



Implementing Creative Strategies into Science Teaching (CREAT-IT): D3.1 Science Theatre (ST) Guidelines

D3.1 – Science Theatre Guidelines

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Short Description:

Guidelines 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 for Science Theatre.

List of Recipients:

Consortium members, public





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1. Introduction & basic concepts

The Science Theater (ST) practice is an innovative method of facilitating creative scientific thought in school pupils, with particular attention to the method of the scientist's work and the dissemination of results.

Science Theater is not a new concept. It goes back several centuries to when groups of people began dramatizing science issues and presenting them in a more informal way so that audiences could reach a greater understanding of scientific fields.

Today, a variety of different practices are called "Science Theatre": theatrical shows, public experiments, and more. Early examples can be found in ancient Greek tragedy and comedy, during Humanist, Baroque, and Enlightenment periods in Europe, and in the 20th century: from Aeschylus to Brecht and Barrow[20][21][22][23].

Science theatre performances may be realized in various places including theatres, science museums and schools. In school two kinds of activities may be realized:

- Performances by professionals, inspired by scientific topics.
- Workshops and lessons which involve students in drama activities based on a scientific theme.

In recent years, several national and European projects¹ have dealt, from various viewpoints, with ST for adults, and many ST practices have been realized in European schools, in both formal and informal contexts.

The CREAT-IT project aims to implement creative strategies in science teaching. The ST practice described in these Guidelines is one of the project's Case Studies. These Guidelines are based mainly on the FormaScienza practice (see bibliography). The practice has been further developed as part of the CREAT-IT Pedagogical Framework.

In Chapter 1 we describe the basic concepts and the CREAT-IT pedagogical framework. Throughout this guidance the reader can find the CREAT-IT pedagogical principles related to the proposed activities. In Chapters 2, 4 and 5 we describe the heart of the ST practice as guidance for teachers engaging in ST activities with their students. Examples of developed topics and activities are provided. In Chapter 3, the inquiry-based structure of ST is defined in detail. In Chapter 6 we describe the discussion and feedback perspective, and the follow-up after the event. Appendices 1 and 2 provide evaluation tools for teachers. Appendix 3 describes some

¹ From ETS to Kid Inn Science.





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possible developments of the practice. Appendix 4 describes common points in the ST processes which we consider to be of relevance.

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

We are looking forward to learning about your ST experiences!

1.1 What to expect from a ST Practice

In this guide, we describe a method that allows teachers to develop students' creative scientific thinking: Teachers and students engage in an interdisciplinary training activity through which they conduct scientific research and then elaborate the scientific topic through a theatrical performance.

The ST practice based on the Inquiry-Based Science Education model enhances student curiosity and allows investigation of scientific concepts which may be challenging to understand.

The main focus isn't on a stage performance², but rather on the process of exploring scientific topics through drama. Through this process, participants can develop skills (such as learning to learn, team working, story-telling, conflict solving, validating the truth based on evidence), develop their creativity in science and the arts, and recognize common points of creative learning process in the arts and sciences³.

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

Furthermore, while the sections in the ST 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).

² We wish to underline that this ST Practice is not a performance. It is a methodology aimed at elaborating scientific contents through drama. It may indeed be used as a basis for working with actors in order to create professional performances and can also be used to create performances with students, but these variations of the ST practice demand more time.

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





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1.2 CREAT-IT Pedagogical Principles

The CREAT-IT pedagogical framework 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 ST, as every 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:

