Contents #107

Information Page

For subscription details etc. see inside back cover.
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Editorial #107

TEMI Special Issue

The Summer 2012 issue of *Chemistry in Action!* (#97) was a special issue devoted to the SALiS Tempus project, of which the University of Limerick was a partner. This issue is another special issue devoted to the TEMI project, Teaching Enquiry with Mysteries Incorporated, an EU-funded FP7 project, which runs from 2013-2016. This special issue marks the conclusion of the project. The project coordinator, Professor Peter McOwan of Queen Mary College, London is himself an amateur magician. His interest in magic and using it as a teaching tool was the genesis of this project. The first project meeting included a memorable evening at the Magic Circle in London.

The nine partners involved in providing teachers' CPD workshops came from 9 countries and different education systems, and represented different areas of science; some came from science departments and others from science education/teacher training departments. Although working to a common brief, this meant that each partner interpreted and fulfilled the TEMI brief in different ways and thus produced a rich diversity of experience and resources. I hope that the articles from the various European partners in this issue will give you a flavour of the project and will encourage you to check out the project website (www.teachingmysteries.eu) . There you can access more details about the project and also a range of scientific mysteries, developed by the project, which can be used to initiate lessons and promote engagement.

The Irish connection

An earlier article (CinA!#105, Spring 2015, 8-12) reviewed the Irish contribution to the project. The Irish TEMI team has run a number of taster workshops for Irish teachers through the Amgen Project and at ISTA conferences, in order to recruit schools and teachers for the project. We are planning a final National TEMI conference in early June. We hope to invite all the TEMI teachers but also STEM stakeholders in Ireland and other interested Irish teachers. If you would like to be informed about this conference, please email me for details.

Why use the TEMI approach?

We are not claiming that the TEMI approach of using mysteries to engage students is the only way to teach science or is a universal panacea to combat student disinterest. It should be seen as another strategy in the teacher's arsenal for teaching science and inquiry. Using the TEMI approach for every class would probably be counter-productive but it can be used at intervals, maybe when starting a new topic, to enrich your teaching and capture your students' interest.

One legacy of the TEMI project, as with other IBSE projects, will be a bank of materials for science teachers to draw on in designing their own lessons. It is also about changing your own perspective and turning the lesson around (see p.62), by using an activity at the start to engage students, in the form of a mystery, that you might usually place later in the lesson to back up or illustrate the theory. In this case it's not about coming up with radical new mysteries that will wow your students, but just using what you already do in a different way to stimulate inquiry rather than just something more to be learned off. There is nothing more demoralising than being asked to 'prove' something you already know.

The structure of the issue

After an introduction by the project coordinators, the 4 TEMI innovations are briefly described and some of the TEMI web-based resources. Each teacher training partner then describes their work, including a sample TEMI mystery that they have used.

We hope that you will pick up some useful ideas about the TEMI approach but also activities you can adapt and use in your classroom or laboratory.

The TEMI project is funded by the European Union in the FP7-programme under grant agreement no. 321403 and has funded this special issue.

Peter E. Childs
Hon. Editor

Education News and Views

The Editor welcomes contributions and news of interest to chemistry teachers in this section.

Science museum finally approved

In the last days of the old government (Feb. 24th 2016) it was announced that Ireland would finally get its first funded science centre, the Exploration Centre. This has been on the drawing board and even on the launching pad for many years. It was originally scheduled for a building near Houston station in 2007 but the project sank in the financial recession. The old UCD building near the National Concert Hall is being refurbished to house the new science centre. Ireland is the only European country without a dedicated science centre, although Dublin does have the very successful Science Gallery housed in Trinity College. It is hoped it will be open in the last half of 2018.

http://www.irishtimes.com/news/education/exploration-station-can-dublin-lead-europe-with-new-centre-1.1656071

http://www.irishtimes.com/news/science/dublin-s-exploration-station-nearly-30-years-in-making-1.2545892

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Professor Dick Butler dies

Dick Butler, former Professor of Organic Chemistry at NUI Galway, died on Feb. 10th 2016. He was well known to many NUIG chemistry graduates and played a major role in past LC Chemistry syllabus committees. He was a distinguished organic chemist. He retired in 2008 but continued to be active in chemistry. He was a former President of the Institute of Chemistry of Ireland and a recipient of its Boyle-Higgins Gold medal. Dick was a great enthusiast for chemistry, particularly organic chemistry, and a good friend to Irish chemistry teachers. He will be missed by his family, friends, colleagues and past students.

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Can you speak Chemistrian?

Check out this video:
http://www.irishmanabroad.com/2013/07/science-saturday-can-you-speak-chemistrian/

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10th Chemistry Demonstration Workshop

This year marks the 10th anniversary of the residential Chemistry Demonstration Workshops at the University of Limerick. There is small charge for the workshop which runs from Monday lunchtime to Friday lunchtime, with accommodation on campus. The dates are:
June 27 – July 1. For more details and to book a place contact: Sarah Hayes at sarah.hayes@ul.ie

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Irish TEMI conference

An Irish TEMI conference is being planned for Tuesday June 7th at the University of Limerick. The conference is free of charge. All TEMI teachers are invited plus other science teachers from their schools. We can also accommodate some other interested teachers – if you would like to come, please contact peter.childs@ul.ie for more details before the end of May.

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7th SMEC Conference in DCU

The 7th Science and Mathematics Education Conference will be held in Dublin City University, 16-17th June. The theme is 'STEM Teacher Education - Initial and Continuing professional development.' For details and registration contact:
http://www.dcu.ie/smec/index.shtml

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Robert Boyle Summer School

The annual Robert Boyle Summer School in Lismore, Co., Waterford will be held this year from June 23-26 and the theme is 'Science and Irish Identity'. For more details contact:
http://www.robertboyle.ie/

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The mysterious road to TEMI

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Have you ever wondered why the Mediterranean Sea is fresh water when it connects to the Atlantic which is salt water? Why do some people believe there is a face on Mars, and is it possible to read minds with a deck of cards? The TEMI project, TEMI or Teaching Inquiry with Mysteries Incorporated, sets out to use Mystery solving to transform science and maths teaching in Europe. By posing a good mystery, like those mentioned, we have found that TEMI trained teachers have the skills to engage and support their students in Inquiry-based learning, as they explore and solve the mysteries presented.

What's TEMI about?

The TEMI project kicked off in February 2013 and ran for 42 months, with the aim to pilot methods to transform European teaching practices through the use of Mysteries. It is a pilot project targeting over 500 science and maths teachers in nine countries. Table 1 lists the partners in the project.

Table 1. Consortium of the TEMI project

TEMI Partners (bold – teacher training partners)
Queen Mary, University of London – UK (Coordinator)
Università degli Studi di Milano - Italy
Bremen University - Germany
University of Limerick - Ireland
Sheffield Hallam University - UK
Hogskolen I Sorost Norge - Norway
University of Vienna – Austria
Weizmann Institute - Israel
Leiden University - Netherlands
Charles University Prague - Czech Republic
Sterrenlab - Netherlands
TRACES – France
Cnotinfor - Portugal

Through its network of Teacher Training Centres, TEMI provided training to teachers to incorporate the use of mysteries in the classroom. It also adds an additional element of up-skilling teachers in communication and drama presentation to carry through engaging and exciting Inquiry-based activity in the classroom.

Research has consistently found evidence that the way science is traditionally taught is a cause of students' declining interest in the subject with age (Science Education NOW: A renewed pedagogy for the Future of Europe, 2007). Inquiry holds out huge promise for science education, to arrest the decline in student attitudes towards science and mathematics, and foster better scientific thinking. Yet, it demands a major shift in existing classroom culture.

What makes a good TEMI classroom mystery?

In science education, a mystery is a phenomenon or event that provokes the perception of suspense and wonder in the learner to initiate an emotionally-laden "want to know" feeling, which leads to a rise in curiosity and which initiates the posing of questions to be answered by Inquiry and problem-solving activities.

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

TEMI supporting teachers' CPD

TEMI takes an innovative approach to professional development (CPD) to help teachers change the pattern of classroom interaction. It adopts a clear definition of Inquiry in terms of a cognitive skill set, and sets out a stepwise progression to push students towards becoming confident enquirers. The project pays equal attention to the affective side of learning. TEMI helps teachers foster a deep motivation to learn, by bringing to the fore the sense of mystery, exploration and discovery that is at the core of all scientific practice.

TEMI aims to transform science and mathematics teaching practice across Europe by giving teachers new skills to engage with their students, and new scientific skills for their students. The project also works to offer exciting new resources, hosted on a multi-lingual website (www.teachingmysteries.eu) and to provide other support resources to effectively introduce Inquiry-based learning into classrooms.

TEMI has involved nine Teacher Training Centres across Europe to develop and implement the pilot programme through 'Inquiry Labs'. Teachers were recruited to participate in a series of training sessions, where they experimented with the TEMI approach based around the core scientific concepts and emotionally engaging activity of solving mysteries, i.e. exploring the unknown. The Inquiry labs used scientists and communication professionals (e.g. actors, motivational speakers, etc.) to mentor teachers through the transition to using Inquiry to teach Inquiry-based science skills.

In TEMI, teachers had access to extensive training programme and at the same time were the participants and educational experts driving the development of the pilot. Teachers were invited to test the approach and materials in the classroom and give feedback on it. As the training progressed, methods and resources were refined in an iterative design-test-feedback cycle. The ultimate objective of TEMI was to provide teachers with methods and resources fully tested by teachers themselves.

The TEMI books

The *TEMI Book of Science Mysteries*, developed as part of the project legacy and available free for download on the TEMI website, contains a series of mystery classroom activities, all of which introduce, explain, and provide examples of the four TEMI teaching innovations (mystery, a structured 5E learning cycle, presentation skills, and the gradual release of responsibility for learning to the student), with practical suggestions and worksheets for use in the classroom.

The book also includes examples of a student hypothesiser lifeline/construct explanations lifeline that helps students document their exploration of the mystery and an activity characterisation sheet. Using the hypothesiser lifeline, students can follow through and reflect on their learning process and proceed in stages, from a working hypothesis to data collection to acceptance or rejection of the current hypothesis. The characterisation sheet is designed to facilitate the use of TEMI activities according to the four innovations to your own needs.

The companion book, *Teaching the TEMI Way: How using mysteries supports science teaching* (TEMI, 2015), is available on the TEMI website in a range of European languages. 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;

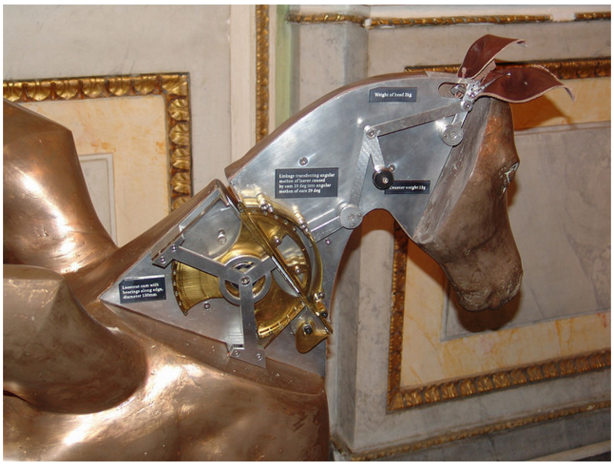
and **finally**, a method by which the responsibility for learning is transferred gradually from the teacher to the student, which flips the traditional learning channel.

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

The Reach and Impact of TEMI

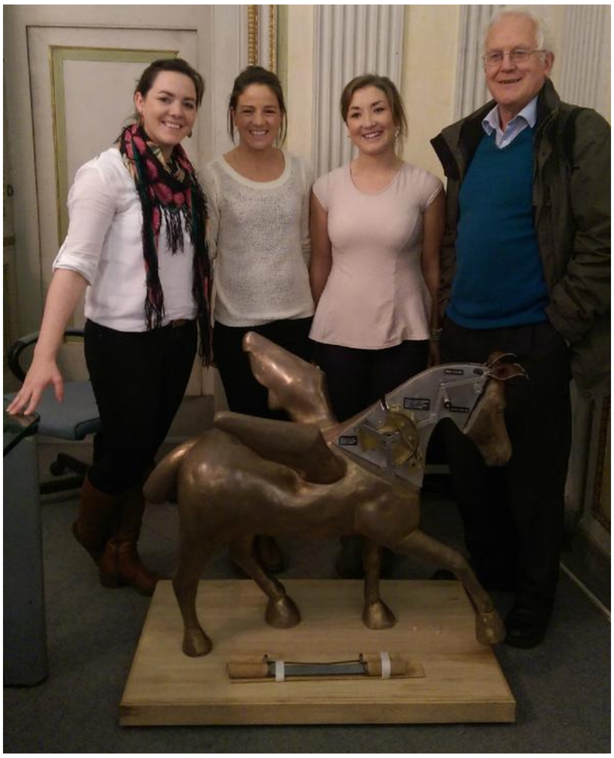
TEMI is an ambitious project that aims to pilot change in classroom practice across Europe, through an innovative programme of teacher training on Inquiry-based learning, the production of multilingual classroom resources and a smart phone app, and the approach using the emotional hook of solving mysteries to engage students. Over the project span, TEMI delivered 54 training sessions across the TEMI partners in 9 countries, which amounts to more than 520 teachers recruited. Training was designed to reflect local country-specific issues around curriculum, suitability of content and classroom practice, and the discovery and compensation for such issues was an important element of the project.

TEMI also explored teacher needs with regard to engaging with the training and in so changing their own classroom practices. The TEMI concepts of gradual release of expertise from teacher to pupil, and the need for teachers to be able to exhibit the communication skills needed to effectively engage students in Inquiry learning, was also explored.



Close-up of the TEMI mascot

TEMI partners attended a range of educational conferences/events to disseminate information on the project. The project also constructed a mechanical mystery mascot, a modern day replica of a famous ancient Greek mystery automaton, Heron's Horse, for the project, to act as a focal point at workshops and conferences. TEMI partners worked to ensure widest possible dissemination of TEMI materials through our networks and other EU teaching events, such as SCIENTIX and the Science on Stage conference in 2015.



The UL team (Joanne Broggy, Anne O'Dwyer, Beulah McManus and Peter Childs) at a project meeting in Milan with the TEMI mascot

The project has risen to the challenges brought about by an extended network of training partners embedded in their own local cultures, curriculums and practices and now leaves a legacy of a unified core of evidenced training methods and resources that are fit for purpose in the countries involved.

TEMI leaves a legacy to provide the teaching community and European teacher training centres with a methodology and materials fully tested by teachers themselves. The "Inquiry labs", where cohorts of TEMI teachers have been supported to increasingly use mysteries in the classroom, will hopefully carry on as part of CPD and curriculum for pre-service teachers.

The TEMI Scientific theatre pilot

TEMI also piloted the use of scientific theatre as a method to engage students and teachers. In this approach, TEMI partners from the University of Milan, Department of Physics, adapted their show 'Light Mystery' and made it an integral part of their TEMI training courses delivered in Italy. In the script, they describe how the play's acts and scenes follow the TEMI methodology. They worked directly with teachers on the use of science theatre as an attractive means to engage students and foster curiosity, scientific reasoning and literacy in young people.

Fittingly 2015, the year of the show's premiere, was the International Year of Light. The title "Light Mystery" represents a playful pun stressing both the scientific focus and the play's accessibility, and reflecting the show's aim to provide entertainment and engagement for the audience, to draw people into the world of physics through wonder and entertainment.

The light theme reflects the importance of this phenomena to a range of scientific fields: chemistry, biology, natural science in general and mathematics.

The Light Mystery was performed at the 2015 Genoa Science Festival and at the Turin Astra Theatre in March 2015 to a total combined audience of 1500 spectators. It will take centre stage at the final TEMI congress in Leiden, The Netherlands, in April 2016. The partners have made the script available to public on the TEMI website, where it is annotated with comments so that it can be used by teachers, theatre companies and school theatre clubs across Europe. English and Italian versions are available.

Summary

Ultimately, this project is part of an EU-wide move to bring about culture change to teachers and students in the way they learn and approach science. Success in this endeavour will lead to a new generation of scientifically-aware school leavers, better able to enter further study in STEM subjects, to boost the EU knowledge economy, but also to support a more scientifically-literate population, who are better able to engage actively and knowledgeably with issues around advances in science and technology and the risks and opportunities afforded by these advances.

In this current volume you will be able to read articles from TEMI partners that summarise their experience and evaluation of the TEMI activity they have undertaken. It makes for fascinating reading.

To download the resources, script and free books and for further information on the project website: www.teachingmysteries.eu

The TEMI project is funded by the European Union in the FP7-programme under grant agreement no. 321403.

References

Science Education NOW: A renewed pedagogy for the Future of Europe. (2007) EU: Brussels

TEMI (2015) Teaching the TEMI Way. [On-line} at www.teachingmysteries.eu

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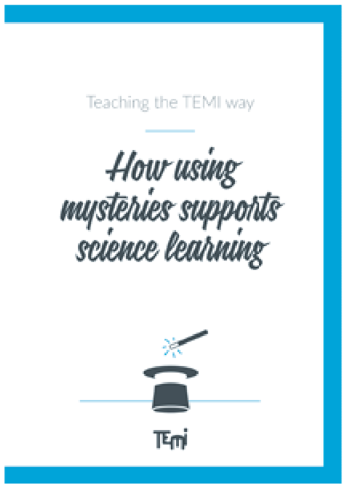
TEMI resources

The TEMI website is the portal of the TEMI project: www.teachingmytseries.eu The website is multilingual and updated with weekly news, Twitter updates, teachers' profiles, dates of trainings and conferences where TEMI is presented. The educational resources developed for the project are available online, together with the bi-monthly newsletter and extra resources like videos and presentations.

In the *Book of Mysteries* (BoM), teachers are able to explore a range of inspiring teaching materials selected from across a range of subjects. These materials are used in teacher training colleges throughout Europe to support inquiry-based learning in the sciences. The lesson plans can also be downloaded as stand-alone, searchable factsheets.

The other TEMI publication available online is *Teaching the TEMI way*, a toolkit to introduce teachers to the TEMI methodology with practical tips and examples.



The Pegasus TEMI mascot is an automaton created by the artist Tim Sargent from Heron's ancient Greek design (see photos on p. 6), to draw the attention of media, teachers and academic centres to the TEMI 4 innovations: mysteries to create curiosity, 5E learning cycle, GRR model and showmanship to maintain motivation.

The Youtube TEMI channel features original clips produced by the consortium and a playlist of clips linked to the TEMI lesson plans they refer to.

The Slideshare account collects presentations by partners that illustrate the TEMI project and methodology.

The Flickr account collects photos related to the project, mainly from the teachers' trainings.

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The four TEMI innovations

(www.teachingmysteries.eu)

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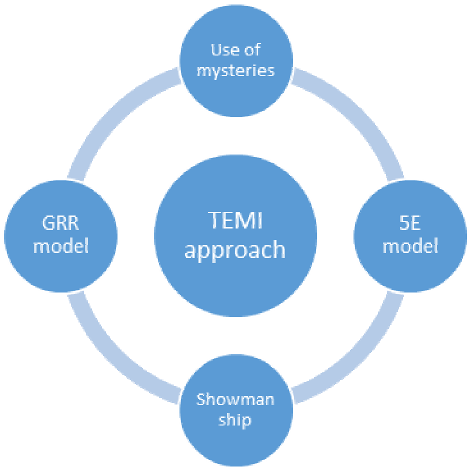
For a detailed description of the 4 innovations see the TEMI booklet, 'Teaching the TEMI way: How using mysteries supports science teaching', available online at: http://teachingmysteries.eu/en/classroom/?guid



The use of mysteries

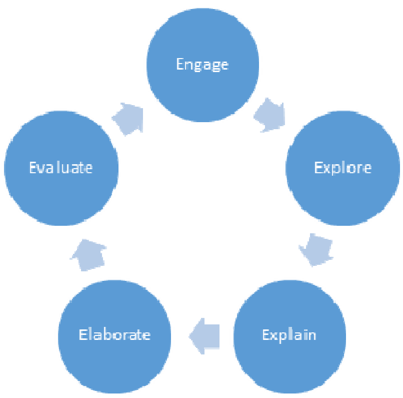
A key idea of TEMI is to engage students by introducing a lesson using a mystery or discrepant event. A mystery raises questions and arouses the student's curiosity and creates a desire to find out the answer. This leads into the 5E cycle of inquiry.

The 5E model

This a 5-stage model of inquiry, originally developed by the Biological Sciences Curriculum Study project in 1987.

It has 5 stages:

- Engage
- Explore
- Explain
- Elaborate
- Evaluate



Although often shown as a cycle with evaluation at the end, it is better to include evaluation in each of the first four stages as formative assessment. http://www.bscs.org/sites/default/files/_legacy/BSCS_5E_Instructional_Model-Executive_Summary_0.pdf

The use of showmanship

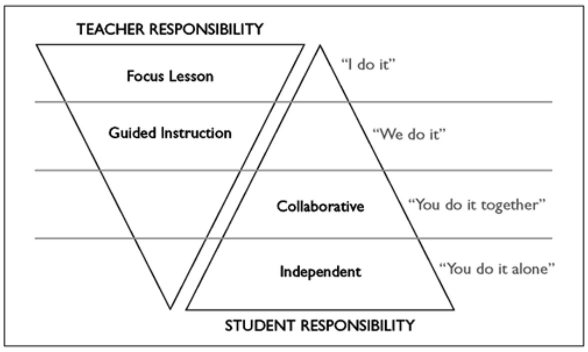
Showmanship is a way of introducing a mystery using drama, mime, storytelling etc. as a way to capture students' interest and motivating them to pursue inquiry to solve the problem. Using showmanship increases the emotional engagement of students in inquiry.

The GRR model

The Gradual Release of Responsibility is a model for transferring the ownership of inquiry from the teacher to the students.

It involves four stages:

1. Teacher-led inquiry: I do it
2. Guided inquiry: We do it
3. Collaborative inquiry: You do it together
4. Independent inquiry: You do it



This cannot be done in a single lesson but is something to be developed over a period of time as students develop inquiry skills and eventually become independent inquirers.

See: Fisher, D. & Frey, N., (2008). Better learning through structured teaching. Alexandria, VA: ASCD.

The articles and examples in this issue show how the different TEMI partners have implemented these four innovations in their own CPD workshops.

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Inquiry experiments with alginate bubbles

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Abstract
Some years ago Bubble Teas became a quite popular trend in many Western countries. Bubble Teas are drinks containing spheres formed compounds based on alginate or tapioca. The spheres were regularly filled with juice or syrup to give the consumer a funny and uncommon sensory experience. This phenomenon that alginate or tapioca is forming spheres can also be used in class to make experiments more fascinating, uncommon, or even mysterious. This article describes some simple ideas for doing experiments with alginate bubbles for inquiry learning.

Introduction
Unexpected phenomena can provoke challenging situations that lead over to scientific inquiry. This is one of the driving ideas in the TEMI-project: Teaching Inquiry with Mysteries Incorporated. TEMI uses the term mystery for such unexpected observations and defines a mystery as phenomenon or event that provokes the perception of suspense and wonder in the learner and initiates an emotionally-laden "want to know" feeling, which leads to an increase in curiosity and initiates the posing of questions to be answered by inquiry and problem-solving activities (Dittmar & Eilks, 2015).

One such phenomenon emerging in the life of students some years ago was the hype around Bubble Tea, also known as Pearl Milk Tea or Boba. Bubble Tea, originally invented in Taiwan in the 1980s, was a trend spilling over from Eastern Asia to Western countries around the years 2009 to 2013. Bubble Tea is a tea-based drink with milk or juice added that also contains fruit jellies or tapioca and alginate based spheres (the bubbles). The bubbles are regularly filled with e.g. fruit juice or syrup.

