D3.1 – Science Theatre - Guidelines

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Short Description:

Guidance for teachers engaging in Science & Theatre activities with their students. Examples of developed topics and activities are provided. Additional examples can be found in the CREAT-IT Implementation Scenarios.

List of Recipients:

Consortium members, public

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0. Plan of the guide

In Chapter 1 we describe the basic concepts and the CREAT-IT pedagogical framework. Along this guideline, in boxes, the reader can find the CREAT-IT pedagogical principles related to the proposed activities. In Chapters 2, 3 and 4 we describe the heart of the S&T practice as a guidance for teachers engaging in Science & Theatre activities with their students. Examples of developed topics and activities are provided. In Chapter 5 we connect the inquiry-based structure of S&T practice (and the CREAT-IT pedagogical Principles) to the Inquiry-based template proposed by the project COSMO. In Chapter 6 we describe some common points to the Science and Theatre processes that we consider relevant for understanding the flow of interactions of the S&T practice. In Chapters 7 we describe how to develop further the activities for realizing a show with the students. In Chapter 9 we describe how to collect the discussion, feedbacks, perspective and follow-up after the event. In the appendix we provide follow-up and evaluation tools for students and teachers. A Bibliography presents the main references.

Additional examples can be found in the CREAT-IT Implementation Scenarios.

The S&T practice is still in a experimental phase and can be improved. We would be greatful to you if you shared with us your experience!

1. Introduction & basic concepts

The "Science and Theater" (S&T) practice is oriented towards the search for innovative methods of dissemination of a creative scientific thought in school.

A large variety of different practices are called «Science Theatre»: theatrical shows, public experiments, show conferences. The first tracks are already seen in ancient greek tragedy and commedy, passing across Humanism, Barocco, Enlightenment, up to the XX century, from Eschilo to Brecht and Barrow[20][21][22][23]. Science theatre performaces take place in several places: theatres, science museums and schools. In science and theatre practice for schools, two kind of activities are recognized:

- shows for schools on scientific topics
- trainings which involve students in drama activities on a scientific theme.

Recently, many continuous and structured Science Theatre practices for Schools are tracked in Europe. Several national and european projects[1] have dealt, under different views, with Science Theatre for adults and for schools, in formal and informal contexts.

The CREAT-IT project aims at implementing creative strategies for science teaching. Science Theatre practice described in this guidelines has been the case study of the project. This practice is a training for shools not a show.

The S&T practice described below is an original practice created by FormaScienza on the basis of previous experiences which are listed in the bibliography. This practice, based on an inquiry and interdisciplinary approach, was developed in 2008, tested from 2010 to 2012 and implemented in 10 classes in a variety of Italian social and geographic contexts in the period 2012-2013 as a project of the Italian Ministry of Education, University and Research. This practice was case study of CREAT-IT project, where it has been further developped in the pedagogical framework of the project.

1.1 Science and Art

"Science does not interest me. It does not take into consideration dream, risk, laughter, feeling and the contradiction, precious things to me. " (Luis Buñuel, 1900-1983)

In common opinion there are tensions between creativity and science, as between art and science. In common opinion, science is related to rules, rigor, objectivity, lack of emotions and inexistence of contradictions. On the other hand, in common opinion, creativity is related with a lack of rules, lack of rigor, subjectivity, emotions and eligibility of contradiction.

[1] From ETS to Kid Inn Science.

Clearly, a scientific researcher reading the Buñuel's worlds would not agree. He/she knows that dreams, risk, feeling and mainly contradiction are essential features of science.

We could assume that Buñuel and a scientific researcher have different images of science and they refer to different feature of science and two different meanings of the word "science". ([16])

Is science the product of science (the theories) or the processes of science (the methods)?

Although the products of science (the theories) may have an icy light, this is not true for the *process* of science, in which scientists struggle with their feelings and rely on imagination to create a theory in order to go beyond the contradictions.

A scientist is creative when he/she *makes* science. The scientist has questions and looks for answers. He/she needs to:

A) invent hypotheses

B) invent and design an experiment

C) interpret data

Scientists work in groups so they will need dialogue and communal interpretation of data. They will also need to invent theoretical tools in order to find agreement and solve conflicts.

The scientist doesn't work alone. Rather, she/he works in a community: The interpretation of data and validation/falsification of scientific theories are elaborated together, and this process often involves changes of point of view and surprises.

Every scientist knows that there is no rule or definition for the large variety of processes or methods of science. The scientist builds her/his own scientific thinking, her/his scientific creativity, through the practice of research.

The process/practice of science is more similar to an art (or artisanship) process/practice.

In Italy, there were different approaches for teaching arts, humanities and science.

The approaches were dogmatic for science (by teaching the theories), historically for humanities while the pedagogy of art was oriented to develop personal expression and creativity.

When we teach the products (theory and concepts – sometimes procedures that someone else has thought out), students don't develop a mastery of the process and creativity. If there is no rule or definition for the large variety of situations, processes or methods of science, they can be learned only by practice. Like in art, there is only one way to teach/learn the process (or methods) of science and scientific creativity: to practice science, to engage in research!

To develop a learning activity that stimulates creativity in science we use the Inquiry based approach, in which we ask the student to *make* science, to make research, and compare the learning process with the learning process and the creation process in theatre practices.

Also, in the case of theater we can distinguish the product (the show) from the process (elaboration of the show).

As in the case of science, in this practice we are interested in the *process* of theater. In some modern dramas, the creation of the performance takes place during workshops, and is an original creation made by the actors, but with very strict rules. The same thing happened in "Commedia dell'Arte".

The present experience is based on the "dramaturgy of the actor" by Josè Sanchis Sinisterra, where the actors don't learn a written text by heart, but create their own dramaturgy.

The artistic creation process needs rules and training, much more than expected in common opinion. Both in science and in theatre we propose to create the rules.

1.2 What to expect from a S&T Practice?

In this guide, we describe a method that allows the teacher to develop creative scientific thinking.

Project activities engage researchers, teachers and students in an interdisciplinary training through which they conduct scientific research and then elaborate the scientific topic through a show, theatrical drama, story or video.

The S&T practice is divided into two parts led by two facilitators: the Scientific Part and the Drama Part. In the Scientific Part, we propose an inquiry-based training, based on the idea that creativity in science as well as knowledge and skills can be learned through the practices in agreement to the constructivist model. In the Drama Part, we propose a drama training, based on "dramaturgy of the actor", through which we can "think" about the process, identify its features (mainly the role of *conflicts* and *errors*), and transpose them metaphorically, thus improving the ability of finding relationships and analogies and the ability of elaborating models.

The focus isn't on the results (the show)[2]: The main focus is the process of elaborating scientific topics through drama. Through this process, the participant can develop skills (as learning to learn, to solve conflict, to validate the truth based on evidence), could develop creativity in science and art and recognize a common point of creative learning process in art and science[3].

[2] We need to underline that this S&T Practice is not a show. It is a methodology aimed at elaborating scientific contents through drama. This method can be used with actors to create professional performances and with students to elaborate contents. It can also be used to create performances with students, but this practice demands more time for longer projects.

[3] See CREAT-IT reports "CREAT-It Pedagogical Framework" and "Effective Creative Science Teacher Profile" (www.creatit-project.eu).

The S&T Guidelines do not represent a finite collection of exercises and ideas in the field of Science and Theater. Each school project is unique with regard to available time, equipment, experience, class size, age of pupils, etc. We therefore propose that practicioners use the S&T Guidelines as a "living document", adding their own ideas where appropriate, and leaving out some of the ideas presented here to fit their time schedule.

Furthermore, while the sections in the S&T Guidelines follow a recommended order, in some projects these sections may overlap, or may even be realized in a slightly different order to take advantage of opportunities (e.g. a visit to a science museum) or make way for limitations (e.g. lack of available practice space on a given day).

1.3 Specific Purposes

As CREAT-IT Case Study practice, the participative use of S&T Practice follow the CREAT-IT pedagogical principle.

Moreover, this specific ST practice encourages students to:

- understand "how science works"
- be creative and use imagination while approaching science
- contribute to an image of science as part of general culture
- learn to learn
- learn to solve conflicts

1.4 Educational approach

The FormaScienza practice introduces elements of drama pedagogy and drama training to improve science learning, in particular to treat the misconceptions in science education, to make students aware of the process of science and to develop scientific skills and creative scientific thinking.

I) IBSE approach is adopted for exploring curricular scientific topics.

