INTRODUCING CHEMISTRY TEACHERS TO MYSTERY INQUIRY-TYPE SKILLS

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Abstract: Despite the advantages of inquiry based science education, some students find it difficult to engage with. Introducing inquiry using mysterious phenomena or surprising stories can potentially engage student emotionally, thus seducing them to solve a mystery through inquiry. This is the rationale of the EU funded Teaching Enquiry with Mysteries Incorporated (TEMI) project. To achieve this goal, the project trains teachers on the use of mystery based inquiry activities. In this study we investigate teachers' attitudes toward using mysteries and stories in teaching inquiry activities and their reflective experiences of enacting these activities in class. Data were collected by videos of teacher training workshops, questionnaires, interviews, classroom observations and reflective accounts. Most teachers were eager to participate in the workshops, felt that the workshops suited their professional needs, and consequently implemented the mystery activities in their classrooms. A few themes concerning the use of mystery activities arise from the data: (1) Authenticity - Many teacher felt that when telling fictive stories in class, they were breaching their students' confidence, (2) Relevance – The mystery activities must directly serve the teacher in their teaching programme and the mysteries must lead directly to inquiry. (3) Obstacles hindering teachers from implementing the mystery activities in class were a lack of confidence in leading such an activity, lack of relevance to the curriculum or lack of materials in the school lab. (4) Most interviewed teachers claimed that the CPD workshops had an effect on their everyday (non-inquiry) teaching as well. This study reveals the affordances and hindrances of teachers' use of mysteries and stories in IBSE. The conference presentation will include an example of a mystery based inquiry activity.

Keywords: Inquiry based science education, Mysteries in education, Teacher CPD, Showmanship, Storytelling

INTRODUCTION

> *" The most beautiful experience we can have is the mysterious. It is the fundamental emotion that stands at the cradle of true art and true science." - Albert Einstein*
>
> *"The purpose of a storyteller is not to tell you how to think, but to give you questions to think upon." - Brandon Sanderson*

Despite the many advantages of introducing inquiry into the science classroom (European Commission, 2007), some students find it difficult to engage with. Varying the instructional techniques in the science classroom is important to address the multitude of students' learning styles (Hofstein & Kempa, 1985). Introducing inquiry using mysterious phenomena or a surprising story can potentially engage student emotionally, seducing them to solve the mystery through inquiry; thus making the transition into inquiry smoother. This is the rationale of the EU funded Teaching Enquiry with Mysteries Incorporated (TEMI) project. One of the main goals of the project is to enhance students' motivation and interest and to vary the science classroom learning environment. This is done by providing teachers with skills and materials needed to conduct inquiry activities in the framework of mysteries (an unexpected science demonstration, a story or a phenomenon).

In order to effectively engage students and lead the mysterious phenomenon into inquiry, teachers must mediate the mystery to the students. With this in mind, a 16 hour training program for chemistry teachers was devised that set out to prepare teachers to conduct inquiry

activities with mysteries. The instructional model of the workshop was that of Gradual Release of Responsibility – GRR (Pearson & Gallagher, 1983), in which teachers acted as learners first and gradually assume more active roles. In order to provide a meaningful and long-lasting effect the programme was divided into four afternoon meetings spread over a period of six months at regular intervals. This allowed teachers to practice what they learnt in their classrooms. The training programme may thus be seen as a continuous professional development (CPD). The CPD focused on three types of activities: (1) Activities aimed at providing teachers with presentation skills such as storytelling, (2) Ready-made inquiry activities based on a mystery, and (3) Activities constructed by the teachers themselves. The workshop also related to theoretical models of teaching inquiry (the 5E model of inquiry, Bybee et al., 2006).

Previous research has shown that many teachers use drama and story activities spontaneously in the science classroom (Dorion, 2009). Others, however, feel a lack of confidence and skills to enact such activities (Alrutz, 2004). In this study we investigate teachers' attitudes toward using mysteries and stories in teaching inquiry activities and their reflective experiences of enacting these activities in class. We thus ask:

1) What are teachers' views on using stories in class as introduction to inquiry-type experiments?
2) What difficulties do teachers encounter when using such stories in class?
3) How can teachers be supported in using mystery stories in class?

THEORETICAL BACKGROUND

Inquiry based science education (IBSE)

The importance of scientific inquiry in science education is well documented: inquiry may increase students' attainment levels, improve their attitudes towards science (Hofstein & Lunetta, 2004; Lunetta, Hofstein, & Clough, 2007) and provide students with deeper understanding of big ideas in science (European Commission, 2007; Harlen, 2013). However some students find it difficult to engage with inquiry (Zohar, 2000).