In some European countries, e.g. Germany, the emergence of Bubble Tea received a highly controversial reception. Bubble Teas were criticized to represent another high calories food specially advertised for the youth. Based on the critical reception of Bubble Teas, teaching about them found even its way into societal-oriented German chemistry teaching (Struckmeier & Sieve, 2014).

With its critical reception in the media the hype around Bubble Tea started disappearing, e.g. in Germany. Anyhow there are still shops offering Bubble Tea. In parallel, but less broadly known, tapioca and alginate bubbles started to be used in molecular gastronomy, another new trend in eating and drinking.

Whatever one may think about the consumption of Bubble Tea, the bubbles, their formation and the chance to fill them with different compounds allows the creation of challenging and aesthetic demonstrations in science class, which can be used to provoke questions to be solved by scientific inquiry. This article presents some ideas to use alginate bubbles in class that were developed in the framework of the TEMI-project.

The nature and formation of alginate bubbles
For the formation of alginate bubbles two ingredients are needed that can be bought in pharmacy stores or via the Internet: alginate (a salt of alginic acid) and either calcium chloride, calcium lactate or calcium acetate. Two solutions are made. One is made by dissolving 2 g alginate in 100 mL of cold water. Stir and wait at least 15 minutes that the dissolution process is complete. The other solution is a solution to contain about 0.2% of calcium ions in water, e.g. by making a 0.4% calcium chloride or 1% calcium lactate solution.

Either with a pipette or a spoon the alginate solution is added into the calcium ions solution. If both liquids come into contact, spherification takes place. This means the alginate and the calcium ions form a membrane that encases the alginate solution. If there were other compounds added in the alginate solution, like aromas, coloring agents, or indicators, they are now encapsulated in the bubbles formed by the gelatinous calcium alginate that is formed. The bubbles are stable and can be removed from the calcium ions solution by a spoon or sieve (Figure 1).

Figure 1: Science teachers in a TEMI workshop in Germany inquiring into the nature of alginate bubbles

Acid-base-chemistry in bubbles

When the alginate solution is mixed with an indicator the corresponding bubbles can deal as acid-base-detectors within any solution. This is an experiment that is long known and was e.g. described by Naoki Kanda, Takayuki Asano, Toshiyuki Itoh and Makoto Onoda from Japan in 1995 or Heinz Brandl in Germany in 1998 under the name 'Chameleon bubbles'. There can be universal indicators or natural indicators used. Among the natural indicators one can take an extract of red cabbage or from garden radish peels, both extracted using ethanol.

The indicator bubbles are put into water. If then any acid or base is added to the surrounding the bubbles will change their color after a certain amount of time. An exchange of hydroxide or hydroxonium ions takes place through the membrane into the bubbles. The indicator within the bubble changes its color although nothing is to be seen in the surrounding solution (Figure 2). Students can play with different diluted acids and bases (e.g. hydrochloric acid and sodium hydroxide solution) to find out the colour changes in the bubbles. Together with a pH-meter the behaviour of the bubbles can be investigated and the students can learn about acids, bases and neutralization in a playful way.

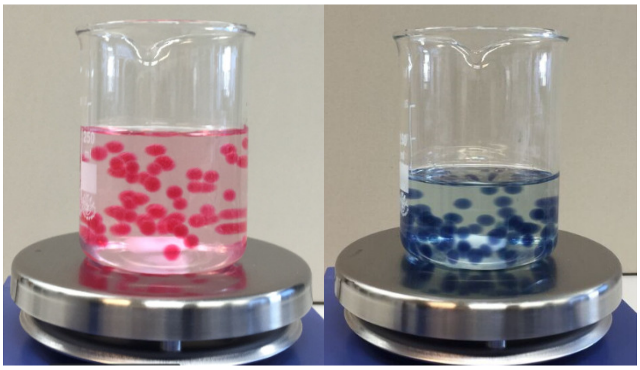

Figure 2: Indicator-filled bubbles in acid and basic environments

Thermochromic behaviour and thermal convection with bubbles

A very unique phenomenon can be created by putting thermochromic substances into the bubbles. One example is to use thermo ink as it is commonly available for school type experiments in Japan (Figure 3).

Figure 3: Thermo ink for science experiments from Japan

Thermo ink (not to be mixed up with the thermo inks used in thermo printers) can be used for illustration of thermal convection and other phenomena in physics education. For example, in Japan, thermo ink is based on a lactone of crystal violet mixed with some other compounds. If the thermo ink bubbles are put into water and the water is heated, the bubbles both indicate the changing temperature as well as show the thermal convection in the beaker (Figure 4). If the bubbles are too heavy (having too high an average density), some salt can be added to allow the bubbles to float up more easily (Yamashita & Yeo, 2016).

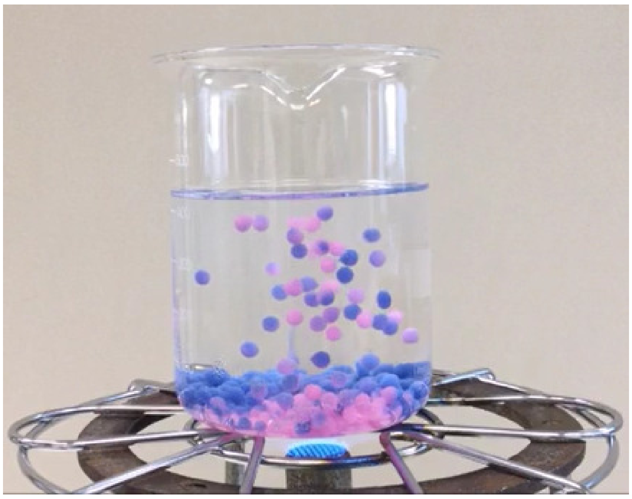

Figure 4: Thermal convection by bubbles filled with thermo ink

Fluorescence in bubbles

Alginate bubbles can also be filled with different coloring agents. One can use e.g. riboflavin (vitamin B2). Riboflavin is a fluorescing compound that can be added to the alginate solution before the bubbles are formed. One can take pure riboflavin, or it can be easily extracted by water (suspend in water for some minutes and filter) from certain instant vanilla pudding powders that contain riboflavin (Figure 5).

Figure 5: Riboflavin extracted from instant vanilla pudding powder

Riboflavin does not dissolve well in water, thus a good mixing is important before the bubbles are to be formed. Then you can shine ultraviolet light on the bubbles (Figure 6). After removal of the light the bubbles are still fluorescing.

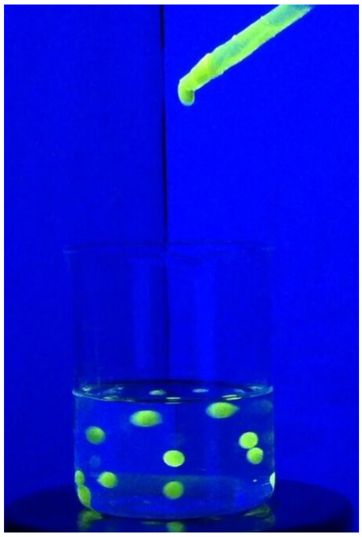

Figure 6: Forming bubbles filled with a riboflavin solution under ultraviolet light

Redox reactions in bubbles

Riboflavin filled bubbles can also be used for demonstrations in redox chemistry. If the bubbles are formed they show fluorescence under ultraviolet light (see above). One can "turn off" the fluorescence in the bubbles by adding a solution sodium dithionite to cause the reduction of the riboflavin (add approx. 10 mL of saturated (20%) dithionite solution to 100 mL of water with bubbles; Figure 6).

Figure 6: "Turning off" the fluorescence in riboflavin-filled bubbles by adding sodium dithionite solution

You can turn them on again by adding hydrogen peroxide (e.g. 30 mL of 30% hydrogen peroxide to 100mL of water with bubbles).

Bubbles and the TEMI philosophy

TEMI mysteries with alginate bubbles can be introduced in many different ways. Stories can be written, e.g., starting from a birthday party where drinks with alginate bubbles are to be served and unexpected events happen, e.g., if the light is shut off and the bubbles in any lemonade start fluorescing. However, some of the phenomena might even not need any specific contextual framing and just can be presented. This might be supported by using music as a background to the experiments. In this case the thermo ink bubbles might appear to dance in line with a certain song. Following the 5-E model of scientific inquiry, the engagement by a story, presentation or with music can lead over to investigations in the explore phase on the nature of alginate bubbles or the corresponding phenomena and reactions by their fillings. Explanations shall be found for the behaviour of certain types of alginate bubbles/fillings, that later can be extended to applications of alginates in the molecular kitchen, before the learning process is jointly reflected on and evaluated.

Concluding remarks

None of the effects described in this paper is really new. However, presenting them in form of alginate bubbles can make them appearing aesthetic – and mysterious. The examples described here are only a small selection of experiments that can be done with alginate or tapioca bubbles. Just recently Sirch and Ducci (2015) in Germany described more examples for luminescent bubbles by using extracts, e.g. from the red Powerade lemonade or of yellow textmarkers. All the experiments are easy hands-on activities that allow for varying the conditions and playfully inquire into the physics and chemistry behind them. For class, it can become even a competition based on student inquiry in a project-based approach to create new bubble experiments, to make small videos of them, and to present them and corresponding explanations on YouTube.

You can find videos of the here described experiments on the TEMI YouTube channel.

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References

Brandl, H. (1998). *Trickkiste Chemie* [Trick box chemistry]. München: bsv.

Dittmar, J., & Eilks, I. (2015). Mysteries – Their nature and purpose in science education. In P. McOwan & C. Olivotto (eds.), *Teaching the TEMI way – How using mysteries supports science learning*. www.teachingmysteries.eu.

Kanda, N., Asano, T., Itoh, T., & Onoda, M. (1995). Preparing "Chameleon Balls" from natural plants: Simple handmade pH indicator and teaching material for chemical equilibrium. *Journal of Chemical Education*, *72* (12), 1131-1132.

Sirch, T., & Ducci, M. (2015). Fluoreszierende Chamäleon Bällchen [Fluorescending chameleon balls]. *Chemie konkret, 22,* 187-189.

Struckmeier, S. & Sieve, B. (2014). Bubble Tea - Experimente um ein Modegetränk [Bubble Tea – Experiments around a trend drink]. *Chemie & Schule*, *29* (1), 5-9 and (2) 11-17.

Yamashita, S., & Yeo, J. (2016). How should fourth grade students express and explain their thoughts about how water is heated?. *Journal of Science Education in Japan, 40(1),* in press.

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Teaching with Mysteries Incorporated in the Czech Republic

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Abstract

Charles University in Prague – Faculty of Science is one of the partners of the European project TEMI (Teaching Inquiry with Mysteries Incorporated), whose focus is mainly on the development of the skills and abilities of science teachers; skills and abilities necessary to realize IBSE in teaching as such. The project is based on four basic aspects stemming from the IBSE requirements and the teachers' professional development. The Faculty of Science at the Charles University, as a partner of this project, prepares, organizes and evaluates training courses for both in-service and pre-service teachers of primary and secondary schools, training them in inquiry-based education with mysteries incorporated. The sessions also introduce newly-created problems that include an engaging mystery, that motivates the students to solve them. The courses are based on the participants' own Inquiry in order to have the mysteries and the IBSE approach form their own experiences and motivate them to use this approach in their practice.

Organisation of the project

The European project TEMI (Teaching Inquiry with Mysteries Incorporated) is a science education project focused mainly on science teachers. Its realization is based on four basic aspects stemming from the requirements of IBSE and professional development of teachers (Banchi & Bell, 2008; Sherborne, 2014; TEMI team, 2015). The Faculty of Science, Charles University, is one of the project's partners, focusing on preparation and realization of training courses for the teachers of primary and secondary schools schooled in inquiry-based science education with mysteries incorporated.

The course organization was preceded by a questionnaire survey. Its goal was to find out the extent of knowledge about IBSE among the teachers in the Czech Republic. The investigation that included over 250 science teachers at primary and secondary schools in the Czech Republic showed that our teachers have very low knowledge about the IBSE approach and its practical application (Čížková *et al*., 2012; Čtrnáctová *et al.,* 2012). For this reason, it was necessary to prepare the contents of the individual courses in a very conscious way and choose the group of invited teachers in order to have the courses interest them in this new way of teaching scientific subjects (Rocard *et al*., 2007).

At first, we approached the teachers we work with as a part of the pre-service science teacher training, and together we created the draft of the future training programme. Because of the training contents, our most important consideration was the use of activating methods in the work of the participants. This was in order to make them see the problem statement as a mystery and go through the inquiry cycle by themselves while solving it (Čtrnáctová *et al.,* 2014).
The seminars were realised with six groups of teachers; each group participated in two two-day courses made up of four workshops. The courses presented newly-created problems with concepts that included engaging mysteries that aim to motivate the students to solve problems.

We have been gradually increasing the programme's quality and approaching larger groups of teachers. The first group that participated in the training courses had 15 teachers, the second to fourth groups had 20-30 teachers, and the fifth and sixth group had over 40. Here, it was necessary to work in two parallel groups in order to actively engage all the participants.
So far, there were 11 two-day courses in Czech Republic for six groups of teachers of science subjects, especially chemistry and biology, with 106 teachers in total.

The first part of the course aims to introduce the TEMI project and its main aspects. Then specific problems follow, all presented in a way that puts the teachers in the role of students, solving the presented mystery under the guidance of a lecturer. 10-12 inquiry-based problems are introduced during each workshop. The results of the problems are then summarized in a short closing lecture followed by discussion. An integral part of the course is a show, usually in the form of a "magician act" full of magical experiments in which both lecturers and guests participate (Figure 1). The act usually consists of some form of story (e.g. "Searching for the elixir of life", etc.). Another motivational practice we use is a detective story (murders, robberies etc.) which can be solved using Inquiry (for example the problems "Murder of the Jeweller Beketov", "Murder of the Researcher", or "The Case of the Robbed Safe"). There is emphasis on all pillars of the TEMI project (incorporation of mysteries, the 5E cycle, gradual release of responsibility and showmanship) (Bybee *et al.,* 2006, TEMI team, 2015). The lecturers and the teachers discuss a lot and try to use the problems – both presented and new – in their practice.

Figure 1: A magician's show

There were 28 lecturers, mostly teachers, in 11 courses, who realized over 50 inquiry-based problems with mysteries incorporated together with the participants. The courses were held in classrooms and laboratories of the Faculty of Science, Charles University (Čtrnáctová *et al.,* 2015a).

For example, Figures 2 and 3 show the activities "Burning Hands" and "Let's Draw with an Electrode" that were presented in one of the most recent courses.

Figure 2: The activity "Burning Hands"

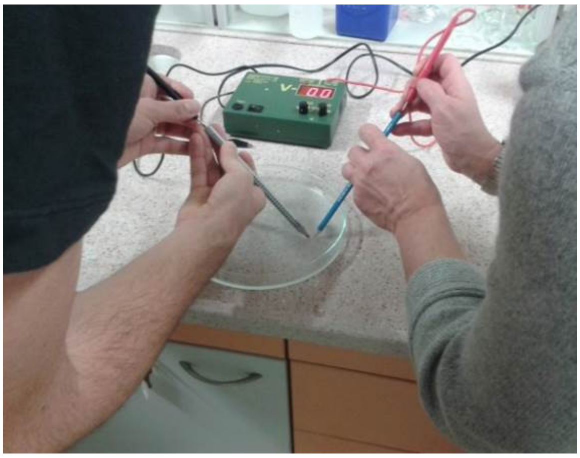

Figure 3: The activity "Let's Draw with an Electrode"

Response of teachers

The teachers evaluated each workshop via questionnaire surveys. We used the TEMI project questionnaires given after each workshop and, at the end, a summary questionnaire evaluating the whole two-day session. We were mainly trying to determine their enthusiasm for the activity, its usability in the class or how entertaining it was Most of the activities got positive evaluation. Activities with lower evaluation usually required more expensive chemicals or nonstandard tools that are not commonly available at schools (like thermal cameras). The interest in the activities was closely related to the subjects a particular teacher teaches.

Based on the questionnaire surveys performed so far, we found that 81% of teachers who participated in the training courses want to try out the TEMI approach in the classroom. The question "What do you think the training session gave you?" was answered as follows: 65% of the teachers gained the motivation to innovate their teaching, 63% gained new teaching tools, 55% gained a new approach to teaching, 52% gained a better understanding of inquiry-based education and 52% gained useful practical examples (Čtrnáctová *et al.*, 2015b).

As far as the applicability of these materials in lessons goes, 83% of teachers consider them suitable and 93% of the participants consider the courses motivating and entertaining. 90% of teachers consider IBSE especially important in the teaching and 96% are interested in the teaching themes shown (Čtrnáctová *et al.*, 2015b).

After the teachers went through the course, they had a chance to try some of these activities in their school practice. In the next course, they could discuss the experience they got from its realisation or present an activity of their own, prepared in such a way as to meet the goals of the TEMI project.

Relevance to science education in the Czech Republic

Activities introduced at the courses or realised in the school practice were thematically chosen to correspond to the educational contents of primary and secondary schools in the Czech Republic. The Czech Republic has seen a gradual introduction of new curricular documents in the period of 2005-2010. While the previous curricular documents were uniform for each school of a given type, so-called framework educational programmes set the frame of teaching on the general level and each school subsequently specifies this frame for its own circumstances using the school educational programmes. The new curriculum provides a general emphasis on the acquisition of knowledge and key competencies, active teaching methods, using experiments to gather new knowledge and connecting the subject matter with the everyday life. Science forms the content of the "Man and Nature" area at primary and secondary level. This area includes the subjects Physics, Chemistry, Biology, Geology and Geography which are put into years 6-9 of the primary level (students' age 11-15 years) and into (usually) years 1-3 of the secondary level (students' age 15-18 years).

For each subject, there is a short summary of the subject matter and the expected student outputs. Despite the briefness of this summary, most of the teachers believe it is necessary to teach as much subject matter as was prescribed in the previous curricular documents, which does not give them enough free space to include the new subject matter. Teachers also tend to use older textbooks bound to the previous curriculum and feel it is necessary to teach everything the way it used to be, meaning they tell the students the facts in the form of a lecture. The students, in the end, usually do not remember even the most basic knowledge because they cannot discern it from what is not as essential. We think that it is more important for the students to "discover" the individual new pieces of knowledge by themselves and to use them to derive further knowledge. This way, they will obtain more permanent and more deeply understood knowledge, and they are able to use it when solving situations from everyday life. This is what we started with while compiling suitable problems for the TEMI project courses. Each problem is tied into a specific part of a scientific subject curriculum.

Incorporating problems created via the TEMI methodology into primary and secondary school education is in full accord with the above-mentioned curricular documents. The teachers have positive reactions to the activities shown and they also positively evaluate their incorporating the activities into their teaching in school and their suitability for it.

Future plans

After the teachers completed the courses, they received a multitude of printed materials, mainly methods sheets and worksheets related to the presented problems and created by the lecturers themselves. Further materials, made available to all the participating teachers, were the TEMI project booklet – Teaching the TEMI Way. Apart from this publication, the teachers have also received four further printed publications containing a large amount of compiled activities and themes for teaching of scientific subjects (mostly Chemistry and Biology).

We assume that the final course will be realized shortly and the successful graduates will receive certificates. As a part of further cooperation with the participating teachers-lecturers, we will focus on preparing a joint publication that should contain a description of most of the TEMI activities that were shown. This publication should be available to all participating teachers, and also to their colleagues if possible (for example in electronic form). We also want to continue our cooperation with other participating teachers, via passing further information about the TEMI project, and especially through following and supporting their own teaching using TEMI methodology.

An example

One of the examples of an activity presented on the TEMI project seminaries is a chemical activity called "How to make silver and gold out of copper?". The students enquire how the lecturer (teacher) could, during a chemical experiment, transform a copper coin into a silver coin, and then into a gold one – a mystery to them.The experiment is put together in accordance with the TEMI methodology – the worksheet contains five parts (Engage – Explore – Explain – Extend – Evaluate), as you can see in Figures 5 and 6.

How to make silver and gold out of copper?

Engage

Task 1: Do you think that silver, or even gold can be made out of copper?

Explore

Task: 1) First, we need to degrease the copper coins:

Put pure copper coins into a mixture of table salt (3 g) and 5% acetic acid (15 ml). Mix until they become shiny. Extract the coins with tongs, wash them with water and dry them off.

2) Now we will change copper into silver:

Put 0,5 g of zinc into evaporating dish and add 3M solution of NaOH (25 ml). Heat the mixture (without boiling) until the solution becomes hot and bubbles start to appear.
Use the tongs to place two copper coins into the hot solution.
Heat up mildly, but constantly, with occasional mixing.
Wash the coins to get rid of the remnants of sodium hydroxide and dry them off.

3) We will change the silver into gold:

Grasp one of the "silver" coins with tongs and heat it in the outer zone of the burner flame. In a few seconds, the coin's color will change; then cool it immediately in a beaker with distilled water and dry it off.

Figure 5: Worksheet, Part 1

Explain

Task 1: Did we obtain real silver and gold in this way?

Task 2: What happened to the coin (originally copper) after it was put into hot solution made from a mixture of zinc and sodium hydroxide? What caused its transformation into "silver"?

Task 3: We heated the "silver" coin in a flame. What caused the change of the silver color into gold?
What substance is created during this process?

Extend

Task 1: We were working with two metals – copper and zinc. What is their position in Beketov's electrochemical series?
Would we expect the reaction to go in this particular direction? Can other types of metals be used as well?

Task 2: The principle of changing copper into silver is often used in everyday life. Can you come up with some practical application?

Task 3: Where in your environment can you encounter the alloy you've made? What is its practical use?

Evaluate

Task: What do you think – did the value of your coin increase?

Figure 6: Worksheet, Part 2

First, the teacher demonstrates the experiment; afterwards, the students themselves can perform it under the teacher's supervision and while observing all safety instructions. First, all the students follow the instructions in the worksheet and try to solve the given problems. The students start by suggesting their own hypotheses, which are then either confirmed or refuted as they work on their worksheets.

There is also an emphasis on a chemistry subject matter. The activity can be incorporated into the teaching of general (physical) and inorganic chemistry, specifically in the following themes: electrochemistry, alloys and chemistry of copper. The activity is closely related to the practical use of electrochemical processes – galvanizing and creation of brass. The worksheet also contains tasks related to further use of these processes.

This activity is not overly demanding as far as the chemistry lab equipment goes. A heating pad can be used instead of a Bunsen burner. After being taken out of the galvanizing bath, each side of the coin is, in turn, put on the heating pad and over several seconds, you can see it going "gold", i.e., the appearance of brass. The coins can be replaced by pieces of copper sheet that can be bought in any hardware store.

Conclusion

During the realization of the TEMI project, there were 11 two-day training sessions in the Czech Republic (so far), training teachers from all over the country. There was a large number of lecturers at the sessions, mostly teachers, but also pedagogical staff from the Czech and Slovak universities, and even a magician. The teachers were introduced to over 50 activities they could try themselves. The results of the questionnaire surveys show that the sessions are evaluated positively which can be also seen in the teachers' willingness to participate in more than just one or two sessions and in the ongoing discussions between the teachers and the lecturers.

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References

Banchi, H. & Bell, R. (2008). The many levels of inquiry. *Science and Children*, 46(2), 26–29.

Bybee, W. R., Taylor, J.A., Gardner, A., Van Scotter, P., Powell, J.C., Westbrook, A. & Landes, N., (2006). *The BSCS 5E instructional model: Origins and effectiveness* [online]. [cit. 2015-05-29]. Available at: www.science.education.nih.gov/houseofreps.nsf/b82d55fa138783c2852572c9004f5566/$FILEAppendix%20D.pdf

Čížková, V., Čtrnáctová, H., Nedomová, M., (2012). Prerequisites for Application of Inquiry Based Science Education in Approach of Teachers. *IOSTE XV Symposium - Science & Technology Education for Development*, Citizenship and Social Justice, Hammamet, Tunisia.