Topics are introduced by **questions** and the students conduct research, going through the **scientific process**: formulating hypotesis and models of explanation on the phenomena, designing and realizing experiments, collecting and interperting data, discussing results and making conclusions and theories. In this approach, not only the curiosity of students is stimulated, improving the knowledge of the theory, but also the main aspects of the experimental method emerge through the experiences.

Inquiry-based approach helps to highligh "how science works" and to develop scientific skills. It is supposed that the students become able to:

- Explore the research procedures
- Perform research efforts that are taking place as a structured discovery within the frame of organized teaching.
- Design and conduct scientific investigations.
- Formulate and revise scientific explanations and models using logic and evidence
- Recognize and analyze alternative explanations and models.

II) The approach proposes drama activities.

Drama activities allow to reflect on:

- the scientific procedure and theory by transposing in metaphor;
- the achievement of scientific thought as a common cultural heritage, historical perspective;
- the social structure of scientific knowledge.

In some modern dramas, the creation of the performance takes place during workshops, and is an original creation made by the actors, but with very strict rules. The present experience is based, among other similar experiences, on the "Dramaturgy of the actor" by Josè Sanchis Sinisterra and on "Paper Canoe" by Eugenio Barba, where the actors don't learn a written text by heart, but create their own dramaturgy.

Specific techniques are proposed for

- facilitating discussion (forum theatre, mantle of scientist, talking stick);
- developing skills of analysis of a scientific model and treating misconceptions in science (game model);
- becoming aware of processes of science (game model and storytelling);
- learning to learn and to move knowledges and skills across different contexts (storytelling).

Drama activities link emotions to the scientific experience and this may trigger and increase interest in Science in the students.

Both in science and drama activities the students interact (e.g. by working in pairs and in groups) and develop **social and collaboration skills**.

3) As CREAT-IT Case Study practice, the S&T Practice follows the CREAT-IT pedagogical principles (see below)

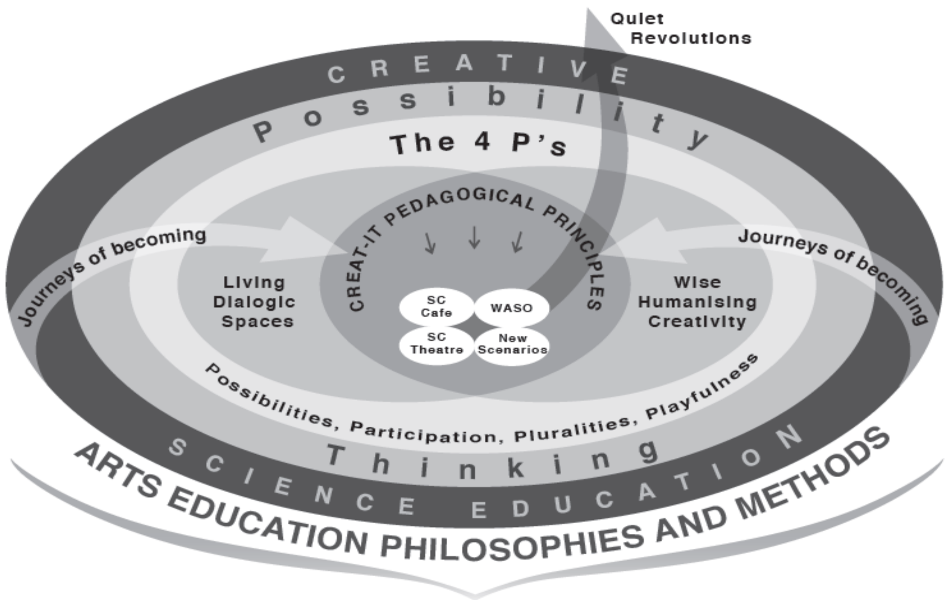
1.5 CREAT-IT Pedagogical Pronciples

The CREAT-IT pedagogical framework developed by Exeter University recognizes 8 pedagogical principles. These are presented below (in no particular order). The Principles are elaborated further in the framework, which may be accessed at www.creatit-project.eu.

"Professional wisdom" is seen as an element which is respected and encouraged across CREAT-IT: it is vital that Science Theatre, an each CREAT-IT practice, has at its heart the wealth of teaching and discipline knowledge and expertise that practitioners bring to the project. This is a deeply contextualized knowledge often informed by intuition, which needs to be in constant conversation with CREAT-IT ideas and theories. This element connects to the survey finding that a creative science teacher is constantly developing and pupil focused: it can be argued that this interrelated development and pupil focus are based in a process informed by professional wisdom.

The CREAT-IT Pedagogical Principles:

1. **Individual, collaborative and communal activities for change**
2. **Risk, immersion and play**
3. **Dialogue**
4. **Interrelationship of different ways of thinking and knowing**
5. **Discipline knowledge**
6. **Possibilities**
7. **Ethics and trusteeship**
8. **Empowerment and agency**



Narrative and visualisation of ideas and practices synthesised within the CREAT-IT pedagogical framework

Throughout these Guidelines, the provided highlighted boxes provide contexts for the principles related to the described activities.

9. **Individual, collaborative and communal activities for change**: practice within CREAT-IT can allow for all three ways of engaging in activities, and particularly in relation to communal engagement can take advantage of the shared identities within which participants will work, allowing for difference but with a shared creative process and purpose. The survey showed collaboration

to be a key characteristic of creative science teaching as well as individual and communal learning as a key strategy, thus reinforcing this principle.

10. **Risk, immersion and play**: CREAT-IT practice can facilitate all three processes across learning and recognizes how pedagogy can assist in creating literal space as well as 'thinking' space for these to occur. This principle is also reinforced by the survey findings, which show risk as being perceived as important to the creative teaching process, and by inference to the resulting learning.

11. **Dialogue**: practice can allow for dialogues between people, disciplines, creativity and identity, and ideas. This dialogue needs to acknowledge embodiment (i.e. dialogue is not simply a verbal activity) and difference and allow for conflict and irreconcilable difference. It is important to facilitate open discussion of the questions generated by pupils (bottom up) and bring these into dialogue with live questions from professional science and science education (top down).

12. **Interrelationship of different ways of thinking and knowing**: CREAT-IT practice can allow space for multiple different ways of thinking (e.g. problem-finding, problem-solving, exploring, rationalizing, reasoning, reflecting, questioning, experimenting) focused around shared arts/science threads or throughlines. At the arts/science interface it can also offer the space for three different ways of knowing (knowing that - propositional knowledge, knowing how - practical knowledge, knowing this - aesthetic or felt knowledge), as well as acknowledging the embodied alongside the verbal.

13. **Discipline knowledge**: CREAT-IT practice understands the importance of allowing space for the rigorous discipline knowledge of both science and art, as well as understanding the importance of materials relevant to those disciplines (e.g. their bodies, with props, with paper and pencil, with sculpting materials, with Bunsen burners and test tubes, with chemicals, with equations). Practice also acknowledges that creativity might interact with these disciplinary knowledge bases differently, albeit in the context of science education.

14. **Possibilities**: – CREAT-IT practice can allow for multiple possibilities both in terms of thinking and spaces, and know when it is appropriate to narrow or broaden these.

15. **Ethics and trusteeship**: CREAT-IT adult professionals and learners consider

the ethics of their creative science processes and products and are guided in their decision-making by what matters to them as a community, acting as 'trustees' of that decision-making and its outcomes.

16. **Empowerment and agency**: through empowering pedagogies, CREAT-IT can allow both learners and adult professionals to gain a greater sense of their own agency and ability to express themselves, and to then know what to do in order to be more creative scientists and to develop more creative science teaching techniques. Enabling pupil agency and encouraging children to try out (and critique) their own ideas in investigations were also key factors that emerged from the survey, thus emphasizing the importance of this principle.

Along the guidelines, boxes help to focalize the principles related to the described activities.

2. How Does the S&T Practice Work?

The following Professional Development workshop provides **late Primary and Secondary** teachers with knowledge and insight needed to realize from 2-3 day long up to longer period projects (several months within the school period) T&S "Introductory Workshop" with their pupils. If needed, the school projects may be extended (see above).

Specific Implementation Scenarios, in which scientific themes and explorations exemplify the process, are provided in additional documents (see the CREAT-IT Implementation Scenarios). Samples of materials produced during the realization of such projects in schools (see the CREAT-IT Samples).

The S&T practice is made of two parts: scientific and drama parts.

