

Teaching the TEMI way

*How using
mysteries supports
science learning*



TEMI

Teaching the TEMI way

How using mysteries supports science learning

Publisher: TEMI – Teaching Enquiry with Mysteries Incorporated

Editors: Peter McOwan, Cristina Olivotto

Authors: Marina Carpineti, Peter Childs, Johanna Dittmar,
Ingo Eilks, David Fortus, Marco Giliberti, Avi Hofstein,
Julie Jordan, Dvora Katchevich, Rachel Mamlok-Naaman,
Ran Peleg, Tony Sherborne, Malka Yayon.

Proofreading: Sirius Interactive

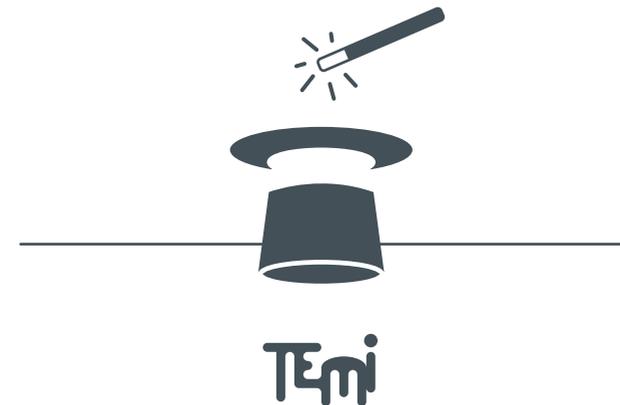
Design: Zetalab

ISBN: 9789491760112

Legal Notice: This project has been funded with support from the European Commission. This publication reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

TEMI Book is licensed under a Creative Commons Attribution 3.0 Unported license.

Published in September 2015. Second edition.



Welcome to teaching the TEMI way.

In this booklet, you will be introduced to an exciting new way to teach science in your classroom. The TEMI project (Teaching Enquiry with Mysteries Incorporated) is an EU-funded project that brings together experts in teacher training from across Europe to help you introduce enquiry-based learning successfully in the classroom and improve student engagement and skills.



What's special about TEMI teaching

The TEMI teaching methodology incorporates four key innovations: first, the use of mysteries to capture the students' imagination and motivation; second, the 5E cycle to help pupils explore and evaluate their learning; third, presentation skills to allow teachers to feel comfortable with presenting mysteries in the classroom; and finally, a method by which the responsibility for learning is transferred gradually from the teacher to the student, which flips the traditional learning channel.



Using this book

This book has **four short chapters** that introduce, explain and provide examples of the four TEMI teaching innovations. Practical suggestions, or **TEACHING TEMI TIPS**, that you can use in the classroom are also included.



Online resources

A significant number of resources are also available on the **TEMI website**, including more classroom mysteries and a smartphone applications that you may find useful for inside - and outside - the classroom learning.

We hope you find this booklet useful and that teaching the TEMI way proves as successful for you as it has for other teachers participating in the TEMI professional development courses.



The TEMI team

University of Bremen
Germany

Charles University
Czech Republic

CNOTINFOR
Portugal

Buskerud and Vestfold University
College
Norway

Leiden University
The Netherlands

Sheffield Hallam University
UK

Sterrenlab
The Netherlands

Queen Mary, University of London
UK

TRACES
France

University of Milan
Italy

University of Limerick
Ireland

University of Vienna
Austria

Weizmann Institute of Science
Israel

1 Mysteries

Their Nature and Purpose in Science Education

What is a mystery

Teaching Enquiry with Mysteries Incorporated (TEMI) intends to prepare students for enquiry learning by introducing them to challenging and fascinating phenomena. TEMI wants to make use of unknown and uncommon observations that we call mysteries. Within the TEMI project, we define a mystery as follows:



A phenomenon or event that induces the perception of suspense and wonder in the learner, initiating an emotion-laden 'want-to-know' feeling which promotes curiosity and initiates the posing of questions to be answered by enquiry and problem-solving activities.



What kind of mysteries is good or bad for the classroom

Whether a phenomenon induces a 'want-to-know' feeling or not depends on the student observing it. To evoke feelings of suspense and wonder, the mystery should challenge the student's curiosity.

However, what piques a student's curiosity will depend on the student's interests, experience and prior knowledge. Since interest, experience and prior knowledge will differ considerably from one student to another, a phenomenon that might be a mystery to one student may not challenge another – for example, if an observation deals with an already known and understood phenomenon or scientific concept.

The varying perceptions can also be linked to age, personal living conditions or cultural backgrounds.

Thus, ***the perception of mystery varies from one individual to the next***. Nevertheless, the TEMI project offers some suggestions that can guide teachers in selecting and developing a phenomenon as a mystery for promoting enquiry learning.



What makes a good classroom mystery?

A mystery can promote enquiry learning if it:

- ① provides affective engagement to the students;
- ② generates curiosity and leads to questions;
- ③ is simple enough to be a 'discrepant event', e.g. causes surprise;
- ④ generates a cognitive conflict;
- ⑤ can be scientifically investigated and explained within the competence and zone of proximal development of the students involved;
- ⑥ 'problematizes' or creates scientific knowledge;
- ⑦ requires the students to use enquiry skills to explain the mystery;
- ⑧ covers a sufficient part of the curriculum to justify the time spent;
- ⑨ can be solved in a limited span of time (1–2 lessons for the presentation of the mystery and finding the solution).