Čtrnáctová, H., Čížková, V., Hlavová, L., Řezníčková, D., (2012). Science knowledge of pupils/students in the time of curricular reform. *Chemistry Education in the Light on the Research* (monograph). Pedagogical University of Kraków, Kraków 2012, 54-58.

Čtrnáctová, H., Čížková, V., Řezníčková, D., (2014). IBSE & Students´ Science Skills. *Profits and Limitations of Inquiry Based Science Education* (monograph). Pedagogical University of Kraków, Kraków 2014, 48-51.

Čtrnáctová, H., Čtrnáctová, L., Šmejkal, P., (2015) (a). IBSE in Chemistry Education – Testing Students´ Skills and Teacher Training. *LUMAT*, 3(4), 556-567.

Čtrnáctová, H., Teplá, M., Čtrnáctová, L., Šmejkal, P., (2015) (b). IBSE as an Important Part of Chemistry Teachers´ Education. *Chemistry Education for Responsible Citizenship and Employability* (6th Eurovariety in Chemistry Education 2015). University Press of Estonia, Tartu, 72-73.

Rocard, M., Csermely, P., Jorde, D., Lenzen, D., Walberg-Henriksson, H. & Hemmo, V., (2007). *Science Education NOW: A renewed Pedagogy for the Future of Europe* [online]. [cit. 2015-05-29].Available at: http://ec.europa.eu/research/science-society/document_library/pdf_06/report-rocard-on-science-education_en.pdf

Sherborne, T., (2014). Inquiry & TEMI CPD: Inquiry based science education & continuing professional development (CPD) [online]. [cit. 2015-05-29]. Available at: www.teachingmysteries.eu/wp-content/uploads/2013/12/Inquiry-CPD.pdf

TEMI Team, 2015. *Teaching the TEMI way: How using mysteries supports science learning.* London: Queen Mary University.

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A flexible CPD framework to support science teachers' professional learning

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Introduction

Developed through a collaborative and rewarding professional learning journey, the TEMI teaching approach has now been cascaded across 9 European countries. For over 3 years, the TEMI team at Sheffield University have worked with EU partners, teacher trainers, science communicators and science teachers to develop a workshop programme to enhance teachers' professional skills, knowledge and confidence to implement IBSE and thereby motivate students to become more motivated scientific thinkers. A flexible and innovative CPD framework is used to facilitate the progressive introduction of four evidenced based innovations in science teaching and learning. Teachers experience the innovations first hand and then adapt and plan TEMI lessons that can be implemented and evaluated in *their* classroom with *their* students.

The TEMI CPD framework adopts the methodology of *'backwards design'*, in other words, the workshop programme was designed by defining the *'professional learning outcomes'* for teachers that we expected and aimed to achieve (Box 1) Using these outcomes, CPD leaders can focus on constructing workshop sessions and activities that are needed to achieve the objectives. The framework can be broken down into components and individual sessions that can be covered in a series of face to face workshops, pre workshop online activities, enhanced by school based implementation and trialling tasks.

Box 1: TEMI CPD Professional Learning Outcomes

By participating in the workshop programme teachers:

- evaluate mystery-based curriculum resources which are used as invitations to Inquiry and which structure and support the lessons
- consider how to use a variety of engagement and discussion techniques through interaction with communications professionals
- explore how the 5E Inquiry learning cycle can be used integrate the teaching of Inquiry with scientific content
- gain experience of tried-and-tested methods for transferring responsibility for thinking to students, using the model of cognitive apprenticeship/GRR
- gain an awareness of how cognitive strategies can be taught to increase students' proficiency with the Inquiry skills

Teaching the TEMI Way - Opportunities and Challenges

One of the early challenges faced by CPD leaders in the UK and other countries was how to accurately convey how the four TEMI innovations *'work together'*. The basic premise is to show how each innovation is *'nested'* in such a way that it is part of a conceptual teaching and learning sequence. Thus, a productive mystery begins the process and is presented using showmanship skills; both of these things are carried out within a clear learning cycle (the 5Es) that facilitates productive student learning. A graphic is used to convey the idea that repeated uses of the TEMI methodology would facilitate the teacher being able to gradually hand over more of the Inquiry process to students (Figure 1). The arrow over the top indicates this. It was at the point of explaining this to teachers on the CPD workshops that the 'Evaluation' phase of the 5Es also required most prominence. Evaluation of the content and process of learning by students going through TEMI is the way that skills are consolidated; ensuring that next time scientific Inquiry is encountered students will be able to build on previous gains.

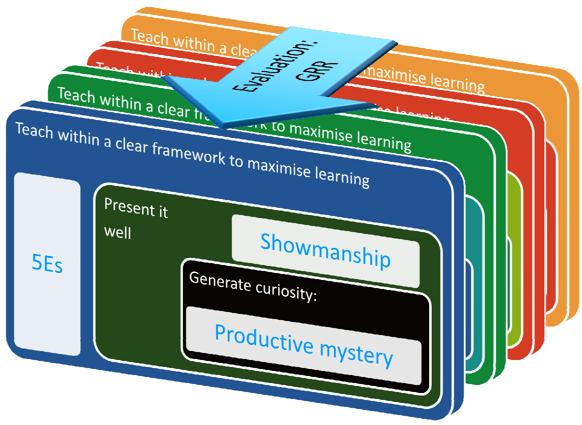

Figure 1: The TEMI Teaching and Learning Model

Teachers' view of TEMI

The word 'mystery' in the CPD programme's title, has been reported as lending a distinctive quality that has aroused science teachers' curiosity. Teachers who have attended CPD workshops or taster sessions have held high expectations and reported a variety of reasons for attending:

- To develop skills in leading Inquiry
- To improve mystery led teaching
- To find new methods to keep students engaged
- To find out how to use mysteries
- To obtain tools to improve teaching
- To learn about the 5Es

The majority of teachers have reported that the CPD has mostly or fully met their professional needs, irrespective of their level of experience. The most frequently cited benefit has been the provision of practical examples of using mysteries in science teaching; closely followed by the improvement in teachers' understanding of inquiry based science education (IBSE). Another benefit frequently given is that TEMI will provide new pedagogical tools for teaching, which suggests that teachers recognise the benefit of learning the TEMI methodology so that they can apply it themselves, as opposed to simply reproducing pre-prepared activities. Given the range of experience of teachers attending the CPD, it is understandable that there was variation in responses about what they found enjoyable and useful but all teachers indicated positive intentions and outcomes. It was interesting to hear how teachers had begun to apply the TEMI principles after day one, as they often generated novel activities or began to use unusual contexts in order to bestow the science content they were teaching with the qualities of mystery they had learned about through the CPD workshops. What was clear however was that an understanding of the TEMI methodology does not diminish the challenge of creating a suitably productive mystery in the first place. To some extent this may arise from limitations inherent in the concept of 'mysteries'. Some teachers, struggling to concoct mysteries from the science they were going to be teaching imminently, gained inspiration when simply considering questions rather than mysteries. To an extent, the mystery materialised once the question was clear, and was largely dependent on how they phrased the question.

The four innovations of TEMI, (Productive mysteries; Showmanship; the 5Es; Gradual Release of Responsibility) are probably of unequal 'weight' in terms of improving IBSE. However, it is hard to state the ways in which their importance differs. Central to the functioning of TEMI is the learning cycle, the 5Es: without this TEMI has no structure. Hence the 5Es is indispensable. Showmanship probably remains the most elusive of the innovations, but by focusing on it as an aspect of teacher repertoire, TEMI aims to make such showmanship skills explicit. Gradual Release of Responsibility is something which will only be realised over time, as students' skills grow and develop, but ultimately holds probably the biggest potential as it is the one thing that will lead to students who can learn independently. Where does this leave the importance of the mystery? This remains central to TEMI, as without it the other innovations have no purpose.

Relevance to UK science education

In England, content is specified in the Science programmes of study for Key Stage 3 and Key Stage 4 (DfE 2015) and in the National Curriculum (NC) for England the content is split into three disciplines of biology, chemistry and physics which should be taught though the theme of *"working scientifically"*. The TEMI approach fits very well with the purposes and aims set out in these documents. In particular, of the three main aims stated, TEMI can clearly help students to "*develop an understanding of the nature, processes and methods of science through different types of science enquiries"* and these should *"help them to answer scientific questions about the world around them*". If done well, "*scientific knowledge and conceptual understanding*" can be developed and the more general notion of understanding the "*uses and implications of science*" can be better appreciated.

The 5Es approach is flexible enough to fit scientific methodologies required for different types of Inquiry and as such it closely match many of the statements for students at KS3 if they are to be *"working scientifically."* For example **Explain** and **Explore** fit in well with the need to work *"objectively, modifying explanations to take account of new evidence", or to "ask questions and develop a line of Inquiry"*. Students are also asked to *"interpret observations and data"* and present *"reasoned explanations."* **Evaluation** has clear links to the need to analyse data and as the level of demand increases, show "*awareness of potential sources of random and systematic error*".

However, the 5Es does more than this. **Explain, Explore** and **Extend (or Elaborate)** all require and encourage language skills, in a "c*ognitive, social and linguistic sense*". The NC states that students "*must be assisted in making their thinking clear, both to themselves and others*" and that the "*quality and variety of language that pupils hear and speak*" are important factors in developing this. TEMI encourages discussion which can play both a powerful role in developing new ideas, and uncovering misconceptions which can hinder future learning. **Extend** presents a way to differentiate learning effectively based on individual understanding and need.

Future plans: the sustainability of TEMI

There is a dilemma felt by many English science teachers due to the competing demands of exam performance in League Tables, inspection by the Office for Standards in Education (Ofsted), and the perceived increase in time that Inquiry based learning takes up. A review by Ofsted of around 90 secondary schools, "Maintaining Curiosity" (Ofsted 2013) concluded that the best teaching "put scientific Inquiry at the heart of science teaching" and the most successful schools set out to firstly "maintain curiosity." In a nutshell, Ofsted are asking is to ensure and show our students are not only engaged, but are challenged and are progressing. Relating the TEMI approach directly to this science education imperative, the use of mysteries and Showmanship clearly sets out to instil curiosity and to "develop a sense of excitement" *and through the use of high quality exemplar curriculum materials, the TEMI team at SHU have been able to model ways that to* set higher-level thinking tasks, tune the *Inquiry level*, and *teach skills systematically. In turn, students not only master the science content needed to pass exams,* but in addition, learning and thinking skills, and a positive attitude towards science. One important aspect of "Working Scientifically" is the need for students to decide for themselves on the appropriate type of scientific Inquiry to work on. The incorporation of "Gradual Release of Responsibility" (GRR) into the TEMI approach is a constant reminder of the need to let students make decisions for themselves. This need not be all in one lesson and in fact might be over several years if the progression implied in the NC is to be carried through. The curriculum increasingly calls for more accurate and reliable methods to be used as students' progress.

An important recent change at GCSE level is the assessment of practical skills through written examination (15% of total). We have yet to see what such questions will look like, but if the questions are written well, students with a sound practical skills base should be at an advantage. The support for such approaches and the prospect of increased exam results may act as drivers to persuade teachers to take up TEMI. A full TEMI mystery every lesson may not be appropriate, but perhaps one for each topic (every few weeks) may be an achievable target. The four TEMI innovations will work individually, at least in part, in most lessons so teachers can also develop their skills, ready to bring these all together to experience the synergy of a full mystery.

Next Steps

In order to ensure the sustainability of this IBSE project, the TEMI team are Sheffield Hallam University are currently developing CPD workshop materials at *'train the trainer'* events, so that they can be used by science subject leaders in schools and other CPD providers. We are also looking at ways to ensure that the TEMI classroom materials can be accessed easily via a range of online repositories, including the Times Educational Supplement Resources website: tes.co.uk, an enormous collection of resources for teachers and the National STEM portal, in addition to the TEMI website. There are currently, five sets of curriculum materials tailored to the English science curriculum that have been created and come complete with designed PowerPoint slides, and full teacher guides. These mysteries were chosen by a group of teachers have proved most popular in the CPD workshops, particularly the Chi Wheel Mystery, which teachers like as a way to focus on teaching the process of hypothesis generation and testing

TEMI will continue to be disseminated at national conferences, Teach Meet events and train the trainer workshops throughout the UK. We are also planning to develop new collaborations with other science education providers and seeking ways to integrate the TEMI approach were their offers to schools.

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A TEMI lesson from Sheffield Hallam is given below.

TEMI at the Cutting Edge of Science

In order to provide a contribution to the European High School Teachers' CPD event at CERN, Switzerland, in July 2015, a 'TEMI-fied' activity was developed. This was presented to the group of 50 teachers during a 90-minute workshop in which they also had a chance to try it out for themselves. The brief for this activity was to provide something which would have relevance to the activities taking place at CERN. Although CERN's work is related to science content that is found on the curricula of most, if not all, secondary schools in Europe, it is obviously at a level considerably beyond that. Therefore the first challenge for the small development team was to identify a suitable productive mystery. Two early contenders which were explored were the double-slit experiment (in which the mystery would be wave-particle duality) and the mystery of how to weigh atoms. For the latter a simple model of a sector mass spectrometer would have been required. Although both of these ideas have potential, they were rejected for practical reasons and because the science is usually not encountered before post-16 study. Ultimately the context chosen was the famous Rutherford gold-foil experiment, with the mystery being that of scientists find out what is inside something as small as an atom.

The TEMI activity was designed as follows:

The **'Engage'** stage involved the use of a simple yet decidedly puzzling artefact, the 'Mystery Tube'. Details of how to make this can be found at www.youtube.com/watch?v=heOzqD88m18. The idea here was to present a mystery which would be an analogy for the behaviour of atoms. In other words, we can see how the tube behaves, but we cannot see inside to see what the internal workings are that lead to this behaviour. This is the essence of most sub-atomic physics of course – the archetypal 'black box' which defies direct observation. The tube was therefore a device to provoke interest and to act symbolically for something to be studied in the next phase, 'Explore'.

The **'Explore'** phase was a hands-on practical which emulated the gold-foil experiment. Small groups of teachers each had a mystery shape, cut from medium-density fibreboard (MDF) and hidden from view by being stuck under a piece of hardboard sized approximately 20cm x 20cm (Figure 1)

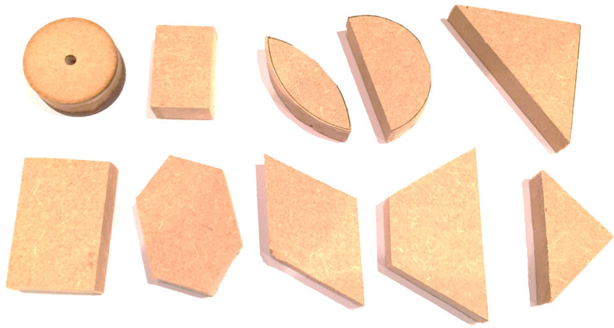

Figure 1: Sample mystery shapes

They were not permitted to 'cheat' by looking under the hardboard of course! The task then involved rolling projectiles under the hardboard and observing the trajectories in order to deduce the size and shape of the mystery shape. Marbles were used as the projectiles.

In order to make the trajectories visible the apparatus was placed on a piece of white A3 paper and the marbles were coated with ink to leave a trace. As a further measure to produce sufficiently observable collisions each mystery shape had an elastic band wrapped around it to increase the bounce of the marble off the MDF block.

The results of this activity were quite encouraging, and the teachers appreciated that it offered plenty of scope for getting their students to understand the importance of repeating measurements to improve accuracy. Sample trajectories are shown here (Figure 2), showing lines ruled over the rather blotchy marble traces:

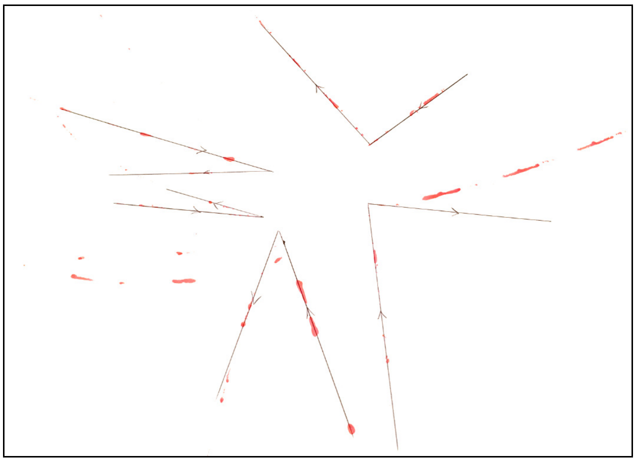

Figure 2: Sample trajectories

Using the same principle as the law of reflection, in that the angle of incidence equalled the angle of reflection, enabled the teachers to deduce the position and direction of the faces of the mystery object. Once enough data was obtained, the teachers could make a deduction about their shape.

The next phase, **'Explain'**, was for the teachers to present their deductions and explain how they had arrived at them, and then to compare these with the actual mystery shapes of course. With a class of students this would be the time to introduce them to Rutherford's experiment, and compare the exercise they had just done with the bombardment of gold foil by alpha particles.

Following this the **'Extend'** activity was to look at some examples of the experiments carried out at CERN (by looking at specific areas of CERN's website) and observing similarities and differences to Rutherford's experiment. The **'Evaluate'** would be an opportunity for teacher and students to review the learning that had taken place.

The teachers at CERN, for whom this was the first experience of TEMI, were very positive about the general concept and the specific activity.

□

The beauty of mystery

The most beautiful thing we can experience is the mysterious. It is the source of all true art and science. He to whom this emotion is a stranger, who can no longer pause to wonder and stand rapt in awe, is as good as dead: his eyes are closed.

Albert Einstein in *Mein Weltbild* (1931), as quoted in *Introduction to Philosophy*(1935) by George Thomas White Patrick and Frank Miller Chapman, p. 44.

Give people facts and you feed their minds for an hour.
Awaken curiosity and they feed their own minds for a lifetime.

Ian Russell

The ‘Austrian Way‘ of TEMI

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Abstract

Inquiry-based science education is an ambivalent matter within the Austrian educational system. On the one hand, the curricula claim student-centred experiments and the work on individual tasks, on the other hand, the teachers complain about conditions under which such approaches are not realisable. The article shows how the Austrian TEMI-team tries to bridge the gap between the current situation in Austrian schools and the recommended application of inquiry-based science education by designing the TEMI workshop series in coordination with the needs of the teachers. After the description of the organisation of TEMI in Austria, we give an overview of the TEMI workshop series we offered, illustrated by selected examples of applied mysteries. Then we briefly analyse some connections between the aims of TEMI and the demands on chemistry lessons in regard to the Austrian chemistry curriculum for secondary schools. At the end of the article we summarise findings from the teachers’ feedback and provide a brief outlook on our future plans.

Organisation of the project in Austria

The University of Vienna has been partner in the TEMI-project since February 2013. Univ.-Prof. Dr. Anja Lembens from the Austrian Educational Competence Centre Chemistry (AECC Chemistry) is responsible for the national management of the project and is supported by Dr. Simone Abels, Elisabeth Hofer, Sandra Puddu, and Katrin Reiter of the AECC Chemistry.

Between October 2014 and January 2016 the AECC Chemistry offered seven workshop series, i.e. cohorts, at five different places: Vienna, Rum (Tyrol), Feldkirch (Vorarlberg), Graz (Styria), and Klagenfurt (Carinthia). The cohorts lasted either two whole days or four afternoons, overall 16 hours, extending each over three to four months. In addition to the cohorts, there were several national and international presentations and teaser workshops at other events like the national “chemistry days”, a meeting of experts in chemistry education, scientific conferences etc.

The recruitment of the participants occurred in different ways. One way of recruiting participants was to send information about the TEMI-project to a great number of teachers by several e-mail distribution lists, such as that of the newsletter of the Institute, the Association of Chemistry Teachers in Austria, the Society for the Advancement of Physics and Chemistry Education etc. Another way to gain attention for the project was to conduct presentations and teaser workshops at national conferences. Furthermore the workshop series were advertised in the teacher education program of the Universities of Teacher Education in five states of Austria. The outcome of the efforts was the number of about 110 participants (young teachers as well as teachers with long-time teaching experience) in the workshop series and a great number of attendees to the several presentations and workshops.

In the course of the project there were several materials, articles and presentations generated and published. The Austrian TEMI-team contributed three mysteries (Gelli Baff, Solid or Liquid, The (un)reliable Indicator) to the ‘Book of Mysteries’ and developed two ‘Mysteries of the Month’ (Genie in a Bottle, Colourless Coke). Moreover, a special issue on TEMI was published by the Austrian teacher journal ‘Chemie & Schule’ [Chemistry & School] in 2015 (Abels & Lembens, 2015). The issue contains information about the four innovations of TEMI (see introductory articles). It provides background information on six mysteries and materials for students.

Outline of the Workshops

The professional development courses were divided in four parts. In every part there were both presentations containing the most important information and hands-on activities to put theory into practice. Thereby, the participants should experience the processes of inquiry-based learning themselves and get ideas for implementing units of inquiry-based learning in their own teaching. It was also important for us to discuss with the participants about their aims, doubts, ambiguous points and their uncertainty concerning content and methodological issues, as well as to reflect about their experiences.

The aim of the first part was to get to know each other and to inform the participants about the general framework of the project. The teachers receive the booklet ‘The TEMI Way of Teaching’. They should know the aims of TEMI and learn about the idea and definition of mysteries, main aspects of Inquiry-based learning (see Figure **1**, Abels, Lautner & Lembens, 2014) and the different levels of inquiry-based learning (Blanchard et al., 2010).

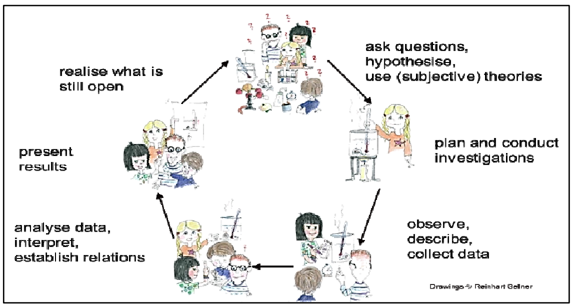
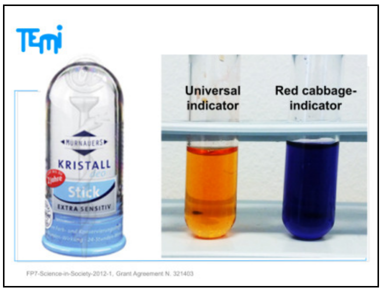


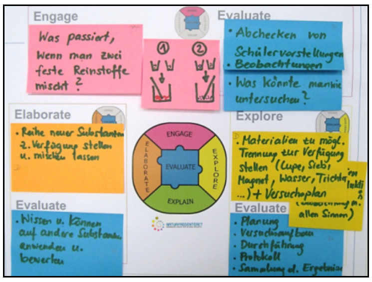
Figure 1: Aspects of Inquiry-based learning (translated after Abels, Lautner & Lembens, 2014)

In part 2 the theoretical foundation was extended by the 5E instructional model (Bybee *et al.,* 2006, Bybee, 2009). In both parts the participants had opportunities to apply the different theoretical models using mysteries in the Engage-phase. The third part of a cohort focused on Showmanship, which was organised in collaboration with the magician Tilman Andris[1] Tilman Andris showed the participants how to present mysteries professionally and effectively. Together with the teachers he developed criteria about engaging presentations which the teachers tried to integrate when presenting an Engage-phase. Finally, the workshop series were concluded with a unit in which the participants were challenged to plan a chemistry lesson according to the 5E instructional model. The detailed outline of the workshop series is shown in Table 1, together with photos illustrating the various stages.

