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Inter – multi - and trans - disciplinary approaches in astronomy education research

Nicoletta Lanciano
Universitá di Roma «La Sapienza» and Gruppo di ricerca sulla pedagogia del cielo del MCE (Movimento di Cooperazione Educativa)
email: nicoletta.lanciano@uniroma1.it

Summary

Looking to the human and natural reality, coming from the experience and from awareness of its complexity, the western-style knowledge conceived disciplines. These have developed, from themselves, languages and different methods in relation to their study objects.

Their separation, useful in some stages of study and the specific development, was often simplistic and damaging both in scientific elaboration, to meet the challenges that nature and the future offer us, that in the didactic transposition.

On the other side studies on general education and cognitive psychology, and more recently neurosciences, show that aspects of different disciplines are formed and stimulated in parallel, but also as motion and cognitive aspects are linked in the brain. The research confirms that cognitive experience is linked to the body and to emotions, more than the school organization often wanted to recognize.

Therefore, inter-, multi- and trans-disciplinary approaches relate to the objects of study, to the teaching methodologies, and teaching research methods.

To analyse these issues, I present reflections started in Astronomy teaching experience with students of different ages, in Italy and beyond, and I present open questions that enquire the teaching-learning, in and out of school, and the teacher training.

1. Introduction

Looking to the human and natural reality, coming from the experience and from awareness of its complexity, the western-style knowledge conceived disciplines. These have developed, from themselves, languages and different methods in relation to their study objects.

What are disciplines? After the natural philosophers in 1600, the disciplines were well defined and in 1800 their rigid compartmentation took place, becoming "classic disciplines."

The word "discipline" descends from Latin *discipulus* that means learner and is connected whit learning. A discipline is not a concept, and is much more of its own content. A discipline refers to *subjects,* content of study and teaching, that is, the field of knowledge which is taught, and an extended *system meaning of rules,* organization and methods.

Ervin Laszlo, a contemporary systems philosopher of science, which says "my job is not to be a specialist", write: "*The disciplines in science are artefacts…. They are often necessary ... There are no boundaries in nature that uniquely match the boundaries of the disciplines."*

Therefore, inter, multi and trans-disciplinary approaches are related to the objects of study, to the teaching methodologies and to the teaching research methods, using points of view of different disciplines on the same assets and the same themes.

For example, general didactics, pedagogy and didactic of scientific disciplines, all together help to address the development of the skills in specific job, with the role of a certain theme, and its insertion into a nature trail, over to analyse the consistency of language.

I wonder about the contributions and the role that different arts and techniques, the activation of all the body, the craftsmanship and the fantastic production, the attention given to emotions may have if we want to teach in a responsible, durable and ethical way.

I show in this paper examples of Astronomy specificity about geographical conditions of countries at different latitude and their impact on perceptual, cognitive and educational aspects. Cultural differences that affect individual, national or local communities are the research field of ethno-astronomy investigation that I don't address in this paper.

Inter, multi and trans-disciplinary approaches in Astronomy education research regard therefore contents and methods. We can define:

- **Inter**disciplinarity which concerns and interests more disciplines, that have as their contact point a theme or object such as the study of the sky. Astronomy, meteorology but also poetry, mythology and philosophy are involved in the study and every discipline participates with its specific methods.
- **Multi**disciplinarity is an epistemological approach. It is related to the destabilization of knowledge, specialized up to the parcelling, even without a common object, but with the same goals, for example developing a skill.
- **Trans**disciplinarity is a new "aptitude", that starts from issues of a different type than those of classical disciplines. J. Piaget in 1970 defined"... *Finally, we hope to see in the future the development of interdisciplinary relationships at a higher level that could be referred to as "transdisciplinary ", which should not be limited to recognizing interactions or reciprocity through specialized research, but which will have to identify those connections within a total system without any stable boundaries between the disciplines themselves*."
  Basarab Nicolescu (a physicist) proposed, however, in 1985 to introduce the concept of "*beyond the disciplines"*. It appears like a paradox that from the heart of an exact science, physics, he comes to the idea of a limit of the same disciplinary knowledge.
- Blanchard-Laville recently proposed the **co-disciplinary** analysis that is a co-constructing meaning on a study object. For example, when I ask to university students about **"**What is latitude on Earth?", I suggest, to better understand this invisible angle with the corner in the centre of the sphere, to realize a 3D model. We can look to the models they realized, with the eyes of the *disciplinary teaching skills*, looking if it is the right angle, but also of the *relational skills*, looking how they work in the groups. Or we can observe the construction of the model and their attention to the *technical skills*: in this case the teacher observes if it is possible to use the model at different latitude because it is a dynamic model and if it is realized in a strong way and it is possible to use it with no breaking risks. This means that several specialist can look at a didactic situation with different questions in mind:
    - Which models and useful knowledge do learners use?
    - Which mistakes they make?
    - Which specific and epistemological difficulties have they found about angles?
    - Do they use a coherent language for the argument?
    - Who has brilliant ideas?
    - Do students accept different, new or divergent ideas?

General education and cognitive psychology, and most recently neurosciences, recognize how aspects of body movement and cognitive relationships are related in our brain realizing synapsis (Dehaene, 2010).
The Chilean psychoanalyst I. Matte Blanco (1975) yet during '70 years wrote that the cognitive experience is related to the body and the emotions, and there is no thinking without emotion.
We need to accept and recognize that we use a bi-logic, in the sense elaborated by Matte Blanco, and not only the Aristotelic logic yes/not, right/wrong, 0/1 that imposes a choice. Our rational logic is linked with the symmetrical logic of the unconscious, so we are living with a bi-logic that mixes different planes. In the symmetrical logic of the unconscious, like we can experiment with the emotions or dreaming, the principle of non-contradiction is not valid. Furthermore, the positive emotion of amazement and discovery in the direct observation of the sky help the attention and the memory.

I perceive great problems of reductionism and simplification in teaching sciences at school at all levels from children to adults. Instead to teach to recognize the levels of complexity and of approximation in a question or a subject, very often books, sites and teachers show simple and linear

presentations. Instead and before teaching questioning, they use answers and affirmative phrases. For example, I analyse the tale about the Eratosthenes's measure of the Hearth meridian. For this measure, in a non-reductionist vision, I show how many questions are possible in different domains and at different levels of historical reconstruction:

- What sources do we have for Eratosthenes's work? (History)
- Where was the tropic of Cancer at that time (III century b.C.)? (Astronomy)
- Were Alexandria and Syene on the same meridian? How could he know it? (Geography-Astronomy)
- Which method they used to measure the distance? (Technology)
- Which kind of sundial did use Eratosthenes? (Astronomy)
- How much did a *stadium* measure in km? (History)
- 360°: 7° 12' = 5000 stadium: x (Mathematics)
- Did he used a Plane shadow or skaphé with a shadow in a spherical convex surface (Astronomy) (Lanciano, Berardo, 2016)
- Wich impression makes us think that a man, more than 2000 years ago, understood how great the Earth is. (Emotion)

We know that we need big models and large spaces to help visuo-spatial reasoning but, on the contrary, a lot of teachers only use the classrooms of the schools or universities. To move in a large space, at solar noon, with teachers in training, we materialize the meridian line first with our bodies on our shadows and after with a rope: this is the South-North line. (Figure 1)

Figure 1

Contributions to education and to school came also from other domains and pedagogy needs other ways of looking and different approaches to be effective in society.

One of these is historically the medicine, which investigative method forecasts observe, record and interpret the symptoms, give very important directions. Some European physicians, in the 20th century became big pedagogical personality. Between them there are: Maria Montessori in Italy, Ovide Decroly in Belgium, Janus Korjak in Poland and Emmi Pikler in Ungary.