What makes a poor classroom mystery?

A mystery is not appropriate for classroom enquiry learning if it:

- ① provides engagement just for the teacher, but not the students;
- ② does not surprise or generates little curiosity and the teacher has to do all the work;
- ③ involves science concepts that are too difficult for students to grasp;
- ④ is peripheral to the subject content of the curriculum; and
- ⑤ is too complex for the students to solve, leading them to simply think of it as 'magic'.

Different kinds of mysteries

Mysteries can stem from many different domains and can have totally different characteristics.



Authentic Mysteries

One type of mystery is what we call authentic mysteries. Authentic mysteries are **phenomena that we encounter just by looking around in our natural or technological environments**. Examples of authentic mysteries found in nature are geysers, certain forms of plants or crystals or polar lights. Even the change in the colour of any item when viewed under light of a certain wavelength can be a mystery, which may be challenging for students learning about light, waves and optics.



Artificial Mysteries

Some of the authentic mysteries can be modelled using experimental setups in class. This as well as all other phenomena recreated to be presented to others can be referred to as artificial mysteries. **Experimental demonstrations or illusionary tricks are a part of artificial mysteries**. An example of an artificial mystery is the Chemical Garden – a beautiful experiment where metal salts are added to a sodium

water glass solution, and the growing forms, which look like mysterious plants, are observed. It raises a number of questions in the minds of those watching or conducting the experiment.



Fictive mysteries

Finally, there are fictive mysteries and myths. ***Fictive mysteries come from stories or are seen in movies or on TV.*** In many movies and television series, fascinating situations are presented. In most cases these are tricks or artificial effects. Thus, scientific enquiry might not be able to solve them. However, it can reveal whether the act was indeed a trick and help in uncovering the underlying scientific truth. There are also numerous myths from different cultures, such as a red moon signalling an earthly disaster, that can be explored. Some myths can be explained by science. Other myths cannot be explained, because the myth is beyond science. This might help students understand the potential and limitations of science.



Teaching mysteries in the classroom

- ① Think about the transition between the mystery and the enquiry process. Think about how you can lead students into the enquiry process beforehand.
- ② Prepare well beforehand and learn as you present. The more you try to present a mystery in a fascinating way the more motivating the mystery will be for your students.

The presentation makes the mystery

An uncommon observation is not necessarily a mystery in itself. Of course, there are many observations in nature that are perceived as mysterious by those who don't know the underlying scientific causes, e.g. the polar lights. However, sometimes a mystery has more to do with how a phenomenon is presented than the actual phenomenon itself.

For example, in acid-base chemistry, the students learn quite early that indicators change their colour according to the pH value. In traditional teaching sessions, acids and bases are introduced and tested based on the indicators. That the indicator changes the colour will not be perceived by the students as a mystery given the description above. A different or subsequent scenario could be introducing the acid-base chemistry concept with the help of a mystery called Chameleon



Bubbles. With a simple experiment you can produce alginate balls as seen in bubble tea. Moreover, you can produce bubbles filled with the indicator solution. If you add an acid or base to the surrounding water to alter the pH value, the colours within the bubbles will also change. This is because the alginate membranes are permeable to hydroxide and hydronium ions, but not for the larger indicator molecules. This is a very interesting phenomenon that might pique the curiosity of the students and motivate them to learn about acids, bases and indicators.

This example shows that even traditional phenomena and concepts from the curriculum can be transformed into a mystery if they are presented differently. More information on how to frame phenomena in mysterious ways is included in a later chapter.

Sources to find ideas for mysteries

To find and create mysteries for the classroom, you can find many resources here:

www.teachingmysteries.eu

The Internet as a source of inspiration

The richest sources of inspiration for creating your TEMI lessons are experimental descriptions or videos of experiments and phenomena on the Internet. [YouTube](#) is full of videos that can inspire teachers to present scientific content and mysteries in different, more creative forms.

For example, if you search YouTube for the keywords magic, acids and bases you will find many videos. One of the first results is a video where a student from MIT in Boston (US) demonstrates a colour-changing trick based on the acid-base indicators and then starts explaining the theory behind it. The best way to find mystery-related approaches to certain topics is to combine the content term that is given in the curriculum with words like magic, show, mysterious, mystery or curiosity.

If you are searching for inspiration without a certain topic in mind, you can search for terms like fascinating experiments, scientific phenomena or magic show.

Books

Nearly every language has books on magic tricks, fascinating experiments or small playful activities for children. Many of these books suggest presenting activities to *raise the students' curiosity*; thus, they *inspire teachers* to present their curriculum content in a different way. To find these books, you can search for terms similar to the ones in the previous section, but in online book stores such as [Amazon](#).

Toys and magicians’ warehouses

Warehouses and Internet stores can also serve as good sources of inspiration for toys or magic kits. These shops often sell small science and technology-based items, like Magic Sand – a type of hydrophobic sand that does not get wet. Other examples include applications of nanotechnology, magnetic toys or tricks involving water and fire.

For all the examples described above, like the Chemical Garden, Chameleon Bubbles or Magic Sand, the TEMI website provides teacher guides and classroom material.

2

Enquiry & the 5E Model

In this chapter we introduce the 5E model, a framework to support enquiry-based learning in the classroom.