The scientific part adopts an inquiry-based methodology. The first thing we need is a **toy**, simple phenomenon that hides surprises or objects with which to play the game of science. [section 3.1] The inquiry starts from a **question** on the toy. [section 3.2] After observation comes the trigger of **scientific process** and the students take on the role of scientists by formulating hypothesis, creating experiments, interpreting data for finding the rules of functioning, developing scientific theories about the toy/phenomenon under inquiry. [section 3.3]

In the drama part, after warm-up exercises [section 4.1], we ask the students to develop **game models**, expanded ways to reproduce or to show the functioning of the "toy". The game should include the toy and rules in the sense that it must show the way the toy works and/or its applications. The game-model can be a theatrical game, for example through the built embodiment, or another phenomenon that functions as the toy model or a complex system (e.g. creation of objects or further models or finding analogies in the real world). Creating a game presents the opportunity to explore and discuss both the theories (the contents of science) and the scientific process behind the toy. It creates a physical memory, emotions and feelings. The game is also preparatory to the construction of a story. [section 4.2]

In the last session of the S&T project we ask the participants to create a **story** that has as its main ingredient the scientific process. In this practice, as in T. Khun's view [6], in the scientific process we will always find a conflict ([3]), and that same conflict will be the base of our story. The story is needed to rework the experience gaining awareness and promoting the scientific process storage. [section 4.3]

There are common elements in the scientific process and the structure of stories: conflict and metaphor [chapter 5]

Allowing space in the process for the rigour of their *Discipline Knowledge (5)* is vital to S & T. The relevance of the *Individual, Collaborative and Communal* (*1*) (ICC) layers of the CREAT-IT principles also resonates strongly within S & T projects as the notion of ICC is derived from understanding creativity in performing arts contexts (Chappell et al, 2011) where a 'group' or 'company' forms for a short time and provides a safe almost family-like space in which participants can create and learn. Again with drama at its heart, this is key to the S & T approach. There also seems to be great potential for *Risk, Immersion and Play (2)* within S & T projects because of the focus on the more playful, and at times risky, aspects of the drama process, as well as the fact that the pupils' own hypotheses are being investigated. The combination of a science question, inspired by student and teacher curiosity, and this kind of drama process then seems to allow for the *Interrelationship of different ways of thinking and knowing (4)*. These can include ways of thinking (problem-finding, problem-solving, exploring, rationalizing, reasoning, reflecting, questioning, experimenting) that perhaps manifest in different ways in sciences and arts processes, but combine together in an S & T interdisciplinary project in order to understand the scientific question or model in hand. *Ethics and Trusteeship (7)* is also highlighted

3. Scientific Part

The scientific part could last for 2 hours or longer, including spanning over several days. This depends on the topic, on the question, on the age of the students and on the needs of the teacher.

This session is an Inquiry-Based Science Education (IBSE) activity

It is important for ideas, knowledge and practices that emerge from 'bottom up' activity to be given space in an environment where often 'top down' can dominate unnecessarily. During the whole scientific part there will especially be *Individual, Collaborative and Communal activity for change (1)* and *Dialogue (3).*

3.1 The toy-object

The first thing we need to define is the object of inquiring. It should be a simple phenomenon that hides within it surprises. We will refer to this object as a "***toy***", to underline that it has to allow the students to play the game of science.

Nothing complicated (this can be a bowl of water and a scale, a candle and a white ball, or a pendulum) but most importantly, an object providing something "real" we can play with.

3.2 The question

Everything begins with a question. The scientific tutor finds a good question. The questions can also come from the students but it is suggested to start from students' questions when teachers and students are more confident with the practice. Framing a good question is a creative task for scientists/pupils and in different ways for teachers.

3.2.1.1 What is a good question?

A question is a good one scientifically when it generates an answer that we can check (true or false) via experiments. For the teacher, a question is a "good" question if it is a question that leads to a scientific question as well as to the production of a *conflict* in the class.

A question will produce a conflict, for example, because it permits more than one answer or because the answer is obvious, simple and…wrong! By making mistakes the students are still learning. In this way we may create a vibrant discussion and/or surprise.

3.2.1.2 Example – The Pendulum

Here an example of toy and good questions to introduce the period of the pendulum.

The object of investigation is the pendulum itself. You can use poor materials, a thread and a plasticine ball. After an observation of the motion of the pendulum, we could ask the students to define the features of the motion (is it periodic or not?).

Then we ask the question: " What makes the time of one oscillation of a pendulum change?"

3.2.1.3 Other examples

Other examples of good questions are

- "Could you convince an ancient Egyptian that the Earth is a globe?"
- "What does an inhabitant of the Moon see in the sky when he/she/it looks towards the Earth?"
- "What distinguishes natural from artificial?" or "Alive from not alive?".

3.3 The process of science

3.3.1 The hypotheses

Let us stimulate the students/scientists to make hypotheses. These hypotheses are in conflict (if a good question has been framed!) The teacher makes each student declare and motivate their own idea, to allow the cognitive models to come out.

Pupils have to take risks (*Risk, Immersion and Play – 2)* and speak in front of the classroom and say what they think. Here many possibilities (*Possibilities – 6)* are created and many ways of thinking (*Interrelationship of Different Ways of Thinking –4)* are confronted.

3.3.1.1 Example – The Pendulum

The teacher stimulates the pupils to propose hypothesis on what creates variation. Different hypothesis come out

- Length of the thread
- Weight (or mass) of the pendulum,
- Height from which it falls
- Amplitude (or Angle between the thread and the vertical line)
- Shape of the weight of the pendulum
- The mean in which the pendulum moves

The teacher underlines the conflicts: does the time of oscillation increase or decrease in function of the mass? Or is it a constant function? All the students explicit their opinion. There will probably be all three these opinions. The opinion that the mass (or the weight) affects the oscillation time is a frequent misconception

Some other questions could point out misconceptions or critical points: Are the mass and the weight the same physical quantity?

3.3.2 Experiments

The facilitator suggests to the student to design an experiment to solve the conflict between the possible answers! If we have posed a good scientific question and we guided the students to elaborate scientific hypothesis, the pupils/scientists will be able to think of, design and build an experiment for falsifying or confirming the hypotheses.

It is crucial to stimulate the students to declare what they expect as possible results before the measurement, and to declare what will be the conclusion in every possible resulting case (when we will be able to say that the hypothesis is right and when we will have to say that it is false). It might happen that the students have to precise the hypothesis in order to make them discriminable trough the experiments.

We suggest to use poor materials such as clay, strings, water, or fire to carry out these experiments.

Here the importance of *Risk Immersion and Play (2)* is focused on as students have to put forward their experiment ideas, as well as the need for acknowledging the importance of materials such as clay, strings, water, fire as these experiments are carried out *(Discipline knowledge - 11).*

3.3.2.1 Example – The Pendulum

An experiment can be, for example, building a pendulum and measuring the time of oscillation with different weights or other variables. The students are divided in groups and each group checks one variable. The experience is simple but some relevant question will come out. Are there some errors in the measurement? What kind of errors? What can we do to avoid these errors? Is one measurement enough to understand if the time of one oscillation is increasing by increasing the length of thread (or the mass, or the angle)? Or do we need to repeat the measurement? How can we collect and represent data?

3.3.3 The interpretation of data

Then students/ scientists have to interpret the **data** and decide if the hypotheses are confirmed or not.

As in the scientific communities, the results of the experiments are not always clearly “evident”, there could be different interpretations and the scientific community has to find an agreement. The process could last for years. In the S&T approach, the pupils act as a scientific community, but suitable scientific problems are used and the process lasts for only a few hours.

To interpret the data and to critique the hypotheses will create an interrelationship of different ways of thinking around a shared 'thread' or 'throughline' *(Interrelationship of different ways of thinking and knowing- 4)* using *Discipline Knowledge (5)* via the *Dialogue (3).*

3.3.3.1 Example – The Pendulum

By observing tables and/or graphics we could deduce that the time of oscillation of the pendulum clearly increases by increasing the length of the thread. Otherwise for the variation of the mass, the pupils who think that the time of oscillation increases with the mass could find some dependence even if it is not so clear. If different groups work on the same "critic" variable and have different elected hypothesis, these groups could disagree, could show some data that make the opposite dependence. The influence of the mass is not so clear. The groups with the help of the teachers could develop tools to elaborate the data and to keep into account the error (maximum or statistical error). At the end the group has to deduce that the times of oscillation found with different masses are compatible and that there isn't influence of the mass on this time, at least in the limit of experimental error. The same will happen for example with the amplitude of the oscillations or the shape of the pendulum.