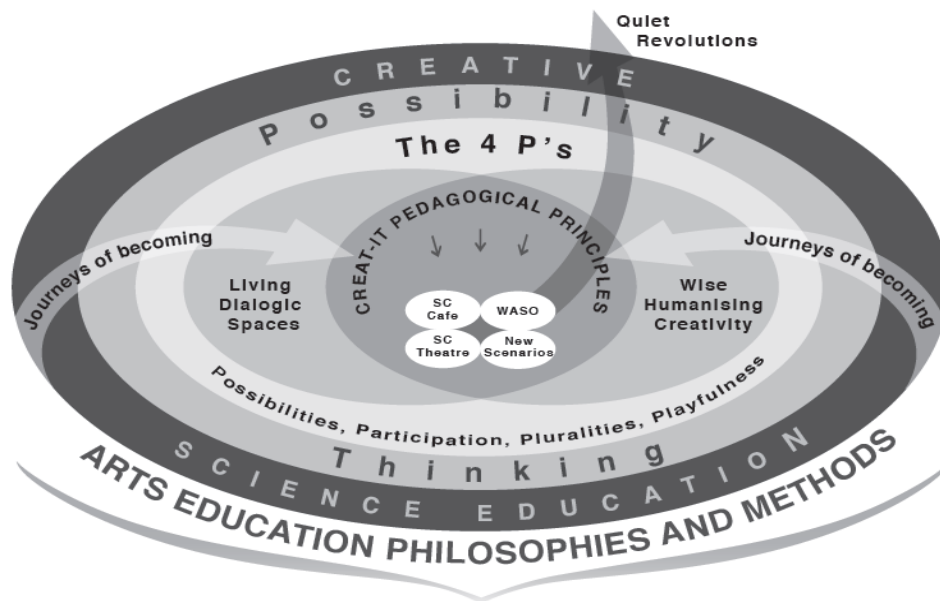
1. **Individual, collaborative and communal activities for change**
2. **Risk, immersion and play**
3. **Dialogue**
4. **Interrelationship of different ways of thinking and knowing**
5. **Discipline knowledge**
6. **Possibilities**
7. **Ethics and trusteeship**
8. **Empowerment and agency**





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

1.3 Specific Purposes

As a CREAT-IT Case Study practice, the participative use of ST Practice follows the CREAT-IT pedagogical principles. Moreover, this specific ST practice encourages pupils to:

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





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2. How Does the ST Practice Work?

The following guidelines provide late primary and early secondary teachers with knowledge and insight needed to realize a wide variety of ST sessions with their pupils. It is advisable to use ST as part of the learning process and as an alternative way of teaching the curriculum, rather than as an extracurricular activity. ST can be used as part of a single session where a specific phenomenon is explored or for a longer project of several months that could lead to a school performance.

The ST practice can be applied very flexibly which means that it can range from simple short drama exercises to full theatrical performances based either on set or improvised scripts. If the teachers choose ST as part of a long project, they should keep in mind that they should involve pupils to the degree that is allowed according to the time and resources available. This means that numerous parameters can vary: script length, the teacher's involvement in developing the script, the number of pupils that will participate, the aspects of the play covered (music, sets, costumes, sound, video) etc.

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 are also provided (see the CREAT-IT Samples).





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3. An Inquiry-based Exercise

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

Phase 1: Question Eliciting Activities/Exhibit Curiosity

Phase 2: Active Investigation

Phase 3: Creation

Phase 4: Discussion

Phase 5: Reflection

The following ST 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).

3.1 IBSE phases in detail

In the following 5 phases, both scientific and drama activities are described in detail, exemplifying their inter-relatedness in the ST Case Study.

Learning activities

Phase 1 Question Eliciting Activities/Exhibit Curiosity

The teacher chooses a topic from the curriculum and poses questions which stimulate curiosity and invites further questions by the pupils. This may be done by using various materials (including videos and the web) to demonstrate natural phenomena, which will be the object of inquiry (see the section "toy" in appendix 3). They then explain to the pupils the Science Theatre concept.

Phase 2 Active Investigation

Students conduct an investigation on the presented phenomenon. From the pupils' active investigation and in-class discussion, various hypotheses are expected to arise. Depending on the time and resources available, pupils should explore the topic through relevant literature or online sources and/or through live experiments, whenever possible. As soon as the pupils have answered their questions and accepted or rejected the initial hypotheses, they are asked to explore and represent them through drama activities. Here they have to invent and find materials and metaphors to communicate their ideas. The pupils may also develop "game





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models”, which are expanded ways of reproducing or showing the functioning of the scientific model. They can use their bodies and imagination to create something that “works like...”.

Should the project be longer and lead to a performance, it is advised for school groups to be divided in work-groups with separate responsibilities depending on the preferences and talents of the pupils. The script-writer/director group is asked to further investigate characters and generate ideas for dialogues/actions. Once the script and characters are finalized, an actors’ group is formed. Another group will be responsible for finding materials and creating the sets and costumes. Provided there are resources and interest by the pupils, there can also be music, dance and video groups. The dance group can create and perform interpretive choreographies that complement the drama. The music group can compose original scores or choose existing (license-free) music pieces to accompany the play. Finally, the video group will be responsible for producing and editing original or existing (license-free) videos that will be projected.