Enquiry-based science education has been adopted worldwide in the 21st century as one of the main models of school science education. Originally used in

primary schools, it has been extended to secondary schools and is being adopted by many countries. Many EU-funded projects are exploring the use of enquiry in teaching science, and **TEMI** is one of them. One of the four innovations on which TEMI is based is the use of enquiry and the 5E model.

The **National Science Education Standards** (NSES, 1996) in the USA provides the following definition of enquiry:



Inquiry is a set of interrelated processes by which scientists and students pose questions about the natural world and investigate phenomena; in doing so, students acquire knowledge and develop a rich understanding of concepts, principles, models, and theories. Inquiry is a critical component of a science program at all grade levels and in every domain of science, and designers of curricula and programs must be sure that the approach to content, as well as the teaching and assessment strategies, reflect the acquisition of scientific understanding through inquiry. Students then will learn science in a way that reflects how science actually works.



The standards outline **six aspects that are pivotal to enquiry learning in science education**:

- ① Students should be able to recognize that science is more than memorizing and knowing facts.
- ② Students should have the opportunity to develop new knowledge that builds on their prior knowledge and scientific ideas.
- ③ Students will develop new knowledge by restructuring their previous understandings of scientific concepts and adding new information earned.
- ④ Learning is influenced by students' social environment whereby they have an opportunity to learn from each other.
- ⑤ Students will take control of their learning.
- ⑥ The extent to which students are able to learn with deep understanding will influence how transferable their new knowledge is to real-life contexts.

Enquiry-based learning is based on a **constructivist model**: students learn to construct their own understanding based on previous experiences through hands-on and minds-on interaction with phenomena and other students. They understand by reflecting on their experiences, communicating their thinking and learning to make connections between their own experience and the real world. The focus is not just on the science content but equally on the processes of science.

This implies a change in the teacher's role. Instead of an instructor, the teacher acts as a coach who carefully scaffolds the constructivist learning processes of the students.

The 5E model

The 5E model is one of a number of models of enquiry, but it has been widely adopted and used as a framework for the TEMI project. The **5E model is a learning cycle with five elements**: it may be seen as a continuous cycle (Figure 1a) or one where the 5th stage, Evaluation, feeds into the other four stages continuously instead of just at the end (Figure 1b).

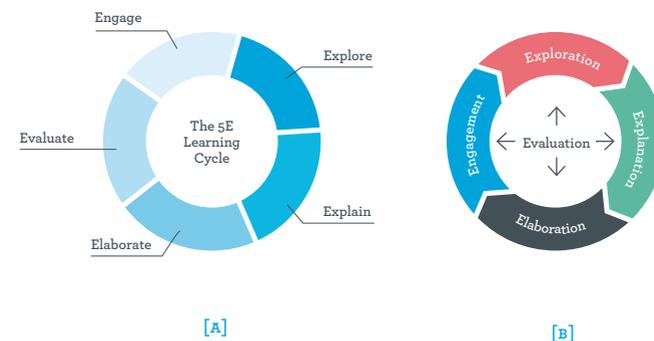


FIGURE 1
Different representations of the 5E model

Two versions of the 5E learning model

The model starts with the Engagement phase and moves through the others in sequence, until the cycle starts again with a new topic.

→ [Table 1](#) lists the five phases and summarises what each phase involves.

Summary of the 5E Instructional Model

(Bybee et al., 2006)

The enquiry model of science teaching is quite different from the traditional, didactic models and requires an innovative approach to professional development for science teachers. Teachers may often be quick to provide answers and tell students what is going on, without giving the students the opportunities to ask and answer questions themselves or to work out the answers or explore the problems through experiments. For example, teachers may ask questions and then answer them themselves or present a problem to the students and giving the answer too soon. The activities relevant to the Engagement phase for both teachers and students are given in [Table 2](#) below. →

