TEMI: Teaching Enquiry with Mysteries Incorporated

Broggy, J.[1,2], Childs, P.E.[1,3], McCormack, O.[2], McManus, B.[1,3], O' Dwyer, A.[1]

[1]National Centre for Excellence in Mathematics and Science Teaching and Learning

[2]Department of Education and Professional Studies

[3] Department of Chemical and Environmental Sciences

University of Limerick, Limerick, Ireland

Beulah.Mcmanus@ul.ie

TEMI is an acronym for Teaching Enquiry with Mysteries Incorporated (http://teachingmysteries.eu/en). TEMI is a new FP7 Science and Society project, which started in mid 2013 and will run for three and a half years. The project is part of a response from the European Commission to tackle "the alarming decline in young peoples' interest for key science studies and mathematics" (Rocard et al 2007), with a focus on Inquiry-Based Science Education (IBSE). TEMI aims to work with schools across Europe to develop and implement innovative training programmes, which assist teachers in using enquiry to teach science. Science teachers across Europe will develop teaching methods using mysteries, unexplained or discrepant events to improve their ability to capture the attention of their students. The idea is to use the mysteries or discrepant events to arouse and engage student interest at the beginning of a lesson, which will then motivate students to enquire further and find out the scientific explanations. The mysteries or unexplained events engage the observer in the learning process, which is the first step of the 5E enquiry process. Each partner of the project will work with 5 or 6 cohorts of science teachers in a series of two one-day workshops. In between the workshops teachers will trial and evaluate the TEMI ideas in their schools and will develop TEMI lessons themselves based on these ideas.

The TEMI project is coordinated by Queen Mary College, University of London. The other partners include: Sheffield Hallam University (UK), University of Bremen (Germany), The Weizmann Institute (Israel), University of Limerick (Ireland), University of Vienna (Austria), University of Milan (Italy), Leiden University (Netherlands), Charles University, Prague (Czech Republic), Sterren Laboratory (Netherlands), Hogskolen in Vestfold (Norway), CNOTINFOR (Portugal), TRACES (France). The University of Limerick (UL) are the Irish partners in the TEMI project. The UL TEMI team have been working with 4 pre-service science teachers over the past year in developing materials for the TEMI lessons. These materials have been used in the first Teacher Training Workshop which took place in January 2014. The participants of the first workshop experienced IBSE in the form of a TEMI lesson, they were informed about the 5E model as a framework for IBSE, helped in developing their own TEMI lessons and were provided with an initial bank of prepared TEMI lesson ideas. Details of the first and second (April 2014)

TEMI Teacher Training Workshops and the participation of the pre-service and in-service teachers of Cohort 1 in Ireland will be outlined in the paper, together with examples of the TEMI materials and approach.

ENGAGING THE DISENGAGED: THE TEMI APPROACH

Introduction

Harnessing the emotional power of magic, myth and mystery is one of the latest trends in science education. TEMI, the EU-funded FP7 Science in Society project is attempting to promote enquiry-based teaching to help young students across Europe develop a passion for science. The aim of this three and a half year teacher training project is to help transform science and mathematics teaching practice across Europe by giving teachers new skills to engage with their students, exciting new resources and the extended support needed to introduce enquiry-based learning into their classrooms effectively. Innovative workshops are being developed among teacher training institutions and teacher networks across Europe which will be based around the core scientific concepts and emotionally engaging activity of solving mysteries, i.e. exploring the unknown. It is intended to train 5-6 cohorts of 10-12 teachers over the course of the three and a half year project, in each country, in a series of workshops. A spoke-and-hub model for coordination and delivery allows the project to both respond to local country needs and to maintain an overall EU-wide sharing of best practices. The central hub of this project is the coordinator Queen Mary University of London, while the spokes comprise of 13 partners from 11 countries (see Table 1).

Table 1: Consortium of the TEMI Project

TEMI Partners	
Queen Mary, University of London	UK
Università degli Studi di Milano	Italy
Bremen University	Germany
University of Limerick	Ireland
Sheffield Hallam University	UK
Hogskolen I Vestfold	Norway
University of Vienna	Austria
Weizmann Institute	Israel
Leiden University	Netherlands
Charles University Prague	Czech Republic
Sterrenlab	Netherlands
TRACES	France
Cnotinfor	Portugal

The 5E Model of Enquiry

The TEMI project is based on the 5E Model of Enquiry (Bybee et al. 2006), as shown in Figure 1.