One way to overcome this difficulty is to tap into the powerful tool of interest, a state of positive emotion and heightened concentration (Hidi & Renninger, 2006). Research literature distinguishes between two types of interest: situational and individual (Hidi & Renninger, 2006). Situational interest is a state of focused attention and the corresponding affective reaction which is caused by an environmental stimulus at the moment. Individual interest is a person's predisposition to engage with certain content based on prior experience or due to a genetic predisposition. The level of a person’s interest (both situational and individual) has repeatedly been found to be a powerful influence on learning (Hidi & Renninger, 2006).

We propose that introducing inquiry based activities with mysteries can be a strong tool to promote situational interest and thus engagement in the activity. It is one of the goals of this study to confirm this premise. Further to triggering students' interest with a scientific mystery, in the inquiry activity we described below, we present the mystery within the framework of a story. We do so as we believe it further helps to trigger students' situational interest but furthermore it helps maintain it. In the next section we provide some details on the use of drama and stories in science education.

Drama and stories in science education

In an attempt to improve students' achievement, attain other student outcomes (such as increased motivation and engagement) and to achieve novel and innovative pedagogies educators have resorted to Drama Based Pedagogies (DBP; Lee, Patall, Cawthon and Steingut, 2015). DBP includes a range of drama-based teaching and learning strategies. Lee et

al. (2015) conducted a recent meta-analysis of research investigating DBP. According to the authors the major features defining DBP are that (a) it is facilitated by a teacher, a teaching artists or other facilitators trained in DBP, (b) it aims at academic and/or psychosocial outcomes for the participating students, (c) it focuses on process-oriented and reflective experiences and (d) it draws on a broad range of applied theatre strategies.

The meta-analysis aimed to discover the factors influencing the effectiveness of DBP. Overall DBP had a positive and significant impact on achievement outcomes with effect being strongest when the drama based intervention was (a) led by a classroom teacher or a researcher rather than a teaching artist, (b) when it included more than five lessons and (c) when it was integrated into English language arts or science curriculums. Despite the overall positive effect of DBP on students learning outcomes, little is known as to the conditions under which it is more or less effective and the domain is under theorized and under researched (Lee et al., 2015, Odegaard, 2003).

Within science education research several accounts of the use of DBP can be found encompassing a variety of domains such as electricity (Braund, 1999), molecules and the states of matter (Metcalfe, Abbott, Bray, Exley, & Wisnia, 1984; Peleg & Baram-Tsabari, 2011), evolution (Peleg & Baram-Tsabari, 2015) and mixtures and solutions (Arieli, 2007). Findings suggest that drama activities might not necessarily improving factual recall (Metcalfe et al., 1984; Ødegaard, 2003) but can lead to deeper understanding of the topic learnt (Arieli, 2007; Braund, 1999). In all studies cited above the learners enjoyed learning through drama.

Research has also shown that many teachers spontaneously use drama and story activities in the science classroom even if they do not consider their pedagogy as based on drama (Dorion, 2009). However, many teachers, while appreciating the potential benefits of DBP feel a lack of confidence and skills to enact such activities (Alrutz, 2004).

In the teacher CPD we focus mainly on storytelling, a simple and accessible form of DBP and one which teachers can relatively easily apply even if they lack formal training in drama and in the performing arts. Stories are a powerful tool to organize, store, describe and communicate knowledge (NRC, 2000; Jonassen and Hernandez-Serrano, 2002; Erduran and Pabuccu, 2015). People seem to have an innate ability to organize their ideas and experiences into a form of a story as can be seen by the young age children develop narrative skills and comprehension (Jonassen and Hernandez-Serrano, 2002; NRC 2000). Narrative forms of explanations are what most people use most of the time when solving everyday problems (Lave, 1988 in Jonassen and Hernandez-Serrano, 2002). From a neuroscience point of view, hearing narratives seems to activate many supposedly unrelated area of the brain (Sabatinelli, Lang, Bradley and Flaisch, 2006). In science education stories have for example been used to teach argumentation in science education (Erduran and Pabuccu, 2015)

METHOD

In order to answer the research questions, data were collected using several approaches:

1) *Observations*. Observations were conducted of seven teachers' enactment of a mystery activity in class. Five of the teachers enacted activities created by the CPD trainers whilst two teachers enacted activities they devised on their own.