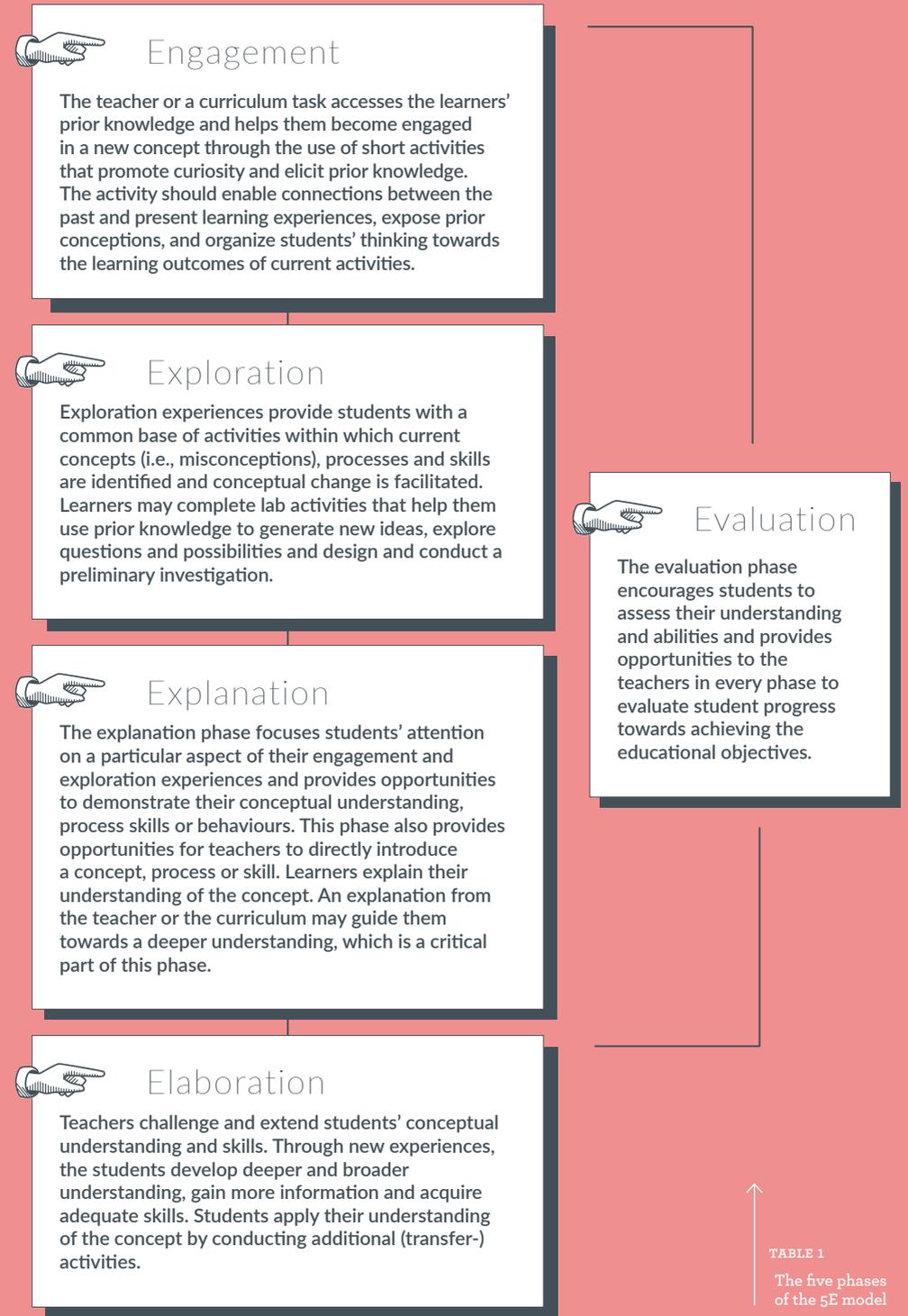


TABLE 1
The five phases of the 5E model



What is and isn't consistent with the Engagement stage of the 5E model

This is a useful table for both teachers and students, taken from "Enquiry, the learning cycle and the 5E model". It describes what is and what isn't consistent with the 5E model for all 5 stages. Here, for example, is a list of what is appropriate and not appropriate in the Engagement phase.



Focus on engagement Teacher

Is consistent

- ① Stimulates students' curiosity and generates interest
- ② Determines students' current understanding (prior knowledge) of a concept or idea
- ③ Invites students to express what they think
- ④ Invites students to raise their own questions

Isn't consistent

- ① Introduces vocabulary
- ② Explains concepts
- ③ Provides definitions and answers
- ④ Provides closure
- ⑤ Discourages students' ideas and questions



Focus on engagement Student

Is consistent

- ① Becomes interested in and curious about the concept or topic
- ② Expresses current understanding of a concept or idea
- ③ Raises questions such as 'What do I already know about this?' and 'What do I want to know?'

Isn't consistent

- ① Asks for the 'right' answer
- ② Offers the 'right' answer
- ③ Insists on answers or explanation
- ④ Seeks closure

3

Presenting Mysteries

As we have seen earlier in this book, TEMI uses unexpected and unfamiliar phenomena or mysteries to pique curiosity and challenge the students into enquiry.

One of the main factors that influence student engagement is the way the teacher implements the mystery. There are various ways to do this: showing a video or a demonstration, asking the students to undertake an experiment, teacher's performing of an unexpected

experiment, using role play or telling a story. You can develop your showmanship skills to make a mystery more exciting.

In this chapter, we first present some models devised for incorporating showmanship into scientific enquiry activities, in keeping the TEMI philosophy, and then elaborate how TEMI activities can be demonstrated in the classroom.

Showmanship in science: Models for introducing showmanship into enquiry activities

Showmanship is not just for the theatre. Teachers do it, too. *Many analogies have been drawn between the role of the teacher and that of an actor or a director.* Both roles involve facing an audience, both must convey a message in a convincing and memorable manner and both must learn to improvise if something takes an unexpected turn. In fact both must be authentic (an audience will drift off if an actor does not fully step into a role – just as the students do if the teacher is not fully engaging them).

That is not to say that the teacher is an actor, but the world of theatre has devised many tools and techniques to improve showmanship and to better master the art of performance, which can be used to let teachers present lessons in a motivating or fascinating way.



Teacher as a storyteller

As teachers we are constantly telling stories. If you think about the history of mankind, stories were the first method of teaching and conveying information. Adults would gather around the fire to hear the stories of the day. Children would be told fables and fairy tales that would teach them to fear and beware of the dangers of the outside world. In that sense, our thinking has developed around stories.

Let's look at an example of storytelling to make a mystery more engaging. In TEMI we have introduced stories and narratives into several of our activities. The [Sea-sand overseas](#) activity for example, begins with the story of James.



James is an old friend of ours who loves sand. Ever since he was a little child, James was outside digging, shovelling, moving sand to build amazing sand castles. He grew to be a very accomplished sand-castle builder as an adult and went on to win many national competitions. One day, we came across an ad on the Internet for a huge international competition in Australia, so we told James and before we knew it he was on a plane to Australia....