Figure 1: The 5E Model of Enquiry

In this model the lesson proceeds through a number of stages (Table 2), of which the first one is engagement. The particular focus of the TEMI project is on this stage of the lesson. Unless students are engaged and motivated, and have their curiosity aroused so that they start asking questions: "Why? How? What if?", then there will be no real enquiry. The idea behind TEMI is to use mysteries, unusual or discrepant events, to capture the students' interest and lead them into the 5E process.

Table 2: The Stages of the 5E Model (Bybee et al. 2006)

Engagement	Students' prior knowledge accessed and interest engaged in the phenomenon
Exploration	Students participate in an activity that facilitates conceptual change
Explanation	Students generate an explanation of the phenomenon
Elaboration	Students' understanding of the phenomenon challenged and deepened through new experiences
Evaluation	Students assess their understanding of the phenomenon

What is a Mystery?

In science education, a mystery is a phenomenon or event that provokes the perception of suspense and wonder in the learner, in order to initiate an emotionally-laden "want to know"-feeling, which leads to an increase in curiosity and which initiates the posing of questions by the students, to be answered by enquiry and problem-solving activities (TEMI 2013). Such mysteries, which have a scientific basis and explanation, are also known in the literature as discrepant events. There is a large body of literature describing discrepant events and their role in science education to facilitate learner understanding and motivation (Liem 1990; O'Brien 2010).

A mystery is a good mystery for classroom enquiry if:

- it can be investigated and explained scientifically and is within the competency of the students involved,
- it provides affective engagement for the students,
- it generates curiosity and leads to student questions,
- it 'problemmatises' or makes knowledge and enquiry skills part of the answer to the mystery,
- it covers a sufficient part of the nationally assessed curriculum to justify time spent,
- it is simple enough to be a 'discrepant event', and generate cognitive conflict,
- the time between mystery and answer is limited (1-2 lessons),
- it is introduced by a pedagogy that relies on the mystery itself.

A mystery is a bad mystery for classroom enquiry if:

- it provides engagement for the teacher only, but the students are not excited,
- it generates little curiosity and the teacher has to do all the work,
- it is answered by science concepts that are too difficult for students to grasp,
- it is peripheral or unrelated to the subject content of the curriculum,
- it is too complex, so that students explain it away as 'magic' (a trick that I don't need to explain).

(TEMI 2013)

The various partners involved in this project are tasked with developing lessons around such scientific mysteries, introducing them to practising science teachers, who will try them out in schools and evaluate their effectiveness in engaging their students.

TEMI TEACHER TRAINING IN IRELAND

The Teacher Training Workshops for the 5 cohorts of teachers to be involved over the course of the project in Ireland have been mapped out below in Figure 2. It is predicted that over 60 in-service and 12 pre-service science teachers will participate in the project in Ireland. Each cohort of teachers will be numbered as 1,2,3,4 and 5. As each cohort will attend two full-day training workshops, the workshops have been labeled as 1.1 and 1.2 for Cohort 1, and will be labeled as 2.1 and 2.2 for Cohort 2 etc. To facilitate the sustainability of the TEMI Teacher Training in each participating school, two teachers from each school will attend TEMI Teacher Training Workshops in successive cohorts. In that way, one teacher from school A will attend the workshops as part of Cohort 1 and a second teacher from school A will attend as part of Cohort 2. The aim of this cascading model is to provide support for individual teachers within their school as they develop and trial TEMI teaching ideas, hence increasing the influence that the TEMI project can have on science teaching in the participating schools.

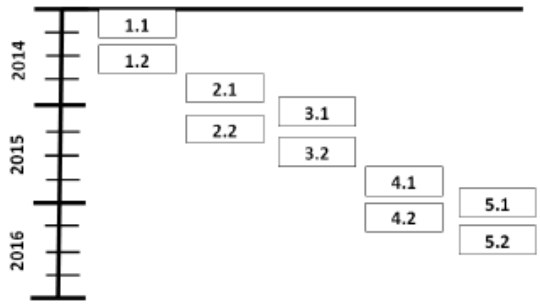


Figure 2: Map of TEMI Teacher Training Jan 2014 to June 2016.

Pilot Teacher Training

As outlined in Figure 2, the first cohort of teachers completed their TEMI Teacher Training in April 2014. Their first workshop (1.1) was in January 2014 and their second workshop (1.2) was in April 2014. This first cohort was composed of 4 pre-service science teachers and 5 in-service science teachers.