Also in catholic thinking area in Italy there is a special figure, don Lorenzo Milani (1923-1967) with his school of Barbiana. He denounces the class selection against the workers and peasants' children in the Italian school. In the *«Lettera a una professoressa»*, a book by Milani's students group, the usual school is defined *"as a hospital that cares for the healthy and rejects the sick"*. In Barbiana's school there was no separation between manual and intellectual work: building tables and writing, calculating or build a precise astrolabe, etc. had the same value and a very close cooperation.

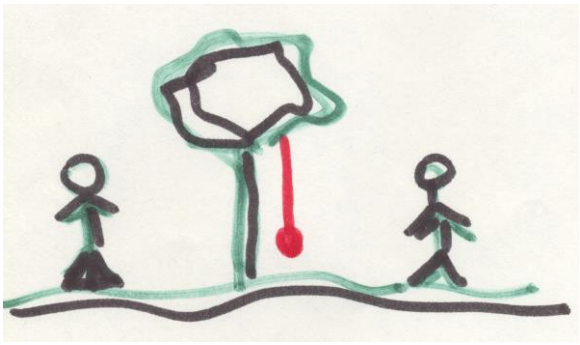
2. Not only Astronomy

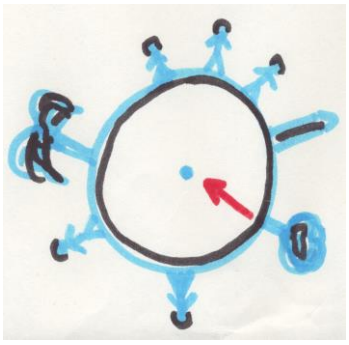
Astronomy education research is in dialog with other disciplines in didactic investigation and teacher training, like investigation in astronomy, maths, physics, and didactic of maths, of physics, of geology, like pedagogy, general didactic, neurosciences, history of science and epistemology.
But in my work a very important help come also from other sectors of human activity like theatre and actor's formation, different arts and craftworks, like the environment with his museums and monuments. For example, actors have very deep visuo-spatial skills, and they make a big work using space and perspective, and illuminating objects and spaces.

2.1 Didactic of Mathematics

In Didactic of Mathematics, and especially of geometry**,** we define the *micro space, meso space, macro space and mega space* in relation with the dimensions of space that we consider. These spaces are different one each other depending from the peculiar definition of some concept in everyone. (Lanciano, 1996)
The vertical direction, for example, is the direction of gravity, of the lead wire. In the meso space, like a garden or a room, the vertical direction is the perpendicular to the horizontal plane. In the mega space of planet Heart, it is the radial direction. (Figure 2,3)

Figure 2, 3





2.2 Epistemology

From epistemology, in didactic of astronomy we have to consider the Copernican Revolution. The epistemological problem is that we look and we speak "like Ptolomeus and we think like Copernic" because:

- we **see** the Sun moving on the horizon from orient to its culmination at noon, and moving to the occident part of the horizon, every day;
- we **say:** "the Sun rises" or "the Sun sets", and not "the Earth rotates so that the Sun ….". We **speak** like if we would be in a central, static Earth;
- but we know and we **think** about a heliocentric point of view and we think of the Earth as a dynamic celestial body.

We accept this coexistence in our perception, in our language and in our thinking

- of a topocentric vision of Sun
- and a heliocentric point of view.

This is an example of complexity, and for the Sun-Earth system we have – the children, the adults, like the astronomers - two different ideas at the same time. Everybody is, in our point of view, "Ptolemaic" and "Copernican" at the same time.
It depends from the situation, which vision, language, schema, vocabulary is better to use:

- if we point a telescope,
- if we are on a boat in the see,
- if we study the orbits of the planets.