Table 1: Outline of the teacher training workshop units

Contents	**Way of proceeding**
Part 1	
General framework of the project	Presentation
Aims and innovations of TEMI and Inquiry-based learning	
Aspects of Inquiry-based learning (Abels, Lautner & Lembens, 2014)	
What does a mystery look like? What is a good mystery?	Presentation Demonstration experiment combined with storytelling: Genie in a bottle.  **Figure 2: 'Genie in a Bottle' presented by Dr. Simone Abels**
Levels of Inquiry-based learning (Blanchard et al., 2010)	Presentation Participants perform an experiment relating to Genie in

	a Bottle at Inquiry level 1 Participants work on 3 station tables with materials to explore mysteries (Never Wet, Liquid or Solid, Gelli Baff) on level 2  **Figure 3: Materials for level 2-experiments on the 'Never Wet'-mystery** Final discussion about the differences between level 1 and 2, learning goals, alternative ways of implementation
Part 2	
5E instructional model (Bybee et al., 2006, Bybee, 2009)	Presentation
Lesson unit according to the 5E instructional model	Presenting one mystery (Engage-phase): The (un)reliable Indicator  **Figure 4: 'The (un)reliable Indicator' - conflicting results for the pH-value of the deodorant-solution** Participants conduct the Explore-phase for the presented mystery on level 2 and present their procedure and results..  **Figure 5: Colour range from the investigation** Supporting participants in clarifying the chemical background of the mystery (Explain-phase) Hints for Extend- and Evaluate-phase

Creating an Engage-phase	Three new mysteries are explored by the participants (Amazing Bottle, Chemical Weightlifting or Magic Sand) Homework: Participants are encouraged to create an Engage-phase for one mystery and present it in the following workshop-session.
Part 3	
Introduction to Showmanship	Tilman Andris (magician) performs magic tricks
Similarities and differences between magic tricks, mysteries, and chemistry teaching	Presentation by Tilman Andris (magician). Tilman Andris orchestrates the 'Amazing Bottle' as a magic trick.  **Figure 6: The magician Tilman Andris presents the 'Amazing Bottle'** Participants and workshop leaders work out the similar and different characteristics of presentations in magic art and teaching
Exercise Showmanship	Participants try to implement the discussed skills in simple exercises. Participants perform their prepared Engage-Phase and get feedback by Tilman Andris, other participants, and the workshop leaders
Part 4	
Repetition Showmanship	Show two different videos of the mystery 'Clock Reaction' developed by the Weizmann Institute Participants explicate observed differences on ways of presentation and recall Tilman's input
Lesson unit according to the 5E instructional model	5E instructional model is repeated Participants plan the five phases of the 5E instructional model based on one mystery with a planning template.  **Figure 7: Detail of a planning template according to the 5E instructional model** Presentation of the lesson units and feedback

How TEMI matches the Austrian chemistry curriculum

To find similarities between the aims of TEMI and the Austrian curriculum for chemistry, we studied the chemistry curricula for secondary schools (grammar school and middle school) (BMBF, 2000, 2004)[2]. The preliminary notes, especially the paragraphs "educational and teaching tasks" as well as "didactic principles", are particularly interesting concerning TEMI. The didactic principles are quite similar in both curricula; the level of subject-matter and skills to be acquired is of course increasing. (BMBF, 2004, 2000)

The introduction to scientific thinking and scientific work is named as one of the main tasks of chemistry lessons in the curricula. To achieve this aim, the students should experience how knowledge can be acquired by investigations. They should observe chemical processes, formulate and test hypotheses, plan and perform experiments, and assess and interpret results. These activities fit well to the Explore-phase of the 5E instructional model. Furthermore, students should be able to come to explanations self-dependently and link phenomena to scientific concepts, like during the Explain-phase of the 5E instructional model. (BMBF, 2004, 2000)

The chemistry curricula also contain components of GRR[3]. Teachers should implement experiments, which range from common observation and interpretation of demonstration experiments to student experiments involving work on individual posed problems. It is explicitly mentioned that the learning environment should enable various learning possibilities in which the students are supported to an appropriate extend. (BMBF, 2004, 2000)

In summary, the approach of TEMI includes many components of the Austrian chemistry curricula for secondary schools. In addition to the obvious similarities to the 5E instructional model and GRR, there are many details which follow a similar idea, for example to develop the ability to solve problems, to use a correct terminology during communicating and to work in a team. So we would say that TEMI can be implemented in chemistry lessons to any extent (of course having regard to a variety of methods) as long as the required subject-matter is addressed.

Conclusions from teachers' feedback

Results from questionnaires and impressions from individual conversations indicate that the participants enjoyed the workshop series and were interested in the contents to a great extent. The teachers liked mostly the mysteries, the input of the magician Tilman Andris and also the exchange with other colleagues. We got the feedback that there was always a very positive working atmosphere, but there could have been even more time for discussion and conversation. Some colleagues were excited to experience Inquiry-based learning from a student's perspective. One of the participants said, *"I felt like a curious child."* Furthermore it was positively mentioned that the content addressed both young teachers and teachers with a long-time teaching experience as well as teachers from different school types. It seemed that the diversity of the group was generally seen as an enrichment. The teachers liked to discuss with colleagues from other school types about the different approaches and experiences. We noted also that the teachers' understanding of the various applications of inquiry-based learning increased over time; anyway some teachers could not imagine by themselves how to implement Inquiry-based learning in their own lessons. Those teachers, who tried out inquiry-based teaching units, reported that the students had liked the mysteries and had been very engaged and motivated. *"Suddenly they [the students] asked questions"*, said one teacher.

After the workshops, most of the participants felt quite competent to implement mysteries and inquiry-based learning in their own classes. The 5E instructional model, the inquiry levels and Showmanship were areas in which the teachers did not see themselves as confident as in the above mentioned. This result shows that the teachers didn't see inquiry-based teaching as product consisting of the main ideas we presented them in the workshops but as an individual part of it (see Figure 8).

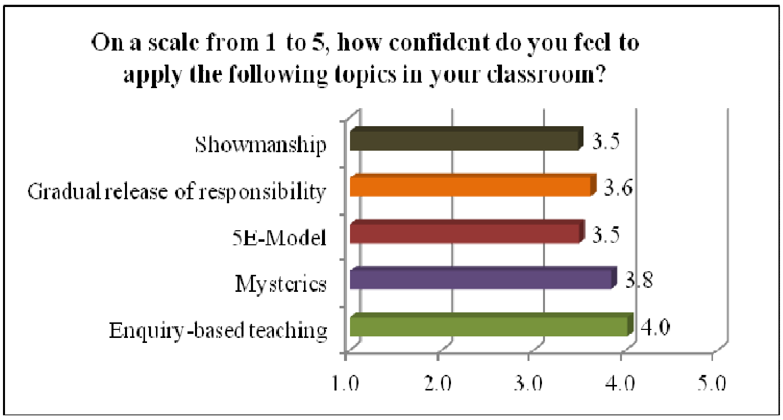


Figure 8: Participants' confidence to apply the main topics of TEMI in class on a scale from 1 (not confident at all) to 5 (very confident) (Lembens & Abels, 2016)

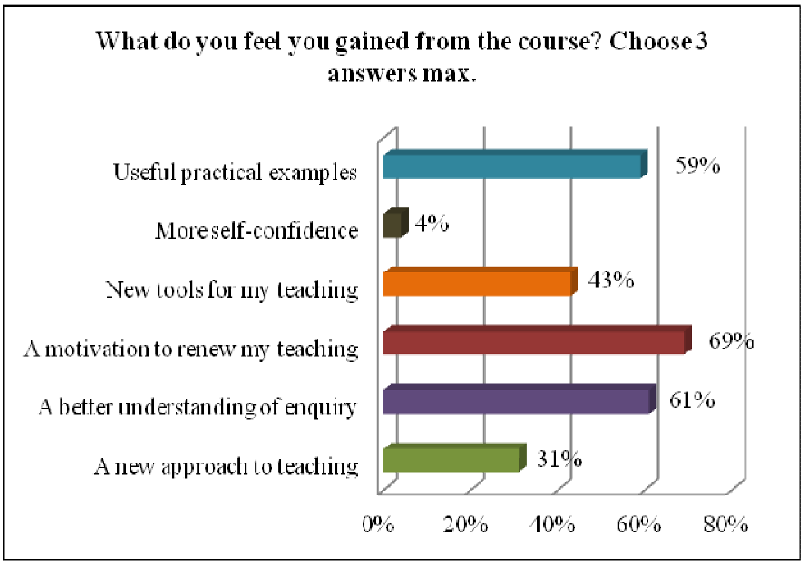


Figure 9: Participant's benefits through the TEMI workshops (Lembens & Abels, 2016)

When asked about what the teachers felt they gained from the course, most of them chose “a motivation to renew my teaching”, “a better understanding of Inquiry-based science education” or “useful practical examples” (see Figure 9). It was generally agreed that the workshops matched the professional needs of the teachers.

All in all, we had the feeling that the participants liked the methods introduced and used during the workshops, as well as the contained scientific contents, but according to the feedback questionnaires only a few of them implemented inquiry-based teaching and learning in their classes. The reasons for that were very diverse. While some did not have chemistry lessons or students in adequate age, others saw problems concerning time and context. We realised that most of them did not feel confident enough to implement inquiry-based teaching by their own. Some of the participants said that they would need more information and materials, which they can directly use in their own classes. Also the teachers, who taught according to TEMI, had problems with the time management and the output of the teaching units, i.e. what students can learn. Some of them were of the opinion that an accompanying guide would be very helpful to implement Inquiry-based learning.

Because of this feedback, we are sure that teachers want to apply inquiry-based teaching and learning in their lessons and if we want them to put their ideas into practice, we have to support them in planning, conduction and reflection.

Plans for the future

As already mentioned, teachers liked the workshops very much, but they asked for further support. So we started to continue working intensively with a small group of interested former workshop participants by planning lesson units, discussing experiences and further developing teaching strategies. The ambitious goal would be to establish a ‘community of practice’, which works together on planning, implementing, and reflecting inquiry-based teaching and learning into teaching practice. Within the group, the teachers will reflect on video scenes of their own and others teaching and they will accompany each other as critical friends to chemistry lessons.

We will also offer some kind of one-day ‘refreshing workshops’ in the school year 2016/17 for teachers who participated in the TEMI-workshops, to achieve sustainability and to support the implementation of Inquiry-based science education in the schools.

Final thoughts

The TEMI-project was disseminated through presentations and workshops all across Austria. A large number of teachers from various school types, with different amount of experience and with diverse beliefs were reached through the workshops. After about three years of intense work, we are happy to have met so many friendly and engaged colleagues, teacher educators and teachers. We enjoyed developing mysteries and it was a pleasure to give the workshops for the teachers. We hope that the workshop participants learned a lot, we did it anyway. Finally, we wish that TEMI helped Inquiry-based learning to find its way into the Austrian classrooms. If the Austrian chemistry curriculum is taken seriously by the teachers, it is necessary to implement some kind of inquiry-based teaching and learning in the chemistry lessons and TEMI would be a suitable possibility to cope with that.

Acknowledgements

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References

Abels, S., Lautner, G. & Lembens, A. (2014). Mit "Mysteries" zu Forschendem Lernen im Chemieunterricht. *Chemie & Schule,* 29**,** 20-21.

Abels, S. & Lembens, A. (2015). Sondernummer TEMI - Teaching Inquiry with Mysteries incorporated. *Chemie & Schule,* 30.

Blanchard, M. R., Southerland, S. A., Osborne, J. W., Sampson, V. D., Annetta, L. A. & Granger, E. M. (2010). Is inquiry possible in light of accountability?: A quantitative comparison of the relative effectiveness of guided inquiry and verification laboratory instruction. *Science Education,* 94**,** 577-616.

BMBF. (2000). *Lehrpläne der AHS-Unterstufe: Chemie* [Online]. Available in German: https://www.bmbf.gv.at/schulen/unterricht/lp/ahs6_780.pdf?4dzgm2 [Accessed 25/11/2015].

BMBF. (2004). *AHS-Lehrpläne Oberstufe neu: Chemie* [Online]. Available in German: https://www.bmbf.gv.at/schulen/unterricht/lp/lp_neu_ahs_09_11861.pdf?4dzgm2 [Accessed 25/11/2015].

Bybee, R. W. (2009). The BSCS 5E instructional model and 21st century skills. Colorado Springs, CO: BSCS.

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. *Colorado Springs, CO: BSCS,* 5**,** 88-98.

Lembens, A. & Abels, S. (2016). Focusing on Inquiry-based Science Education within a European In-Service Teacher Education Programme. In J. Lavonen, K. Juuti, J. Lampiseelka, A. Uitto & K. Hahl (Eds.), *Science Education Research: Engaging Learners for a sustainable future*. E-Proceedings ESERA 2015.

Footnotes:

[1] Tilman Andris is a magician working in the Netherlands who collaborates with Leiden University, the University of Bremen, and the University of Vienna in the TEMI-project. www.tilmandandris.com (26/11/2015)

2 BMBF (Bundesministerium für Bildung und Frauen, Ministry for education and women) is the department which publishes the curricula in Austria.

3. GRR: Gradual Release of Responsibility (see p. 8.)

□

The outline for the ‘Genie in the Bottle’ TEMI lesson used by the Vienna team is given on the next three pages.

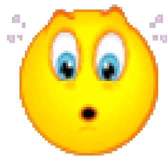
The Genie in a bottle

Genies are magical creatures, which often live in bottles. If you are able to free a genie out of the bottle, the genie must fulfill at least three of your wishes. Wouldn't it be marvelous to create your own genie so that all of your wishes come true?

But how can you create a genie?

Find out what happens in the mysterious bottle. Note your assumptions, observations and results in your exercise book.

Engage



Task: Your teacher will show you a genie in a bottle. Observe carefully what happens. Write down your observations and try to answer the following questions by making assumptions.

What does escape from the bottle?

Touch the bottle. What can you notice?

What has been in the bottle? Liquids, solids or gases?

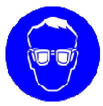
Why does the genie stay in the bottle until the plug is removed, even though there is an opening in the plug?

Which function does the aluminium foil have?

Task 1: Explore the reaction of manganese dioxide with different liquids.

Materials: 5 test tubes, spatula, pipets, distilled water, 3% hydrogen peroxide solution, 10%°sodium chloride solution, 1diluted sodium hydroxide solution, diluted sulfuric acid, manganese dioxide

Steps:



1. Take a spatula tip of manganese dioxide and put it into every test tube.
2. Take 2 mL of one liquid and put it into one of the test tubes. The same procedure is being applied to the other four liquids and test tubes.

Which of the liquids does react with manganese dioxide? How can you see that a reaction takes place? Write down your observations!

Get the other worksheet!

Explore

Task 2: You could observe a reaction between manganese dioxide and hydrogen peroxide solution. But which substances are produced during the reaction?

Materials: spatula, test tube, test tube holder, syringe 10 mL, syringe 20 mL, plug with 2 cannulas, splint, tea light, lighter or matches, manganese dioxide, 3% hydrogen peroxide solution

Steps:

1. Take 3 spatula tips of manganese dioxide and put the powder into the test tube.
2. Close the test tube with the plug containing the cannulas.
3. Fill the small syringe with 10 mL of the hydrogen peroxide solution and insert the syringe into the opening of one cannula. (See figure!)
4. Take the 20 mL syringe and press the plunger until it stops. Insert the syringe into the opening of the second cannula.
5. Check if the test tube is well closed and if both syringes are fixed well on the cannulas. Add the hydrogen peroxide solution in drops to the manganese dioxide.
6. Empty the big syringe when it is filled for the first time and insert it into the cannula again.
7. Take the big syringe when it is filled for the second time and perform the glowing splint test. You can repeat this test several times.

What gas is produced? Is this gas the only substance which is produced? Look carefully at the test tube! Do the products arise from the liquid, from the solid or from both?

Explore

Task 3: Examine how the concentration of the hydrogen peroxide solution influences the reaction and observe what happens to the manganese dioxide.

Materials: spatula, 3 small beakers, 3 test tubes, manganese dioxide, 3% hydrogen peroxide solution

Steps:

1. Take 3 small beakers and fill each with 2 mL of the solution.
2. Don’t do anything with the content in the first beaker. Dilute the solution in the second beaker with 2 mL of distilled water and dilute the solution in the third beaker with 10 mL of distilled water.
3. Now take 3 test tubes and fill 1 g of manganese dioxide into each of it.
4. Put 1 mL out of beaker 1 and fill it into test tube 1. Do the same with beaker 2 and test tube 2 respectively beaker 3 and test tube 3.

What can you observe? Does the concentration of the solution influence the reaction? And if so, how? Don’t forget to touch the test tubes!

How does the manganese dioxide look after the reaction? What happened to it?

Explain

Task 1: Discuss the following questions with your colleagues and your teacher. Justify your statements by using the findings of the three investigations and answer the questions. Write this in your exercise book.

Which substances do react in the ‘genie-reaction’?

Which new substances are formed through the reaction? How can they be characterised?

From which of both reagents do the products arise?

What happened to manganese dioxide during the reaction? Which task does manganese dioxide have in the reaction?

Is energy released in the reaction? And if so, in what form?

In what way does the concentration of hydrogen peroxide influences the reaction?

What is the purpose of the aluminium foil? And why does the reaction only begin when the plug is released?

Task 2: Take your chemistry book and define the following terms: educts, products, reaction velocity, catalyst, endothermic/exothermic reaction

Connect the terms with the ‘genie-reaction’ in your exercise book.

Task 3: Complete the reaction equation of the ‘genie-reaction’:

$$2\ \square \xrightarrow{\square} \square + 2\ \square$$

Extend

Task 1: Use an Internet research and find other possibilities except catalysts and concentration of educts to increase the reaction velocity. Make notes in your exercise book.

Task 2: Which relevance do catalysts have for your life? Read the short text on the website and write down notes in your exercise book.

http://www.infoplease.com/encyclopedia/science/catalyst-types-importance-catalysts.html

Evaluate

Task: In which situations could it be advantageous to use catalysts instead of other possibilities to increase the reaction velocity?

Discuss with your colleagues.

The Israeli TEMI case: Adaptation of TEMI modules to the local context

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Organisation of the project

In Israel, the TEMI team at the Weizmann Institute of Science led two types of training programs: One which was open to all chemistry and science teachers (four cohorts), and the other which was part of a chemistry teachers' course at the Weizmann Institute (two cohorts). Overall, 120 teachers underwent intensive TEMI training at the Weizmann institute. The teachers were recruited through: (1) personal communication (via teachers who have undergone a CPD course at the Weizmann Institute previously), (2) the National Center for Chemistry Teacher, and (3) advertising in appropriate local science education websites.

The TEMI training programmes at the Weizmann Institute consisted of a two day intensive workshop over the summer school break. It allowed teachers to be immersed in the TEMI philosophy and the specific TEMI teaching style as well as learn practical examples that they could use in their classes. The summer workshop was followed by several afternoon meetings scattered over the school year. The scattering of these meetings allowed teachers to enact TEMI activities in class and report about them.

In the Israeli context, IBSE has been an integral part of the chemistry curriculum for many years. Many science teachers in Israel are familiar with IBSE, and therefore we were able to focus on the other TEMI innovations, specifically on showmanship. In our workshops we included many elements of storytelling, drama and presentation skills. We invited actors and experts to provide sessions on good storytelling, drama, presentation skills and physical theatre using masks. All training programmes were performed using the GRR methodology, in which the teachers act as students experiencing the mysteries. They gradually were responsible to develop their activities, gained a sense of ownership towards the program, and as a consequence presented the activities at local and national meetings. One of the science teachers who attended a conference in which TEMI activities were presented, claimed:

"I always thought that Chemistry was interesting enough … but there are always those [students] who are simply not interested, so I understood that I can reach a wider student audience if I will tell a story … now I also know that I can't come to class with a hunched back, because the body communicates as well.."

Teachers' feedback

Many of our teachers from the first TEMI cohort continued their collaboration with us, and they kept asking and looking for new TEMI activities. “Ready-made” TEMI activities were welcomed by the teachers, but they revised them according to their needs. They created their own TEMI-style activities, tried them out in class and reported about their experience to the workshop leaders as well as to their colleagues. This enabled a significant exchange of ideas.

We found out that teachers needed to feel confident with using the various strategies in teaching mysteries. For example, some of the local TEMI activities begin with a short story. In teachers' feedback we found out that teachers adapted the story to their own style. Those who were 'natural' story-tellers took the basic story and elaborated on it by adding details and narratives. Those who did not feel comfortable in telling a story, found other way, such as adapting the activity with a little introduction that did not require intricate story-telling skills.

The activities that were least welcomed in the CPD were those that had to do with pure drama. Teachers often found it outside their comfort zone and difficult to engage with. However, despite this sense of discomfort, these activities had an impact on teachers' awareness of their teaching.

Relevance to science education in Israel

Most of the Israeli teachers follow the Israeli science national curriculum, and therefore, in the

TEMI workshops we try to match the contents of TEMI modules to its requirements. Moreover, we plan some activities according to the national holidays, e.g., "A candle activity around Hanukah". The chemistry matriculation examinations also influence the development and implementation of TEMI models in Israel. The chemistry examinations include an IBSE unit, based on portfolio assessment which each student has to submit. Most of TEMI activities were developed with this in mind. For example, while implementing “The sea sand overseas” activity, the teacher engages students with a short story of a friend who was invited to a sand castle building competition, and received special hydrophobic sand to build a sandcastle. Students are then led to explore the properties of the sand and subsequently design and conduct a semi-open inquiry experiment which they place into a portfolio, in which they collect all their IBSE activities.

Future plans

Many of the TEMI activities were presented in different CPD workshops and we thus hope their legacy will continue. The main strength of the TEMI approach is in its powerful engagement of students. We filmed some of our activities to facilitate future implementation of TEMI in class. Most activities are easy to conduct, and do not require special equipment, but there are still some teachers who feel uncomfortable presenting a story, or doing some form of showmanship. Therefore, we conclude that despite the good will of many science teachers, those who will not attend a TEMI workshop will face difficulties in implementing TEMI's activities properly. However, we hope to be able to integrate TEMI workshops all over the country in different science programs.

Examples from the Israeli context

The Israeli team has planned several original TEMI activities such as "The Chemical Clock", "The Sea-sand Overseas" and "The Disappearing Lab Report". These can be found in the TEMI Book of Mysteries (http://teachingmysteries.eu/wp-content/themes/temi/pdf/Temi_teaching_guidebook.pdf) and in several other publications. In this article we want to describe the process by which TEMI-style activities can and should be adapted to the local context.

One of the goals of TEMI program was to exchange ideas between the different partners. Thus we incorporated several activities planned by different TEMI partners into our teacher training. Upon doing so, we realized that these activities must be adapted to the local context and seasoned with local spices in order to be suitable for use by the Israeli teachers. To highlight the adaptation process we provide three concrete examples. We hope that these examples can help educators who wish to use TEMI.

(1) Chemical Garden

The Chemical Garden TEMI activity was originally planned by the German TEMI team from the University of Bremen. The "Chemical garden" experiment is based on a well-known demonstration used to discuss the chemistry of salts, solubility, diffusion, and solutions (Dittmar, Mueller, & Eilks, 2015; TEMI project, 2015). The Bremen team adapted it to TEMI's rationale. In the experiment different salts are added to a water glass solution (sodium silicate). Within minutes or hours colourful structures are formed through precipitation, hence the name chemical garden (see Figure 1).