2) *Questionnaire*. A specially devised questionnaire was administered on-line to the teachers. Replies were received two to three weeks after the last CPD meeting. The questionnaire included both closed and open objective-type items intended to capture teachers' reflective experiences of the CPD and enactment of activities in class. Responses were received from 14 teachers.

3) *Reflective account*. As part of the CPD, teachers were asked to provide a written reflective account of the classroom enactment of the mystery activity. A reflective account was received by ten teachers.

4) *Interviews*. Two months after the last CPD meeting, ten teachers were interviewed face-to-face or by phone. Interview questions related to enactment of the activities in class and reflections regarding the CPD.

5) *Video recording of the CPD workshops*. All CPD workshops were recorded. This allows us to glimpse into teachers' beliefs and acceptance of the teaching approach.

All data (apart from closed questionnaire items) were analysed using qualitative content analysis by one of the researchers. Initial categories were derived from the research questions. These categories were refined and categories were added with emerging themes. The data from the different sources was used for triangulation.

FINDINGS

The findings will first concentrate on teachers' views of the CPD programme. We will then focus on several themes that emerge from the overall data.

Teachers' views of the CPD

Our findings showed that most teachers were eager to participate in the workshops. Most teachers felt the training met their professional needs (86%) and most teachers felt the training matched their expectations entirely or to a high degree (64%).

When asked what they gained from their workshops, the most rated answers were 'a motivation to renew my teaching' and 'new tools for my teaching' (figure 1). Many of the teachers also choose 'a new approach to teaching and 'useful practical examples'.

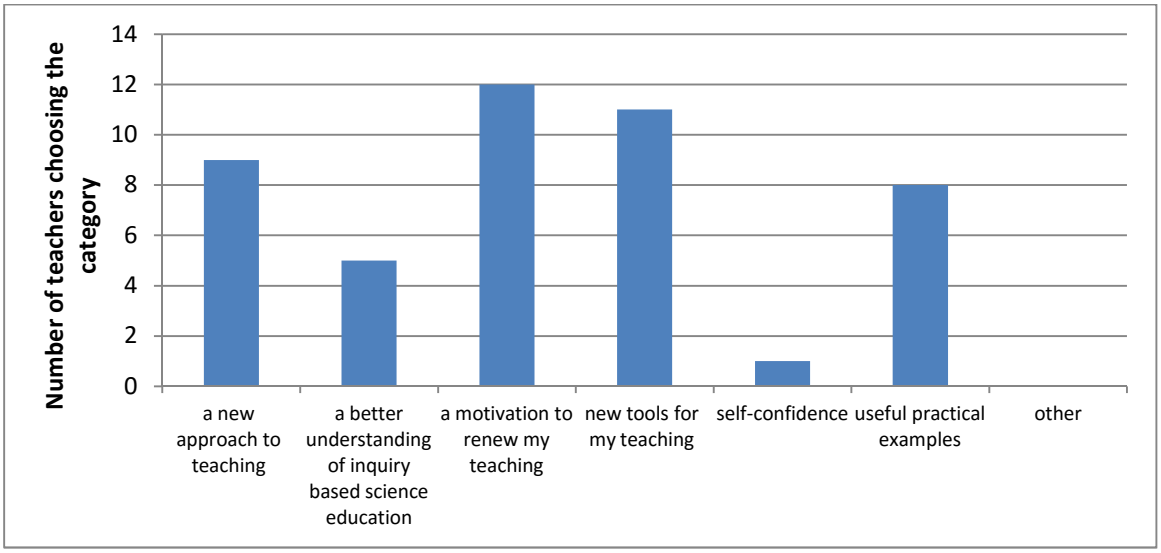

Figure 1. What teachers (n=14) felt they gained from their training. Teachers were asked to choose up to three options.

The CPD was successful and relevant as most teachers claimed they tried the TEMI activities in class (12 of the 14) with 8 of the teacher trying out two or more TEMI activities and many (70%) recommended TEMI teaching materials to their colleagues.

Most of the teachers (10 of the 14) claimed to regularly use IBSE whilst another two teachers claimed to have taught IBSE at least once. Only two teacher were unexperienced with IBSE teaching. This group reflects well the general Israeli teachers' experience with IBSE. Inquiry has been integrated into the science curriculum in chemistry for many years. Thanks to teachers' familiarity with IBSE, the CPD did not have to concentrate on the basics of IBSE and could elaborate on other features such as using mysteries and the use of stories. Teachers were mixed in their level of experience. Half (7 out of 14) had over 15 years of experience whilst almost a half (6 out of 15) had less than five years worth of teaching experience.