Phase 3 Creation

Pupils incorporate learning from their initial questions in a dramatized concept/script. In the case of a long ST project, this phase includes rehearsals on all levels and the final performance of the play for an audience of fellow pupils, teachers and parents.

Phase 4 Discussion

The whole process is discussed among teachers and students. The discussion revolves around what pupils have appreciated, but also what they would change in such a process should it be repeated. Scientific findings and learning are also discussed as well as the realization of common creative impulses between art and science. Last but not least, 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

After the process has been completed, it is important to write reports of what has been learned and experienced. In the following table, specific ST activities, including both teachers’ and pupils’ inquiry processes, are based on IBSE and the CREAT-IT Pedagogical Framework (see “Recommended Literature” for further details).





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Case Study Approach: Science Theatre

<p>Science unit topic</p> <p><i>Pendulum</i></p> <p>Class information</p> <p>Year Group: <i>Early secondary schools</i></p> <p>Age range: <i>11-12</i></p> <p>Sex: <i>mixed</i></p> <p>Ability: <i>mixed</i></p>	<p>Materials and Resources</p> <p><i>What do you need?</i></p> <p><i>Cheap materials: thread and plasticine balls.</i></p> <p><i>Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc.), or one?</i></p> <p><i>Science Lab and Drama Classroom</i></p> <p><i>Health and Safety implications?</i></p> <p><i>Technology?</i></p> <ul style="list-style-type: none"> - <i>Teacher support? (e.g team teaching with arts and science expertise)</i> 	
<p>Prior knowledge</p> <p>Pupils were taught:</p> <p><i>How to draw a cartesian graphic</i></p> <p><i>Direct and inverse variation</i></p>	<div style="border: 2px solid red; border-radius: 15px; padding: 10px;"> <p><i>What do pupils know and understand of the science topic?</i></p> <p><i>What relevant arts skills and knowledge do they have?</i></p> </div>	
<p>Individual session project objectives (What do you want pupils to know and understand by the end of the lesson?)</p> <p>Session 1: <i>Identify variables in the pendulum, define direct and inverse variation.</i></p> <p>Session 2: <i>Test hypothesis and recognize direct and inverse variation through graphics,</i></p> <p>Session 3: <i>Understand that the mass does not influence the oscillation of the pendulum and the time for the free fall of physical bodies</i></p>		
<p>Assessment</p> <ul style="list-style-type: none"> - <i>Students write final reports in which the scientific process is described. A scientific paper format is recommended. This report can be an object of assessment, while it is recommended to avoid any judgment during the process. Students should</i> 	<p>Differentiation</p> <p><i>There must be continuous attention to the needs of each student. Special attention should be given, when the work is split in pairs or groups, to ensure that each group has equal opportunities.</i></p>	<p>Key Concepts and Terminology</p> <p><i>Oscillation, Direct and Inverse Variation, Pendulum, Mass, Length, Angle</i></p>





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feel free to make mistakes to allow for a continuous process.

Learning activities				
IBSE Activity	Potential arts activity	Student Activity	Teacher Activity	8 CREAT-IT Pedagogical Principles
Phase 1: Question Eliciting Activity / Students exhibit curiosity	<i>After the warm-ups we could ask: How can we find a game that can be used as a metaphor for the hypothesis above?</i>	- Pupils 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 pupils to develop “ game models ” to reproduce or to show the functioning of the scientific model	- Pupils formulate hypothesis and plan how they will test the hypothesis - Pupils conduct an investigation to test the hypothesis	- Support pupils by asking further questions to prompt thinking	
Phase 3: Creation	- Pupils elaborate a story or a drama on the theory or on the process. - Rehearsals during which each group presents its work	- Pupils perform what they have prepared.	- Support pupils through questions, guidance and provision of resources - Video recording of the performances will allow teacher and pupils to discuss after the performance.	
Phase 4: Discussion	- Discussion of the challenges that arise as part of the working	- Pupils prepare and present their results for	Assess pupils' knowledge	





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	<i>process.</i>	<i>discussion</i>	
Phase 5: Reflection	- Pupils and teachers discuss various specific focus issues	- Ask: How successful was their investigation? What would they change to improve the results' reliability?	Assess pupils' understanding





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4. Drama

4.1 Warm-ups

Sessions should begin with a warm-up, regardless of the session's length. Warm-ups provide physical motion (stretching, running, breathing exercises etc.), musical exercises (rhythm/pulse exercises), vocal exercises, creative exploration and establishing a group dynamic. Some basic exercises are provided in the list below. In addition, teachers of physical education, drama, music and dance will be able to add their own repertoire of exercises.