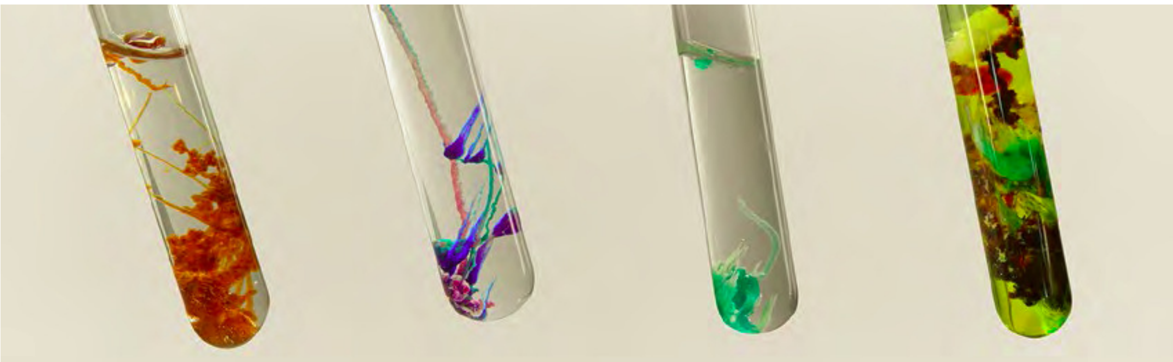

Figure 1: Samples of the "Chemical garden". Each colour is caused by a different metal salt added to the water glass (from TEMI project, 2015, p. 26)

The Chemical Garden has a special Israeli context. In 2003 the first Israeli astronaut, Ilan Ramon joined a NASA mission (STS-107) on the space shuttle Columbia. During the mission Ramon performed experiments designed by Israeli high school students. One of these experiments was the "Chemical garden". The purpose of the experiment was to try understanding the mechanism of crystal growth by performing the experiment in microgravity aboard the orbiting NASA space shuttle, which was suggested to be influenced by gravity (at the same time a control experiment was conducted simultaneously on earth). Sorrowfully, the mission ended in a tragic explosion of the shuttle as it entered earth atmosphere.

This story is strongly embedded in the Israeli collective memory and we thus wanted to use it to engage students and teachers in this activity. We started the activity by asking participants to close their eyes. We then played an audio track of space centre control (in Houston, Texas) playing a Hebrew love song (the first Hebrew song to be heard in space) picked by Ramon's wife (the Israeli astronaut) to wake up the astronauts in orbit. At the end of the song we told the story of Ramon, the mission, the students' involvement in the "Chemical garden" experiment, and the tragic end:

"On February 1, 2003, NASA mission STS-107 was to come to an end with the landing of Columbia in Cape Canaveral, Florida. Due to the historic significance, a live coverage of the event was broadcasted in several Israeli channels. The families of the astronauts were seen waiting on a podium with a clock counting down the time to the landing. When the clock showed zero no space shuttle was to be seen. A few minutes later the families were taken off the podium. Something had gone wrong. The space craft never landed. It disintegrated upon its return from Orbit above Texas."

The rest of the activity was performed followed the 5Es learning cycle as suggested by the Bremen TEMI team: In the explore stage we let participants try making their own "Chemical garden". We then explained the phenomenon in the "explain stage". The "extend stage" went back to the original story. We presented the results of the space experiment and explained how they differed from the results obtained on earth. Finally, in the "evaluate stage", participants were asked to photograph their "Chemical garden", and explain in their own words how it is created.

The "Chemical garden" activity is a well-known fascinating experiment. In planning our activity, we took advantage of an emotionally engaging context of space travel to attract the participants to do this experiment. The emotional motivation is prolonged, since the results of the experiment are not presented until the end of the activity (the "extend phase").

(2) How can we produce silver and gold out of copper? The activity *"How can we produce silver and gold out of copper"* was introduced by the Czech TEMI team from Charles University in Prague (see p. 16). In this activity, a copper coin is dipped into a boiling solution, and when it is removed from the solution the coin magically turns into "silver". The coin is then placed on a hot plate and magically transforms its colour into "gold".
The first stage involves the production of zinc which coats the copper coin and looks like silver. In the second stage, when the zinc-coated coin is heated, the zinc coat reacts with the copper and a golden coloured alloy, brass, is formed on the coin. The coin looks as a gold coin. Our review of this experiment revealed different implementation directions:

- Adding a short story that is set in the historical background of the alchemists, who tried to transform simple metals into gold. They were working in the framework of Aristotle's theory, and their ideas seemed to be unrealistic. However, modern science indicates that it can be done by radiochemical reactions. Referring to historical events in science, may show a broader picture of the development of science and the meaning of the nature of science. In this case, for example, teachers may point out the contribution of the alchemists to developments in metallurgy or in pharmacology.

- A few teachers suggested connecting the experiment to Archimedes' law, and asking students to experiment and calculate the density of the metals and then decide whether the coins were made of gold and silver. The results of this experiment were not good. However, after experimenting and many deceptions, the teachers who suggested this direction abandoned it as well.

- One of the teachers came up with the idea to combine the experiment with a real story about the alchemist Nicolas Flamel who lived in Paris, 1330-1418 (mentioned in "Harry Potter").

In summary, the above experiment is one of the most favorite TEMI activities. Teachers who implemented it in their classes have presented it to colleagues in various teacher meetings.

In the context of the curriculum, teachers have used this activity as an introduction to Oxidation-Reduction reactions or to experiments on alloys.

(3) Genie in a bottle

The activity was originally devised by the Austrian TEMI team at the University of Vienna (see p. 30). The activity begins with a demonstration showing a corked bottle. Upon removing the cork nothing happens at first, but then a stream of white 'smoke', i.e. the Genie, gushes from the mouth of the bottle (see Figure 2).

Figure 2: Genie in a bottle.

Hydrogen peroxide decomposes into water and oxygen at a slow rate. Adding a catalyst increases the rate of reaction. The 'genie' is produced as water and oxygen gases are produced in the reaction and water is condensed as fog. SHU and UniVie TEMI teams use the demonstration to deal with catalysts and method of measuring oxygen production, Our team decided to deal with one common misconception: students think that fog (condensation of water) is smoke. Since the Israeli TEMI team focused on the showmanship skills and storytelling, this mystery was wrapped into a story, a personal story that the teacher tells about her/his grandmother who left a mysterious bottle before she died.

To adapt it to suit the Israeli context we made a couple of changes:

(1) We wanted to set the activity within a story;
(2) We extended the discussion about "What the Genie is made of".

Conclusions

In this article we describe the Israeli context in which TEMI operates. We described three TEMI activities developed by other partners and adapted to the local context. We hope that these examples and the process of adaptation will support and encourage teachers to consider adapting TEMI activities into their local context (national, local and even school contexts). The adaptation can be characterized by two aspects.

(1) Connecting the activities to the Israeli curriculum, which makes their implementation in class much easier, and

(2) The connection to the local context, which makes it more appealing for the teachers and students. We may conclude that making these adaptations made the activities more engaging and relevant to our Israeli teachers.

Acknowledgements

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References

Dittmar, J., Mueller, S., & Eilks, I. (2015). Inquiring into the mysterious chemical garden. *Chemistry in Action*, *105*, 32–36.

TEMI project. (2015). *The book of science mysteries*. (D. Loziak, P. McOwan, & C. Olivotto, Eds.). http://teachingmysteries.eu/wp-

Teaching Inquiry with Mysteries Incorporated (TEMI) (2012). FP7-Science-in-Society-2012-1, Grant Agreement N. 321403.

□

On the next page the Weizmann team describes a TEMI lesson in detail.

The tell-tale key

Developed by Ben Osher (who participated in one of Weizmann's TEMI cohorts)
Adapted to print by Malka Yayon, Dvora Katchevich and Ran Peleg

The tell-tale key is an activity suitable for 10-11th grade chemistry students. Students need to know about ionic materials, dissolution reactions and precipitation reactions. They should also know about redox reactions and oxidizing and reducing agents.

Special caution: Students need to wear gloves and safety goggles. During the magnesium's combustion, students should avoid looking at the flame since it is a very strong source of light.

Special materials: A roll of Magnesium ribbon ~€5 and 100 g of Silver Nitrate ~€70.

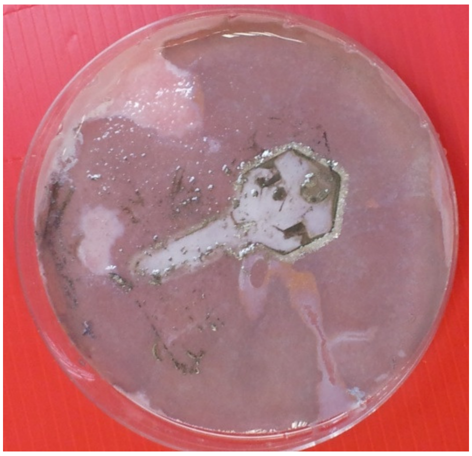

Figure 1. Sample of an impression of the tale tell key.

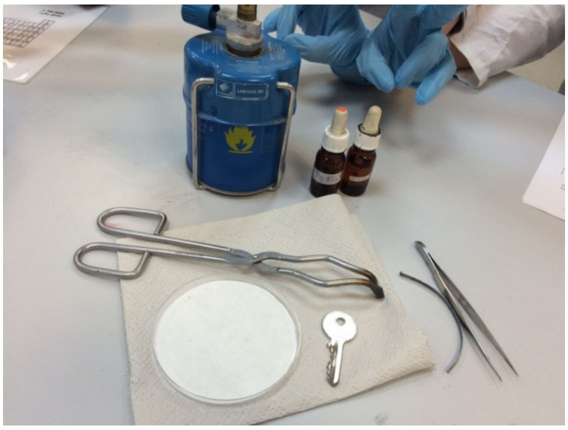

Figure 2. Preparations for the experiment.

The activity begins with a story about a break-in into the school's lab: Yesterday, the lab technician prepared all the materials for today's experiment, but during the night there was break-in, during which all materials and solutions spilt on the floor. Due to a strange coincidence the lab technician was able to identify the culprit – his/her key left an impression on the floor (hence the tell-tale key, see Figure 1). Students then perform the experiment according to the instructions given to try and understand how an impression of the key could form on the floor (Figure 2). They then investigate the optimal conditions for obtaining a clear impression of the key (see Figure 3).

A summary of the experiment is provided in Table 1 and a full student worksheet is in Box 1.

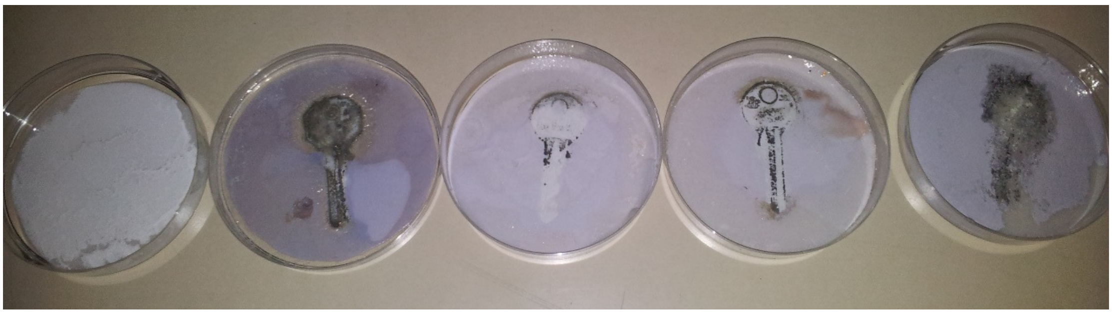

Figure 3. Investigation of the impressions left by different light sources.

Table 1. Summary of the activity *"The tell-tale key"* laid out in the formal of the 5E pedagogical model.

Stage according to the 5E model	Description of the activity *" The tell-tale key "* in relation to the 5 E's
Engage	The activity begins with a story about a break-in into the school's lab: Yesterday, the lab technician prepared all the materials for today's experiment, but during the night there was break-in, during which all materials and solutions spilt on the floor. Due to a strange coincidence the lab technician was able to identify the culprit – his/her key left an impression on the floor (hence the tell-tale key).
Explore	Students are asked to help the police investigators understand what happened and to issue picture forensic report. They perform the experiment according to the instructions given to try and understand how an impression of the key could form on the floor.
Explain	Students gather observations and plan how to investigate the optimal conditions for obtaining a clear impression of the key. All these to understand what happened.
Extend	Students perform the experiments; each group investigates another aspect of the investigation.
Evaluate	Students are asked to submit: • A detailed lab report • A report for the police explaining how the key imprint was obtained and how it helped them get to the culprit. This report should include photos. • An answer to the question: What did the lab technician mean when she shouted: "It's all about the silver (money)!!"

Box 1: Detailed student instruction sheets

Engage stage:

The following story is told to the students at the beginning of the activity:

"This story is about Edna my lab technician. Besides being a good friend she is the best lab technician ever! And today we discovered that she could also be an amazing detective. They might even recruit her to CSI… Do you want to know why?

Edna is a very well organized person and is meticulous about good order in her lab.

Each morning she opens the lab, and makes sure everything is in order. She prepares the materials for the next day's experiments. At the end of the work day she never forgets to turn off all electric devices, to lock the closets containing hazardous materials and she always double-checks that the door lab is closed before leaving.

This morning she had to come in late to school. Since she is always very punctual she had a bad intuition. And indeed .. when she entered the lab she was shocked!!! The door open, lights were on, tools and materials were all in a big mess and the experiments she prepared for today were scattered on the floor. After checking no dangerous substances that may ignite are spilled, she ran to the phone and called the school's principal who contacted the police.

Half an hour later, two police investigators began questioning poor shocked Edna. The policemen's questions made Edna feel uncomfortable – she felt that they suspected her. Suddenly in all the chaos Edna screamed: "It's all about the silver!! I know who did it." [In Hebrew as in Spanish and French silver also translates as money adding to the suspense]

Just next to the materials intended for today's experiment she saw a black imprint of a key on filter paper. Edna immediately recognized the special key's silouhette.

The police investigators were confused what silver (money) has to do with the break-in and how the key imprint appeared on the paper.

Explore stage:

Students try out the phenomenon that helped Edna identify the culprit. Following are the instructions to the students.

Your job is to help the police investigators understand what happened and to issue picture forensic report.

Preliminary experiment:

Read all the instruction before you start working

Make sure that u have all the equipment and materials

Arrange your observations in a chart.

Materials and equipment:

- Petri dish
- Filer paper cut to the shape of the petri dish

- A vial containing solution A
- A vial containing solution B
- 2 Pasteur pipette
- An old key
- 4cm magnesium strip
- Bunsen burner
- Matches
- Clamp

Procedure:

1. Make sure that the paper fits the Petri dish
2. Use a Pasteur pipette and Drip few drops of solution A on the paper until it is all soaked
3. Use another Pasteur pipette and Drip solution B. Write your observations.
4. Keep drizzling more from vial B until all the paper is covered evenly (it is crucial that the Petri dish will not contain extra fluids and avoid shaking the Petri dish).
5. Place the key on the filter paper.
6. Hold the magnesium with the clamp
7. Light the burner on and bring the magnesium to ignite.

Make sure you don't look directly into the light. Practice your "side watch"

8. Place the burning magnesium above the Petri dish until the end burning ends.
9. Remove the key from the paper use gloves or the clamp.
10. Take the paper out carefully and leave it to dry.

Check the paper and write down your observations.

Explain stage:

1. Make a detailed list of the observations you saw in Activity 1.
2. Compose five questions that you can ask from the observations.
3. Try to ask inquiry questions that checks the connection between two variables. Example: how does *the amount of sun light* affect *the growing of a plant*? Alternatively ask a question relating to what the best conditions are for getting a clear imprint.
4. Pick one inquiry question and write a scientific hypothesis for your question. What do you think will be the answer? Explain your hypothesis using relevant knowledge in chemistry. You can use information sources like text book and internet to write your assumption.

Extend stage:

1. Plan an experiment that will confirm or refute your hypothesis:
   a. Define the dependent and the independent variables.
   b. How will you measure your dependent variable?
   c. How will you control and change your independent variable (you will have to perform the experiment in at least 3 different sets including a control set.
   d. What are the constant factors/variables?
   e. Write a detailed account of the stages of the experiment. Don't forget to relate to a control set. You may want to produce a graphic chart.
2. Make a detailed list of materials and equipment for your experiment.
3. Give the list you made to Edna.

Now you can perform the experiment after it has been approved by the teacher

4. Conduct the experiment as you planned above.
5. Make sure you keep a clear, detailed and accurate account of all observations. You may use your mobile device to document the observations.
6. Present your observations and results in an organized manner (table or illustration).
7. Try to process your results into a graph.
8. Explain any trends in the results.
9. Analyze and explain the results you got based on relevant scientific knowledge

Conclusion

10. Based on all your experimental results, what conclusions can your reach?
11. Relate to you hypothesis – were you able to accept or refute it?
12. In a group discussion:
    a. In a critical way relate to your results (how accurate were they, what are the limitations, etc.)
    b. In a critical way relate to the validity of your conclusions.
    c. What changes would you make to the experiment (would you change the hypothesis or the experimental design?)
    d. Write further questions arising from the whole lab.

In your opinion write why an imprint of the key was obtained. What were the conditions that let to the imprint appearing? What happened that morning?

Evaluate stage:

- Write a detailed lab report
- Write a separate report for the police explaining how the key imprint was obtained and how it helped them get to the culprit. This report should include photos.
- What did the lab technician mean when she shouted: "It’s all about the silver (money)!!"

“Guess the colour!”: A mystery to approach the vision of the colours

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Abstract

The colour of the objects around us depends on many elements, such as their surfaces, the colour of the light that illuminates them, and on the human perception system. In order to investigate the great variety of meaningful phenomena when the focus of our attention is on colour, we propose here experiments that can be done in every classroom, because they mainly need easily available and cheap materials, as coloured cardboards and LED coloured lights.

By the mystery presented here, we would trigger off a qualitative study on the additive synthesis of lights, on the subtractive synthesis of the coloured pigments, and on the vision on the colours under coloured lights. After some guided experiences described in this paper, we are expected that students would have the possibility to answer to questions such as “why this T-shirt is red?” and “what colour would be the same T-shirt under a green light?”

*In this paper we present a TEMI lesson, addressed to secondary school students, and consisting of a 5E’s complete cycle (Bybee,et. al., 2006) (**Engage, Explore, Explain, Extend, Evaluate**). The lesson develops as a GRR2 activity. After the engaging games played by the whole class with the teacher, students start their activities discovering monochromatic lights and non-monochromatic lights. Then, they will work with one monochromatic light at a time and different coloured cardboards in order to understand how absorption and reflection produce the particular colour perceived by our eyes.*

The additive synthesis of lights will be presented by mixing two or three coloured lights together, and observing the resulting light, or the coloured shadows produced by an object.

Since during the (last in our path) observation in blue light the phenomenon of fluorescence clearly appears, the first aim of the Extend phase will be the observation of fluorescence phenomena, much more common than expected in everyday life.

Moreover, in the Extend phase we will drive students towards the subtractive synthesis of coloured pigments, by mixing them as already done with the lights at the beginning of the path.

Introduction

This mystery pertains the world of colours. Since the proposed approach is qualitative, students do not need any mathematical tools or any particular background in optics and colours, but only the knowledge that the light may be composed of different colours. This path is designed for secondary school students, because our training cohorts were always addressed to secondary school teachers, but we think that the presented path can fit well also middle school teachers’ needs.

The path can be followed entirely, or partially, especially for what concerns the Extend phase. For this reason, the duration of the activity can vary from 1 to 3 hours. Although the technical and the mathematical aspects are not present in the proposed activity, we would like to emphasize the importance of giving students enough time to look carefully at what they are doing, to their hypothesising and to their ability in solving problems, even if only qualitatively. Moreover, in order to be used without practical difficulties, we have chosen low-cost experiments realized with easily available materials: green, red and blue laser pointers, diffraction gratings, coloured LED lights, white lights, coloured filters, coloured and white cardboards, black cardboards with a circular hole in the centre to mix coloured monochromatic lights, some drinks such as tonic water, a cube of Plexiglas, red, green and blue inks.

We emphasize that the experiments proposed in this path need the dark, especially during the Explore phase, in which students use one monochromatic light source at a time. For the same reason, it is mandatory that all students use the same colour at the same time. If the teacher finds this synchronization difficult in her/his class, she/he can have the help of some blackout blankets to be used to isolate each working group. We found the use of blankets supported by chairs placed over the work tables works well. Once everything is prepared, the activity can start!

Engage phase

In the classroom, when the game starts, the main light is off and at a certain point a monochromatic light is turned on, for example a green light. Six different coloured cardboards (see Figure 1) are on the table. A volunteer student is asked to pick up a cardboard of a certain colour (the teacher has checked before that the selected colour is markedly different under the monochromatic light that will be used). The game can involve also other students, both to pick up another differently coloured cardboard, and to discuss with the first students which is the right-colour cardboard. In the example shown in Figure 1, the colours requested are cyan and purple. Then, the students insert the cardboard into an envelope, that reports the name of the colour that should be contained in the cardboard inside, and close it. The number of envelopes will be equal to the number of the chosen colours. This procedure is repeated with three different colours of illuminating lights: red, green, and blue. Then, under white light the envelopes are opened and the students observe with surprise the "true" colours of the cardboards they have just chosen.

Figure 1: Pictures of the same set of cardboards: on the left under sunlight, on the right under a green light. Students are asked to pick up the purple cardboard (D on the white label on the cardboard) and the cyan cardboard (F).

Since showmanship is an important part of the TEMI philosophy, we emphasize that it is convenient that the game is performed using a precise theatrical grammar: students should enter the classroom when the darkness is already done, and three sets of coloured cardboards (one for each monochromatic light) are well placed on the table. Moreover, to prevent the vision of a cardboard set when illuminated by the "wrong" light, every set has to be covered by three black cardboards, which will be removed when appropriate. In Figure 2 is shown a picture of the classroom where we started this game. Another useful detail that must be stressed is that the combination of appropriate light and cardboards is to be chosen carefully, so that it is particularly difficult to identify the "true" colours of the cardboards in the set. Scientific theatre is another good, but different way of presenting Scientific Theatre Mysteries like the one here proposed; see for instance the website of the scientific theatre activities of the Physics Department of the University of Milano (Lo Spettacolo Della Fisica, 2004). You can also have a look at two trailers that contain experiments similar to those here mentioned (Facciamo luce sulla materia, 2004; Luce dalle stelle 2009).

The white light of the sun or the artificial light of the room will be introduced only at the end of the game; therefore only at the end students will know if they have guessed the right colour.

In general, students have lot of fun when changing rapidly from monochromatic light to the white light, and they need time to become familiar with the changing vision of the colours. We believe that all this work has to be postponed to the **Explore** phase, and has not to take place during the **Engage** phase, because it would be dispersive.

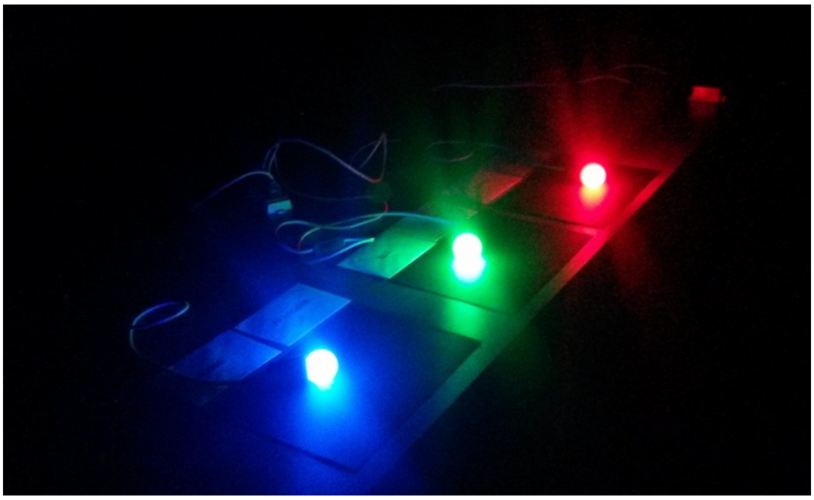

Figure 2: The classroom as it is prepared before students enter. It is already dark and black cardboards cover the three sets coloured cardboards that have been selected for the three monochromatic lights.