Role of the mystery story

From teacher interview data and from our observations we learned that the mystery story was an affective way of building situational interest of the students. One of the teachers in her reflective report of the enactments quoted students she interviewed as saying:

> *"Experiments such as this one are the reason I chose to study chemistry in the first place."*
>
> *"Can you give us more such activities?"*
>
> *"I have finaly understood what fire is all about [referring to an activity about candles and fire]."*
>
> *"I learnt about new things that I never though about yet are so daily."*

Many of the teachers reported that students stayed in the break to continue their work on the mystery stories (as was also seen in the observations) suggesting that situational interest was not only aroused, but also sustained during the activity and beyond.

It seems that the situational interest was built in one of several ways:

(1) By igniting interest and engagement in the activity through the story. In the words of the teachers who tried using a mystery story "The story built up their interest in what happened and set up an appropriate atmosphere. .. I think the story contributed a lot to the lab and gave students the motivation to decide what they had to do in order to identify each of the white powders [relating to an activity described in more details in (3)]."

(2) By the power of a surprising and mysterious phenomenon that are counterintuitive to students' daily lives. Relating to an activity with erasable pens one of the teachers claimed that "it was very interesting. I'm not sure how interesting the story was, as much as the pen that they use in their everyday lives. We need to ask them. I started the activity with the story, but I'm not sure to what extent it contributed to the activity."

(3) By promoting a sense of urgency and competition amongst the students. One of the teachers gave an activity in which she first handed out a cake which tasted salty to the students. Amongst the students' reaction to the ill flavored cake, she took out five unlabeled jars of white powders (salt, sugar, baking powder, corn starch and tartaric acid). She then claimed that she must have replaced the sugar with the salt and that maybe the students can help her distinguish between the powders. In the past she attempted this activity without the introductory story and without having students taste the cake (i.e. simply handing out vessels with five different unlabeled powders). She claimed that the addition of the introductory story added "a heightened motivation to find out what went wrong" and that "each team battled the others to find out what happened first".

To what extent each of these components helped build situational interest is not yet know, and further research may investigate this. However, it seems that they synergy of all three

elements is what makes these activities successful in engaging and maintaining interest amongst the students.

Use of fiction and authenticity

One of the themes that continually emerged in both the CPD video recording and interview data was the question whether it was okay to use fiction in class. It is expected that teachers always say the truth when teaching. After all no one expects a teacher to lie or say half-truths about the science being taught. However, in many of the TEMI activities teachers begin with a introductory story that is not necessarily true.

Some teachers had no problems with using such stories as long as they served the purpose of increasing their students' motivation: "The story was very welcomed by the students. Students love to hear stories, even if they find out at the end that the story was not real".

Other teachers felt that they weren't really lying or that they were saying stories that were half true. For example one of the teachers prepared little greeting cards which she wrote with an erasable ink that disappears upon heating and reappears upon cooling (see TEMI project, n.d.). She intentionally heated the cards to make the ink disappear, however told her students that it happened unintentionally and that she doesn't know what made the ink disappear and how to make it return. Relating to the issue of authenticity, she claimed that:

> *"It didn't bother me at all. There isn't any fault in the mystery. They still had to discover where the ink disappeared to. It wasn't as if I lied to them and there was nothing written on the cards. I really wrote something and that something disappeared; now they have to make it come back. I don't see a problem with the story."*

Other teachers found it more difficult to overcome the hurdle of telling a story that is not real which they felt breached their students' confidence by 'lying' to them:

> *"I am not very good in pretending – that's just my personality. The presence of [one of the researchers] in the activity helped me overcome my inhibitions and made my students believe the cover story was real. In the following lesson after the activity I discussed the issue with my students and they admitted that they weren't expecting me to lie to them. But they highly enjoyed the activity."*

In discussions that were held in the CPD sessions teacher claimed that what helped them tell the story was to tell it as if these stories really happened to them or to a friend of theirs in order to make them more credible. The most important thing in making the story effective is to have the teacher telling it feel comfortable, be it by altering the story, by simplifying it or by not telling it at all. In an interview, one of the teachers summed this up by saying that just like different students have different learning styles different teachers have different teaching styles – some will like the stories and some won't.

Relevance

For the teacher to use the mystery activity must align with the teacher's overall teaching programme and the curriculum. Thus if the teacher is preparing the students for a national high-stakes exam, the topic of inquiry must fit into the teaching curriculum.