Role of the Pre-Service Science Teachers

The pre-service science teachers were in their final year of a four-year Science Education teaching degree programme in the University of Limerick. As part of their Final Year Research Project (FYRP), the students developed classroom teaching materials in the form of TEMI lesson plans and activity sheets in the areas of chemistry, physics and biology (for both the Junior Cycle – general science, and the Senior Cycle – single subject science). One of the students developed an 8 week science module for Transition Year science students, Scientific Mysteries, which includes physics, chemistry and biology units. The pre-service science teachers trialled and evaluated the developed TEMI classroom materials while completing their final year school placement (Sept- Dec 2013). The Transition Year module was also piloted by a number of the in-service science teachers in advance of workshop 1.1 in January 2014. The pre-service science teachers played a key role in the TEMI Teacher Training by:

- Providing information to the in-service teachers on how they sourced and developed TEMI classroom ideas.
- Providing feedback on their own experiences of implementing the TEMI lessons.
- Providing feedback on their pupils' learning experiences and attitudes towards the TEMI lessons.
- Mentoring and facilitating in-service teachers in developing and planning new TEMI ideas.

Workshop1.1

This was the first TEMI Teacher Training Workshop. The workshop was divided into 4 sessions which are detailed in Table 3. At this workshop, participating teachers were provided with a resource folder containing all of the necessary documents for their participation in the TEMI project. The contents of this folder included a list of all TEMI contacts and participants in Ireland, previously developed TEMI ideas, Lesson Planner templates to guide the development of their own lessons, as well as selected relevant literature about IBSE and the 5E Model.

Table 3: Content of TEMI Teacher Training Workshop 1.1.

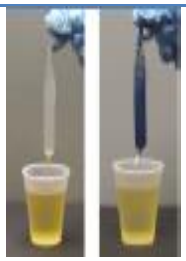
Session	Outline
1	Vision for TEMI project in Ireland TEMI enquiry lesson simulation 5-E model
2	Teaching to Motivate
3	Teaching Mysteries Designing a TEMI lesson
4	TEMI lesson resources TEMI Community of Practice

The in-service teachers found the workshop very useful as it was "applicable to real life & work of the teacher". They enjoyed working on a possible TEMI lesson in the workshop, with a suggestion of allowing more time for such lesson planning. The use of the Google + and Google Drive platforms was praised by the teachers as they found them to be "really helpful resources for future reference". Some teachers had previously "tried to implement mystery/enquiry into [their] lessons" but thought that it was "nice to have a structure" to do this. One teacher explained how they found it "extremely useful to be reminded to reflect on what [they] are doing in classrooms as teachers & how to develop & improve student experience[s]". The teachers were conscious that a lot of time and effort is required for this project but they believe that "the benefits and positive aspects are huge". One concern that was raised by the teachers was that using a discrepant event to introduce a scientific concept may be too challenging for lower ability pupils. The teachers felt that this teaching approach would be more suited for higher ability pupils.

TEMI Lesson Ideas

In the intervening time between both workshops, the in-service teachers trialed 5 of the TEMI lesson ideas that were developed by the pre-service teachers. They also developed 2 TEMI lessons of their own where they chose their own topics within the Junior and Senior Cycle science curricula. The lesson ideas were prepared using a structured Lesson Planner and the details were then organized on a prepared Lesson Template. Each of the teachers completed the TEMI Lesson Templates for each developed lesson. This document then provided all of the details for another teacher to use the TEMI idea e.g. the scientific concepts, appropriate age levels, necessary prior knowledge, preparation of chemicals and materials, safety hazards, resources for pupil exploration, extension activities etc. Table 4 provides some examples of the TEMI lesson ideas developed by the science teachers in cohort 1.

Table 4: TEMI Lesson Ideas Developed by the Teachers in Cohort 1.

Subject (topic)	Lesson Name	Brief Description	
Biology **(The Digestive System)**	A Lot of Guts!	The sizes of the 'small' and 'large' intestines are compared by presenting lengths of rope representing both. The importance of their size in relation to their function is investigated.	
Biology **(Osmosis, Diffusion)**	The Leaking Bag!	Osmosis and diffusion are explored by immersing a fully sealed zip-lock bag (or dialysis tubing) containing a starch solution into a beaker of iodine solution.	
Chemistry **(Redox)**	Decolourising $KMnO_4$ with steel wool	To introduce the topic of oxidation and reduction by introducing potassium permanganate as a strong oxidising agent.	
Chemistry **(Water, Bonding, Solutions)**	Burly Bubbles	Compare the properties of homemade (water and washing up liquid) bubble solution with burly (water, washing up liquid and glycerol) bubble solution.	
Physics **(Pressure)**	Under Pressure	To introduce the topic of pressure, a balloon is pressed against a bed of nails. However, the balloon does not burst easily.	
Physics **(Boyle's Law, Atmospheric Pressure)**	Boyle-ing Point	Differential pressures cause water to be 'sucked up' into an upside-down wine bottle.	

