. They have been retained along with the informal spoken-word style of the presentation.

To educate youth
Means to foster and tend
In matter the spirit,
In today the tomorrow,
In earthly life,
The spirit's existence.
– *Rudolf Steiner*

In the previous article (*Research Bulletin,* Vol. XVIII No. 2), we looked at science teaching in terms of the grand rhythms of child development. In this article we will look at the same subject in terms of the rhythm of day and night.

Our teaching can utilize four rhythms that correspond to the four members of the human being. The rhythm of the year is the rhythm of the physical body. As the year cycles through the seasons, so does our body slowly grow and respond to the world around us. The rhythm of the month is the rhythm of the etheric body. That is why it works so well to have main lessons blocks of four—rather than three—weeks, for it takes a month truly to integrate one's experience. The rhythm of the week is the rhythm of the astral body. We utilize it to give each day of the week its character. And the rhythm of the night is the rhythm of the ego. This rhythm is captured by the phrase that we considered: "In today the tomorrow." Like a little death, the night is a time when our soul and spirit excarnate from our body. That process plays a profound part in the process of digesting our earthly experiences and uniting them with our spiritual essence.

Methods of science teaching

Waldorf education does not provide formulas for teachers to follow; rather, it demands that teachers develop pedagogical practices out of an anthroposophical understanding of the human being. The foundations for this understanding were laid by Rudolf Steiner, but teachers must work to make them their own. Through study, practice, and reflection upon our experiences, we can derive a method that truly addresses the whole human being.

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Because in this article we are going to examine the topic of science teaching in depth and detail, it may feel dense—perhaps even indigestible—to those who are unfamiliar with these ideas. It is important, however, to penetrate these ideas if we want to understand the process of thinking. For thinking is the means by which we penetrate and grasp the world of matter with our spiritual forces. Heaven is brought down to earth whenever we think. For this reason we need to understand how to teach the children to think in a living way.

The philosophical background

Of all the subjects in the Waldorf curriculum, science and math most directly address the students' thinking. They give us the opportunity to help students become logical and flexible in their thinking and to develop confidence in their own powers of thought. Today we will examine in detail how we can approach this task, so that we can help our students come to recognize that "the world is true."

Rudolf Steiner stressed the importance of teaching students to learn to think, and he gave specific instruction for how to school their thinking in Lecture VIII of *The Foundations of Human Experience,* and in Lectures II and III of *Education for Adolescents.* According to Steiner, thinking occurs in three stages. These stages are interwoven and occur, to some extent, simultaneously. He called these three stages drawing conclusions, forming judgments, and arriving at concepts. The first two of these stages can happen almost simultaneously, or they can be more widely separated. The third is a lifelong endeavor.

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In my work through the years, I have found that the clearer I am about such basic ideas, the better I am able to penetrate my teaching so that it becomes more effective. So, if this is a review for you, I hope that you will enjoy juxtaposing your understanding with mine and seeing whether we agree or not. And if this is new to you, then I welcome you to the years-long task of penetrating this important set of anthroposophical ideas.

Conclusions: Conclusions are perceptions brought to consciousness. Any sense impression can become a conclusion, but only if we become aware of the impression. When you look at me, for instance, you are forming conclusions. You are aware of my body—its size and form; you are aware of my features and my clothes, and you may take note of other details of my appearance. At the same time you may be having impressions of which you are not conscious.

While you are straining to understand my words, you may not catch the expression on my face, or if you start taking note of my expressions, you may miss some of my words. We often have impressions of which we are not aware, because the world is full of possible percepts. For instance, we might hear, but not listen to, a sound. Hearing consists of receiving the sensations of the sounds around us, while listening requires the active involvement of the person. We have all experienced being in a crowded room and hearing many conversations, but if someone mentions our name, we hear that word emerge from the cacophony of sound. In order to draw conclusions we must, so to speak, listen to what we hear. It is possible to draw conclusions about only some of our perceptions.