4.1.1 Big fish / small fish

This is a fundamental exercise for the ST practice. It not only shows that errors are important but also what games and scientific research are made of:

- 1) The group stands in a circle. The facilitator explains the rules. When someone calls out «small fish», all hands must be far away from the body (mimicking a big fish). When someone calls out «big fish», each student's hands must be close to their own body.
- 2) The group splits into two circles. When someone calls out the wrong word or makes the wrong gesture, they must move to the other circle.

At the end of the game, participants are asked what they think the features and meaning of the exercise are. Some will answer about the role of mistakes: We must make mistakes to make the game go! No punishment, no exclusion: just a demonstration that the game is better, and more fun, the more «mistakes» have been made.

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 s\he has a "tube", puts it on the other's (A) mouth, and starts "inflating" the pupil on the floor by moving their leg as though it were a "pump". The pupil who is lying on the floor inflates his\her belly and then starts moving like a "balloon", first standing and then moving around in the room. After a short time (about 10 seconds), student B pretends to disconnect the "tube". Student A deflates and «floats» back to the ground.

4.1.3 Moving and counting games

All pupils are asked to walk around in the room. The facilitator starts naming numbers. For example: "Let's define speed 5. Speed 5 is when you are going to school and are not late. Speed 5 may differ from person to person. Speed 11 is running, meaning that at some point neither foot is touching the ground. We then define speed 0 as standing still. We can now start playing





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with numbers. At first, the facilitator calls out numbers of different speeds. Later on, a pupil can assume this role. With this exercise, students become used to measurements and physical units.

Variations: You can work with the concept of weight by asking pupils to perform «weight 1» (simulating a balloon), or «weight 10» (heavily, like lead). Another parameter may be length (high/short).

Variations: You can invite pupils to move as though they were on the moon, in water, in mud or anything they choose, thus “playing with”, exploring, different surfaces and densities. This is an excellent way to introduce such scientific concepts.





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5. Staging a Science Theatre

A theatrical event can be organized should pupils and their teacher(s) agree on this, and time allows for it. The audience will usually include other pupils, teachers, and parents. Pupils can be involved in preparing the sets, lights, costumes, music and everything needed for the performance.

5.1 Script-writing

The pupils should be the main authors of the text. While it would be an advantage, it is not of highest importance to learn it by heart, but rather that pupils know the text's *meaning*. The final text might be a collage of different ideas and styles. It is important that the different parts are held together by following the chosen scientific theme: The main aim of the practice is to develop and communicate specific scientific topics.

5.1.1 The structure

Storytelling is one of the most compelling ways of communicating contents and inspiring imagination. A good place to start is by telling the pupils stories about science and scientists. The selected material is brought to life as the pupils develop the theme through their dramatic actions. Small groups might act out a particular section of the material. To build the dramaturgy, it is suggested to use the Narrative Arc Structure as follows:

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: the story's circumstances change (for better or for worse) 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 many times and can be related to one another in order to create a longer, and more complex, structure.

It is always important to clarify when and where the action takes place (e.g. in the year 2020, in London). It is possible to have a voice-over and to mix storytelling to connect different scenes.





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5.1.2 Character Types-Functions-Actions

For the creation and choice of characters, you could refer to the seven roles of Vladimir Propp, *in Morphology of the Folktale*. These seven roles, which any character may assume in the story, are:

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

5.2 Working on characters

Good questions to ask pupils in order to get them started exploring the scripts are "What is your character trying to communicate through this specific line?", "What are his/her feelings and emotions?".

5.2.1 Impossible Interviews and Letters

A good way of becoming familiar with a character's way of thinking is by "interviewing" them about their key attitudes and emotions. Choose one pupil to represent that character. A costume, a prop, a chair, or just inviting the character to enter a physical space may all be useful in order to provide pupils with the sense that they are in fact interviewing a specific character. The interview can also be staged as part of the performance.