In the story James is given special sand that repels water as part of the competition. Some of this special hydrophobic sand is provided to the students, and their assignment is to figure out how James can build his castle. The activity may then be developed into a full formal enquiry activity by asking students to develop 'research' questions and design experiments that would help James build a perfect castle.

Students here are performing a classic enquiry activity. The TEMI approach is to frame the enquiry in a story with a relevant or real-life context. The story acts as a bridge linking students' everyday experiences and ways of thinking with the formal world of scientific research. The story along with the mysterious sand draws the students into the experiment. In effective classes, students often stayed back in class during their break time to try more experiments, designed creative experiments, deepened their thinking about solubility and (perhaps most importantly) greatly enjoyed the activity.

How to build a good story for the classroom

So if stories are so great, how do we go about writing them and presenting them in class?

Storytelling is a complex and multifaceted art form.

However, for the purposes of the class, some simple building models should suffice. The TEMI project has consulted experts in storytelling who provided us with three simple complementary models for storytelling, which you may recognize from movies or books that you know.



Method I

Suggests that every good story must have sufficient levels of three components: **action, colour and emotion.** Action is the driving force of the story - 'what is going on'. Colour refers to the details that wrap the story and help the audience imagine themselves in the situation. Emotion refers to the feelings of the protagonists and other characters, thus enticing the audience into the story through empathy.



Method II

Characterises the story from the **audience's point of view.** People who listen to the story will ask themselves the following questions; therefore the

storyteller should answer these during the story: 1. Who are the characters of the story? 2. Where and when is it taking place? 3. What's going on? 4. Why do I care? 5. How does it end? The answers to questions 1 to 3 constitute the information in the story. The answers to questions 4 and 5 are the most important part of the story since they are those that engage, excite and surprise the listener and motivate him or her to continue listening until the end of the story.



Method III

Defines **five essential sequential steps** in a story in order for it to deliver information in a dramatic structure. At the end of each step there are 'turning points', which create a dramatic transition towards the next step.

- ① **Exposition** - refers to the state of routine ('Once upon a time there was a...') *Turning point:* A reference to a particular time ('One day...', or 'And then one night...').
- ② Something comes up / there is a necessity / an opportunity that causes the hero to act. The hero does not know yet that he is the hero - he is still only the main character. *Turning point:* There is a change, a surprise ('suddenly and here...').
- ③ The plot thickens and becomes more complex. This is where the

main character becomes a hero by discovering characteristics and skills about herself/himself that were previously unknown. In this step the story develops, and more details are given about the locations, persons, colours, etc. *Turning point*: The hero is close to unravelling the problem and finding a solution.

- ④ The hero achieves his goal, and returns 'home' after passing through a physical or spiritual experience. We know that life does not always have a solution, but it is important to loosen the story. *There is no turning point*.
- ⑤ **Closure**. The plot returns to the starting point or a new routine situation is created ('And they lived happily ever after').

We discussed how showmanship may support enquiry activities in science classrooms. In this section we provide information on how teachers may implement the different strategies and activities in the classroom. Teachers should also be aware of students' expectations shaped by their prior knowledge.



The following are guidelines on which teachers can base any showmanship element, incorporated to make the performance more motivating.

- ① The term 'mystery' should be clear in your mind: What are the characteristics of a mystery; how will I make this alive for the students?
- ② Do I understand (1) Enquiry – the sorts of themes and activities which contain and explain a mystery, (2) Open-ended stories that motivate enquiry in order to allow students to solve and fully understand the mystery and (3) How these stories can be processed into useable student worksheets?
- ③ You should ask for, observe collect, record and analyse students' ideas and feedback in order to constantly improve the presentation, engagement and content of the mystery.

There are a number of methods we use in the TEMI programme to help teachers gain confidence in showmanship skills:

For example creating an activity such as Panto-physics – Investigating Newton's Laws of Physics Using Mime (→ see "Science - The biggest drama in the class" on Youtube TEMI channel) is not a classic TEMI activity, but it illustrates a possible combination of science, teaching and drama (mime) in the context of space, gravity and forces. Undertaking the creation or direction of such exercises may give you a chance to develop your skills in showmanship.

'Classic' TEMI activities, according



to our definition, are those in which the trigger for conducting the enquiry is a story that prompts the students to undergo an emotional experience, identify with the protagonists of the story, help them solve the mystery by conducting an enquiry and finally present the solution to the mystery.



Drama for the benefit of group dynamics ('pure' drama)

We allocated time for fostering good group dynamics and atmosphere for the following reasons:

- participating in drama activities can generate an open and embracing environment, whilst also promoting acquaintance between the teachers.
- it is important that the teacher experiences a lesson in which a “contract” is agreed upon. This contract establishes the rules which form a safe and embracing environment and which allow learning through drama to take place.

Drama for the benefit of better teaching

In effect, teachers perform in front of an audience in their classroom. If they learn how to tell a story in an effective way, their students will be more engaged and will show higher motivation to learn. The purpose is not to educate the teachers to be actors, but rather to use the ‘teacher as an actor’ metaphor in order to equip teachers with tools from the world of drama that can benefit them in their teaching.