3.3.4 Theories

The hypothesis that the group confirms becomes a Thesis and becomes part of the knowledge of the group.

The confirmed hypothesis and models become the theory of the class.

Some question could remain unanswered and/or other question could be opened during the process and the process could be start again.

If it is the case, at the beginning or at the end of the process, it could motivate the students to know that some famous scientist has elaborated the same theory (for example Archimedes in example 1, Galileo in example 2, Kepler in example 3).

Conflicts could be solved via the *Dialogue (3)* This improves the *Discipline Knowledge (5).*

3.3.4.1 Example – The Pendulum

The students could conclude that the time of oscillation of the pendulum depends only on the length of the thread. If we are working in secondary schools we could develop also an experimental rule for the period of the pendulum and find the constant.

We could also ask the students to find the suitable length to have the time of oscillation equal to 1 second.

3.4 How to guide/facilitate the process

"Science is anything that is always open to discussion" (Ortega y Gasset)

3.4.1 The discussion

Within the dialogue, the conflict between hypotheses, as in the scientific community, makes surely the control efficient: The students, who defend their own hypotheses, are able to detect mistakes in the experimental procedure that some classmates are using to confirm their own opposite hypothesis. The conflict motivates the students to find theoretical and practical tools, e.g. statistical tools, to avoid the errors and to force the experiments to give the answers and eliminate the wrong hypothesis.

3.4.2 The role of facilitator

It could help the teacher/facilitator to think that s/he is a master of research. S/he has to seem like someone who doesn't know the laws of the phenomena, and who, like the students, is discovering the phenomena for the first time. The difference between the student and the master of research is in the experience of the game of research more than in the knowledge of the contents.

Guiding the discussion is a critical task for the facilitator. S/he has to:

- ask questions
- encourage the student to formulate hypotheses (the experiment has to follow the hypotheses)
- encourage the student to defend the ideas (explaining why)
- create factions (and to ensure the students take a stand)
- to feed the discussion emphasizing the points of conflict
- to listen and to ensure the students listen to each other
- do not give the answers, these are expected to emerge from the discussion
- do not correct the misconceptions (until the end)

The facilitator has to highlight that the "error" is considered good: It is a way to discover new things and to improve the model.

It is important for ideas, knowledge and practices that emerge from 'bottom up' activity to be given space in an environment where often 'top down' can dominate unnecessarily. During the whole scientific part there will especially be *Individual, Collaborative and Communal activity for change (1)* and *Dialogue (3).* The whole process has at its heart in the Professional wisdom.

4. Drama Part

4.1 Warm-ups

Warm-ups provide physical motion (stretching, running, breathing exercises, etc.), musical exercises (rhythm\pulse exercises), vocal training, creative exploration, as well as positive social exchange and group dynamic.

Sessions should begin with a warm-up, regardless of the session's length.

In the list below, some basic exercises are provided. In addition, teachers of physical education, drama, music and dance in your school will usually be able to add their own repertory of exercises..

4.1.1 Big fish small fish

This is a fundamental exercise for the T&S practice.

It shows that not only errors are important but are what games (and scientific research) are made of

1) the whole group is standing in a circle. The facilitator tells the rules. When one says small fish hands must be put a part far away (as miming a big fish) and when one says big fish hands must be put near. You can give a go at it.
2) The group splits in two circles, when someone tells the wrong word or does the wrong gesture he/she is movs to the other circle.

At the end we ask the participant what they think the features and the meanings of the exercise are.

Someone will answer about the role of mistakes: **We must make mistakes to have the game go!** No punishment, no exclusion: just a demonstration that the game is better, and more fun more errors there are.

Many other answers can come out. Each answer has to be accepted and adds meaning to the game.

4.1.2 Breathing Exercises- The balloon

Pupils work in pairs. One is lying on the floor (A) the other one is standing (B). The one standing (B) pretends she/he has a pipe, pretends to put it on the other's mouth, and starts to pretend to inflate the one on the floor moving her/his leg like a pump. The pupil who is lying inflates his/her belly and then stars to move like a balloon, first standing and then moving in the room. After a little time (10 seconds) the student A pretends she/he takes the tube off and student B deflates and goes back to the ground.

4.1.3 Moving and counting games

All pupils are asked to walk in the room. The the facilitator starts giving numbers. Let's define speed 5. Speed 5 is when you are going to school and you are not late. Speed 5 can be different from person to person.

Then we define speed 11. It is running, this means that at some point no foot is touching the ground. We define speed 0, it is when we are staying still. Then we can start playing with numbers. At first the facilitator says out the numbers of different speeds and then a pupil can take this role.

When we have a measurement system we can start playing with other measures through fantasy.

We can work on weight. We can ask the pupils to move with weight 1 (like the balloon exercise), or weight 10 could be lead. We can work on lengths. We can ask pupils to become very high or small.

With this exercise students become used to measurements and physical units.

We can now ask students to move as if they were on the moon, in water, in mud or anything they choose, playing with different surfaces and densities.

Students through this game will get in touch with the concept of density.

4.2 The Game Model

We ask the students to develop a "game model", i.e. a game that "works like the scientific model". The game model is an expanded way to reproduce or to show the functioning of the "toy", that is the object under inquiry, and the theory elaborated during the scientific part of the practice.

Here the students have to invent, find materials and metaphors. Following the Mimic Method, they can use their body and imagination to create something that "works like the scintific model". They can create an embodiment of a physical rule, a physical exercise for the laws of genetics or for the movement of planets and stars.

We can also ask the student to find analogies with other phenomena that work with the same rules, for example in every-day life.

All the students work on the same problem. Students could work individually, in pairs, in groups or collectively (see the examples below)

When the students invent a game that "works like the scientific model", they should identify the elements (variables) and the relation between the element (laws).

In game models, we allow for "mistakes" or "errors": this is a way to discover new things and to put out misconceptions. The students are encouraged to improve their game model to make it conform as much as possible with the scientific model. The game model will be improved via trial and error and via subsequential approximations. Game models are discussed phase after phase until the best possible grip on the studied phenomenon is achieved. By changing or improving the drama metaphor, there is an improvement in the understanding of the phenomena and models from a scientific point of view. By allowing the mistakes and working on misconceptions, the students replace their naïve model with the scientific one.

The students explore different ways of thinking around a shared 'thread' or 'throughline', as in the pedagogical principle *Interrelationship of different ways of thinking and knowing (4).* Here metaphor, as a kind of poetic thinking material, connects to the CREAT-IT pedagogical principle of the *Discipline knowledge (5)*

4.2.1.1 Example – The Pendulum

We ask the students to look for pendulum in their bodies. How many pendulum could you find?

At the beginning students work in pairs, one look for the pendulum in the other's body. Then they form groups of 3 students: One student (A) stay in the center, closing his/her eyes. The other two (B and C) push and pull A carefully, taking care that the feet of A remain on the floor and giving to his/her body an oscillator motion like a pendulum. Then we ask thi groups to stay in line and the whole class works like a single pendulum and must find a rhythm.

The scientific knowledge needed is given in the first part of the practice, described above.

4.2.1.2 Other examples of Game model

Example – Evolution

We can ask the students to create a "danced model" of genetics in which they try to find a rule such that the information passes from one generation to the other. All students work together, as a "population", to build with their bodies a possible model of evolution.

The students decide to copy each others' movement. Students all start making the same movement, let's say moving an arm up and down. How does evolution work? How does "change" get in the model? By chance, one student will introduce an other movement, let's say moving an arm from one side to an other. When someone introduces a change the others will all change by copying the new movement. And so on. We ask students if there were mistakes in this game. They recognize that this model is linear, because in the game the changes involve all individuals, while, in the scientific model of evolution, the changes involve only some individuals and at the same time we have mutate individuals and non-mutate ones. This is true also for the species. The students modify their game model to represent the complexity of the evolution model. They decide that, when someone introduces the change, each one of them can take this new movement or not: At some time we will have many different movements simultaneously. This is an embodied model of evolution.

Example- Astronomy

A game models can be the creation of an astronomic clock using the students' bodies, moving in the room like the planets. A student could be the Earth and could stand in the center while the moon and sun are external and move around. Students have to recreate the movement to reproduce the night and day alternation. This could be made with the Earth and Solar System but also with other planets in the center, to create the clock of that extraterrestrial planet.

4.3 The Story

Students create a plot with characters and then decide how to perform it. They choose their space and if or not they want costumes, scenery and props. Attention to timing must always be careful.