Let's try this: Hold a pencil vertically at arm's length in front of your face. Focus your gaze on the pencil and notice what happens to everything in the distance. Now focus your gaze at something in the distance and notice what happens to the pencil.

While you are drawing conclusions about the pencil, you are not really taking in the scene in the distance; while you are drawing conclusions about the distance, you are not really able to take in the pencil. This is not just a matter of focus; it's also a matter of attention.

We live in the realm of continual conclusions. When we speak, we express conclusions; when we listen, we draw conclusions; when we read, we draw conclusions; when we use any of our senses

consciously, we draw conclusions. One of the main tasks of the teacher is to present the students with conclusions that are rich and varied, and that engage the students' interest.

According to Rudolf Steiner, conclusions can live only in the fully waking soul. They are a result of the working of the ego, which is why the act of drawing conclusions works so powerfully on the students. This is why we have to be careful not to stuff our students so full of conclusions that they suffer a form of soul or spiritual indigestion.

The way our students learn to draw conclusions affects the way they will think for the rest of their lives.

The way our students learn to draw conclusions affects the way they will think for the rest of their lives. What does this mean? On the most foundational level, it means that the very environment in which our students learn and work forms their thinking. Our colleagues in early childhood know this well. They know that the order and beauty of the classroom work powerfully on their children's growth and engender well-being. In our classrooms, order and beauty foster clear thinking. On the etheric level it means that rhythmical and hygienic lessons will support the development of living thinking, while working in a more disorganized or capricious manner will make it harder for students' thoughts to grow and thrive. Although we may not always recognize it or accept it, we have a great responsibility towards our students, because what we do will affect them for the rest of their lives.

Judgments: When we become conscious of our perceptions, we begin to form judgments. This process arises out of the human being's desire to transform the process of perception into knowledge. A conclusion consists of the awareness of our perceptions, but a judgment allows us to know those perceptions more fully. While conclusions live more in our sense impressions, our judgments allow us to "make sense of" our impressions.

We do this by bringing our percept into relationship with our prior percepts from the past. We are continually forming judgments, and it's rare that we become aware of them. When we see or hear or taste or feel something we've never sensed before, there is a moment when we are fully in the judgment realm as we try to understand what we're sensing.

We form judgments by bringing our percept into relationship with our prior percepts from the past.

For instance, as you listen to me speaking in English, you are aware of the sounds and perhaps some of the meanings of the words. But what if I said:

> Wodon þa wælwulfas for wætere ne murnon,
> wicinga werod, west ofer Pantan,
> ofer scir wæter scyldas wegon,
> lidmen to lande linde bæron.

I imagine that almost no one understood any of that but you tried to make sense of the sounds. That is the stage of forming judgments. It happens more quickly when we are familiar with whatever we encounter and much more slowly when we encounter the unfamiliar. According to Steiner, judgments live in the dreaming soul, so we are not fully aware of them. They are a result of the working of the astral body.

While the manner in which our students learn to draw conclusions affects their thinking, the way they learn to form judgments affects their life of habits, their very character. Thus the teacher has a special responsibility to help students form judgments in a way that supports healthy soul and moral development. What does this mean? It means that if we present students with rich and varied

experiences, especially with opportunities that awaken interest and awe, they will develop a love of life, which can express itself in a sense of optimism. An example of this that bears reflection is Steiner's suggestion that the best way to help students develop a healthy relationship to their bodies and their sexuality is to make sure that they experience the majesty of nature and the beauty of art. Try explaining that to parents!

Conclusions and judgments are inextricably linked. There is a constant interplay between our awareness of a percept and the process of comparing it with our prior experience. A conclusion is complete as soon as we become aware of it. The finality of a conclusion is well expressed by the German word for it: *Schluss*. *Schluss* means "finished" or "done," or "the end." While the process of drawing conclusions is finished quickly, the process of forming judgments is not over so quickly. One can continue to dwell on one's impressions for a while, but at some point this process also comes to an end.

Concepts: The process of drawing conclusions and forming judgments sets the stage for concepts to germinate, grow, and develop. Concept development is more complicated, for it involves not only the thinker but the thought, not only the thought, but the archetype of the thought.