The following activities were found to be useful in the TEMI training program:

Neutral masks

Neutral masks are white masks with a neutral expression (i.e. not happy, sad, or angry). It is interesting to note that despite its neutral characteristics, even a slight tilt of the head lends the mask some expression of feeling. When worn, the mask hides the face, thus the person wearing it can only express emotions using the body. At the same time, while hiding the face, the mask 'strips' the body. The body can no longer 'hide' behind a facial expression. Working with the mask helps bring awareness to the body and to non-verbal communication.

Still pictures

A simple group exercise to help you and others learning the rules of drama activities is 'still pictures'. Participants are given instructions to work in groups and depict something (a scientific phenomenon, something which happened at school) in three silent 'pictures' - i.e. three dimensional sculptures formed with their bodies. The groups prepare a short presentation in which they start in a neutral position while stating the name of the piece; they then show one body picture after another, giving



the audience enough time to digest them. This exercise allows teachers to experience what it is like to perform with no words and how they can be more effective with their body language.

In general, when presenting a mystery, the teacher should be aware of one's body gestures, try to be relaxed, conduct a fluent conversation, maintain eye contact, adapt the tone of the voice to the context, avoid nervous movements, etc.

Some of the points:



Coordination

Coordination is a combination of speech, body and space. A teacher who has good coordination can manage to deliver information and feelings to the audience by talking, moving, setting the tone according to the space and context, making eye contact with.



Changes

Changes during the presentation - it is important to introduce changes in location, body position, tone of voice and pace to adapt to the differences in the context of the information transmitted.

Learning and using your showmanship in class

Using some of the group and individual exercises detailed here will help you experiment and grow more confident with your showmanship skills. Presenting mysteries with good showmanship skills in class may engage more students into science and may lead to improved understanding, interest and motivation among students.

Some thoughts on showmanship and scientific theatre

One of the meanings of showmanship is 'the art of making something look interesting and great'. This art comes from the ability of a good showman to direct the attention of the public to what he/she wants and highlight the most interesting and surprising aspects. Interesting phenomena are in front of our eyes every single day, but, often, we are not able to see them because of the huge amount of stimuli hitting us simultaneously. When some aspects are isolated and put under a spotlight, we are suddenly able to appreciate the phenomenon as if we are noticing it for the first time; we look at it with new eyes and, generally, we are much impressed by it.

Consider for example the [phenomenon of oscillations](#). They are a part of everyday life: a leaf on a tree

is moved by the wind, a small piece of wood floats on the waves, an oscillating swing on which the children play. All these objects perform oscillating motions, but we are so used to them that we hardly pay attention to what we see: we are not able to look at them with wonder or find any similarities between them. But if we could, we'd understand that most of them move with the same motion: harmonic motion. To appreciate the peculiarities and the ubiquity of harmonic motion, our eyes must be driven, our attention held and our mind engaged creatively. Our engagement will be particularly effective if we are involved at an emotional, in addition to the rational, level.

Take the video:

["The Swing" on Youtube TEMI channel](#)

We see a child who understands that his legs must be moved at a precise frequency to let the swing oscillate. Until the final formula, the video tells us a story that has apparently nothing to do with science. We participate in the sadness of the child, and we are interested in the development of the story.

The video is emotionally involving, but it also works at another level. If students watch a video like this, it would surely be easier for the teachers to introduce forced harmonic oscillations since the idea would already be etched in the students' memory, thanks to the power of images. Good videos are important in teaching; however, scientific theatre can be even more powerful than videos. In fact, theatre has many more ingredients to capture people's attention, to engage, and to raise questions.

Theatre shows are performed in the dark, and the viewers watch them in silence without distractions. The same ingredients – [lights, darkness, music and silences](#) – can serve to highlight the science that is presented, giving students more possibilities to grasp

new things and to think about scientific themes from different perspectives and at different levels. Moreover, when experiments are presented, the use of theatre guarantees that no cinematic special effects are used: people see with their own eyes what is happening really on stage.

Different **theatrical techniques** can be used to highlight a physical experiment, depending on the emotional content one wants to attach to it. For example, a concept such as the compression and expansion of gases with temperature can be demonstrated through a very spectacular experiment (see for example an excerpt from the show *Alice in Energyland* [on Youtube TEMI channel](#)) as well as through a small activity (from the show *Let's Throw Light on Matter* [on Youtube TEMI channel](#)).

The previous example shows how theatre can be used in TEMI: as an additional tool for presenting mysteries, for engaging students and for planting ideas in the students' memory.

Theatre also finds its way into TEMI tasks where teachers or students are asked to identify a fundamental aspect of a problem and highlight it in a two-minute video. The importance of this approach lies in the fact that, to **make the video**, participants have to build a script that, besides being scientifically correct and focused on the key points of the selected topic, must also convey emotions, such as those coming from the answers to the following questions: 'where can I encounter this phenomenon in my life?'; 'why is this phenomenon important to me?'; 'how is it connected with the rest of the landscape?'; 'do I have some relevant personal anecdote to share?'

Not just teachers, even students can improve their showmanship skills greatly. This is also a practical approach to gradually transitioning the responsibility of their learning to the students – the topic of our next chapter.

4

Gradual Release of Responsibility (GRR)

The Apprentice Model

Levels of enquiry and apprenticeship

The TEMI method also lets teachers gradually release the responsibility of learning to the students. Through a series of different levels of enquiry, the student becomes more able to carry out his or her own independent enquiry, and the assistance of the teacher becomes

different, less instructive, but more enabling and flexible. This can seem quite unusual for some teachers, but enquiry-based learning provides students with not only a better understanding but also a stronger scientific approach in the study of science.