It can be useful to know that both, the game and the **Explore** phase, are more successful if the three monochromatic lights are used in the order: red, green and blue. In fact, the red LED light is usually the most monochromatic, therefore the effect of the "disappearance" of the colours is very marked. By contrast, the blue LED light, because of its short wavelength, often triggers fluorescent effects on some cardboards (especially for the yellow and light green cardboards), which are a different phenomenon from that of the vision of the colours in monochromatic lights here discussed.

Explore phase

Students do their observations in the darkness in groups, and if they need to illuminate their cards with white light, they have to use a flashlight, so not to disturb the other students too much. The exploration is divided into three steps, described here below.

(1) Laser light on a diffraction grating

Each group has a diffraction grating and many different kind of lights, from the monochromatic ones to the incandescent (white) ones. At the beginning of the activity students have to become familiar with a monochromatic light and a red or green laser can be observed on a wall after it has passed a diffraction grating. Students will see on the wall many dots, all of the same colour as that of the incident light. This means that the laser light is monochromatic. Afterwards students can look at other (not too intense) light sources through the diffraction grating. Depending on the type of source (light bulb, fluorescent lamp, LED light, laptop screens and so on) they will see different colours: the spectrum of the source. They can also experience that, in general, the greater the number of colours "contained", the higher the brightness of the light obtained. This way of using a diffraction grating, just as an instrument to detect monochromaticity, without explanations of the physics beyond, is proposed for beginners. If it is not so, teachers can easily implement their explanation about diffracting gratings.

(2) Additive synthesis

Using the black cardboard with a circular hole in the centre and two monochromatic LED lights at a time: red + green = yellow, red + blue = magenta, and green + blue = cyan. Using lights two by two it is possible to see that the colour given by the sum of the two monochromatic light is always brighter. The most surprising effect is obtained using the three lights at the same time: where they overlap, there the light is white.

(3) Coloured cards in monochromatic light

In this third step, students observe all the cards they have (about 12-15 colours) using one monochromatic light, from red to blue, at a time. The teacher's guidance in this step consists only in the request of dividing the cardboards in no more than three sets (very bright, dark, in the middle), and writing down, for each light used, what are the colours contained in each set, as shown in Figure 3, in the case of the red light.

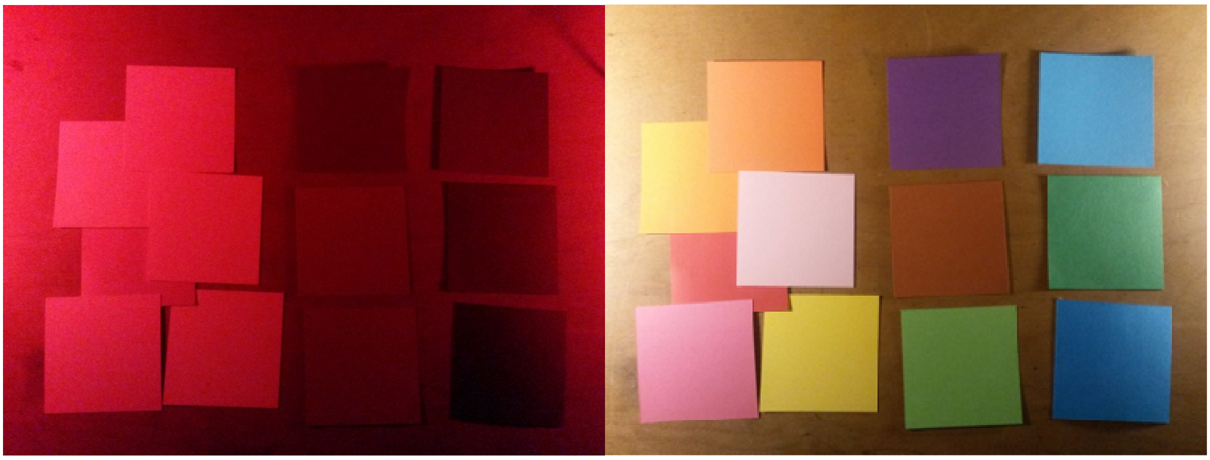

Figure 3: Division of the cardboards in three sets depending on the brightness of the cards in red light.

When the blue light is used, something strange occurs for the yellow and the green cardboards: they seem to glow, as if they were alight. It is possible to suggest the elimination of those cards for the blue light, but this should be done only after a discussion with students, as they should realize that there is something different from the previous cases.

Explain phase

Through the observations of the light used and the colour observed and catalogued, students should recognize that the set of the very bright cards contains white, very light colours such as pink and all the pastel colours, but also cards having a colour very similar to that of the light used to illuminate them. Instead, grouped into the set of dark cards are the dark colours, but also the cards of colours similar to the complementary colour of the light used.

At this point, the vision of a colour can be qualitatively described: an object is red when it can reflect a red light, therefore, if it is under a white light, it absorbs all the other components and will reflect the red component, but if it is under a green light, it absorbs the green light and cannot reflect any red light, and therefore it appears black. The mechanism seems quite simple and easy to be understood.

Now, when everything seems to work well, the teacher should suggest another experiment, especially if students have not yet understood that there is something more to sort out. What happens if a green laser is pointed on a red cardboard? On the basis of the previous explanation, one should answer that the green light should be absorbed and one should see nothing more than a nearly black card. But this, evidently, does not happen! In fact, a percentage of green light is anyway reflected by the red cardboard. Students can have a proof of the meaningfulness of this description, pointing a green laser alternatively, but very quickly, from a red card to a white card, and *vice versa*, a certain number of times. They will see the luminosity of the green dot of light changing a lot passing from the red to the white. Therefore the previous explanation should be modified by saying that an object appears red when it reflects most of red light and absorbs most of the other and so on.

The teacher then takes the blue laser and points it on a yellow card, or on a red card, green card, pink card, and so on: now the bright spot changes its colour, not its brightness! What is happening?

Extend phase

(1) Fluorescence

The phenomenon that appears so strange (the changing of the colour of the monochromatic light), is actually a changing of the colour of the object that is under the light. For instance a yellow cardboard “reflects” orange light when illuminated by a blue laser or by a blue LED. How can it be that light different from blue is reflected by a given cardboard? It is also very surprisingly to throw a blue laser through a bottle of tonic water, as you can see in Figure 4.

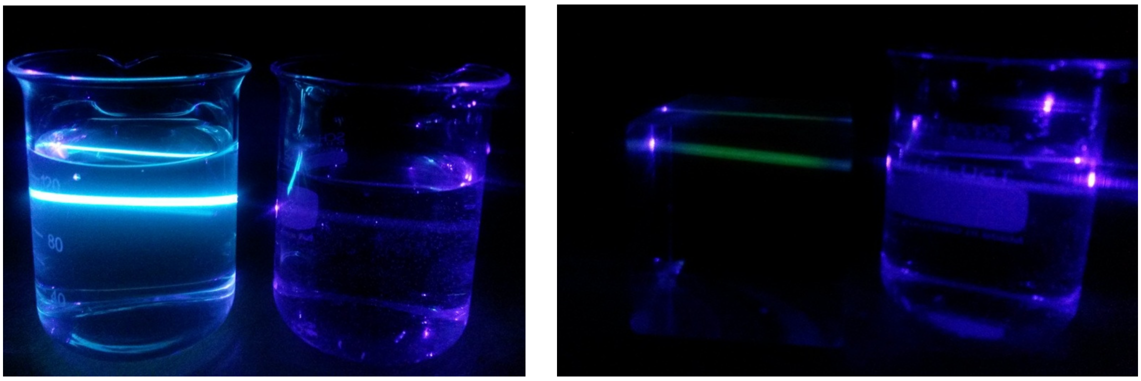

Figure 4: A blue laser light, thrown from the right, passes first through water and then through tonic water whose light blue fluorescence is clearly showed (left). A cube of Plexiglas fluoresces in green when a blue light passes through it.

What is marvellous in the fluorescence phenomenon is the brightness that is generated using a certain light: the object (the cardboard, or the liquid) seems to glow, and the light seems to be generated, and not only absorbed or diffused. A similar effect can be also obtained illuminating a piece of Plexiglas and of an enormous variety of materials with blue or UV lights.

(2) Subtractive synthesis

After having mixed coloured lights (and having therefore experienced the additive synthesis) and after having had fun exploring fluorescence, it is possible to explore what happens if the experiment of mixing colours is done using inks rather than lights. This set of experiments will give completely different results from the previous one, because coloured pigments illustrate the subtractive synthesis. In practice, this means that by mixing the brightest pigments (lemon yellow, cyan and magenta) we obtain a resultant colour that is always darker.

(3) Linking colours and wavelengths

With students who are studying optics we suggest a discussion about the lack of a one-to-one correspondence between wavelengths of light and colours. Moreover, in the same discussion it could be mentioned that not all the colours we can see are present in the spectrum of the white light, that is, in the visible portion of the electromagnetic spectrum, or in the rainbow. For instance brown, magenta, pink etc. are not spectral colours (Mould, 2013). This is a very important point that should be emphasized and deepened with students, depending on their age and motivation. A very helpful and fascinating activity can be the observation of spectral lamps through a diffraction grating.

Evaluation phase

The mystery proposed is qualitative, including the **Explanation** phase. Nevertheless the inquiry activities related to the presentation and the solution of this mystery can engage students in scientific questions, especially because they can be answered in subsequent steps, by going deeper and deeper in the problem. For this reason it becomes important to formulate explanations from evidence and the communication and the justification of the explanations to others. The evaluation phase should emphasize just these aspects of the inquiry process and, therefore, a possible way to evaluate students is through oral interviews, during which the teacher poses to a couple of students problems to be discussed, or eventually solved, both from a theoretical point of view, and from a practical point of view.

For example:
"Write on a white sheet with a blue pen, then illuminate what you have just written with red, green and blue lights. What do you expect to happen?";
or "Find a way in which a certain word, written in red on a white sheet, can disappear";
or "Can you write a message whose words give two different meanings when illuminated with lights of different colours?"
It could be also useful that students try to pose questions of this kind by themselves.

A final comment

In our experience, teachers often use the present mystery described here as a first trial to implement the TEMI way of teaching with their students. Their choice is probably due to the engaging power of the darkness, and of the coloured lights, together with the quantity of physics involved in the mystery, that however does not need mathematics.

We think that it could be useful, for the reader, to know that the teachers often found it difficult to grasp the link between the additive synthesis of lights and the subtractive synthesis of the inks (as it happens for example in a printer). The two phenomena are related to each other. The following two examples may clarify how to approach in a simple way the problem.

As it is standard, let us call R, G, B the colours Red, Green and Blue, while let us indicate with M, Y, C the colours Magenta, Yellow and Cyan. Why do I see that a certain object is, for instance, R under white light (that is, in our scheme R+G+B light)? It looks R because it emits R light, or equivalently, it absorbs B+G lights. Therefore we have that R, G, B objects (and inks, being particular cases of objects) are somewhat "dark" objects because they absorb two colours out of three (in this very simplified model). Applying the same way of reasoning, we can easily understand that an object is for instance C because it emits C light, that is B+G lights, and therefore it will absorb only R light. Thus it is that M, Y, C objects (and in particular inks) are somewhat "bright" objects, because they absorb only one coloured light. This is the reason why colour printers use M, Y, C inks.

In addition, let us find out what happens by mixing (ideally) two "dark" inks, for example R+B, to obtain Violet. Why does this trial not work properly? Using R, B+G lights are absorbed; and using B, R+G lights are absorbed. In total, the mixing implies that R+G+B lights are absorbed, and thus a very dark colour will be obtained, something like a black colour, that has little to do with a bright Violet. We leave to the reader to find out why the right procedure to obtain a bright Violet is to mix (ideally, at least) C+M inks instead of using B+R!

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References

Bybee, R., Taylor, J. A., Gardner, A., Van Scotter, P., Carlson, J., Westbrook, A., Landes, N. (2006). *The BSCS 5E Instructional Model: Origins and Effectiveness.* Colorado Springs, CO: BSCS.

Facciamo luce sulla materia (2004). Available at: https://www.youtube.com/watch?v=W5-zqAMnWUo

Lo Spettacolo della Fisica (2004).
Official site: http://spettacolo.fisica.unimi.it

Luce dalle stelle (2009). Available at: https://www.youtube.com/watch?v=9IZCXr_lPdo

Mould S. (2013). Available at: https://www.youtube.com/watch?v=iPPYGJjKVco

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The Irish TEMI experience

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Abstract

The experience of the Irish TEMI team based at the University Limerick in implementing the TEMI programme is described in this article. The main intended beneficiaries of TEMI are in-service science teachers (ISSTs) but the UL team also actively involved pre-service science teachers (PSSTs) in the project, both as part of the professional learning community with the ISSTs and in working with the UL project team. Each ISSTs attended two 6 hour workshops at the University of Limerick, separated by 8-10 weeks. Between workshops, ISSTs were required to spend at least 7 hours implementing the TEMI approach in their schools. In addition, ISSTs were asked to keep in touch though a Google forum and to use the Google+ drive to share lesson ideas with each other. The 11 PSSTs who took part in TEMI over 3 years were involved in developing, trialling and evaluating TEMI lessons during their fourth (final) year school placement, and their work was written up in a Final Year Project (FYP) thesis. In addition the PSSTs shared their experience and materials with the ISSTs both at the workshops and online. The UL TEMI team also disseminated the TEMI concept in Ireland through conference presentations, conference workshops, articles and through short TEMI taster workshops. While evaluation is ongoing, written reflections by both ISSTs and PSSTs were positive regarding the TEMI innovations. Teachers were particularly positive towards the use of mysteries to engage students, and the opportunity to develop and use inquiry in their teaching.

Introduction

The paper outlines the approaches taken by the TEMI team to involve both pre-service science teachers (PSSTs) and in-service science teachers (ISSTs) in the TEMI project at the University of Limerick (UL) in the Republic of Ireland. An earlier paper introduced the TEMI project in Ireland. (Broggy *et al.,* 2015) The TEMI project ran from 2013 to 2016, and was based on four innovations (see p. 8). These are: the use of mysteries to engage students; the use of the 5E model to structure inquiry; the use of showmanship to enhance engagement; the use of the Gradual Release of Responsibility (GRR) model to embed inquiry in the science curriculum.

First the UL TEMI team is briefly introduced. This is followed by an outline of the differing ways in which the UL team implemented TEMI within the Republic of Ireland. This includes work with ISSTs, PSSTs, the use of professional learning communities and additional workshops at conferences. The issue of impact, sustainability and dissemination of the project are briefly explored. Some examples of TEMI lessons are also provided. Previously published articles (McManus *et al.*, 2015; Broggy *et al.,* 2016), by the UL TEMI team, describes the TEMI project in more detail, and in particular the involvement of PSSTs.

The UL TEMI Team

The UL TEMI team, outlined in Table 1, were well positioned to engage with the TEMI project and the concepts underpinning it. Team members came from both a science and initial teacher education background. Some members of the team were previously involved in the SALiS Tempus Project (www.salislab.org), which proved a valuable resource when developing TEMI materials (Childs & Hayes, 2012). In addition, members of the team have run annual Chemistry Demonstration Workshops for teachers since 2006, which again fed ideas into the TEMI project.

The initial TEMI team (column one) ran the project in Ireland from the start of 2013 to August 2015. In September 2015 two new members were recruited to replace three members who left to take up teaching positions in different institutions.

Table 1 The Irish TEMI team (2013-2016)

From January 2013 – August 2015	From September 2015 – July 2016
Peter Childs (coordinator)	Peter Childs (coordinator)
Orla McCormack	Orla McCormack
Anne O'Dwyer	Sarah Hayes
Joanne Broggy	Laurie Ryan
Beulah McManus	

Implementation of TEMI in Ireland

a) Recruitment of teachers and PSSTs

One challenge in running a project like TEMI is the recruitment of enough teachers, who will be able to commit time and energy to attending the two workshops and implementing TEMI in their schools. Schools and teachers were recruited in several ways: through promotional articles in Irish science teacher magazines; through personal contacts with team members; by running taster workshops and during school placement visits. We were looking for enthusiastic and committed science teachers, whose schools were also supportive of the TEMI innovation. When interest was expressed, the school principal was sent an information sheet and a letter of commitment, whereby the school agreed to take part and nominate two teachers to attend workshops. Generally this worked well but in some cases schools made an initial commitment, which was not followed through. Some schools could only find one teacher willing to take part and a few teachers attended one, but not both workshops. When teachers had attended both workshops and completed their in-school assignments, they were awarded a certificate of attendance, as evidence of their involvement in CPD.

The PSSTs were recruited by advertising the project and looking for volunteers from the science education cohorts over the course of three years. The students who volunteered to get involved were interviewed and the selected students met with the project team to outline their brief. Each PSST then worked closely with one of the project team over the course of their FYRP for a period of about 9 months to conduct research on TEMI.

b) In-Service Science Teachers (ISSTs)

Six cohorts of teachers have been involved in the TEMI workshops, involving 53 teachers from 30 different schools spread around Ireland. The first workshop ran in January 2014 and the last in March 2016. Each cohort attended two one-day workshops, each lasting 6 hours, separated by 8-10 weeks. The aim was to have at least 2 teachers from each school involved in the project; these two teachers were usually enrolled in subsequent cohorts. The idea was to embed the TEMI approach in the school by having more than one teacher aware of and involved in TEMI. In a few cases only one teacher was involved and in a few cases both teachers came to the same cohort. A small number of schools sent three teachers. In addition four of the cohorts also included input from the PSSTs involved in the project, as outlined in point c) below.

Figure 1: ISSTs and PSSTs working together at a workshop 1

The first of the two workshops aimed to introduce teachers to the TEMI approach through the use of mysteries; comparing traditional approaches and the TEMI approach to teaching science; the idea of turning the lesson around (see article on p.62) in this issue; an introduction to the 5E model of inquiry and an opportunity to work in groups to develop their own TEMI ideas using the 5E model of Inquiry. Teachers were also introduced to a Community of Practice and given access to a Google+ forum and access to TEMI resources. In the first workshop we asked either one or more of the PSSTs to talk about their own experiences in developing and trialling materials or we asked back a teacher from a previous cohort to share their experience. This approach proved very beneficial as the novice TEMI teachers were able to hear from someone who had already tried out the ideas in the classroom. (See Figure 2) In the first workshops from cohort 4 onwards we found it beneficial to have a discussion with the teachers right at the start, on their prior experience of inquiry.

Figure 2: One of the teachers from a previous cohort sharing her experience of TEMI in a workshop 1

Between the two workshops the teachers were asked to do a number of tasks:

- Try out at least five TEMI ideas from the bank produced on the TEMI website (in order to give them the experience of starting lessons in a different way).
- Develop and try out at least two ideas of their own (to develop their own expertise and to embed the TEMI methodology in their own teaching).
- Complete a teacher diary describing their experience of using the TEMI approach.
- Share their ideas and ask questions on the Google+ forum.
- Get feedback from their own students using a questionnaire on the TEMI approach.

Figure 3: A teacher showing her TEMI idea to other teachers at a workshop 2

The main focus in the second workshop was to get each teacher to share a TEMI mystery they had developed and to share their experience on teaching the TEMI way. 'Showmanship', one of the four innovations underpinning the TEMI project, was also introduced to teachers in an interactive and engaging manner by a professional communicator. Finally the teachers were introduced to the GRR model as a model for transferring ownership of inquiry from the teacher to their students. At this stage, teachers returned their completed student questionnaires and teacher diaries. We found the most valuable part of the workshops was when the teachers shared their own prior experience of inquiry (in the first workshop) and shared the mysteries they had developed and trialled with their class groups (in the second workshop) and the effect of participating in the project on their view of and practice of inquiry.

c) Pre-Service Science Teachers (PSSTs)

While ISSTs were the main focus of TEMI, the UL TEMI team also involved fourth year PSSTs in the project. The involvement of trainee science teachers was a unique feature of the Irish TEMI project. The Final Year Research Project (FYRP), completed by all undergraduate pre-service teachers in their fourth and final year, was used as a vehicle to engage the PSSTs to research and develop ideas for TEMI lessons, trial them in schools on their school placement, evaluate their effectiveness, write up their findings and reflect on their own experiences of TEMI. The resources developed by the first set of four FYP students (in 2013) were used with the first cohort of ISSTs (2014). In total, 11 PSSTs were involved over 3 years. Table 2 shows the area and number of resources they developed for Chemistry, Biology and Physics for both the lower secondary and upper secondary cycles, for Agricultural Science in the senior cycle, and for the Transition Year.

Table 2 Materials developed by the PSSTs*

Group 1 (2013-2014) 4 students (no of lessons)	**Group 2 (2014-2015) 5 students (no of lessons)**	**Group 3 (2015-2016) 2 students (no of lessons)**
JC Chemistry (5)	LC Chemistry (5)	Showmanship (5)
JC Biology (5)	LC Biology (5)	Agricultural Science (5)
JC Physics (5)	LC Physics (5)	
TY Science (8)	TY Science (8)	
	TY Science (8)	

*JC = Junior Certificate Science (lower secondary level); LC = Leaving Certificate Science (upper secondary level); TY – Transition Year, an optional year between the junior and senior cycles.

Each student was given the brief to develop 5 TEMI lessons in their subject area; the students developing TY modules were asked to develop an 8-week teaching modules, with each of the 8 units starting with a TEMI mystery (for more detail see below). Taken together the PSSTs developed 64 TEMI lessons.

Our work with PSSTs as part of their Final Year Research Projects has been described in detail elsewhere (Broggy *et al.,* 2016; McManus *et al*., 2015) As part of this work three of the PSSTs developed 8-week modules for the Irish Transition Year (TY), each consisting of 8 mysteries used to introduce a week's work. The Transition Year is an optional year between junior and senior cycle, without a set curriculum and no external examination. Schools do not have to offer the Transition Year and within schools that do take it, it is not always compulsory. When TY is offered it means that teachers are much freer to innovate and to try out new teaching approaches during this year. The TEMI modules provide an off-the-shelf resource for science teachers to use and introduce the TEMI approach. The Transition Year is an ideal opportunity to develop inquiry skills using a TEMI approach, even though it perhaps comes too late in the secondary students' experience. Table 3 shows a list of the modules developed for one of these modules (developed by Laurie Ryan) and Figure 1 shows the covers of the Student's Handbook and Teacher's Handbook produced for this module. Figure 2 shows the layout of the worksheets in the module.

The other PSSTs developed TEMI lessons in Physics, Chemistry, Biology for both the junior science and senior science courses as well as Agricultural Science at senior cycle. Another student looked specifically at the use of showmanship to introduce inquiry.

Table 3: List of TEMI topics in the Homemade Heroes TY module (Author: Laurie Ryan)

Topic Title (scientific topic covered)
1 What floats your boat? (Density)
2 Bubble trouble (Surface Tension)
3 Move your body (Centre of Gravity)
4 Food for thought (Enzyme denaturation)
5 The disappearing act. (Absorbent Polymers)
6 Now you see it! Now you don't! (Acids, bases and Indicators – hidden messages)
7 Ice, Ice baby (Depression of fpt. of Ice)
8 What's going on? (Alcohol Fermentation)

This bank of resources (Table 2), shared on the internet forum, provided an invaluable source of lessons for the TEMI teachers to try out. The first group of four PSSTs was involved before the first workshop for ISSTs and this meant that we were able to provide teachers with sample TEMI ideas from the start of the project. The bank of TEMI lessons has been added to throughout the project, by both the ISSTs and PSSTs.