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





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5.2.2 Movement

The teacher can ask pupils to move around in the room while making sure that their movement starts from a certain point in their body (belly, neck, toes, head). Then the teacher asks them what kind of character moves like that (a professor, a mother, a fat person, a pregnant woman, etc.). During the staging phase of the theatre, students will be asked to choose from which point of their body the main movement of their character starts. During staging, space is a very important issue. Students should try to always face the audience and not stand in front of each other in order to always be seen and heard by the audience.

5.2.3 Voice

During the warm-up, a pupil acts as conductor, while the rest of the group is the 'orchestra'. Using their voices, the group follows the conductor's movement with their voices. The leader can control sound by raising their hands to increase the volume or lowering them to touch the floor for silence, and/or opening them wide for lower tones and then narrowing them for higher ones. After warming up, the teacher asks pupils to choose a voice for their characters.

5.3 Costumes, props and scenery

Rent or even create costumes, props and scenery from leftover and recyclable materials. Make sure you have good props: Consider what kind of clothes would be suitable for your performance in order to be comfortable and move freely. Keep your budget in mind, and remember that imagination, creativity and quality communication amongst pupils do not depend on expensive materials.

5.4 The Performance

Key questions to consider before the performance:

-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 accommodates more than 250 people, a good sound system is essential.





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-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 can be costly, but you may be able to borrow them.





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6. After the ST Event: Discussion, Feedback, Perspectives and Follow-Up

After the ST event has taken place, you can have a discussion with pupils and teachers about potential uses of this practice.

Classroom work after ST is crucial: pupils can revise the topics, address questions that remain open and discuss them.

The pupils' reports can be an object of evaluation, yet we recommended avoiding the evaluation during the process: Pupils should feel free to make mistakes in order to allow for the continuation of the process.

The ST practice is a creative process which will continuously develop every time new teachers and pupils engage with it. Please, document your experience and share it with us! Our portal can be found at portal.creatit-project.eu.





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





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Appendix 1: Evaluation of ST Activities with Students

This is a short guideline that will help you get valuable feedback from your pupils 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 pupils 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. Consider 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 pupils at the end of the class (or at the end of the complete project). Give your pupils 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. The written responses could also serve as an additional source of information while summarizing pupils' feedback.





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A1.1: QUESTIONNAIRE FOR THE STUDENTS

Note: This questionnaire appears in the CREAT-IT project's Deliverable D6.2 (Evaluation) for general cases. In the following version, it has been adapted specifically for SCIENCE THEATRE.

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?





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A1.2: Discussion

Start a group discussion following the questionnaire which pupils 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 improvement, 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...").

A1.3: Summary

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

A1.4: Report

Report on pupils' feedback by answering the following questions:

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

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





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the most inspiring?

the most engaging?

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





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Appendix 2: Evaluation Questionnaire 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 using Science Theatre? 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 pupils
- f) Opposition among colleagues
- g) Opposition among superiors
- h) Opposition among pupils' parents
- i) Something else. What? _____

2. How did you deal with these difficulties?

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





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

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

4. What is your assessment of the **level of pupils' engagement** during the Science Theatre 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 pupils, is there anything you would change in the project, or do differently next time? What? Why?

6. After your experience with implementing Science Theatre, 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 realize the Science Theatre or a similar, independently designed project again in the future?

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

8. What would encourage you to realize a Science Theatre or similar project again in the future?





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Appendix 3: More about the Scientific Exploration Process

The scientific exploration could last for 2 hours or longer, or even span several days. This depends on the topic, the question, the age of pupils and the needs of the teacher.

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

- **Relation to the CREAT-IT Pedagogical Principles:** It is important for ideas, knowledge and practices that emerge from a 'bottom up' activity to be given space in an environment where, often, 'top down' can dominate unnecessarily. During the scientific exploration we experience *Individual, Collaborative and Communal activity for change and Dialogue*.

7.1 The toy – an object of exploration

The first thing needed is an object of inquiry: A simple phenomenon that has the potential to surprise us. We refer to this object as a "toy", so as to underline that it invites students to play the «game» of science. It need not be complicated (a bowl of water and a scale, a candle and a white ball, a pendulum, etc.). But it must be an object providing something "real" students can play with.

7.2 The question

The journey begins with a question⁴. Framing a good question is a creative task for scientists, for pupils and for teachers.