There are various levels of enquiry in science education – the initial level where the teacher directs every aspect to

the highest level where the student is in control. The aim of enquiry-based learning is to move students through these levels, from closed, directed enquiry to open-ended enquiry, where they need the intellectual and practical skills to become investigators and researchers.

Banchi and Bell (2008) discuss four levels of enquiry-based learning in science education: confirmation enquiry, structured enquiry, guided enquiry and open enquiry.



Level	Nature of enquiry	Question	Method	Answer
③	Open-ended	Student	Student	Student
②	Guided	Teacher	Student	Student
①	Structured	Teacher	Teacher	Student
④	Confirmation	Teacher	Teacher	Teacher

TABLE 2

The four levels of enquiry

Asking questions that are researchable at school is a challenge for many students initially. Teachers need to reflect with the students on what 'good' questions are *level 1 or 2*. It is recommended that teachers carry out a *level 2 or 3* enquiry beforehand and pay attention to students' follow-up questions in the same topic area. These questions can be collected in the classroom (on a box, pin board or flip chart) and used when a *level 3* enquiry is to be pursued for a lesson. Martin-Hansen (2002) calls this coupled enquiry.

TABLE 3

The four levels of enquiry

Shifting the showmanship

Students as presenters (teacher as facilitator)

Another approach to bringing showmanship into enquiry activities and passing on the responsibility for learning and giving students more autonomy in their learning is to let the students present in front of the class. The teacher is then in a way a director. Students can be given limited or full freedom with respect to the activity, but it is very important to set out the rules before beginning the activity. It is also important to remind students that while they might be performing a drama activity, it is still part of the science lesson with clear educational purposes. Following are two examples which illustrate



00 | Confirmation Level

Under confirmation enquiry, students are provided with the question and the procedure (the method), and the results are known in advance. Confirmation enquiry is useful when a teacher's goal is to reinforce a previously introduced idea, introduce students to the experience of conducting investigations, or have students practice a specific enquiry skill, such as the collecting and recording of data.



01 | Structured Level

In structured enquiry, the question and detailed procedure are provided by the teacher; however, the students generate an explanation supported by the evidence they have collected. They are responsible for uncovering the answer. The teacher provides support or materials so that the students can experience a sense of success when working at this level.



02 | Guided Level

In guided enquiry the teacher provides students with only the research question, and students design the procedure (method) to be explored, test their questions and share the findings. Because this kind of enquiry is more involved than structured enquiry, it is most successful when students have had numerous opportunities to learn, practice and plan experiments as well as record and interpret data. Although teachers are less instructive here, they provide a framework for the process when needed, prepare resource lists or help cards so that students can manage this level of enquiry.



03 | Open Level

At the fourth and highest level of enquiry, students have the greatest opportunities to act like scientists, who often work on deriving their own questions or answering questions from others, designing and carrying out investigations and communicating their results. This level requires advanced scientific reasoning skills and can often place the greatest cognitive demand on students.

how showmanship may be introduced into enquiry activities through student participation.

An example of showmanship shifting and its use in the transition of responsibility is given here.

The **Chemical Clock** activity consists of two translucent liquids that upon mixing turn black but after a time lag. Thus the two translucent liquids remain clear, but suddenly, without further intervention, after a few seconds turn black. There are ways in which showmanship enhances this activity and also allows students to explore their learning autonomy. To start off with, students are split into working groups and they try out the phenomenon. Teachers then ask them to prepare their experiment to demonstrate it in front of the class. What the students do not know is that each group has received mixtures consisting of different quantities of reactants so the solutions turn black after different time intervals. The result is a colour **'xylophone'**. The xylophone on the one hand highlights the mysterious phenomenon, and on the hand raises the question of what causes the delay in the colour change. In this case the teacher plays the role of a director in that she/he has to make sure the students are standing in the right order and that all the groups mix the solutions at the same time.

The teacher must also decide how and whether to provide a commentary on the experiment during the presentation.

A more advanced version of this activity, in which the students take more control of their learning, involves asking the students to choose their favourite song and find a key segment in the song (e.g. the music gets louder, singing begins, a solo starts). They should then find a way of timing their experimental setup such that the solution turns black in sync with the music. For this to happen, the students

will need to perform many iterations in order to calibrate the demonstration correctly. They must draw a calibration curve, learn to use it and try out their experiment a few times before presenting it to the class. After a short explanation of the phenomenon, students can be asked to devise a little live drama piece showing the explanation. This allows them to digest the explanation of the phenomenon and think of an imaginative way of presenting it. Showmanship here allows the students to think of the different aspects of the phenomenon and allows the teacher to assess the students' understanding, while opening up opportunities for further discussion. One group, for example, chose to demonstrate the phenomenon by having some students walk into the classroom with inflated balloons (representing the colour turning black). These balloons were quickly popped by another group of students with thumbnails. However the former group (the 'ballooners') out-numbered the latter group (the 'poppers'). Thus after a while, the inflated balloons filled the room but were not popped - representing the accumulation of the black colour. While not a perfect metaphor, it serves as a sound basis for discussion. Discussing the limitations of the model also helps refine students' understanding of the phenomenon.