Students work in groups of 3 or 4. Each group should have equal opportunities, girls and boys should be mixed. Things have to be kept short and simple (max 5-10 minutes for every work), no longer that 30 minutes preparation and 30 minutes rehearsing. There must be enough time for seeing everybody's work and for comments.

The game is preparatory to the construction of a story. Creating a game helps to understand the content of the scientific process, it creates a physical memory and emotions and feelings. All this can then be put, as an elaboration, in the creation of a story that has as its main ingredient the scientific process.

In the scientific process we will find conflicts, and these conflicts will be the base of our story. Conflicts can be found both in the history of science and in the experience of the students in the class during the scientific part. Mistakes and misconceptions solved during the process, different hypothesis, different points of view in the design and realization of experiments, can be seen as conflicts. Students are encouraged to search for the conflicts that they have experienced in the scientific phase and to analyze them.

The teacher could ask: Are the problems that materialized similar to ones scientists have dealt with during the history of science? Can we see the life of different scientists and, for example, create a script from the life of that scientist? If the problem of the experiment has been, e.g. the measurement of time, can pupils relate to when we they have had problems with the measurement of time? or weight? or mass? Can we put the process itself in metaphor?

The story is needed to rework the experience and thus gaining awareness and promoting the scientific process storage.

With this work students elaborate scientific concepts through their own imagination so the process becomes personal and part of their own experience. Also an emotional attachment to those contents is created. students will remember better and longer subjects they have shaped with their own hands and fantasy.

The creation of the story allow for multiple possibilities both in terms of thinking and spaces, as in the CREAT-it pedagogical principle *Possibilities (6)* There is a strong theoretical connection here to the 3th CREAT-IT Pedagogical Principle, *Dialogue*, as well as to some of the background Exeter theory which posits the importance of narrative as a key driver or context for the process of Possibility Thinking per se (Cremin et al, 2012)

4.3.1.1 Example – The Pendulum and the Story of Laura Bassi

We connect the experience of the process of science with the history of science. In this example, the students have worked on the pendulum. The physicist Laura Bassi has been chosen because she was the first woman who implemented experiment based research. She was Italian, lived in Bologna (1711-1778) . Scientists from all over Europe came and visited her. She created her lab in her own home. The students have just experienced a process of discovery during the scientific part. Now they compare their processes of discovery with those experienced by famous scientist.

If the curriculum allows connections with the history of science, stress can be put on Laura Bassi's difficulties and her every day life. She has had seven children. Scientists are not aliens they have a life like everybody else. The students can image links between their emotions with those of this scientist. The teacher can also relate to gender issues.

Students split in groups and create a story or a script.

They the have to create a story-plot with a conflict. Conflict is the base of drama.

They need to:

a) relate their experience to the life of Laura Bassi

b) create a metaphor of their own experience. Then can create whatever story in which, for example, the length of a string makes the difference. They use data and experience and they create an original plot.

c) use the conflicts of the discussion or errors or difficulties they have found themselves for telling the story of famous scientists of the past (they so understand that the scientists are human, make mistakes, they can play that role and so also in real life maybe they could become a famous scientist)

E.g. The city of Bologna is under attack. To save the city the citizens should organize a counterattack but they need to build and to sincronize many clocks. They can use a pendulum but they need to build these pendulums. They have only stones of different weight. Laura Bassi should convince the others that the weight is not relevant...

5. Common points in Science and Theatre processes

This methodology is based on many iterations, discoveries and integration of knowledge. It can be modulated, widened and enriched. Feel free to feed this approach with your own propositions, practices and reflections, so that your group can appropriate the project.

5.1 Conflict

As the S & T approach shifts into its second part, there is a particular acknowledgement of how the scientific process is quite similar to the dramatic arc, or progress of a narrative through a climax within a drama. Both the drama and science process are moved by a ***conflict*** drives a narrative.

The second part of the S & T workshop encourages students to use the conflict in the science process as a starting point for an original drama plot. Students are asked to transpose the scientific conflict into a metaphor, taking advantage of the fact that metaphor plays a role within science too.

There is a strong theoretical connection here to the 3th CREAT-IT Pedagogical Principle, *Dialogue*, as well as to some of the background Exeter theory which posits the importance of narrative as a key driver or context for the process of Possibility Thinking per se (Cremin et al, 2012), related to the 6th CREAT-IT Pedagogical Principle *Possibilities*.

5.2 Metaphor/Model

The **metaphor** is useful in understanding a phenomenon; moreover, there is a relation between metaphor and scientific models. In some cases, a metaphor is also the first step for a scientific model. Scientists can imagine different models at the same time, or work to understand which one is right. For example in astronomy, quite different models are used to understand what can be seen in the sky: Ptolemaic, Copernican, Keplerian or perturbation models. The elementary particles can be described both as particle and as waves: These are two different models/metaphors. Here metaphor has the characteristics of poetic thinking material.

Of course model exist which are not preceeded by methaphor or for which metaphor doesn’t exist (i.e. Quantum Mechanics). Nevertheless we can see also the mathematical model as a mathematical metaphor of nature.

Clearly there are some differences between the use of metaphor in the sciences and the arts. In particular, the sciences’ metaphors/models have to give “predictions”: Through the model, we must be able to calculate the value of the relevant variables in function of certain conditions or parameters. A kinematic model is an system of equations through which we can calculate and predict the position of a physical body in function of the time, e.g. an astronomic model predicts the position in the sky of a planet. This adds knowledge. Of course, also a metaphor can add knowledge: through methaphors you can discover new characteristics of a phenomenon or you can see the phenomenon under new points of view. Nevertheless, the capacity to give predictions is a crucial feature that discriminates scientific models and non-scientific ones, because if the model can produce predictions we can test the model through an experiment. If the prediction is falsified the model will be refused (or «adjusted»). Moreover, in science, models are presented, argued for and defended; they have to be validated by the community. Validated models can be overcome and replaced by new models if the new ones give more detailed predictions. In the arts it works in a different way; it is not necessary to build an argument in the same way and the metaphor don't have to give testable predictions.

Students develop the drama metaphor, having to link that with the scientific model. By changing or improving the drama metaphor, there is an improvement in the understanding of the phenomena and models from a scientific point of view.

The explicit use of metaphor relates back to the CREAT-IT Pedagogical Principle of honouring *Interrelationship of different ways of thinking and knowing (4)*

Stepping back to wider University of Exeter theory, the idea that every student can come up with their own metaphor, connects to the idea of 'little c creativity' (Craft, 2001), which underpins the notion of Possibility Thinking (CREAT-IT Pedagogical Principle *6 – Possibilities*). The creativity is needed to invent the model; it is in the science itself. This relates to the CREAT-IT Pedagogical Principle of *Empowerment and Agency (12).* Creativity is then used again to elaborate the metaphor through drama, so there is a balancing act and a flow from creativity in the first part of the process through to the second. With the development of the drama metaphor to aid in understanding the science there is then a sense of flow from the drama back to the science.

5.3 Errors

An other common point is about the role of errors/mistakes.

In science the errors are undeletable. Of course there is no measurement without error.

But there is an other kind of "error".

To make science we have to formulate many hypothesis. When we make a hypothesis we don't know if it's true or false: We need an experiment to decide. When a hypothesis is false the students who formulate the hypothesis could be feel this as a mistake. This especially happens for the girls. It's a very critical point to leave the judgment and to see the error like something good. We must make mistakes to have the game go!

In modern dramaturgy was pointed of the role of the error, like a way to discover new possibilities of expression.

As in drama exercise "Big fish small fish", no punishment, no exclusion should be: the game is better, and more fun more errors there are.

This detailing above of the two parts of the S & T approach – scientific hypothesis generating and defending and then transposing this into the drama process - demonstrates one final important CREAT-IT Pedagogical Principle that of *Interrelationship of different ways of thinking and knowing (4)*. S & T has the potential to facilitate 'knowing that' (propositional knowledge or facts – e.g. the elements in the periodic table), 'knowing how' (practical knowledge or how to – e.g. how to physically carry out an experiment using a Bunsen burner) and 'knowing this' (aesthetic or felt knowledge – e.g. how to create a strong drama piece that has involved aesthetically judging how to represent ideas in a powerful way) (Reid, 1981).