7.2.1 What is a good question?

A question is scientifically "good" when it generates an answer that can be verified (true or false) through experiments. For teachers, "good" questions lead to further exploration.

7.2.2 Example – The Pendulum

The object of investigation is the pendulum itself. You can use simple materials such as a thread and a plastic ball. After an observation of the motion of the pendulum, the teacher could ask pupils to define the features of the motion (is it periodic or not?). Then they may ask the question: "What impacts the time of one oscillation of a pendulum?"

⁴ Questions can also come from pupils, but it is suggested to start from pupils' questions when teachers and pupils are more confident with the practice.





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7.3 The process of science

7.3.1 The hypothesis

Let us stimulate pupils to create hypotheses. These hypotheses are in conflict (if a good question has been chosen!). The teacher makes each pupil declare and support their own idea, to allow for the cognitive models to come out.

- Pupils have to take risks (*Risk, Immersion and Play*) by speaking in front of the classroom and saying what they think. Here many possibilities (*Possibilities*) are created, and many ways of thinking (*Interrelationship of Different Ways of Thinking*) are confronted.

7.3.1.1 Example – The Pendulum

The teacher stimulates pupils to propose hypotheses on what creates variation. Different hypotheses result:

- 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\weight of the pendulum
- The way in which the pendulum moves

The teacher underlines the conflicts: does the time of oscillation increase or decrease as a function of the pendulum's mass? Or is it a constant function? All pupils present their opinions. All three options will probably be discussed. The opinion that the mass (or weight) affects the oscillation time is a frequent misconception. Some other questions could point out misconceptions or critical points such "Are mass and weight the same physical quantity?"

7.3.2 The experiment

The teacher suggests to the pupils to design an experiment aimed at solving the conflict between the possible answers! If a good scientific question has been posed, and pupils have elaborated scientific hypotheses, they should be able to think of, design and build an experiment aimed at falsifying or confirming the hypotheses.

It is crucial to stimulate the pupils 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 correct, and when we will have to say that it is false).





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

- Here the importance of *Risk, Immersion and Play* is focused on as pupils 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*).

7.3.2.1 Example – The Pendulum

An experiment can consist of, for example, building a pendulum and measuring the time of oscillation with different weights or other variables. Pupils are divided into groups, and each group checks one variable. The experience is simple but some relevant question will result. Are there errors in the measurement? What kind? What can we do to avoid these? Is one measurement enough to understand if the time of one oscillation increases when we increase 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?

7.3.3 Interpretation of data

Pupils/scientists have to interpret the collected data and decide if the hypotheses are confirmed or not. As happens in the scientific community, the results of the experiments are not always clearly “evident”. There could be different interpretations and the scientific community has to reach an agreement. The process could last for years. In the ST approach, the pupils act as a scientific community, but suitable scientific problems are used and the process lasts for only a few hours.

Interpreting the data and critiquing 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*, using *Discipline Knowledge* via the *Dialogue*).

7.3.3.1 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. Pupils who think that the time of oscillation increases with the mass could find some dependence even if it is not obvious. If different groups work on the same “critic” variable, and have different elected hypotheses, these





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groups could disagree and present conflicting data. The influence of the mass is not obvious now. With the help of teachers, the groups could develop tools aimed at elaborating the data and taking into account the maximum or statistical error. Finally, the pupils have to deduce that the times of oscillation found with different masses are compatible, and that the mass did not influence this time (at least not within the limits of experimental error). The same will happen with the amplitude of oscillations or the shape of the pendulum, for example.

7.3.4 The theory

The hypothesis that the group confirms becomes a Thesis, and part of that group's knowledge. The confirmed hypothesis and models become the class's theory. Some questions could remain unanswered and/or opened during the process. The process could then start again.

At the beginning or at the end of the process, the pupils could be motivated by being told that important scientists have 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*, thus improving *Discipline Knowledge*.

7.3.4.1 Example – The Pendulum

Pupils may now conclude that the pendulum's time of oscillation depends only on the thread's length. In secondary schools, we could develop an experimental rule for the period of the pendulum and find the constant factor. We could also ask the pupils to find the length which will allow the oscillation time to be equal to 1 second.