What is a concept? I like to think of it as a seed, for a seed expresses the essence of a plant, the potential of all that the plant will become. But I also think of it as being like a fruit that contains the seed, for a concept both embraces and expresses a thought.

For instance, you are all sitting on chairs, but the chair you are sitting on is not synonymous with your concept of *chair*. This morning you might have sat in a chair while eating breakfast. That chair was different from this chair, but it was still a chair. Think of a stool. Think of a bench. Are they chairs?

Your concept of *chair* embraces all the chairs you've experienced, seen, read, or heard about. That concept expresses itself in all the chairs that have ever or will ever be created. And each chair, no matter how different it is from other chairs, contains some of the essence of that concept.

Because concepts are large and varied, they grow gradually in the human being, and so they should. Ideally they should never be fixed or finished but should always remain capable of growing, of becoming. It is our task as teachers to help students cultivate the process of forming concepts in such a way that the concepts can grow and become increasingly developed and refined. If that happens, the concepts can serve the students for the rest of their lives and even their lives beyond the threshold of death.

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While conclusions develop awareness, and judgments result in knowledge formed by relationship, concepts form the basis for wisdom, allowing us to understand ourselves and the world around us. Concepts live in the sleeping soul and are a result of the working of the etheric body. According to Steiner, the concepts that we form have an effect on the physical body. Our very features and bearing reveal the types of concepts that we formed in our early lives. This places a very special responsibility on the teacher to strive always to engender living concepts in her students.

While fixed or dead concepts result in the hardening of the soul, living concepts allow a person to remain mobile and flexible in his thinking, and they provide the basis for inner freedom. Just in case all this sounds too abstract, let's examine how a concept might be developed throughout the grades.

Let's take one of the most important concepts in a human being's life: the concept of light. In the earliest school years, children just experience the light and the darkness. Their experiences are not brought to consciousness, but we know that these experiences have a deep impact on the child's soul. In the early grades children will recite poems and sing songs that describe or express the light. They will say the morning verse that begins, "The sun with loving light… ." They will hear stories and legends involving light and darkness. They may begin to associate light with goodness and truth, beauty and love, and darkness with evil and falsehood, ugliness and hatred. These associations remain rooted deep in the soul.

In the third, fourth, and fifth grades, students will hear about the creation of light in the stories from the Old Testament and various mythologies. They will also hear about light in their studies of the animals and plants. In their studies of farming and in geography classes, they will come to understand the effect of light on crops, animals, and people. In the sixth, seventh, and eighth grade study of physics, students will now begin to study light in all of its manifestations. They will learn the characteristics of light, its behavior, its laws. Now the concepts they form can be expressed in concise and concrete terms.

Throughout the high school years, students will return again and again to the study of light. In astronomy and meteorology, in physics and chemistry, in economics and philosophy, they will come to understand and express the many aspects of light. Through these years the concept of light grows ever more complex and also ever more refined. Let us hope that this process will continue for many years and that the light will serve as an inspiration and a consolation throughout their lives, that the "common light of day" will always evoke a hint of the "clouds of glory"[1] that we trail as we come to our lives on earth.

Let's summarize what we have covered so far in this table:

Logical Process	*Aspect of Person*	*What it affects*
Conclusion	ego	thinking
Judgment	astral body	habits/character
Concept	etheric body	physical body

The structure of a main lesson

All this sounds so theoretical, and so it is. But just as Waldorf education is the application of anthroposophy to the task of education, so too the way we structure our lessons and the methods we use are the application of anthroposophy to the task of teaching. So how do we put all this theoretical knowledge into practice?

In Lecture III of *Education for Adolescents,* Steiner indicated how physics lessons can be scheduled on a two-day rhythm to engage the whole human being. Such a schedule consists of a demonstration and a recapitulation on the first day and a review on the second day. This process allows students to draw conclusions, form judgments, and arrive at concepts in a living way. Although there is much talk in North America about the "three-day rhythm," I know of no indications by Steiner concerning such a rhythm. While one is welcome to extend the two-day rhythm so that it encompasses more than two days, I think it is important to recognize that we are essentially working with a two-day rhythm in our teaching.