6. An Inquiry-based Exercise

The CREAT-IT activities are conceptualized as Inquiry-Based Science Education (IBSE) activities. This is structured around five IBSE phases using a specific 5-phase template which was developed during the the Cosmos project (2008) in order to facilitate teachers:

Phase 1: Question Eliciting Activities/Exhibit Curiosity
Phase 2: Active Investigation
Phase 3: Creation
Phase 4: Discussion
Phase 5: Reflection

The following S&T activities are based on an understanding of IBSE, including both teachers' and pupils' inquiry processes, as described in the CREAT-IT Pedagogical Framework (see "Recommended Literature" for further details).

6.1 IBSE phases in detail

In the following 5 phases, both scientific and drama activities are detailed, exemplifying their inter-relatedness in the S&T Case Study.

Scientific learning activities

Phase 1 Question Eliciting Activities/Exhibit Curiosity

The teacher chooses a topic from the curriculum and stimulates curiosity and questions from the students. This may be done showing materials or a simple phenomenon, which will be the object of inquiry (see the section "toy" in appendix 3)

Phase 2 Active Investigation

Students conduct investigation on the presented phenomenon.

- Hypothesis: Discussion may lead to different hypotheses. E.g. in the case of the pendulum, students formulate hypotheses on a variable that could influence the time of oscillation, such as the length of the string, the pendulum's weight, the force put in the oscillation, etc.
- Designing experiments: The teacher stimulates the debate and suggests designing an experiment to solve the conflicts. Who is right? Why? How can we demonstrate it?

Phase 3 Creation

In the case of experiments, students must realize the experiment in order to falsify or confirm the hypothesis. It is a hand-on opportunity to learn. They must invent the instruments for testing their hypothesis. They must find strategies for measurements and collect and present data

Phase 4 Discussion

Students have to interpret data and decide if the hypotheses are confirmed or not.

Phase 5 Reflection

Reflections and feedbacks. The students evaluate the hypothesis. The verified hypothesis become thesis and theory. Other questions could be discussed during the process. If this is the case, the cycle could restart, inspiring further creative learning.

After the process has been completed, it is important to write reports of what has been done and experienced.

Potential Arts Activities

Phase 1 Question Eleciting Activities/Exhibit Curiosity

The teacher may ask the students to elaborate scientific theories, models found in the scientific exploration through drama. (e.g. asking the students: How can we find a game that can be used as a metaphor for the hypothesis above?)

Phase 2 active investigation

Students explore the scientific contents through drama activities. Here they have to invent, find materials, and metaphors. The students may also develop "**game models"**, expanded ways of reproducing or showing the functioning of the scientific model. They can use their bodies and imaginations to create something that "works like..". They can create an embodiment of a physical rule, a physical exercise for the laws of genetics or for the movement of planets and stars.

Phase 3 Creation.

The students elaborate a story or a drama on the topic. Other requests could be added, e.g. connecting their experience to the life and research of a famous figure in the history of science. Characters are chosen and the students assume theatre roles. Costumes and scene are also developed.

Phase 4 Discussion

The whole process is discussed among teachers and students. The questions evolve around what students have appreciated but also what they would change in such a process should it be repeated. It is shown that conflict is a way of learning and trying to do better, not something that must be avoided at all costs.

Phase 5 Reflection

Reflections and feedbacks. After the work it is important to write reports of what has been done and experienced. It will settle and can be open to changes.

In the following table, specific S&T activities are based on the IBSE, including both teachers' and pupils' inquiry processes, based on the CREAT-IT Pedagogical Framework (see "Recommended Literature" for further details).

<table>
<tr><th colspan="3">Case Study Approach: Science Theatre</th></tr>
<tr><td colspan="2">Science unit topic
Pendulum
Class information
Year Group: Early secondary schools
Age range: 11-12
Sex: mixed
Ability: mixed</td><td>Materials and Resources
What do you need? poor materials: thread and plasticine balls.
Where will the learning take place? On site or off site? In several spaces ?(e.g.science laboratory, drama space etc), or one? Science Lab and Drama Classroom
Health and Safety implications?
Technology?
Teacher support? (e.g team teaching with arts and science expertise)</td></tr>
<tr><td colspan="3">Prior knowledge
Pupils were taught:
How to draw a cartesian graphic
Direct and inverse variation
What do pupils know and understand of the science topic?
What relevant arts skills and knowledge do they have?</td></tr>
<tr><td colspan="3">Individual session project objectives (What do you want pupils to know and understand by the end of the lesson?)
Session 1: Identify variable in the pendulum, define direct and inverse variation.
Session 2: Test hypothesis and recognize direct and inverse variation through graphics,
Session 3: Understand that the mass do not influence the oscillation of the pendulum and the time for the free fall of the physical bodies</td></tr>
<tr><td>Assessment
Students write final reports in which the scientific process is described. A scientific paper format is recommended. This report can be object of assessment while it is recommended to avoid any judgment during the process. Students should feel free to mistake to allow for a continuous process.</td><td>Differentiation
There must be continuous intent listening to the needs of each student. Special attention should be given, when the work is split in pairs or groups,to each group getting equal opportunities</td><td>Key Concepts and Terminolgy
Oscillation Direct and Inverse Variation Pendulum
Mass Length Angle</td></tr>
</table>

Learning activities				
IBSE Activity	**Potential arts activity**	**Student Activity**	**Teacher Activity**	**8 CREAT-IT Pedagogical Principles**
Phase 1: Question Eliciting Activity \ Students exhibit curiosity	*After the warm-ups we could ask: How can we find a game that can be used as a metaphor for the hypothesis above?*	*Students think about questions they have (e.g. regarding the motion of the pendulum and variables that could influence it)*	*Exhibit the toy (e.g. a pendulum). Ask questions. Provide pupils with materials.*	*Highlight the relevant principles* *1. Individual, collaborative and communal activities for change* *2. Risk, immersion and play* *3. Interrelationship of different ways of thinking and knowing* *4. Dialogue* *5. Discipline knowledge* *6. Possibilities* *7. Ethics and trusteeship* *8. Empowerment and agency*
Phase 2: Active Investigation	*We ask students to develop “**game models**” to reproduce or to show the functioning of the scientific model*	*Students formulate hypothesis and plan how they will test the hypothesis*	*Support pupils by asking further questions to prompt thinking*	
Phase 3: Creation	*Students elaborate a story or a drama on the theory or on the process.*	*Pupils conduct an investigation to test the hypothesis*	*Support pupils through questions, guidance and provision of resources*	
Phase 4: Discussion	*Rehearsals during which each group presents its work, and discussion of the challenges that arise as part of the working process.*	*Using the arts pupils prepare and present their results for discussion*	*Assess pupil’s knowledge*	
Phase 5: Reflection	*Students and teachers discuss various specific focus issues*	*How successful was their investigation. What would they change to improve the reliability of their results?*	*Assess pupils’ understanding*	

7. Staging a Science Theatre

Teachers and students may decide together if they want to perform this work or not. If so, your audience will usually include other school pupils, teachers, and, possibly, parents.

A theatrical event can be organized and students can be involved in preparing scenery, lights, costumes, music and everything needed for the presentation. Please remember that this is not a methodology for creating performances. The goal is not to create "artistic" expectations. Real theatrical performances need solid texts and rehearsing. If you'd like to develop it but it take time and skills.

The structure

Storytelling is one of the most compelling ways of passing contents and moving imagination. A good place to start is by telling stories about science and scientists to the students.

The selected material is brought to life as the students develop the theme through their dramatic actions. Small groups might act out a particular section of the material. Every group develops an original dramaturgy on what has been discovered in the Scientific IBSE and through the storytelling.

It is suggested to use the Narrative Arc Structure to build the dramaturgy

Exposition: introduces characters and setting; provides basic information about relationships between characters and an initial **conflict** between them. (e.g. two scientists disagree on a theory)

Turning Point: characters or circumstances change (for the worse or the better) due to an action. (e.g. an experiment is realized on the discussed question)

Conclusion: resolution of conflict and celebration of a new order, new identities and a harmonious end to conflict. (e.g. The scientific problem is solved)

These cycles can be repeated various times and can be related to one another in order to create a longer and more complex structure.

It is always important to make clear when and where the action takes place. It is possible to have a voice-over and to mix storytelling to connect different scenes

Working on characters

Character Types-Functions-Action

Impossible Interviews and letters

Movement

Voice

For the creation and choice of characters we can refer to the seven roles of Vladimir Propp, *in Morphology of the Folktale*.