7.4 How to facilitate the process

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

7.4.1 The discussion

As often happens in the scientific community, the pupils are able to detect mistakes in the experimental procedure that some classmates are using to confirm opposite hypotheses. This conflict motivates pupils to find theoretical and practical tools, e.g. statistical tools, to avoid the errors and to improve their experiments in order to result in correct answers by eliminating the wrong hypothesis.





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7.4.2 The role of facilitator

It could help the teacher/facilitator to think of himself\herself as a master of research, or someone who doesn't know the phenomenon's laws, and who, like the pupils, is discovering it for the first time. The difference between the student and the master of research is in the *experience* with the game of research more than in the knowledge of the contents. Guiding the discussion is a critical task for the facilitator. They have to:

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

The facilitator has to highlight that "error" is considered as a positive motor for further exploration, as it is a way to discover new things and improve the model.

7.5 The Game Model

We ask the pupils 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 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 pupils must invent, find materials and metaphors. We can also ask the pupils to find analogies with other phenomena that work with the same rules, for example in every-day life. When the pupils invent a game that "works like the scientific model", they should identify the elements (variables) and the relation between the elements (laws). All the pupils work on the same problem individually, in pairs, in groups or collectively (see the examples below).

In game models, we allow for "mistakes" or "errors": this is a way to discover new things and eliminate misconceptions. The pupils are encouraged to improve their game model so as allow it to conform as much as possible with the scientific model. The game model will be improved via trial and error and subsequent approximations. Game models are discussed, phase by phase, until the best possible grip on the studied phenomenon is achieved. Through changing and improving the drama metaphor, an improvement in the understanding of the phenomena and models from a scientific point of view will occur.





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

7.5.1.1 Example – Experiencing the Pendulum

We ask the pupils to look for pendulum examples in their own bodies. How many pendulums could they find? In the beginning, students work in pairs. Each may look for the pendulum in the other's body. Then they form groups of 3 students: One student (A) stays in the center, closing his/her eyes. The other two (B and C) push and pull A carefully, ensuring that A's feet remain on the floor, while setting his/her body in oscillator motion like a pendulum. Then we ask the groups to create a line, and the whole class works like a single pendulum by finding a common rhythm.

7.5.1.2 Other examples of Game model

Evolution

Pupils are asked to create a "danced model" of genetics, in which information passes from one "generation" to another. They work together, as a "population", to build a possible model of evolution with their bodies. They may decide to copy each other's movements: They may all start making the same movement, such as moving an arm up and down. But how does evolution "work"? How does "change" enter the model?

A pupil is asked to introduce a new movement, such as moving an arm from one side to another. When someone introduces a change, the others will all change by copying the new movement. And so on. We ask pupils if there were mistakes in this game. They recognize that 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 individuals with or without mutations. The pupils modify their game model to represent the complexity of the evolution model. They decide that, when someone introduces a change, each one of them can take this new movement or not: When this happens, we will soon have many different movements simultaneously. This is an *embodied model* of evolution!

Astronomy

Another game model may include the creation of an astronomic clock using pupils' bodies, moving in the room like planets. Students have to recreate movements of the "Earth", "Sun" and





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“Moon” in order reproduce the night and day alternation. This could also be done with the Earth and Solar System.

7.6 The Story

Pupils are asked to create a plot with characters, and then decide how to perform it. They choose roles, and decide whether or not they will use costumes, scenery and props. They work in groups of 3-4, mixing boys and girls. Each group should have equal opportunities.

The game prepares the construction of a story. Creating a game helps understand the content of the scientific process, it creates a physical memory, and feelings. All this can then be included in the creation of a story that has as its main ingredient the scientific process.

As part of the scientific process, we will find conflicts which will provide the base of our story. Conflicts can be found both in the history of science and in the experience of the pupils in the class during the scientific exploration. Conflicts may be mistakes and misconceptions solved during the process, different hypotheses, and different points of view regarding design and realization of experiments. Students are encouraged to analyze these.

The teacher could ask: Are the problems which materialized similar to ones scientists have dealt with during the history of science? Can we look at the life of different scientists and, for example, create a script based on the life of one of them? If the problem of the experiment has been, e.g. the measurement of time, can pupils relate to when problems with the measurement of time occurred? Or weight? Or mass? Can we put the process itself in metaphor?

With this work, pupils elaborate scientific concepts through their own imagination so the process becomes personal and part of their own experience.