The two-day rhythm harnesses the power of the night, expressing the phrase "in today the tomorrow" in our pedagogical work.

The two-day rhythm consists of presenting a topic to the students on the first day and following the presentation by a recapitulation on the same day, then reviewing the topic on the following day. This rhythm harnesses the

power of the night, expressing the phrase "in today the tomorrow" in our pedagogical work. Since we are speaking about science teaching, let us see how this rhythm applies to the parts of the science main lesson, but we could just as easily apply it to a subject such as history, geography, or literature.

The demonstration: The first part of the lesson I will describe is the demonstration, even though it does not come first in the lesson. It can occur after the review of the previous day's work, or it may come at the end of the lesson after the students have completed their main lesson book-work.

When the demonstration is performed, students draw a series of conclusions from their observations and impressions. The demonstration acts powerfully, affecting the whole being of the student, and it requires the strength of the ego to bring perceptions to consciousness. According to Steiner, the ego has its basis in the legs and feet. It is no surprise that when we reach maturity, we are ready to "stand on our own two feet."

Just as we try to organize our school day so that we don't tire the students by excessive physical activity, we also need to limit the amount of time that they spend drawing conclusions because they work so powerfully on the students. Here is an example that happened recently in my class.

During our chemistry block, I presented a series of demonstrations with oxygen. I showed the students how oxygen can be generated with hydrogen peroxide and baker's yeast, and then I had them generate some oxygen in their own test tubes and test for it with a glowing splint. Next I showed them how to gather a larger amount of oxygen in jars through the water displacement method and demonstrated how various substances burn in oxygen. We started out with a candle burning in a jar of oxygen. It took almost two minutes for the candle to burn out. Then we burned sulfur in oxygen, and it burned with an intense blue flame. Next came steel wool, which burned like a sparkler, shedding bright sparks. Finally I burned a strip of magnesium in a jar of oxygen, and it was even brighter (if that is possible) than the magnesium we had burned in the air.

When we reviewed all of this during the next main lesson, the students remembered almost nothing of what we had done. Almost nothing! "How is that possible?" I thought. "Weren't the experiences dramatic and memorable?"

This is what can happen when we perform too many demonstrations and tax the students' souls too strongly. The students must have been overwhelmed and overloaded with impressions. As a result, they were not able to lift their perceptions into their imaginations during the recapitulation. They were not able to take them healthfully into sleep and retrieve them again upon waking. While the oxygen demonstrations may have been entertaining, they did not educate the students. The students did not learn from them. We have to work to avoid this kind of experience.

The recapitulation: Rudolf Steiner said that right after the demonstration, the teacher should verbally recapitulate it for the students, briefly stating what was done and what occurred. Here is a typical recapitulation:

> Today we observed what happens when a candle burns in a closed jar. When the jar was first put over the candle, the candle continued to burn brightly. In a few moments, the inside of the jar became a little bit murky, and we saw very fine droplets forming on the inside of the glass. Then the candle began to burn less brightly, and its flame diminished in size and brightness. After about half a minute, the flame became very small and eventually went out. A long wisp of grey smoke rose from the wick, which continued to glow red for a little while longer. Tomorrow we will explore some of

the gases involved in combustion." (Note how one can lay the seeds of anticipation for what is to come by mentioning it at the very end of the recapitulation.)

Such a recapitulation allows the students to re-experience in their imagination the events they have observed with their senses. The experiences that took hold of the whole body are now lifted into the rhythmic system, and as the students form imaginative pictures, the astral body becomes involved. The recapitulation allows the students to continue to form the judgments that were engendered by their sense impressions. This process of hearing the recapitulation and forming imaginative pictures will aid the students during sleep to begin the process of arriving at living concepts.