Seven roles which any character may assume in the story

1.the *Villain*, who struggles with the hero;
2. the *Donor*, who prepares and/or provides hero with magical agent;
3. the *Helper*, who assists, rescues, solves and/or transfigures the hero (can be merged with Donor);
4. the *Princess*, sought-for by the hero (and/or her father) who exists as goal and often recognizes and marries hero and/or punishes villain;
5. the *Dispatcher*, who sends the hero off (can be merged with Donor and/or Helper);
6. the *Hero*, who departs on a search (seeker-hero), reacts to the Donor, defeats the Villain, and weds/rules at end;
7. the *False Hero*, who claims to be the Hero, often seeking and reacting like a real Hero but always discovered/punished (sometimes merged with Villain role).

It is not necessary to use all characters for each performance. The pattern can by simplified. We can also have monologues. Pieces with protagonist and deuteragonist, or protagonist and deuteragonist and tritagonist etc.

Impossible Interviews

A good way of entering our character's way of thinking is to interview him/her. A role can be adopted quite simply to communicate the key attitudes and emotions of a character. A piece of costume, a prop, a chair or just entering a special space can be useful to denote when the student is stepping into and out of a certain role. The interview can also be staged as part of the performance.

An other good way of entering the character's feelings is asking students to write a letter in their name. The students will get in touch and will relate the deepest dreams, hopes or disappointments of the character. Through this work students feel empathy for the characters of scientists that can sometimes look a bit icy and distant. The letters can be also added to the final script and staged.

Movement

The teacher can ask students to move in the room making their movement start from a certain point in their body (belly, neck, toe, head) Then he/she asks them what kind of character moves like that? a professor, a mother, a fat person, a pregnant woman etc. In the staging phase we will ask students to choose from which point of their body the main movement of the character starts.

Voice

A student acts as conductor, whilst the rest of the group are the 'orchestra'. Using their voices the group follows the conductor's movement with their voices. The leader can control the sound of the piece by raising his/her hand to increase the volume or bringing it to touch the floor for silence and opening them wide for lower tones and thin for higher ones. After warming up the teacher asks students to choose a voice for their characters.

The final text will be like a collage of different works and styles. It is important that there is a red thread that keeps together the different parts, this can easily obtained following the chosen theme. We must here remind that the main aim of this practice is to elaborate specific scientific topics.

The students are authors of the text. It is not important that they learn it by heart word by word, It is more relevant that they know what the profound meaning of each line is.

Teacher's tip. Good questions are " What is your character trying to communicate through this line?" "What are his/her feelings and emotions?"

While staging, space is a very important issue. Students should try to always face the audience and not stand one in front of the other in order to be always seen and also to be better heard from the audience.

Costumes, props and scenery

Costumes are important unless they are casual clothes for a more every day setting. Rent or even create costumes props and scenery. Make sure you have good props. Think what clothes would be suitable for your performance in order to be comfortable and move freely. Keep in mind your budget.

Sharing – The Performance

Equipment

Key questions

What kind of performing space do you have? Any room that is spacious enough and in decent shape is worth considering

Where will you rehearse? Most school auditoriums have multiple users, and you may not always have access

Do you need a sound system? If your space is outdoors or seats anywhere over 250 people, a good sound system is a must.

What kind of lighting and sound equipment do you have? If you are not sure, you will want to have a qualified expert to look things over. These items have a cost. You may be able to borrow them

8. After the S&T Event: Discussions, Feedbacks and Perspective and Follow-Up

After the Scientific and Drama parts have taken place, you can have a discussion with students and teachers on the utility of this practice.

Classroom work after S&T is crucial: students can revise the topics, addressing questions remained open and discuss them.

The students' reports can be object of evaluation while it is recommended to avoid the evaluation during the process. The students should feel free to mistake to allow for the process going on.

The S&T practice is still in a experimental phase and can be improved.

Please, document your experience and share with us!

9. Bibliography

[1] Rocard report (2007) "Science Education Now: A New Pedagogy for the Future of Europe" . Luxembourg, Office for Official Publications of the European Communities.

[2] National Science Foundation, (1999) Inquiry, Thoughts, Views, and Strategies for the K-5 Classroom. Foundations, A monograph for professionals in science, mathematics, and technology education .

[3] J. Osborne, J. Dillon, (2008) Science Education in Europe: Critical Reflections , London, The Nuffield Foundation

[4] C. Belmonte, T. Castellani, L. Maggi, E. Pontecorvo. **Una proposta didattica per l'insegnamento delle scienze** Naturalmente n. 3 (2008)

[5] Emilio Garroni **Creatività**, introduzione di Paolo Virno, Macerata, Quodlibet, 2010 ISBN 9788874622979

[6] Kuhn, T.S. **The Structure of Scientific Revolutions**. Chicago: University of Chicago Press, 1962. ISBN 0-226-45808-3

[7] Sala, M. (2007). L' arte di (non) insegnare e l'autoorganizzazione dei bambini nel gioco e nelle conversazioni scientifiche[Torino] Change.

(The art of (not) teaching, and the self-organization of children in games and in scientific conversations)

[8] Telmo Pievani, Marcello Sala, Emanuele Serrelli (2011) **La scoperta tra scienziati e bambini: il caso dei Taccuini giovanili di Charles Darwin** ETS – Naturalmente Scienza, Pisa, 2011

(The discovery between scientists and children: The case of youth Charles Darwin's Notebooks)

ISBN: 9788846731500

[9] Marco Crespi. **Narrare la scienza. Necessità di una morfologia.** in "Atti dell'VIII Convegno Nazionale sulla Comunicazione della Scienza" (2010) ISBN: 978-88-7699-201-8

"Telling science. The need for morphology") in "Proceedings of the Eighth National Conference on Science Communication"

Italian Policies documents releting Inquiry-based method and creativity in teaching of science:

[10] DPR 15 marzo 2010, n. 87; DPR 15 marzo 2010, n. 88; DPR 15 marzo 2010, n. 89. (ministerial decrees for the reorganization of school) Regulations, profiles, timetables, guidelines, national guidelines relating to the reorganization of high schools and technical and vocational schools are available on nuoviprofessionali.indire.it , nuovitecnici.indire.it , nuovilicei.indire.ithttp://nuovilicei.indire.it/

[11] DM n. 9 del 27 gennaio 2010 (ministerial decree for the reorganization of school)

[12]*Documento d'indirizzo per la sperimentazione dell'insegnamento di "Cittadinanza e Costituzione"* del 04-03-2009. (ministerial guideline for the testing of the teaching of "Citizenship and Constitution")

[13] *Documento d'indirizzo sulla diversità di genere*, siglato dal Ministro pro-tempore dell'Istruzione, Università e Ricerca e dal Ministro per le Pari Opportunità nel giugno 2011, nell'ambito della sperimentazione dell'insegnamento Cittadinanza e Costituzione (L. 30.10.2008, n. 169) (ministerial guideline on gender in the experimental teaching "Citizenship and Constitution", June 2011).

On drama

[14] Michael Chekhov**, To the actor**, Psychology Press, 2002

[14b] Barba E. The Paper Canoe: a guide to Theatre Anthropology. London and New York: Routledge, 1995

[15] Craft, A. (2013).Childhood, possibility thinking and wise, humanising educational futures.International Journal of Educational Research, 61 pp. 126–134.

[16] Parisi A., Parisi G., Perozzi E., Tonello A. in Governare la scienza nella società del rischio. Atti del 4° Convegno nazionale sulla comunicazione della scienza, 2009

[17] Banchi, H., & Bell, R. (2008). The Many Levels of Inquiry. Science and Children, 46(2), 26-29.

[18] Yoon, H., Joung, Y. J., Kim, M. (2012). The challenges of science inquiry teaching for pre-service teachers in elementary classrooms: Difficulties on and under the scene. Research in Science & Technological Education, 42(3), 589-608.

[19] M.Mayer Kid Inn Science Project http://www.educationduepuntozero.it/studi-e-ricerche/esperienza-progetto-europeo-kidsinnscience-4057498765.shtml

[20] A.Bisicchia (2006) Teatro e Scienza. Da Eschilo a Brecht a Barrow. UTET

[21] D. Raichvarg (1993) Science et Spetacle. Figures d'une reincontre. Z'editions.

[22] C. Djerassi. (2002) *Contemporary «science in theatre»: a rare genre,* in *Science and Theatre*, Interdisciplinary Science Reviews, Volume 27, Number 2. Maney, London.