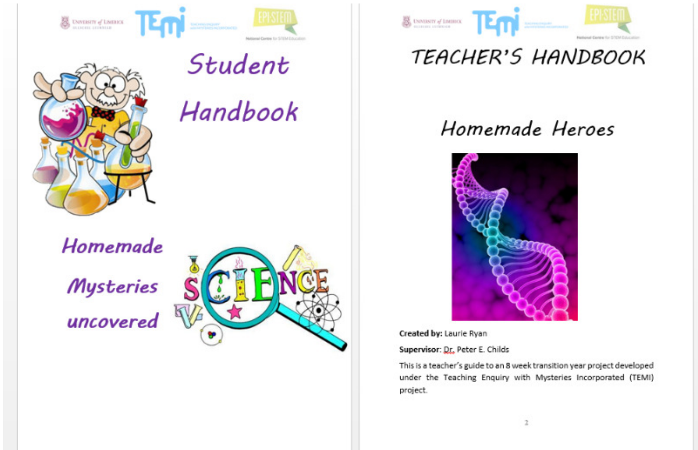

Figure 1: The Homemade Heroes books: Student Handbook (L) and Teacher's Handbook (R)

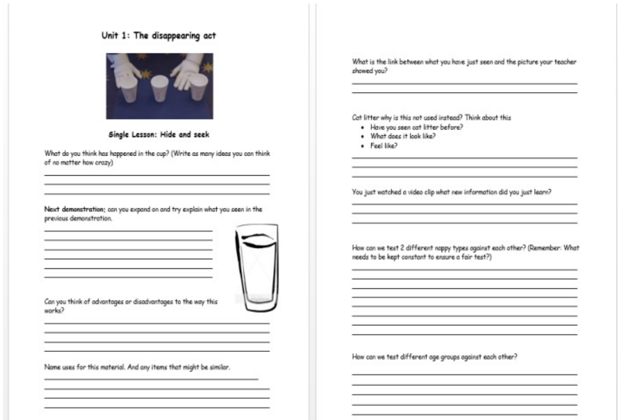

Figure 2: Example of student hand-out, lesson 1–The disappearing act.

d) The Professional Learning Community (PLC)

The UL team attempted to create an active professional learning community (PLC) in a number of ways. Firstly, PSST and ISSTs worked together during four of the workshops. PSSTs shared their experiences of sourcing ideas, developing, trialling and evaluating TEMI lessons with the ISSTs. Each PSST worked individually with ISSTs to facilitate their initial development of

TEMI lesson ideas, as they had had prior experience of sourcing TEMI ideas, which the ISSTs had not. The PSSTs' experience also meant that they could share their insights into the challenges of implementing the ideas into Irish schools and classrooms.

Secondly, the online forum, Google+™, was also utilised to support the development of a virtual PLC. All participants, both ISSTs and PSSTs, signed up to a shared TEMI Folder in Google Drive™. Participants also joined the private TEMI Google Community™. The TEMI Google Drive™ folder contained all of the TEMI resources that were developed and trialled by the PSSTs and later by the ISSTs. The forum was used as a way of supporting teachers in between the two workshop days, as well as providing them with a variety of additional resources and ideas and a space in which they could engage in online discussion forums related to TEMI. From time to time the UL TEMI team would also post articles, books and links to useful materials. The teachers used the online facility to post and share ideas and draw on other teacher's ideas.

e) Other workshops

In addition to running the official TEMI workshops, the UL TEMI team has taken every opportunity available to run additional, TEMI taster workshops with different groups. In total an additional 127 teachers and 40 pre-service teachers have been reached so far through these workshops. TEMI workshops were run at the Irish Science Teachers Association (ISTA) Conferences in 2014, 2015 and 2016 and at an AMGEN workshop (2014). (AMGEN is an international biotech company, with plants in Ireland, who run an international STEM Education initiative. The TEMI workshops were run as part of this project.) A TEMI workshop for primary teachers is planned in 2016, although this is outside the formal brief for the project.

These workshops usually lasted 1-2 hours and aimed to give participating teachers an insight into the philosophy and methodology of TEMI. This included facilitating interactive TEMI lessons and also providing an opportunity for teachers to work in small groups to develop a lesson using the TEMI approach. The teachers were given resources to take away, with sample TEMI lessons, to encourage them to try these out in school. The taster workshops were also used as a recruitment strategy for the project.

Evaluation of impact

While initial feedback on the project (via teacher feedback) is positive, the evaluation of the impact of TEMI in Irish schools is ongoing. We intend to do this in four ways:

a) Through a follow-up questionnaire with TEMI teachers after the completion of the second workshop;

b) A teacher's diary completed while trialling TEMI lessons between workshops;

c) A questionnaire given by teachers to their own students after experiencing TEMI lessons;

d) Feedback from teachers after the end of the project to see whether involvement in TEMI has changed teachers' practices and encouraged them to do more inquiry.

Sustainability and Dissemination

As we approach the end of the project, it raises some crucial questions. How can we ensure that the TEMI approach and TEMI materials continue to be used in Irish schools beyond the completion of the project (July 2016)? How can we encourage additional schools, outside of those already involved, to begin adopting TEMI ideas?

We intend to support both of the above in a number of ways. Before the end of the project we plan to hold a national TEMI Conference (June 2016). While all previous participants will be invited, other science teachers from our TEMI schools will be invited to the conference. We will also invite a number of Irish stakeholders (see Table 4) and science teachers from non-TEMI schools in the vicinity of the University of Limerick. Researchers who have been involved in other EU-funded IBSE projects in Ireland will also be involved.

Table 4: Relevant Irish Stakeholders for the national conference in June 2016

Irish researchers on EU projects (PROFILES, ESTABLISH, SAILS, Fibonacci, SALiS)
National Council for Curriculum and Assessment (NCCA)
Professional Development for Secondary Teachers (PDST)
School science inspectorate
Science education teacher trainers in Irish universities
Pharmachemical Ireland (Education officer)
Irish Science Teachers Association (ISTA)

The main aim of the conference will be to showcase what TEMI teachers have done (though a science fair), to allow them to share their ideas with the other teachers, and to introduce other teachers and stakeholders to the TEMI innovations. We feel it is important to bring together as many of the TEMI teachers from the 6 cohorts, in order for them to meet each other and to share their experiences and ideas. This interaction between teachers has been one of the most positive parts of the workshops and we would like to build on this in the final conference. Access to TEMI materials developed in Ireland will be opened up to all interested teachers from July 2016 on a dedicated TEMI website. We also intend to regularly publish TEMI teaching ideas in *Chemistry in Action!* and *SCIENCE* magazines, which reach many Irish science teachers. We will continue to offer TEMI taster workshops e.g. a workshop with primary teachers will be run in April 2016 and a workshop will take place at the ISTA Annual Conference in Limerick in April 2016. It is also planned to offer regular TEMI workshops to the final year PSSTs at the University of Limerick, so they can take the idea into schools on their final school placement and when they graduate.

Conclusion

During the project the UL TEMI team have reached 53 ISSTs in 30 schools and 11 PSSTs and provided TEMI taster workshops to over 170 ISSTs and PSSTs. Our hope is that these teachers will become TEMI ambassadors and will share their own experience and successful practice with other science teachers in their schools and other forums.

One of the challenges in running the project has been the relative lack of inquiry in Irish science education, as evidenced by discussion with the different cohorts. Irish science teachers are not familiar with the 5E model. Many showed some understanding of inquiry but the level of implementation into classroom practice varied, in both the junior or senior secondary cycles. Reasons given for this include: lack of familiarity with inquiry and lack of exposure to inquiry in their own education or in their teacher education courses; the time demands of the curriculum; the focus on preparing for state examinations (at the end of both the junior and senior secondary cycles); lack of resources for extensive practical work. This is an area that demands more research.

The UL TEMI team has valued the experience of working on the TEMI project – with the TEMI partners, with our TEMI teachers and schools, and with our PSSTs. The idea of using mysteries to motivate and engage students in their science lessons has proved to be a fruitful and stimulating one for the team, for the ISSTs and the PSSTs involved in the project. We hope that the teachers will continue to use the TEMI approach in some of their science lessons and will share their experience with other teachers, so that the TEMI pedagogical virus infects other teachers and schools. In Ireland the project has resulted in a large bank of ideas (over 100), developed by TEMI teachers and by the PSSTs as part of their FYRPs, and it is intended that these resources will be made widely available within Ireland.

Acknowledgments

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References

Broggy, J., Childs, P.E., McCorrnack, O., Mcmanus, B. & O’Dwyer, A. (2015) TEMI: Teaching Inquiry with Mysteries Incorporated, *Chemistry in Action!,* #105, Summer. 8-12

Broggy, J., Childs, P. E., Hayes, S. , McCormack, O., McManus B., O’Dwyer, A., Ryan, L. (2016) Engaging pre-service science teachers in TEMI. In J. Lavonen, K. Juuti, J. Lampiseelka, A. Uitto & K. Hahl (Eds.), *Science Education Research: Engaging Learners for a sustainable future*. E-Proceedings, ESERA 2015.

Childs, P.E. and Hayes, S. (2012). Using Science Demonstrations to Develop Thinking and Inquiry Skills. Chemistry in Action! #97 Summer 28-32 [On-line] http://134.102.186.148/chemiedidaktik/salis_zusatz/material_pdf/special_issue_on_chemistry_in_action.pdf Accessed 14/1/16

McManus, B., O’Dwyer, A., Childs, P.E., Broggy, J. & McCormack, O. (2015). Teaching Inquiry with mysteries incorporated: the benefits of involving pre-service teachers. LUMAT 3(4) 512-528 [On-line] file:///C:/Users/User/Downloads/LUMAT_2015_3_4_512-528-GEN-McManus%20(2).pdf Accessed 14/1/16

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On the following pages one of the UL TEMI ideas, on ‘The blue bottle’, is presented.

The amazing blue bottle

An amazing bottle changes colour when you shake it and then returns to colourless on standing. More shaking turns it blue again. How does it work? Is it magic or science?

Engage

A stoppered bottle or flask half-full of colourless liquid is shaken. It turns blue. After a while the blue colour slowly disappears. Students are asked to observe and record what they see.

Explore

Students are encouraged to formulate some possible explanations. Some possible questions include:

Why does it turn blue? When does the colour last longest? If it is shaken again for longer, the blue colour is stronger and takes longer to disappear. Is it a chemical or a physical change? Why is the blue colour disappear on standing? How could you test out your ideas? What happens if some tap water is added to the bottle? What happens if the bottle is filled to the top with water and then shaken when it is colourless? What sort of process (chemical or physical) is going on? If chemical, how many reactions are there? If we change the air in the flask for another gas, will it still work? E.g. flush the bottle out with carbon dioxide or natural gas.

Explain

What is the simplest explanation for your observations? For the need for shaking? For the effect of adding tap water? For the fact that the blue colour slowly disappears on standing?

The bottle contains a solution of glucose and sodium hydroxide, with a few drops of methylene blue indicator. An alkaline solution of **glucose** is a **reducing agent** and reduces methylene blue from a blue to its colourless form.

• *Shaking the solution causes oxygen to dissolve from the air and this* ***oxidises*** *the methylene blue back to blue.*

• *When the dissolved oxygen has been used up, the methylene blue is slowly reduced back to its colourless form by the remaining glucose.*

• *The cycle can be repeated many times by further shaking.*

• *When tap water is added the bottle turns blue due to dissolved oxygen in the water.*

• *If filled to the top with water, and left to go colourless it does not turn blue on shaking because there is no air (oxygen) left to dissolve and react.*

Extend
Connects to redox chemistry, chemical kinetics (rate it turns blue and decolorizes), dissolved oxygen in water. You can set up a similar red bottle using indigo carmine as the indicator. Does this work in a similar way?
What would happen if we bubbled air or another gas into the solution?

Evaluate
Richness of the student discussion and possible answers they come up with. Recognition that the production of the blue colour and its disappearance indicates a reversible chemical reaction. The amount of reaction is linked to the amount of shaking. Thus shaking must increase one of the reactants. Design of and trying out suitable simple experiments to test their hypotheses. Plausible explanation even if they do not know the chemicals involved. Awareness that air or one of its constituents (probably oxygen) must be involved.
e.g. $A + B \rightarrow C$ (blue) $C + D \rightarrow A$ (colourless)

Comments for the teacher

This activity can be set up very quickly (in ~ 5 minutes) and will last long enough for a single or double period.

- ~5g each of NaOH and glucose should be weighed out. (The amounts are not critical. The greater the amounts used up to 15 g, the longer the process will continue to function.)
- A 500 mL flask should be half filled with water and the NaOH added.
- Shake to dissolve.
- When the NaOH is dissolved add the glucose, and shake to dissolve.
- Add a drop or two of methylene blue solution (in alcohol) or 1-2 small crystals (not as good) to give a blue colour (do not add too much).
- Stopper the bottle and allow the blue colour to disappear. The blue bottle is now primed for use.
- You can set this up as a student investigation by giving each student/group a stoppered boiling tube or small conical flask, half full of the mixture.
- **Safety glasses must be worn if students handle the chemicals themselves.**
- At the end the solution can be diluted with plenty of water and disposed of down the sink.

Background information

http://www.rsc.org/learn-chemistry/resource/res00000729/the-blue-bottle-experiment
http://www.nuffieldfoundation.org/practical-chemistry/blue-bottle-experiment
Campbell, J. A., 1963. Kinetics - Early and often. *J. Chem. Educ.* **1963,** *40,* 578.
Engerer, S.C. and, A.G., 1999. The Blue Bottle Reaction as a General Chemistry Experiment on Reaction Mechanisms *J. Chem. Educ.*, 1999, *76* (11), p 1519
Vandaveer IV, W.R., and Mosher, M., 1997. The blue bottle revisited *J. Chem. Educ.*, *74* (4), p 402

The TEMI project in Norway

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Abstract

The TEMI-team in Norway consisted of science teacher educators at The University College of Southeast Norway (USN) in addition to external experts on 5E, inquiry-based science education (IBSE) and showmanship. One hundred teachers have participated at the six cohorts, which all consisted of two full days of training workshops. In addition, 50 teachers have taken part of various dissemination seminars. With a few exceptions, the teachers teach grades 8-10 (lower secondary in the Norwegian educational program). Since the university college serves the southeast of Norway, we recruited from this region only, using a top-down strategy, ensuring commitment from local school authorities. A science conference with over 300 participants held on April 6th 2016 marked the end of TEMI. The conference was also a part of a national program to increase quality of science and mathematics education.

Generally, teachers appreciated the opportunity for sharing and discussing teaching materials, the hands-on approach, found showmanship inspiring and valued 5E as a tool for lesson planning. Although inquiry is an important part of the national curriculum, our experience and data indicate that teachers are most accustomed to work on a low level of inquiry. Although this was expected, it verifies the need for teacher training with continuous focus on inquiry.

Organisation of the project

The Norwegian TEMI team and recruitment strategy

The University College of Southeast Norway (USN) is the country's second largest state-owned university college, with approximately 17,000 students, a staff of 1,500 and eight campuses in the southeast of Norway. Teacher education comprises an important part of the educational program.

At the start of the project, the Norwegian TEMI-team consisted of two science teacher educators. Later, one new member was added but the team was stable for the remainder of the project. In addition, external experts on 5E, inquiry-based science education and showmanship made invaluable contributions throughout the project. A stable team has been an important factor for the project, facilitating continuity. For example, one specific recruitment strategy was used throughout the project. The goal for the recruitment was to:

- Ensure that school management was committed to TEMI throughout the project.
- Use TEMI as an opportunity to build and sustain regional networks of science teachers, and thereby accelerate dissemination of the project.
- Make sure that at least two science teachers from each school attended training in order to support dissemination and implementation locally.

In order to achieve these goals, we opted for a top-down approach where teachers were recruited via the school management in each municipality, which again made the necessary arrangements with each school headmaster. Although some exceptions were made (for example in the case of very small municipalities), this strategy successfully recruited teachers for all six cohorts. Our primary targets were teachers teaching grades 8-10. In total, 100 teachers have participated at the workshops. These teachers work in 12 different municipalities. Norwegian municipalities are small, so the majority of lower secondary schools in each municipality were represented.

The TEMI training

The framework of the workshops remained, with a few minor exceptions, unchanged throughout the project. All teachers received two full days of training. More workshops with fewer hours could potentially have made a larger impact, but such an organisation would be more disruptive for the teachers' day-to-day work, and therefore recruitment could also be more difficult. However, in order to maximise each teachers' time spent on TEMI, all teachers read two short articles from a magazine for science teachers, *Naturfag*, before the first workshop. The articles summarise the 5E model and give examples of implementation (Fiskum and Korsager, 2013, Skår and Vidnes, 2013).

Inquiry-based science education and formative assessment are important parts of the science curriculum in Norway, and as these topics are found the 5E model, 5E was chosen as a starting point and core theme for the training. Notably, a version of the 5E model with evaluation at the centre was used (Fiskum and Korsager, 2013).

The 5E model was the focus of training day 1 (Figure 1), with Kirsten Fiskum and Majken Korsager leading the workshop. Kirsten Fiskum is currently assistant professor at the Norwegian Centre for Science Education (http://www.naturfagsenteret.no/), has a master's degree in chemistry and a postgraduate degree in education and diverse teaching background. At the beginning of the project, she worked as senior advisor at The Norwegian Directorate for Education and Training. The Directorate also contributed with one or two additional senior advisors for the first two cohorts.

Figure 1: Teachers exploring a mystery (cohort 2, workshop 1)

Majken Korsager is currently an associate professor at the Norwegian Centre for Science Education, with focus on education for sustainable development, inquiry based science teaching and ICT in science education. She has a varied teaching background.

Between workshop 1 and 2, the teachers built upon the work done at the first workshop and designed and tested a 5E-lesson in their own science classes. Their lesson plans and experiences were subject to discussion on the first half of workshop 2.

The second half of workshop 2 was dedicated to the remaining TEMI innovations - showmanship and gradual release of responsibility (GRR). For the two first cohorts, communication expert Marte Amalie Johnsrud Kaardahl, led the part on showmanship. From cohort 3 and for the remainder of the project, magician and medicine student Kristine Hjulstad was our external expert on showmanship. With her experience and background in the field of magic, the teachers were given several examples and techniques of how to catch students' interest and to keep them motivated through a learning cycle.

It is common knowledge that changing teaching methods is difficult. Therefore, it was important to consider dissemination and sustainability at several stages during the project. To maximise dissemination, the first two municipalities received one extra workshop. At this workshop, all science teachers teaching grades 8-10 in a given municipality were invited, in addition to previous participants. The former teachers were introduced to the TEMI methodology, while the latter group worked more deeply on showmanship and engagement. Due to time limitations, the last four cohorts did not receive extra workshops.

To mark the finish line of the TEMI-project and spread the TEMI ideas further, USN arranged a science conference April 6 2016 with above 300 participants. All of the TEMI-teachers were invited, as well as their colleagues, students and faculty. The conference aimed to disseminate the ideas from TEMI, particularly inquiry and showmanship.

As an additional step in dissemination, students at USN teacher training and teachers enrolled in CPD programs have also been introduced to the TEMI methodology through practical sessions and workshops.

Relevance to science education

As in other countries, an important aim for policymakers is to implement inquiry-based science education. The national curriculum is divided in several main subject areas, one being *The Budding Researcher*, which is basically about inquiry (Directorate for Education and Training, 2006):

> *Teaching in natural science presents natural science as both a product that shows the knowledge we have acquired thus far in history and as processes that deal with how knowledge of natural science is developed and established. These processes involve the formulation of hypotheses, experimentation, systematic observations, discussions, critical assessment, argumentation, grounds for conclusion and presentation. The budding researcher shall uphold these dimensions while learning in the subject and integrate them into the other main subject areas.*

Science is a mandatory subject for all students from grade 1 through 11 (i.e., compulsory school and first year of upper secondary). Science is one, integrated subject in these years, and is only split up to the single scientific disciplines (chemistry, physics, etc.) in grades 12-13 (i.e., last two years of upper secondary school). Since all the scientific disciplines must be covered in these lessons, the subject is very "crowded". A normal workload for a teacher at lower secondary school is approximately 23 lessons weekly. Reporting, correcting student hand-ins, and other duties come on top of this.

Through the program *Promotion of the status and quality of teachers (Ministry of Education and Research, 2015)* the government has implemented several initiatives to increase the level of science education, for example has one extra science lesson weekly in grade 5, 6 or 7 been added. The project *Realfagskommuner* (The Norwegian Directorate for Education and Training, 2015) is a key part of the ministry's program. Funds are granted to municipalities with coherent efforts to improve mathematics and science education from kindergarten to upper secondary school (grade 10). Networks are important parts of the project, and while the municipalities initiate and sustain networks, universities and university colleges assist the municipalities. Two municipalities taking part in *Realfagskommuner* have also participated in TEMI, and USN assists these municipalities. In addition, there is a significant of focus on formative assessment, for example the project *Vurdering for læring* (The Norwegian Directorate for Education and Training, 2014). In the version of the 5E model used by Fiskum & Korsager (2013), evaluation is placed in the center of the model, emphasizing formative assessment. Overall, the TEMI project aligns well with current trends in Norwegian science education.

Response of teachers

The internal evaluation and our impressions from talking to the teachers revealed a general positive attitude towards the TEMI innovations, although some aspects of the training were more easily adopted than others. One statement from an experienced teacher summed up a general idea: *"This is the first time science teachers from our municipality are together in the same room discussing science"*. In our view, one of the most successful part of the training was to provide teachers with time to reflect upon and refine teaching methods. As mentioned above, the teachers used their time on the workshops to prepare for coming lessons. This way of organising the training, closed the gap between the more or less theoretical innovations and concrete application in the classroom. Other important responses, which will be taken into account in the further dissemination of TEMI, are outlined below:

- Several teachers reported back that 5E is ambitious, and it may be too much to apply all the E's for a given subject or lesson. This is understandable, however, it is our belief that many teachers think of inquiry as equal to lab work, and in order to have done proper inquiry, the class must do real lab work. If inquiry is defined to include activities such as discussions and other activities, 5E can more easily be implemented. In addition, a 5E teaching sequence may span several lessons, not just one 45-minute lesson.
- During the presentations, we also noticed the elaborate stage often receives too little attention. As mentioned above, the 5E model is perceived by some teachers as too ambitious, and disregarding the elaborate phase is taken as a way to stay within the time constraints. On the other hand, students often think that science is fragmented, and applying a carefully thought-out elaborate phase, may be an important step towards integrating the subject.
- Teachers are accustomed to explain first and explore later. However, if the mystery is explained before the inquiry, the motivation for doing inquiry may fall dramatically.
- The participants took part of a survey that charted their opinions on inquiry. Findings will be published elsewhere, but preliminary findings indicate that the main subject area *The Budding Researcher* is not integrated into the other main subject areas. In addition, teachers may prefer traditional lectures instead of higher-level inquiry for difficult scientific content. These two points may prove to be important barriers for spreading inquiry.
- Although teachers enjoyed and found the training on showmanship inspiring, internal evaluation indicated that some teachers found this part of the project the least applicable. This is expected: while the training on the 5E model was hands-on, showmanship was to a larger degree observed, showing some examples and explaining ideas, but with less practical and training on showmanship skills.