Every model, like every point of view, can be more useful in such a situation.
In our didactical experience on Astronomy, with different aged people, we found that it is necessary to become a good "Ptolemaic observer", with a solid geocentric and geostatic experience, before became a convinced "Copernican" one.
We refuse to say that in the school we want to **move** students **from** a Ptolemaic vision **to** a Copernican vision. We want to improve the observation of phenomena in real time, the rise and the set of the Sun, of the Moon, of the stars… and the description of these observations **before** giving the question "who does move?". It is not very interesting, in my opinion, to know the scientific answer "The Earth rotate around the Sun" if a student never observes a reciprocal movement!

2.3 Pedagogy

In pedagogy we find in Comenius, an european pedagogist of the XVII century, an authoritative and precious source. Thus, *the principle for which any teaching must begin from the activity of the senses, against the teaching way* of his time (1650) that *was all around the words*! Comenius, in his book *Didactica Magna*, he denounces and criticizes as ineffective a method which begins with abstract rules and, only after, utilizes the examples that clarify the rules.

Again in 1996 Mario Lodi an Italian teacher of the Freinet Pedagogy, wrote: "*Never as today the child needed to use the senses and mind to relate to the real world in which ways, to return to making concrete experiences*." (Figure 4)

Figure 4

We have to pay attention! Learning to look, interrogating, is a spontaneous action only in early childhood; with high school students, the teachers need to invite them to rediscovery that way to observe and to be in relationship with environment and put questions.

3. Rethinking astronomy for teaching

Many people are astonished and are ready to smile or to scandalize for the "bad" results of national and international investigations (IEA, PISA), and journalistic communications about scientific analphabetism which show the lack of knowledge of elementary type and related to daily experiences also in the field of astronomy for adults and students: but many countries, where it happens, invest small, very small quantity of money in school and teacher training. Also in the university, teaching research is a penalized sector in terms of value given to specialist publications, places in universities: as to *know a disciplinary sector* means automatically *to be able to teach it appropriately*.

A response in Europe came from the Group coordinated by Michel Rocard in 2012. The group report (by Valerie Hemno) is a reference for scientific education at the OECD Global Forum for Science, was published on 2007 by the European Commission: Scientific Education Today: Education Renewed for the future of Europe. In the Introduction they write: "*Since it has been found that the*

greater responsibility for the decline of young people's interest in scientific studies lies in the ways in which science is taught in school, the central core of the study of the committee is to teach teaching methodologies of the sciences." An example is the IBSE *Inquiry Based Science Education Method.*

With Yves Chevallard (didactic of maths) we call "didactic transposition" that process of transformation that we have to do because a content, expressed by the scientific community, can be brought into school curricula and from those to content actually taught in classes of a certain level. Encyclopaedic knowledge is organized in a different way from a teaching knowledge. And a further transformation of concepts order is useful when we want to teach them, in that class, with that goal.

3.1 Steps of educational research

I discuss some steps of educational research in Astronomy, bearing in mind some features very special of the discipline: the astronomer is a passive observer because he can't plan an experiment like a physicist or a chemist. To see an eclipse, it is necessary to wait it happens. Furthermore, the big spaces and long times of the evolution in astronomy have a very different scale in front of our quotidian life. Below I describe some steps. (Lanciano, 1996)

3.1.1 Collection of initial conceptions

Learners, often have already some previous ideas about subjects that someone teaches them: some ideas are more structured also if not completely correct or similar to that accepted in the scientific community. It can be dangerous to ignore that Learners have previous ideas. Collection of initial conceptions is made watching and listening learners; their initial conceptions are often solid and resistant, articulated real conceptions.
If students say, "*In Summer the Earth is closer to the Sun*", they perhaps know that there are seasons when the relationship between Earth and Sun change, they know especially that there is a difference in distance. But they do not consider the difference between what happens in the two hemispheres and they show an egocentric and local vision thinking that *in their* Summer the Sun is closer to the Earth. Perhaps they think that the distance is the cause of the season. In fact, it is very difficult to "perceive" a difference between the period when the Sun is closer and when it is farther away.
Another example of initial conception is synthesized in the sentence "*At noon the Sun is at the Zenith*". Italian students know that, in a day, there is a difference in the length of the shadow but they didn't observe what happens at noon at an Italian latitude (37°- 47° lat Nord). They are ready to understand the symmetric situation of the position of the Sun between sunrise and sunset reaching its peak at noon. The problematic aspect of their conception concerns the position of the Sun at noon and the observation of the shadow at noon: in Italy it doesn't disappear, because of the latitude of the country. In fact, this sentence show that it is not so deep for students the idea of a spherical planet.