After the recapitulation, no further conscious work is done that day with these phenomena. That part of our teaching is done for the day, but perhaps the most important part of the students' learning occurs during the night. Although this part may be invisible to those of us who are not clairvoyant, that doesn't mean that we shouldn't take it into account. Sometimes what lies just beyond our consciousness is what is most important.

During sleep, the ego and astral body leave the physical and etheric bodies and enter the spirit realm. By this process, the sense impressions of the demonstration and the imaginative pictures that the students formed during the recapitulation are lifted into higher realms. What happens there? What might the students encounter in the spiritual world?

I think that as the students spend time in the spiritual world during sleep, they encounter the archetypes of the forces that they have experienced in the material world. I don't know this to be true, but I suspect that these archetypes are the beings that embody these forces and that are expressed by earthly phenomena. So if students have been studying the relationship between the length of the strings and the consonance of a musical interval, they might experience the archetype of consonance when they enter the spiritual world. They might sit at the knee of Euterpe, the muse of music, and learn from her. When the students wake up the next morning, the impressions and pictures they formed the previous day live in their etheric body as memory pictures and as the germs of living concepts. Steiner referred to these memory pictures as spiritual photographs. I wonder what simile he would have used if he were surrounded by today's technology.

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The review: When the students return to school, the first part of the lesson includes a review and discussion of the previous day's work. Now the students are asked to summarize their observations and articulate their judgments. New judgments may be formed at this time as students listen to each other's experiences and hear about aspects of the demonstration that they may not have observed or remembered. During the review students will consider questions and grapple with aspects of the phenomenon that they didn't fully grasp. Ideally, the review in the upper grades—and certainly in the high school—will contain three kinds of questions: questions to which the students know the answers; questions to which they don't know the answers; and questions that the students never thought to ask.

During the discussion, as students begin to come to a deeper understanding of what they have experienced, the concept begins to emerge. Because the concept is usually still in a germinal form, we should not be concerned if it

is phrased in general terms. If we are too quick to settle on the wording for a concept, we fix it in the students' minds and deprive the concept of the opportunity to grow and develop.

Once the concept has been stated, perhaps tentatively or provisionally, the students will be able to build upon or develop the concept further by new demonstrations or activities. They also have opportunities to express the concept in their written and artistic work, and through further work they will begin to recognize the concept's manifestations and applications in their daily lives. Although I won't spend any time today describing what the students might do during this work time, I want to stress that the time they spend working individually is one of the most important activities in the main lesson.

The three parts of the main lesson correspond to the three processes of thought and address the threefold human being. During the demonstration students primarily draw conclusions about the phenomena. The process of drawing conclusions takes hold of the whole human being and calls strongly upon the student's ego and strengthens the will. During the recapitulation, students primarily form judgments. The recapitulation helps the students take the content of the demonstration into their sleep life. The recapitulation lifts the experience of the demonstration into the rhythmic system and engages the astral body, nourishing the students' feelings. During the review on the next day students begin to arrive at the concept. Calling on the forces of memory, the review engages the etheric body, developing the students' thinking. This can be summarized in the following table:

Part of the lesson	*Thought process*	*Aspect of person*	*Soul faculty*
Demonstration	Conclusion	Ego	Will
Recapitulation	Judgment	Astral body	Feeling
Review	Concept	Etheric body	Thinking

I think that it is important to understand the process of thought and the process by which we teach children to think. Even if you don't remember the details, I hope that you recognize how important it is to structure our teaching so that we engage the whole human being and that you realize that it is possible to use the rhythms of learning to help the students develop concepts that can continue to grow throughout their lives.

This approach will give students the confidence that through their thinking they can address the many problems and circumstances that life will present them.

If we use this form of applied anthroposophy, we will give our students a foundation that will allow them to think true thoughts. They will be able to reach the spirit through their thinking. This will give them the confidence that through their thinking they can address the many problems and circumstances that life will present them.

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Endnotes

1. William Wordsworth, "Ode on Intimations of Immortality." A section of this poem formed the basis for the description of the science curriculum in the previous lecture.