The idea of cognitive conflict is a new idea for some teachers. Similarly, some teachers reported back that they wanted more practical and concrete examples, that is, not general theories. Practical training over longer periods is probably necessary in order to integrate the general idea behind productive mysteries into the classroom.

Future plans

As mentioned above, USN is part of the project *Realfagskommuner*. We hope to integrate our experiences from TEMI into this project, especially providing teachers with opportunities to practice on higher levels of inquiry and continue to develop teaching materials with good examples of cognitive conflict. We will continue to implement the TEMI-innovations for pre-service science teachers and in CPD-courses. Depending on funds and other factors, the science conference may serve as a forum for the TEMI legacy.

References

Ditecortae for Education and Training, (2006). *Læreplanverket for Kunnskapsløftet,* [Oslo].

Fiskum, K. & Korsager, M. (2013) 5E-modellen i utforskende undervisning. *Naturfag*, 34-35.

Ministry of Education and Research. (2015) *Promotion of the status and quality of teachers* [Online]. Available: https://www.regjeringen.no/en/topics/education/innsikt/larerloftet/id2008159/.

Skår, A.R. & Vidnes, B. (2013) Naturfagdagar om vatn. *Naturfag*, 36-47.

The Norwegian Directorate for Education and Training. (2014) *Nasjonal satsing på vurdering for læring* [Online]. Available: http://www.udir.no/Vurdering-for-laring/Nasjonal-satsing1/Nasjonal-satsing-pa-Vurdering-for-laring/ [Accessed 15.03 2016].

The Norwegian Directorate for Education and Training. (2015) *Realfagskommuner. Realfagskommunene har som mål å forbedre barn og unges kompetanse i realfag* [Online]. Available: http://www.udir.no/Lareplaner/Forsok-og-pagaende-arbeid/realfagskommuner/ [Accessed 15.03 2016].

An example of a TEMI lesson developed in Norway, 'Sweet Blood', is given below.

Sweet blood?

Introduction:
A TV-commercial a few years back stated that "empty stomach equals empty head". Is this true? If so, how what happens in your body?

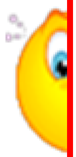
In the following lesson, we will explore our blood glucose level, and experiment on how it reacts to the type of carbohydrates we eat.

May blood glucose level be an explanation to the statement from the TV-commercial? Let's try and find out!

Learning goal:

- Explain what blood glucose is, and why it is affected by what we eat.
- Formulate a hypothesis about blood glucose level and food intake.
- Design an experiment to test the hypothesis
- Compare, discuss and present the results from the experiment.

Task 1: Let us watch the movie about biological molecules (https://www.youtube.com/watch?v=H8WJ2KENIK0). After the movie, summarize the most important facts together with your learning partner.



Engage

Explore

Task 1: Work in groups of four students. Your mission is to design and test an experiment in which you explore how the blood glucose level is affected by different types of carbohydrates.

Materials: Blood glucose meters, test strips, disposable blood lancets, desinfectant, food sources with different types of carbohydrates (chocolate, candy, coke, salad, whole-wheat bread, etc.)

Procedure:

1. Supervision and careful instruction is required due to work with needles and blood. Lancets and strips must be disposed safely.
2. Formulate a hypothesis (something you think will happen), and design an experiment on how you think the blood glucose level will be affected when we eat slow and fast carbohydrates. Choose three test subjects. One person will eat fast carbohydrates, the other will eat slow carbohydrates, while the last person will not eat anything.

3. Fill in the table below with your results. Are there any errors in the measurements?

Time of blood glucose measurement	Blood glucose level testperson 0	Blood glucose level testperson 1	Blood glucose level testperson 2
*Before eating: 0 min			
*After eating: 10 min			
20 min			
30 min			
40 min			

Extend

Have you ever heard about the effect the hormone insulin has on blood glucose level? Take a look at this movie about how insulin works: https://www.youtube.com/watch?v=OYH1deu7-4E

Task: Make a poster where you and your group describe diabetes type 1 and 2, explain how insulin works in healthy people vs. people with diabetes, where it is produced etc. You can search the internet to find this information, but you have to remember to write down the sources you use. Think critically about the websites presenting the information.

Evaluate

Task: Present your poster to a different group. The group listening should come up with 6 questions for a quiz, as well as two positive comments, and two comments about what can be improved.

Evaluation of the mystery

This inquiry was tested with two different science classes of approximately 20 students in each class. Both classes were grade 10. In the national curriculum, one of the learning goals in the main subject areas *Body and Health* is: *explain how own lifestyle can affect the health, including diets and eating disorders, compare information from different sources, and discuss how damage to health can be prevented* (Directorate for Education and Training, 2006). This inquiry focus on the first part of the goal; *explain how own lifestyle can affect the health*. The goal is broken down into several sub-goals, which the students achieve by exploring their blood glucose levels and by doing their own research on how diabetes type 2 may develop due to bad nutrition.

It turned out that the students, when they got a chance to test something on themselves and to experience how food affects their blood glucose level, they became engaged and eager to learn. It was also necessary to make forms (as seen above) for the students to fill in during the experiment. During the first round of testing, the students were told to make their own hypothesis and carry out the experiment. However, several of the groups lacked experience in setting up hypotheses, making detailed descriptions of the experiment and documenting their results. As a response, detailed forms with the different steps of the experiment were handed out to the students in the second science class.

□

The TEMI approach: turning the lesson around

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L'art d'enseigner n'est que l'art d'éveiller la curiosité des jeunes âmes pour la satisfaire ensuite.
The whole art of teaching is only the art of awakening the natural curiosity of young minds for the purpose of satisfying it afterwards.
Anatole France

Introduction

The EU-funded FP7 project TEMI, Teaching Inquiry with Mysteries Incorporated, aimed to encourage inquiry-based science education, IBSE, in classrooms across Europe using mysteries or discrepant events to capture students' interest and motivate them to pursue a science topic through Inquiry. (See *CinA!* #105, Summer 2015, for more detail on the project in Ireland and on p. 48 of this issue) The 5E model is used as the model for Inquiry but this is just a convenient framework to structure a lesson and should be not be thought of as a straitjacket. The 5E is a cyclical model of inquiry around 5 steps: **Engage, Explore, Explain, Extend and Evaluate.**

The basic idea behind TEMI is to motivate students to get involved in scientific Inquiry by using a scientific mystery or discrepant event – something that presents a challenge to the students' understanding, or raises a question or causes cognitive conflict and makes them want to find out more. The mystery can take the form of a demonstration, a mime, a story, a video clip etc. However, some teachers think that the mystery has to be something completely new and original and have found difficulty thinking up ideas. This is not necessary as in many cases the TEMI approach just involves turning a lesson around and this is described here and some examples are given.

Very often in a science lesson the teacher introduces the theory first and then moves on to a demonstration or a student experiment or activity to illustrate or confirm the theory. The demonstration, activity or experiment do not then present any challenge to the student and are not real experiments, as the students already know the answer and there is no mystery or suspense or discovery involved. However, if we start the lesson with the same demonstration/activity/experiment **without** explaining how it works or what the theory behind it is and with textbooks closed and in schoolbags, then this is a totally different scenario. The teacher knows what is going on and why it happens but to the students it is new and is a mystery. A mystery is something that evokes curiosity. Too often we defuse the mystery of science and short-circuit any possible discovery by students because we (the teachers) tell them everything. This destroys the mystery before it has had time to work its magic on the students' imagination, and prevents them from thinking about the problem themselves. Telling students the answer, explaining the theory before they know what there is to explain, kills curiosity stone dead! Many things, that we as teachers take for granted because they are familiar and we understand the science behind them, are mysteries to our students when they first encounter them: plants following the sun around; air bubbles appearing on the glass when cold water stands in a warm room; a coloured crystal throwing out coloured streamers as it dissolves and the solution diffuses; a can of diet drink floating while regular drink can sinks in water etc.

By moving the activity to the start of the lesson and presenting it as a mystery (an unexplained event), we turn the lesson around and make the activity the starting point for investigation and not the end of the process. This means that we don't always need new experiments or activities; we just have to present and use them differently in our lessons – as the initiator of inquiry and not the end-point of a lesson. We need more questions and less pre-digested answers. Some examples are given below of using this TEMI approach in familiar topics. What this means is that for science teachers to use the TEMI approach to kick-start IBSE, they don't necessarily have to invent new ideas themselves. Often all that it needs is rethinking the structure of the lesson and seeing how our activity appears as a mystery to the learner when seen for the first time.

TEMI Idea #1
Dancing raisins (Physics)

Imagine that we want to introduce the idea of density and buoyancy and why some things sink and others float in water. Traditionally we do it by starting with definitions of density, the equation, some calculations and then some 'experiments' to explain and reinforce the theoretical ideas. One result of this approach is that students can repeat the definition and do the problems but they don't understand the concept of density or why some things float and other sink. Another way to start the topic is to show the students a mystery and get them thinking and asking questions about it.

Engage

Get a large (2 L) bottle of clear lemonade and drop some raisins in. (This can be done as a group activity, where each group gets a plastic cup with lemonade in it or a 500 mL plastic bottle). The raisins sink to the bottom. But then they start to float up the top, stay there for a while and then sink down again. They will keep on doing this for some time and this is often called 'the dancing raisins.'

(See https://www.youtube.com/watch?v=0u2tS6fpGaQ)

Explore

So what is going on? Get the student to observe closely and try to come up for an explanation of why they sink, why they rise up and why they sink down again. Close observation shows that the surface of the raisins is covered with little bubbles. What are the bubbles made of? What is their effect on the raisins? Does the same thing happen in water or just in lemonade? Get them to try this with water and see what happens. Does it have to be lemonade? Try it again with a different carbonated drink. Does the behaviour change when the bottle top is on and when it's off?

Explain

The bubbles are full of gas (CO_2) coming from the carbonated drink and nucleating out on the surface of the raisin. When there are enough bubbles they act like balloons and lift the raisins up, just as helium balloon can life a streamer. (You might want to refer to and show a picture from the film *Up* here.) What happens to the bubbles when they reach the surface of the liquid? Close observation will show that they burst, their lifting power (buoyancy) is lost and the raisins sink again. The raisins sink because in some way they are 'heavier' than the water and the gas bubbles are 'lighter' than the water, and like balloons, will rise to the top. Enough bubbles and you can lift a raisin.

Extend

The lesson could develop in different ways: you could explore sinking and floating further using, for example, identical cubes of different materials – same volume but different masses. Which ones sink and which ones float? They could compare the mass of the cubes which sink and those which float and compare them with the mass of a cube of water the same size. What does this tell you? Cubes which are heavier than a cube of water will sink; those that are lighter than a cube of water will float. You could take a ball of plasticine (mala) or aluminium foil and show that the balls sink in water, but when made into a boat shape, they float – they have the same mass, so why do they float? How can you make a boat out of iron or even concrete, even though a piece of iron or a lump of concrete will sink in water?

Evaluate

The purpose of these fun activities is to get the students thinking about the relationship between mass and volume, and sinking and floating. The aim is to reach the point where they realise that it's not mass or volume but both of them that matter and it is the combination of the two that is important. The students should be able to explain this in their own words and give a sensible explanation for the dancing raisins. They should come to a realisation that it's not just mass or volume but both together that matters. We are now ready to introduce the idea, the definition and the equation for density. They can then go back and see how this idea explains their previous observations. This is a simple activity to set up; it is cheap and it is fruitful in developing curiosity and scientific questions.

(The 'dancing raisins' is a fun activity that can be done at different levels. It can be done as an exercise in observation and a simple explanation in primary science. In junior secondary science it can be used to develop the idea of density and related ideas.)

TEMI Idea #2
Why do things mix? (Chemistry)

We often tell students what diffusion is and then illustrate it. But diffusion is quite exciting and wonderful if encountered as a mystery.

Engage

Start with a large beaker of cold water – ideally each group of students should have their own. Now drop in a largish crystal of potassium permanganate (use tongs!) so that it falls to the bottom. Get students to observe carefully and write down what they see. After some time (maybe 10 minutes) get them to put this beaker on one side, and repeat the experiment using hot water. Get them to observe and record what they see. Now have a class discussion based on what they saw – streamers of purple liquid rising up from the crystal and mixing up with the water. In hot water the same thing happened only much faster, What was in the purple streamers? They may suggest that the potassium permanganate first dissolves to give a purple solution, and then this seems to rise and mix with the water. When the water was hot this happened faster. Remember there was no stirring to mix the solution so what happened was spontaneous (of its own accord). For this to happen something has to move. The coloured particles in the solution must be moving and mixing with the colourless water molecules. What would happen if we left it for a long time? They should suggest that the purple solution will rise and mix until the whole solution is purple. Leave the solutions on one side until the next lesson to see if this is true.

(See https://www.youtube.com/watch?v=Bz02z4GSS0k)

Explore

Does this only happen with coloured substances or only with solids? How could they test to see if this is a universal phenomenon?

If a colourless crystal of sugar or salt or washing soda is used, and they look carefully around the crystal, the students will see streamers of concentrated solution rising, visible because of the different density and refractive index. They will see the streamers shimmering and moving. So it happens for colourless crystals as well.

What about liquids? How could they test if liquids do the same in water? Starting with a concentrated, coloured solution – it could be potassium permanganate again or an indicator solution. Use a pipette or dropper to put a drop of the solution at the bottom of a beaker of cold water. Observe what happens. Do they see the same behaviour of coloured streamers rising and mixing? Is it faster or slower than with a solid? Will hot water have the same effect?

Explain

How do liquids mix without being stirred? They must be stirring themselves. If the particles (molecules) of the concentrated solution and the water particles (molecules) are both moving them they will mix up, just like people mix when new people move into a crowded room. Using coloured solids or solutions helps us to see this happen. Heat speeds up the process and this suggest that at higher temperatures the molecules move faster and thus mix faster. Eventually the solution will be a uniform colour and will be fully mixed even without stirring. This process, based on the movement of molecules, is called **diffusion.** The same end results happen if you shake or stir, because you are giving the molecules extra energy of movement. You could use a simple model to illustrate diffusion. Put some balls of the same colour in a transparent plastic bag and then add some balls of a different colour and shake. Here the shaking is used to make the balls move. What happens? The balls will mix up. At a molecular level, diffusion (mixing) happens without shaking or mixing because the molecules are already in movement. [The teacher might like to demonstrate Brownian movement here to illustrate molecular movement.]

Extend
Would you expect this process to happen with gases as well? Would you expect it to be slower or faster in gases? The teacher should open a bottle of ammonia or perfume at the front of the class. Ask the students to put their hands up when they can smell the ammonia or the perfume. Eventually, starting at the front, the whole class can smell it. How did this happen? Gases contain molecules in movement and they are spread out more and are moving faster in a gas, so that we would expect diffusion in gases and it should be faster than in liquids. This is how we can smell food cooking without being in the same room.

Evaluate
Careful observation and accurate recording of what they see. Good suggestions for why mixing happens. Good ideas to test out their ideas with colourless solids or liquids. At the end by their ability to explain in their own words how diffusion can be explained if matter consists of molecules in motion. Temperature spends up the molecules and thus diffusion. Liquids are more closely packed than gases and so diffusion is slower in liquids than in gases. Would they expect it to be possible in solids? Would diffusion be slower or faster in solids?

TEMI Idea #3
Now it works, now it doesn't (Biology)
Students may be familiar with a classic chemistry demonstration known as the iodine snake, where a measuring cylinder containing hydrogen peroxide and washing-up liquid erupts into foam when a liquid or solid is added. To start the topic of enzymes the biology teacher could use this demonstration with a biological twist.

Engage
The teacher sets up three identical measuring 100 mL cylinders – each with 10 mL 30% (or 20%) hydrogen peroxide and a few drops of washing-up liquid. To the first the teacher adds a small spoonful of black powder (manganese(IV) oxide). The mixture starts to foam and erupts over the top of the measuring cylinder and down the side. Why does this happen only when we add the solid? The solid acts as catalyst to release gas (oxygen) from the hydrogen peroxide and the gas forms bubbles and foam with the washing-up liquid. The teacher now adds either a piece of fresh liver or fresh celery (either will do) to the second measuring cylinder. This also starts to foam up and out of the cylinder. What has happened? It is the same behaviour so the liver (or celery) must have had the same effect as the black powder. The food sample has had the same effect as a chemical – it has acted as a catalyst for this reaction. The teacher now takes another sample of liver (or celery) but this time one that has been cooked by boiling in water. He adds the piece to the third measuring cylinder. What happens? No foam is produced. What is the conclusion? Cooking the food sample makes it stop functioning as catalyst. Why might that be?

(See https://www.youtube.com/watch?v=w-nsa7DeXnY)

Explore
This lesson can be developed by asking the question and testing it experimentally: which types of food contain the catalyst that causes hydrogen peroxide to decompose into oxygen and form foam? Using test-tubes and small pieces of raw fruit and vegetable (or meat), the students can set up an experiment to see which foods contain a catalyst and they can be classified accordingly. The next question to answer is: do all these foods lose their catalytic activity when cooked? The students can cook samples of the substances, which tested positive in the first test, in a beaker of boiling water and then repeat the test. Does heating destroy the activity in all cases or only in some?

Explain
These activities can now form the basis of discussing biological catalysts, known as

enzymes, and their properties. Why do they stop working when heated? They know that heating often makes chemicals react and change their properties. Heat is clearly changing the enzyme, which is acting as a catalyst here, and destroying its catalytic activity. This process is known as **denaturation**, where the enzyme loses its natural ability to act as catalyst. They will have found out that several raw foods contain the same enzyme and all are inactive when cooked.

Extend

This activity is relevant for senior cycle classes and so the teacher could introduce the idea of enzyme structure, in relation to the lock and key model, and if we change the key (by heating the enzyme) it will no longer fit the lock or make it work. The other interesting question is, why do many foods contain the same enzyme (peroxidase)? What is its biological function in the substances? How is it that it found both in liver (animal origin) and in a potato or celery (plant origin)? The students could do some research on the internet on this topic. Is denaturation a property of all enzymes or only of this one? They might want to check out whether heating manganese(IV) oxide stops it working as a catalyst or not.

Evaluate

Students would be assessed on the design, carrying out and conclusions of their experiments. They should be able to come up with an explanation in their own words, referring to structure and the lock and key mechanism, why heating an enzyme destroys its catalytic activity. Can they use their ideas to explain why raw pineapple causes the proteins in meat to disintegrate into a soup, whereas cooked pineapple has no effect on them.

Conclusion

I hope this article has shown how a teacher can 'temify' their lesson without having to develop new activities but merely by turning their lessons around. The same experiments or demonstrations can be used to engage students in inquiry, instead of just being used to confirm, prove or illustrate what you have just told the students. This TEMI approach puts the student in the role of a discoverer, trying to solve a mystery and extend their scientific understanding of the world, by harnessing their curiosity. These are very simple experiments, and they are cheap and easy to set up, and could be used at different levels of explanation from primary school upwards.

The approach also emphasises the role of good questioning to stimulate the students' thinking. This quotation from Einstein on the importance of questioning and curiosity is a good place to finish this article.

"The important thing is not to stop questioning. Curiosity has its own reason for existing. One cannot help but be in awe when he contemplates the mysteries of eternity, of life, of the marvellous structure of reality. It is enough if one tries merely to comprehend a little of this mystery every day. Never lose a holy curiosity."
Albert Einstein (1879 – 1955)

□

Diary

2016

TEMI Final Conference
14-15 April
Leiden, NL

TEMI National Conference
7 June
University of Limerick
Peter.childs@ul.ie

Primary Science Conference
9-11 June
Waterfront Hall, Belfast
www.primaryscienceconference.org

7th SMEC
16-17 June
Dublin City University, Dublin
http://www.dcu.ie/smec/index.shtml

BCCE 2016
University of Northern Colarado, Greeley, USA
31 July – 1 August
http://www.unco.edu/bcce2016/

24th ICCE
15- 20 August
http://www.icce2016.org.my/
Kuching, Sarawak, Malaysia

13th ECRICE
7-10 September
Barcelona, Spain
http://ecrice2016.com/

ChemEd-Ireland
15 October
Dublin City University, Dublin
Odilla.finlayson@dcu.ie

ICASE World Science and Technology Education
Conference
1-5 November
Antalya, Turkey
http://www.icase2016.org/

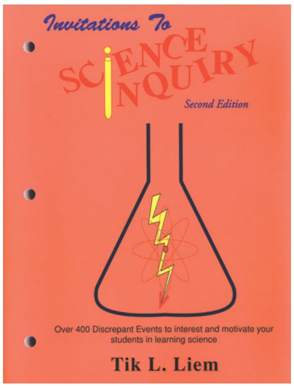
Discrepant events

An alternative name for mysteries in the literature is that of 'discrepant events'. There is a large literature of books and articles under this heading and this is a fruitful source of ideas for mysteries to start TEMI lessons. Here is a definition of a discrepant event:

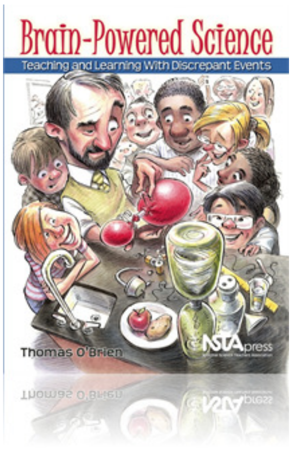
"A Discrepant Event is something that surprises, startles, puzzles, or astonishes the observer. A discrepant Event piques our curiosity and leaves us wanting to know more about the event. The human mind is intolerant of discrepancies, that is, observing something that does not fit with what one believes should be happening. They encourage the observer to ask questions in their search for answers. Often a discrepant event is one that does not appear to follow basic "experience of nature" and the outcome of a discrepant event is unexpected or contrary to what one would have predicted. A discrepant event challenges the intuition. The event throws the observer "off balance" intellectually which most likely will motivate them to further investigate the concept related to the event."
Sandra and John Eix
(http://catalystforscience.ca/pdf/PoS/DiscrepantExplanationsCatalyst2011.pdf)

It is clear that discrepant events and TEMI mysteries are one and the same and have the same function in teaching. This gives the science teacher, who wants to use the TEMI approach in teaching science and encouraging inquiry, access to a vast range of tested ideas in physics, chemistry and biology, in addition to those developed through the TEMI project. Some sources are given below, all of which are easily available online.

One of the pioneers of the use of discrepant events in teaching was Tik Liem, a Canadian science teacher, whose influential book *Invitations to Science Inquiry* 2nd. Edition is available on line for download at http://www.stmary.ws/HighSchool/Physics/home/links/techStuff/TikLiemScientificInquiry.pdf



In the introduction to the book Tik Liem writes: *"In the teaching of a science concept, it is important for the teacher to arouse the student's curiosity. Once curiosity is aroused, the students will learn much more on their own than the teacher can ever teach them. The use of discrepant events in the teaching of science is one of the best methods to arouse this curiosity. This book is a collection of thoroughly testes discrepant events. They can be used to initiate or sustain a lesson in virtually any topic of science at the upper elementary or intermediate level. They can be used as reinforcement activities or as challenging problems for further inquiry."*



Another useful source of ideas for inquiry using discrepant events is the book *Brain-powered Science: teaching and Learning with Discrepant Events* by Thomas O'Brien **from the** NSTA, also available as a free download at http://static.nsta.org/files/PB271Xweb.pdf.

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You can contact the editor by email at: **peter.childs@ul.ie**

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Chemistry in Action! is in the process of being put on the Internet at URL:
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It is hoped to put back issues will be put on the Internet one year after publication. This is not yet fully operational and only issues 38 - 68 are now available. In time I hope that most back issues will eventually be available, 3 issues after publication.

At the same site you will also find the University of Limerick's science and technology magazine for schools, *ELEMENTS* and also information on SICICI, ChemEd-Ireland and other chemical education activities.

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