In didactic of sciences literature, we found different terms that put in evidence very important differences among the researchers all over the world, from years '70 until today, in the investigation about *mental representations*. Like Giordano and Gagliardi observe (Giordano, Gagliardi, 2014) we found negative terms like *misconceptions, errors and mistakes, misunderstandings, preconceptions* and positive ones like *spontaneous or alternative conceptions, initial conceptions, fantastic childhood hypotheses*.

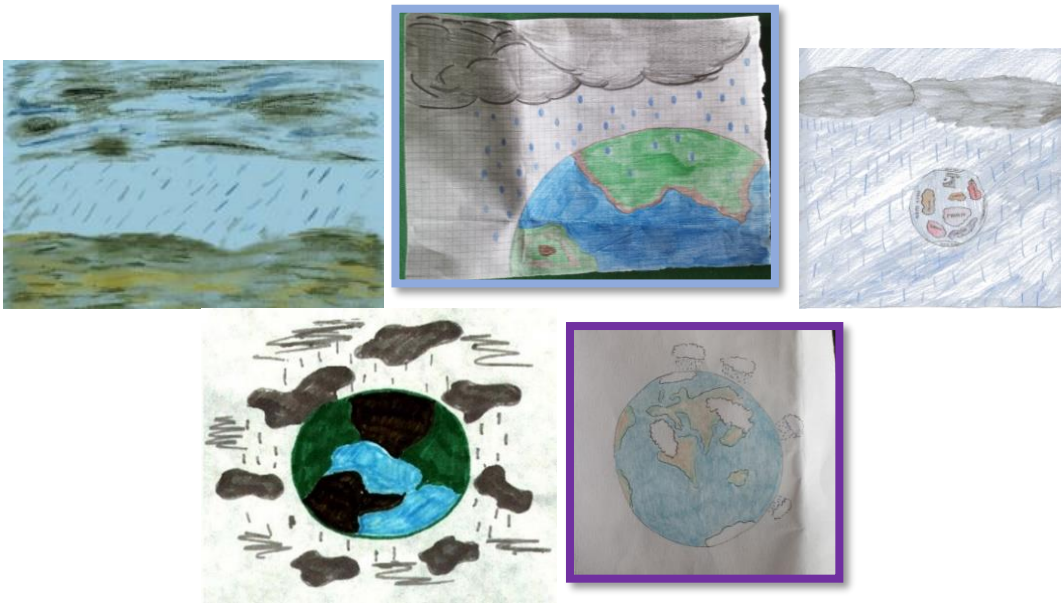
3.1.2 Analysis of difficulties, obstacles and mistakes

Difficulties, obstacles and mistakes can be perceptive, conceptual-epistemological or psychological-emotional.

In the years 1990-95 some researchers asked to young children to draw *People where they live on the Earth with clouds and rain*. I changed a little the question and I ask to learners, aged from 8 to 80, to draw EARTH WITH RAIN AND CLOUDS. My question is "ambiguous" because in Italian the same word

“earth” means as the planet as the ground (Figure 5, 9). I found some *difficulties* like to overcome the egocentrism of one's position on Earth and not to consider other positions on it, at different latitudes; some *obstacles* like that of flat representation of a 3D space phenomenon, and *mistake*s like to take in account the sense of gravity around the Earth and the picture of a round Earth in a space with an absolute high (Figure 6,7,8).