What to think of when shifting the responsibility for learning

- ① What level is your class starting at? What evidence is this based on? How far can you move them? Plan the stages but make sure that you get feedback on their progress through the evaluation phase.
- ② Decide in advance which questions you will answer, which you will answer with an-other question, and which you won't answer.
- ③ Shifting showmanship, as discussed, can be an easy, natural and effective way to start the shift from the ground level.

“ Final Thoughts

Hope this book has given you an introduction to the TEMI method, the four innovations, ways in which you can allow your students to become better independent learners and strategies for developing the skills needed for enabling enquiry-based learning using mysteries. There are a number of resources for further reading listed at the end of this book.

The TEMI website features many more classroom resources and a smartphone app that you can use in your teaching. We believe that applying TEMI to your teaching will improve student attainment and create more impactful teaching. We hope you will try out the method and agree.

The TEMI Team ””



Acknowledgements and Further Reading

This book was written with contributions from the **entire TEMI project team**, but we would like to thank, in particular, the following individuals for their inputs: **Johanna Dittmar and Ingo Eilks** for the mysteries; **Rachel Mamlok-Naaman, Malka Yayon, Ran Peleg, Avi Hofstein, David Fortus** and **Dvora Katchevich** for the chapter on presenting mysteries; **Peter Childs, Tony Sherborne** and **Julie Jordan** for the 5E cycle and GRR; **Marina Carpineti** and **Marco Giliberti** for the part on scientific theatre; **Cristina Olivotto** for the editing. **Peter McOwan** coordinated this book project.



Further reading that may be of interest

For finding examples of mysteries:

www.chemicum.com/chemistry-videos/
www.video.about.com/chemistry/
www.illusioneering.org
stwww.weizmann.ac.il/g-chem/temi/movies.html

Selected websites of department stores
for finding new ideas:

www.stevespanglerscience.com/
www.thinkgeek.com/geektoys/
www.sciencetoymaker.org/

You can learn more about the story of James and the sea-sand and find examples of mysteries on the Youtube TEMI channel and on the TEMI website.



Books that may be of use in creating your own mysteries

Chemical Curiosities

Herbert W. Roesky and Klaus Möckel
Wiley
ISBN 3527294147 (1996)

Even More Everyday Science Mysteries: Stories for Inquiry-Based Science Teaching

Richard Konicek-Moran
National Science Teachers Association
ISBN 1933531444 (2009)

Everyday Science Mysteries: Stories for Inquiry-Based Science Teaching

Richard Konicek-Moran
National Science Teachers Association
ISBN 1933531215 (2008)

Mark Wilson's Complete Course in Magic

Mark Wilson
Running Press – U.S.
ISBN 0762414553 (2003)

The McGraw-Hill Big Book of Science Activities: Fun and Easy Experiments for Kids

Robert Wood
McGraw-Hill Education – Europe
ISBN 0070718733 (1999)



The 5E model and selected educational literature

Banchi, H., Bell, R. (2008)

The many levels of inquiry
Science and Children, 46(2), 26–29

Bruner, J. (1985)

Narrative and paradigmatic modes of thought, 97 - 115. In Learning and teaching the ways of knowing

E. Eisner (ed.)
National Society for the Studies of Education (NSSE)
ISBN: 9780226600871

Bruner, J. (1991)

The narrative construction of reality
Critical Inquiry, 18(1), 1–21

Bybee, R. W., Taylor, J. A., Gardner, A., Van Scotter, P., Powell, J. C., Westbrook, A., & Landes, N. (2006)

The BSCS 5E instructional model:
Origins and effectiveness

[www.science.education.nih.gov/houseofreps.nsf/b82d55fa138783c2852572c9004f5566/\\$FILE/Appendix%20D.pdf](http://www.science.education.nih.gov/houseofreps.nsf/b82d55fa138783c2852572c9004f5566/$FILE/Appendix%20D.pdf)

European Commission (2007)

Science education now: A renewed pedagogy for the future of Europe

www.ec.europa.eu/research/science-society/document_library/pdf_06/report-rocard-on-science-education_en.pdf



Martin-Hansen, L. (2002)

Defining inquiry. Exploring the many types of inquiry in the science classroom.

The Science Teacher, 69(2), 34–37

Sherborne, T. (2014)

Enquiry & TEMI CPD: Enquiry based science education & continuing professional development (CPD)

www.teachingmysteries.eu/wp-content/uploads/2013/12/Enquiry-CPD.pdf

Wellcome Trust (2012)

Perspectives on education: Inquiry-based learning

www.wellcome.ac.uk/stellent/groups/corporatesite/@msh_peda/documents/web_document/wtvm055190.pdf



The TEMI consortium

Coordinator, App & Website Development, Impact Evaluation



CNOTINFOR
Portugal



Queen Mary,
University of London
UK



TRACES
France

Promotion, Dissemination and Networking



Sterrenlab
The Netherlands

Teacher Training Centres



Charles University
Czech Republic



Buskerud and Vestfold
University College
Norway



Leiden University
The Netherlands



Sheffield Hallam
University
UK



University of Milan
Italy



University of Bremen
Germany



University of Limerick
Ireland



University of Vienna
Austria



Weizmann Institute
of Science
Israel



The research project has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement No. 321403.
teachingmysteries.eu

FP7-Science-in-Society-2012-1, Grant Agreement N. 321403



Co-funded by
the Seventh Framework Programme
of the European Union