The creation of the story allows for multiple possibilities both in terms of thinking and spaces, as in the CREAT-IT pedagogical principle *Possibilities*. There is a strong theoretical connection here to the CREAT-IT Pedagogical Principle, *Dialogue*, as well as to the importance of narrative as a key driver or context for the process of Possibility Thinking.

7.6.1.1 Example – The Pendulum and the Story of Laura Bassi

The pupils have just experienced a process of discovery during the scientific exploration. Now they can compare their processes of discovery with those experienced by a famous scientist.

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, an Italian who lived in





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Bologna (1711-1778), has been chosen because she was the first woman who implemented experiment-based research.

If the curriculum allows connections with the history of science, emphasis can be placed on Laura Bassi's everyday life and difficulties. This will help the pupils make links between their emotions and those of the scientist. The teacher can also relate to gender issues.

Students split in groups and create a story or script. They then have to create a 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
- c) use the conflicts of the discussion or errors\difficulties they have found themselves to tell the story of a famous scientist of the past

An example of this plot could involve the city of Bologna being under attack. To save their city, the citizens should organize a counterattack but they need to build, and then synchronize, many clocks. To achieve this, they need to build pendulums. They only have stones of different weights. Laura Bassi should convince the others that the weight is not relevant...





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Appendix 4: Common points in Science and Theatre processes

This methodology is based on many iterations, discoveries and integration of knowledge. The science and theatre creative processes are compared.

This 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.

7.7 Conflict

As the ST approach shifts into its second part (drama), there is particular acknowledgement of how the scientific process is quite similar to the dramatic art, or progress of a narrative through a dramatic climax. Both the drama and science processes are moved by a conflict that drives a narrative.

The second part of the ST workshop encourages pupils to use the conflict in the science process as a starting point for an original drama plot. They are asked to transpose the scientific conflict into a metaphor, taking advantage of the fact that metaphor plays a role within science, as well.

There is a strong theoretical connection here to the CREAT-IT Pedagogical Principle, *Dialogue*, as well as to the importance of narrative as a key driver or context for the process of Possibility Thinking. This relates to the CREAT-IT Pedagogical Principle *Possibilities*.

7.8 Metaphor/Model

The metaphor is useful in understanding a phenomenon; moreover, there is a relation between metaphors 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 correct. For example, elementary particles can be described both as particles and as waves: These provide two different models/metaphors.

Clearly, there are differences between the use of metaphor in the sciences and the arts. In particular, sciences metaphors/models have to give "predictions": Through the model, we must be able to calculate the value of relevant variables, such as a function of certain conditions or parameters (e.g. an astronomical model predicts the position of a planet). In the arts, it is not necessary to build an argument in the same way and the metaphor doesn't necessarily have to give testable predictions.





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

- The idea that every pupil 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 – *Possibilities*). 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*. Creativity is then used again to elaborate the metaphor through drama, so there is a balancing act and a flow from creativity throughout the process. The drama metaphor facilitates an understanding that there is a flow from the drama back to the science.

7.9 Errors

In science there is no measurement without error. When we formulate a hypothesis, we don't yet know if it's true or false: We need an experiment in order to prove this. When a hypothesis is false, the pupils who formulated the hypothesis may interpret this as a mistake. It's very critical to *avoid being judgmental* at this point, and to see the error as having positive potential. We must make mistakes to have the game work! *Note: Modern dramaturgy has also pointed out the role of error, as a way to discover new possibilities of expression.*

This detailing above of the two parts of the ST approach – scientific hypothesis generating and defending, and then transposing this into the drama process - demonstrates an important CREAT-IT Pedagogical Principle that of *Interrelationship of different ways of thinking and knowing*. ST 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).





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Appendix 5: Educational Approach

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

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

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

Students become able to:

- Explore research procedures.
- Perform research efforts that are taking place as a structured discovery within the framework 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 which reflect on:

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

In some modern dramas, the performance creation takes place during workshops, and is an original creation made by the actors, but with very clear rules. The present experience is based on the "Dramaturgy of the Actor" by Josè Sanchis Sinisterra and on "Paper Canoe" by Eugenio Barba, in which 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 "transpose" knowledge 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 pupils interact (e.g. by working in pairs and in groups) and develop social and collaboration skills.





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III) As a CREAT-IT Case Study, the ST Practice follows the CREAT-IT pedagogical principles.



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