Teachers' most and least favourable parts of the CPD are detailed in table 1. Teachers most appreciated ready-made demonstrations and activities. They saw these as relevant to their teaching. Only about a third of the teachers mentioned the storytelling and drama components of the CPD as a favourable part of the programme. Interview data helped reveal that many of the teachers did not see this as relevant and did not quite see the rationale of these components, even though they did realize the potentials of stories to the activity.

A junior high school teacher who tried out a TEMI activity she developed with other teachers in the CPD stated about the use of a story in the activity that: "I think it had a more attractive,

inquisitive side to the activity. It gave a feeling of 'we are doing something different' which engaged the students more." Further in the interview she stated that: "The story telling activitie in which you get a script and tell a story – I can link to. The rest of the activities, I didn't see a take away message I can use with the students. That's why I didn't engage with them – all the making faces and the laughing [referring to the drama activities]. That's not me. What can I do."

Table 1. Teachers' responses to the element they liked best in the CPD and elements they would like to see improved (two open items, responses coded with emerging theme analysis).

Aspect of the workshop mentioned favourably	**Number of teachers mentioning this aspect**
Demonstration of experiments and activities	11
Storytelling and drama activities	5
Interaction with other teachers and hearing their experience of enactment in class	3
Working like a student	1
General organization of the workshop	1
Aspect of the workshop that should be improved	**Number of teachers mentioning this aspect**
More ready-made activities and experiments	5
More time on tools to build our own activity and on storytelling	4
Make the workshop longer	3
Address more scientific disciplines (s.a. Biology)	2

Another aspect of relevance that came up in the CPD videos was that the mystery story must lead directly into the inquiry. Teachers felt that a story that is just used as a gimmick will initially capture students' attention, but will not sustain it during the inquiry process.

Obstacles and suitability

Interview data and discussions in the CPD videos revealed some of the obstacles hindering teachers from implementing such mystery activities in class. One of the main factors hindering teachers from implementing the mystery activities in class was a felt lack of confidence in leading such an activity (see figure 1). Teachers were not always comfortable in implementing activities that required varying degrees of showmanship such as storytelling. Another main hindrance is misalignment to the curriculum and lack of time. One teacher described the lack of confidence, time and curricular pressure as:

> *"I need the holidays to think about implementing such an activity. During the year I find it difficult to organize and learn a new activity. The thing is, if I try one of these activities and it doesn't go well then I lost a whole lab report. I always think. Will I be confident enough to implement the activity in class?"*

Many of the mystery activities require one or more materials that are not readily available in the lab (such as erasable pens, hydrophobic sand or a superabsorbent polymer). This may put a logistic constraint on performing the activity.

In the CPD we tried to provide teachers with ready-made activities and where possible even supply them with the relevant materials. We also made sure they experienced each of the ac

Transfer into everyday teaching

Whether they enacted the mystery activities in class or not, most interviewed teachers claimed that the CPD has had an effect on their everyday teaching. Many claimed that participating in the CPD has given them the tools and confidence in telling stories, so that once in a while they would spontaneously engage in storytelling during class time:

> *"I always used to tell stories, but up to now my stories were not complete. In the workshop I learned how to properly construct a story."*
>
> *"I don't really know, but I think that now when I tell them a story I use all the three elements we were taught. But to tell the truth I now do it automatically."*

One of the teachers declared that changing their everyday teaching style was the reason she chose to attend the CPD:

> *"I came to the CPD to learn a new teaching style. I want my students to like the lessons more – not necessarily the chemisty – rather I want them to like listening to me. I want them to like being in class with me. Not necessarily the chemistry. It's not always 'wow'. I want them to enjoy the lessons."*

DISCUSSION AND CONCLUSIONS

In this study we sought to reveal or identify the effect of a CPD programme that focuses on training teachers in teach inquiry using mysteries and stories. We wanted to see the effects of the CPD from the teachers' reflective point of view.

We found that overall the CPD was regarded as relevant and important. The parts of the CPD that were most welcomed were those that were most relevant and most applicable to classroom teaching (such as ready-made activities). Those parts that were of a more abstract were less engaging for the teachers (such as general drama activities aimed at improving presentational skills but that did not involve a scientific topic). We found adding a mystery story to the activity can greatly enhance students' interest in the activity both by engaging the students and maintaining their interest. However, this must be done in a manner that is within the comfort zone of the teacher, it must be relevant for the inquiry that follows and must be relevant to the curriculum.

We believe that training teachers using these methodologies provides teacher not only with increased confidence to teach inquiry, but also with additional tools for their everyday (non-inquiry) teaching as well. However in order to engage the teachers, it is recommended that the CPD be based on concrete, relevant and applicable activities which align with the curriculum.

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