Figure 5, 6, 7, 8, 9



Between the **didactical obstacles,** first I consider the lack of direct observation of the sky, in the day and at night, in teaching astronomy. Books, virtual instruments and programs, planetariums, can’t substitute the vision of the sky, on its horizon: the path between what you see and what you know is dialectical and needs to be outdoors, with children and with adults!

The languages used in school, in particular in science, are verbal and the highly symbolic: this is a reason for stumbling for those less dominant learners, or who prefer other communicative ways: the use of expressive forms, such as iconic language, and also the language of poetry, of body movement and of touch, of arts are often useful to involve everyone. “*When it's just the head that we use I feel blocked. Singing opens up and creates immediate intimacy that makes me feel free to bring people around in the group to help me when I do not understand*.” like wrote Margherita, a teacher in training in a residential Course of the Gruppo di ricerca sulla pedagogia del cielo of the MCE.

3.1.3 Introduction of useful activities to expand the concept validity

The purpose of the didactic action is to expand the concepts range of validity rather than replace a previous concept with a new one or just add new concepts.

Introducing directly the astronomical horizon does not help to build this concept firmly, especially in relation to the movements of the stars and the directions of their rise and set. To observe the movements of the celestial bodies, we need a system of reference, so we have to give attention to the local horizon, in our local and topocentric vision (Lanciano, 1986). To better observe the 360° in all around, I suggest some gestures with its arm and hand well open, to take angular measurements and, then draw by each one a portion of the 360° of the horizon. Using the pictures together the learners “construct” a material reference system where they can mark what they observe, the rise, set and different positions, in the time, of the Sun and the Moon

So from the local horizon they can see, learners can expand the concept of horizon to the astronomical one which they only can imagine, to the astronomical horizon of every place on the Earth, to the lunar horizon and so on.

Also the vision of the Earth and his representation in our mind can evolve to include the model of the globe. But also, people that accept that the Earth is round, and is a sphere, with inhabitants all around, with a correct perception of the gravity, say in Italian language: from Rome "salgo a Milano" (I climb to Milano) or "scendo in Sicilia" (I go down to Sicily). The same in France: from Marseille they say "Je monte à Paris". In Latin languages the everyday speaking confuses *going up, going to the bottom, going down* with the *directions of the space North-South on a sphere,* like if… the Earth is plane like a map, a map on the wall of the classroom in a vertical position.

To help a vision of the Earth and their model we organize the International Globolocal Project that promote the instrument I named "**parallel globe**" (See: www.globolocal.net)
The «commercial» globe we buy, is equal in Alaska and in Argentina! In this globe always, the north hemisphere is on the top and a lot of adults forgotten why the axis is inclined and what does it represent. So, we suggest to put the globe, free from the axis, in a homothetic position with the Earth planet in space: in every point of the Earth that point will be on the top, and the axis North-South pointing to North and South. In this way the model began an instrument and placed at Sun light, it is possible to see where is day or night, where is Winter or Summer. Therefore, it respects the relativity of the point of view with his symbolic, geographical and cultural aspects. It is a challenge for the people of the North, the West and the rich and technological countries because they could be in a down-under position, if the globe is in Kenya or Argentina! The use of the parallel globe put in evidence that there is an implied, hidden, potentially dangerous power in a map!