Workshop 1.2

The second TEMI Teacher Training Workshop for Cohort 1 was held in April 2014. Table 5 provides a brief outline of the content of the full-day workshop.

Table 5: Content of TEMI Teacher Training Workshop 1.2.

Session	Outline
1	Feedback from in-service teachers Feedback from pre-service teachers
2	Engage Phase: In the chemistry laboratory
3	Implementing enquiry throughout a lesson Developing a complete TEMI lesson Alternative types of mysteries
4	Sustainability of TEMI

The second workshop was mostly led by the in-service and pre-service science teachers, as each of them gave presentations on their work. This is following the Gradual Release of Responsibility Model (Fisher 2008), following the dictum: 'I do it, we do it, they do it.' The overall aim of UL's TEMI Workshops is to transfer ownership of the TEMI idea to the participating in-service and pre-service science teachers, so that they in turn will be able to pass this on to their students. According to the teachers in the second workshop, they enjoyed sharing their experiences of developing and trialling the TEMI lessons. Much of the feedback from the teachers was similar. Interesting points that the teachers agreed on included:

- The TEMI lessons were better received by Junior and Senior Cycle classes rather than pupils in Transition Year.
- The lower-ability pupils engaged and participated better in the TEMI lessons than the pupils who are usually 'high-achievers' in the classroom.
- That it was very easy to source TEMI lesson ideas and resources online.

The laboratory session was the teachers' favourite part of this workshop. In this session, each of the in-service teachers had the opportunity to teach the 'Engage 'part of their TEMI lesson in the chemistry laboratory. This gave the teachers an opportunity to share the ideas that they had developed and also to gain further feedback from the whole cohort on adaptations that could be made to their ideas.

PARTICIPATING TEACHERS' EXPERIENCES

All of the participants (pre-service and in-service teachers) completed an evaluation form at the end of both TEMI Teacher Training Workshops. Teachers' confidence ratings in sourcing, developing and implementing TEMI lesson ideas after both workshops were quite high, with confidence ratings of over 4.4 on the 5 point Likert-Rating Scale. At the end of Workshop 1.2, the teachers noted how they would still have liked further time to learn how to implement the other four E's of the 5E Model following engagement; exploration, explanation, elaboration and evaluation. All of the teachers were intent on using the TEMI ideas in their future teaching. 37% of the teachers said that they would implement the TEMI ideas as they have been presented in the TEMI project, while the majority of the teachers (63%) said that they would adapt the TEMI lesson ideas to implement them with other teaching approaches. It is

intention of all TEMI partners to revise subsequent workshops in the light of our experience following a partners' meeting in November 2014.

Final Teacher Questionnaires

Overall, the in-service science teachers enjoyed their experience in the TEMI project. They felt that it "improved [their] teaching", and has provided them with "new ideas, resources and motivation". Some teachers commented on how they liked the opportunity to have to use their "creativity and personal ideas" for the development of their own lessons and all teachers noted that they would continue to use TEMI teaching ideas in their future teaching. Interestingly, it was reiterated by one of the teachers that the "challenging and fun" ideas in the TEMI lessons benefitted the academically "weaker" pupils as the academically "stronger" pupils "were less engaged by the mysteries".

It was agreed by all of the teachers that the 5E Model of Enquiry is a good approach to use in science teaching. Of the 14 trialled 5E TEMI lessons, 11 of those lessons motivated pupils to understand the underlying scientific concepts, with teachers being unsure about 3 of those lessons in their ability to motivate pupils to enquire further. The development of pupils' conceptual understanding was not affected negatively by using the TEMI approach, according to the participating in-service teachers. Furthermore, 11 of the 14 trialled TEMI lessons were reported as being easier to use to teach the particular topics as opposed to teachers using their usual lesson plans. No teacher was of the opinion that the TEMI lessons were more difficult to use to teach a topic than their usual teaching approach. It was pointed out by one teacher however, that the TEMI approach is "less suitable at Leaving Certificate level, or at least may need to be modified, as large amounts of information needs to be 'covered' in each lesson".

WHAT IS UNIQUE ABOUT TEMI?

TEMI is an EU funded IBSE project. However, the approaches taken in the implementation of the Teacher Training and development of resources in this project are unique from other such projects.