[23] S. Quinn, J. Bedworth (1987) *Science Theatre: an effective interpretative technique in museums*, in *Communication of science to the public*. Wiley, Chichester (Ciba foundation Conference) pp 161-174

Appendix 1: Science and Art

"Science does not interest me. It does not take into consideration dream, risk, laughter, feeling and the contradiction, precious things to me. " (Luis Buñuel, 1900-1983)

In common opinion there are tensions between creativity and science, as between art and science. In common opinion, science is related to rules, rigor, objectivity, lack of emotions and inexistence of contradictions. On the other hand, in common opinion, creativity is related with a lack of rules, lack of rigor, subjectivity, emotions and eligibility of contradiction.

Clearly, a scientific researcher reading the Buñuel's worlds would not agree. He/she knows that dreams, risk, feeling and mainly contradiction are essential features of science.

We could assume that Buñuel and a scientific researcher have different images of science and they refer to different feature of science and two different meanings of the word "science". ([16])

Is "science" the product of science (the theories) or the processes of science (the methods)?

Although the products of science (the theories) may have an icy light, this is not true for the *process* of science, in which scientists struggle with their feelings and rely on imagination to create a theory in order to go beyond the contradictions.

A scientist is creative when he/she *makes* science. The scientist has questions and looks for answers. He/she needs to:

a) invent hypotheses
b) invent and design an experiment
c) interpret data

The scientist doesn't work alone. Rather, she/he works in a community: The interpretation of data and validation/falsification of scientific theories are elaborated together, and this process often involves changes of point of view and surprises. The scientists also need to invent theoretical tools in order to find agreement and solve conflicts.

Every scientist knows that there is no rule or definition for the large variety of processes or methods of science. The scientist builds her/his own scientific thinking, her/his scientific creativity, through the practice of research.

The process/practice of science is more similar to an art (or artisanship) process/practice.

In education, there were different approaches for teaching arts, humanities and science. In most European countries, the approaches appear dogmatic for science (by teaching the theories), historical for humanities while the pedagogy of art is oriented to develop personal expression and creativity.

When we teach the products of science (theory and concepts – sometimes procedures that someone else has thought out), students don't develop a mastery of the process and creativity. If there is no rule or definition for the large variety of situations, processes or methods of science, they can be learned only by practice. Like in art, to teach/learn the process (or methods) of science and scientific creativity it is recommended (see [1],[2]) to practice science, to engage in research!

To develop a learning activity that stimulates creativity in science we use the Inquiry based approach, in which we ask the student to *make* science, to make research, and compare the learning process with the learning process and the creation process in theatre practices.

Also, in the case of theater we can distinguish the product (the show) from the process (elaboration of the show).

In some modern dramas, the creation of the performance takes place during workshops, and is an original creation made by the actors, but with very strict rules.

The present experience is based, among other similar experiences, on the "Dramaturgy of the actor" by Josè Sanchis Sinisterra and on "Paper Canoe" by Eugenio Barba, where the actors don't learn a written text by heart, but create their own dramaturgy.

The artistic creation process needs rules and training, much more than expected in common opinion. Both in science and in theatre we propose to create the rules.

Appendix 3: Evaluation of ST Activities with Students

This is a short guideline that should help you to get valuable feedback from your students about their perception of the SCIENCE THEATRE project they've participated in. We encourage you to ask additional questions if needed.

Before you begin, please consider some general suggestions for gathering feedback from your students:

- *Make sure you tell your students that you are not grading their responses, but rather trying to get a feel of their perception*
- *Respond to any feedback, good or bad, with gratitude, and reflect upon it – ask for and/or suggest actions that might result from it*
- *Do not get discouraged by the inevitable few negative comments. Try to see everything as constructive criticism*
- *Take notes– write down your impressions and conclusions made during the evaluation*

Print out the following questionnaire and hand it out to the students at the end of the class (at the end of the project). Give your students about 5 minutes to fill it in – ask them to do it in silence, without commenting out loud. They should not sign the questionnaires. The main purpose of this is to provoke individual reflection among students. The written responses could also serve you as additional source of information while summarising students' feedback.

A3.1: QUESTIONNAIRE FOR THE STUDENTS

Note: This questionnaire appears in the CREAT-IT project's Deliverable D6.2 for general cases. In the following version, it has been adapted specifically for SCIENCE THEATRE projects It is meant for students (pupils) who have participated in a SCIENCE THEATRE project.

1. What is your strongest impression of the SCIENCE THEATRE project you participated in?

2. How difficult was it for you to participate in the SCIENCE THEATRE project? Would you say it was:
    a) too difficult
    b) challenging
    c) neutral
    d) too easy

3. Did you feel motivated to participate in the activities of the SCIENCE THEATRE project?
    a) Not motivated at all
    b) Motivated to some extent
    c) Very motivated

4. What could be done differently to make the project more motivating for you?

5. What did you enjoy doing most?

6. Was there something you did not enjoy doing? What? Why?

7. What was, for you personally, the most useful part/activity of the SCIENCE THEATRE project with regard to understanding/learning the lesson?

8. If you compare it with the usual class in this subject, are there, in your opinion, advantages of SCIENCE THEATRE? If yes, what are they?

9. Are there any disadvantages in comparison with the usual class? If yes, what are they?

10. Anything you would like to ask/ add about the SCIENCE THEATRE project?

A3.2: Discussion

Start a group discussion following the questionnaire students answered, question by question. While gathering the answers we encourage you to:

1. Ask for a rationale/explanation for each answer by posing the "why?" questions and asking them to compare impressions with the traditional class.

2. Ask for suggestions for improving and try to agree upon the actions that result from it.

3. Summarise at the end.

You do not need to focus much on the quantitative data (e.g."*5 pupils liked it, 6 didn't, 7 were indifferent*") but rather try to gain more in-depth information and to draw conclusions (e.g. "*majority/minority* ***felt****...* ***because...***").

A3.3: Summary

Summarise the findings using mainly the feedback gathered during the group discussion, but also using written students' answers, if available.

A3.4: Report

Report on students' feedback by answering the following questions:

1.Which activities/aspects of SCIENCE THEATRE project were, from the students' perspective

the most enjoyable?	
the least enjoyable?	
the most difficult?	

the most inspiring?	
the most engaging?	

2. Based on the feedback you gathered from the students, is there anything you would change in the project, or do differently next time? What? Please explain.

Appendix 4: Demonstration Activities EVALUATION QUESTIONANNAIRE FOR TEACHERS

Dear Sir/Madam,

We want to know about your experiences with implementing SCIENCE THEATRE with your pupils. The questionnaire is short; it takes less than 10 minutes to complete.

It is very important to stress that we need your ***honest opinion****. All critics, good or bad, will be understood only as your support to the CREAT-IT project's activities and project outcomes. Please note that the questionnaire should be completed individually.*

The survey is anonymous. Data gathered will serve only for the purposes of this project.

Thank you for your time!

1. Have you encountered any (significant) problems while delivering the lesson using WASO/Science Theatre/Junior Science Café case study? If yes, what were the problems?

(MULTIPLE ANSWER POSSIBLE)

a) I've encountered no (significant) problems
b) Lack of financial/technical support
c) Lack of time for my own preparation before the project
d) Lacking skills/knowledge I needed to implement SCIENCE THEATRE
e) Opposition among students
f) Opposition among colleagues
g) Opposition among superiors
h) Opposition among students' parents
i) Something else. What?____

2. How did you deal with these difficulties?

1. From students' perspective, which activities/aspects of SCIENCE THEATRE project were **the most enjoyable**?

____

2. From students' perspective, which activities/aspects of SCIENCE THEATRE project were **the most difficult**?

____

3. From students' perspective, which activities/aspects of SCIENCE THEATRE project were **the most engaging**?

____

4. What is your assessment of the **level of students' engagement** during participating in WASO/Science Theatre/Junior Science Café project, in comparison to their engagement during the traditional class?

   a) They are less engaged than after traditional lesson
   b) They are more engaged than after traditional lesson
   c) I am not sure

5. Based on the feedback you gathered from the students, is there anything you would change in the project, or do differently next time? What? Why?

6. After your experience with implementing WASO/Science Theatre/Junior Science Café, do you feel confident to independently design and conduct project that foster creative science teaching in the future?

   a) I do not feel confident enough
   b) I feel confident enough

7. Do you plan to realise the WASO/Science Theatre/Junior Science Café or a similar, independently design project again in the future?

   a) Definitely not
   b) Probably not
   c) Probably yes
   d) Definitely yes

8. What would encourage you to realise the WASO/Science Theatre/Junior Science Café or similar project again in the future?

____