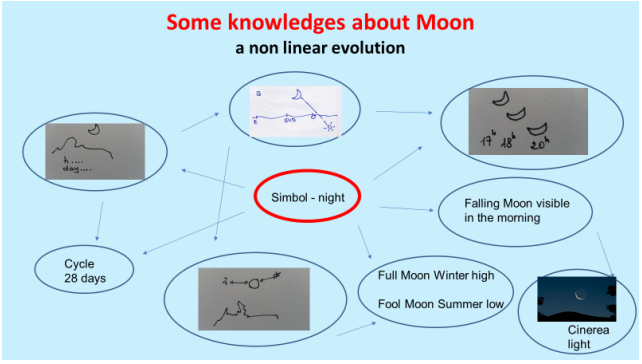
3.1.4 Analysis about the evolution of the conceptions

In Primary school we have recorded changing the way to describe the shadow phenomenon at Sun. The evolution of the conception is expressed in these sentences in successive periods:

- "In the early morning the Sun is low *and* the shadows are long, at noon the Sun is high *and* the shadows are short*"* (Descriptive expression)
- "In the morning the shadows are long *because* the Sun is low*"* "(Causal expressions)
- "*If* the Sun is low, the shadows are long" (Conditional expressions) (Di Ianni, 2012)

In every group of university's students, I teach, I record the evolution of the conceptions and knowledges about the observed Moon, with a non linear evolution (Figure 10) it means that one group discover before or after some aspects and it is difficult to programming exactly this path, because it depends from what we can observe in that period, if the sky is clear, and more. The group works through: the observations of the sky, models with their one bodies, discussions, drawings, new observations, observations of models (Figure 11), during 2 or 3 months.

Figure 10, 11



Very young children show symbolic abilities in recognize the representations and the pictures of the Moon. Furthermore children, at the beginning, ask "*How many moons are there?"* and "*Do people in every country see the same Moon today*?". Teachers must to help learners to continue to put questions and look for causal relationships.

The aspect of speed during the activity and of little time used for a study, gives us a didactical model, that in my investigation, I can define like very dangerous: a little time to think or to work in hurry are problematic aspects of western, virtual and testing school. Instead write Maffei, an Italian neurologist "*Apparently the network communication speed also affects the brain by moving it to rapid thinking, but it is the slow thinking that is the basis for reflection and responsible decision making. ".*

Conclusions

Teacher's training and researchers in education

In teaching the methods are often very similar to those of scientific divulgation which shows many arguments very quickly, without giving the time to reflect and to ask questions. For example, the strong use of the "virtual" reality that atrophies the body and his perception.

Among which languages, which sectors, such as communication registers, are we ready to adopt inter, multi and trans-disciplinary approaches? I think that we have to be very open, rich on experience, having different meetings with artists, artisans, decision makers, scientists, to be able to help students to develop and understood themselves and take responsibility in front of the world, in communication and in his social involvement. In my research I found that *examples* and not *words* are very important in people's formation and they are more stable in memory and become the example to imitate.
I think we need a lot of fantasy but to deal with issues that make sense.
Our horizon is the basis for recording the position of the stars, like I wrote before, also to collect and writing our memory and our tales related to the places (Figure 12) and also for "singing shapes", such as a musical score. We accept and we promote explicitly our bi-logic, in the sense of Matte-Blanco, to develop topics of a scientific nature as well.

Figure 12

Many researchers say that is very important to develop visuo-spatial thinking.: also to this goal we can attempt different way and languages: in a residential course we worked starting from a Caravaggio painting, projected in a big format on a room wall. People are invited to paint on the wall the projected image and pay attention especially to the light and shadows and colours. After the painting in 2D, people are invited to choose the characters of the painting and to place themselves in that positions, look for the clothes of the same colours, and arrange the lights to obtain the same effects. In this way we realized a 3 D transposition of the painting.

Openings

The Buddhist Monk Thich Nathan (1926 - Vietnam) speak about *inter-connectedness* and *inter-dependence* of people, of people and nature, of everything exist and is made. This vision removes the borders and helps to see behind a sheet of paper the tree, the Sun and the rain on the tree, and the cutter that has cut the tree ...
Karen Michelle Barad (1956), an American feminist theorist, introduce a neologism, *Intra-action*, and *signals an important challenge to individualist metaphysics.* For Barad, phenomena or objects do not precede their interaction, rather, object emerge through particular intra-actions.

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