Cascading Recruitment of Teachers

As outlined in the introduction and illustrated in Figure 2, a cascading mechanism has been adopted in the recruitment strategy for teachers in the TEMI project. In this manner, participating teachers will not be isolated in their attempts to trial new ideas and reform their teaching approaches. By having more than one teacher implementing the 5E Model of Enquiry in a school, pupils may also develop better enquiry skills and become more familiar with the teaching approach. Hence, each cohort of TEMI teachers will be encouraged to involve other science teachers in their schools by sharing their experiences and materials, acting as mentors in their own schools. Figure 4 summarizes some of the ways in which the first cohort of in-service teachers intend to recruit their colleagues for participation in future cohorts

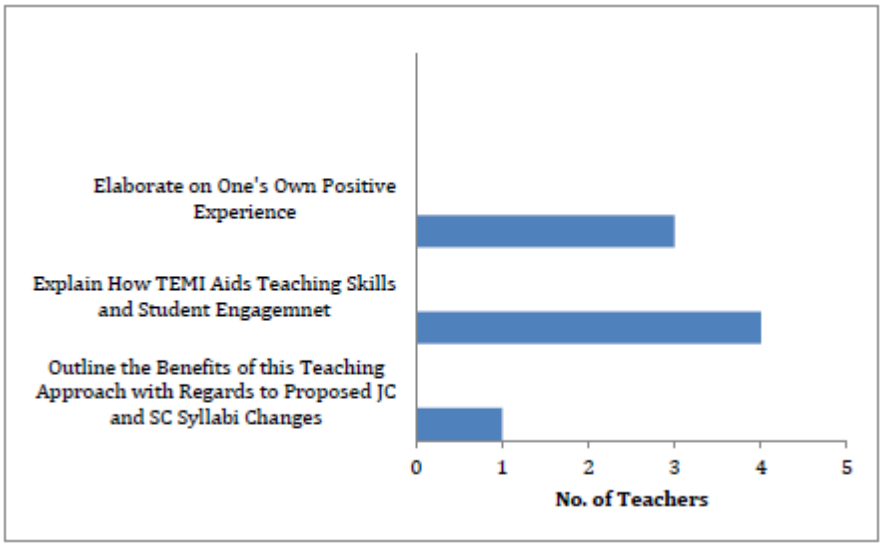


Figure 4: How Teachers Plan to Recruit their Colleagues to Participate in TEMI

Teacher Participation

Although the authors of this paper are the core Irish TEMI team, they see themselves as facilitators of pre-service and in-service science teachers' professional development. In the TEMI Teacher Training Workshops, teachers are given the opportunity to lead and direct their own learning. The pre-service teachers in Cohort 1 led the development of TEMI lessons. The in-service teachers had input into the planning for workshop 1.2. The areas of expertise of the individual in-service teachers were used by the UL team to enhance the teacher participation in both workshops. One of the sessions in Workshop 1.1 and three of the sessions in Workshop 1.2 were teacher-led. One teacher from cohort 1 will be involved as 'lead' teacher in cohort 2. This model of teacher participation will be continued in the following cohorts. By giving the teachers more ownership over their personal development in this project, the teachers were confident and honest in discussing the challenges they faced in a supportive environment.

Pre-Service Science Teacher Participation

The Irish TEMI team believes that involving pre-service science teachers in the project from the beginning has been a valuable part of the project, both for the participating students and for the teachers. They have made significant contributions in developing lesson materials and in doing preliminary evaluations of them as part of their FYRPs. We hope to continue this in subsequent years and also to provide training workshops on the TEMI approach and materials for a wider group ofpre-service science teachers in UL.

Virtual Community of Practice

A TEMI (Ireland) Community of Practice has been established with the first cohort of participants. To facilitate communication between all participants between the workshops and following the final workshop, a virtual community was set up using the Google™ Community. The aim of the TEMI (Ireland) Google forum is to allow teachers and the UL TEMI team to easily interact with each other online and to share their experiences of implementing TEMI lessons. The TEMI Google Drive folder,

which is an online cloud storage facility, serves as a storage bank for the developed curriculum materials. This will be continuously added to by the team members and participants of future cohorts throughout this project. It is intended that all members involved in all cohorts of the TEMI project will continue to use and develop TEMI-style materials after their own workshops. All teachers in the community of practice will be able to use the resources throughout the lifetime of the project and after the project has ended. The idea is to develop a continuing community of practice with pre-service and in-service teachers and science education researchers for the duration of the project and beyond.

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