TEACHING ENQUIRY
with MYSTERIES INCORPORATED

D7.4 Internal evaluation yearly report

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Abstract (for dissemination)	This report analyses the last part of Phase 3 of the project, in the period between 01/08/15 and 30/06/16, and draw a perspective on the project as whole. In this phase, besides the focus on the TEMI materials and the transfer of ownership to the teachers and schools, the impact on other stakeholders such as policy makers or science centres professionals is analyzed. It takes into account the feedback of teachers, organizers of CPD workshops, students, and interviews with various stakeholders.

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1. Executive Summary

The European project TEMI, co-funded by the 7th Framework Programme of the European Union, is a teacher training project aiming to transform STEM teaching practice across Europe by giving teachers new skills to engage with their students, exciting new resources and the extended support needed to effectively introduce enquiry based learning into their classrooms. This internal evaluation report is intended to give all partners and stakeholders a better understanding of what has been achieved, as well as lessons to be learned and leads to maximise the project's impact. This report is focusing on period 3, i.e. the training implemented between 01/08/15 and 30/06/16, involving 480 teachers. A general perspective on the project as a whole is also given. The details of previous periods are reported in previous Internal evaluation reports D7.2 and D7.3.

The global satisfaction of teachers after the TEMI trainings is high – all the rates in the last period are **above 80% of satisfaction**. The training offered are considered very interesting, clear, enjoyable and – though this criteria is scoring slightly below the other ones – practical. These rates are similar to the ones obtained during period 2. Teachers perceive the trainings are well suited for the curricula and fitting their professional needs. The main improvement between period 2 and 3 concerns the information sent to teachers before the trainings.

In terms of teachers learning outcomes, the majority of teachers stated they gained useful practical examples and a motivation to renew their teaching. About half of them considered they got a better understanding of Inquiry Based Science Education (IBSE) and new tools for their teaching. Forty per cent of them gained a new approach to teaching, and only 5% of them built more self-confidence. **Implementing the TEMI way, more than 80% of the teachers reported observing a better motivation in their students.** The most frequent learning outcome for students was a gain in curiosity and engagement. Increases in the number of questions and interactions as well as more cooperation among students have been noted. TEMI also fostered the students' autonomy and critical thinking.

Some challenges are still remaining, such as dealing with interdisciplinary teams of teachers or being more comprehensive on the Evaluation part. This methodology may sometimes be disorienting for students used to classical teaching – fully succeeding in the Gradual Release of Responsibility (GRR) would require more time and efforts than what it is normally allowed. Although it was implemented with enthusiasm, the methodology is still perceived as time consuming.

Insights of TEMI's impact were also given by policy makers, science centres professionals and other science education stakeholders. The interviewed stakeholders stressed the power of the TEMI teachers networks and community, which will make a difference in the long term by spreading the approach and supporting their peers. They identified TEMI as a relevant tool to build "skills of the 21st century", fitting with the evolution of curricula. Last, they pointed out how the TEMI approach could be extended to a number of new situation and settings: primary schools, science centres and museums or non-scientific settings can all benefit from the TEMI project.

2. Introduction

This report summarizes the outcomes of the evaluation conducted on the third stage of the TEMI trainings. We include in this introduction some general trends. In depth considerations and data interpretation are provided in the following chapters, following the organisation set out in the Evaluation Strategy (D7.1).

2.1. Methodology of this report

This report follows the evaluation plan set in D7.1, which detailed the goals and workplan of WP7 evaluation, thought as an internal learning instrument to ensure communication and progression throughout the project and to promote reflexivity among the partners, focusing on the teacher training programme of TEMI.

In the evaluation plan, we identified the following elements to be evaluated, which we will address in the sections of this report:

A – The training programs in relation to D4.1 (see section 2 of this report)

B – The practical implementation of the trainings (see section 2 of this report)

C - The learning outcomes for the teachers (see section 3 of this report)

D - The training methodology (see section 4 of this report)

E - The mysteries and the training materials (see section 5 of this report)

F – The minimum thresholds and quantitative indicators (see section 6 of this report)

The first part of phase 3, the roll-out phase, was evaluated in report D7.3 (M31), which covered the period between 31/07/14 and 31/07/15. It concentrated on teachers and organizers of training workshops like Phase 2, but added information on students and other stakeholders as well. The focus was on the materials and the transfer of ownership to the teachers and schools.

The present report will evaluate the training workshops held between 01/08/2015 and 30/06/2016 in the same way, and will also shed light on the evolution of each element throughout the project lifetime. Last, it will also evaluate more in depth the impact on other stakeholders such as institutions that seek to gain knowledge in IBSE, policy makers and science centres.

To gather the information needed to provide this analysis, we have used in the first place the same set of tools as in D7.3, designed in coordination with other work package leaders. We also added new input gathered during the TEMI congress (April 15-17 2016) and through semi-structured interviews with stakeholders. In synthesis, the tools consist in:

- A simple satisfaction questionnaire filled in by teachers, aimed at understanding which elements of the training were more appreciated, and for which reasons
- An in depth questionnaire filled in by the teachers, aimed at understanding their perception of the different components of the trainings, materials distributed and impact on students
- Semi-structured interviews with stakeholders (partners, institutions, policy-makers, science centres).
- Written feedback from the TEMI congress participants, in particular from the ideas wall.
- Elements stemming out of the workshop “It could have been worse, it could have been raining”, held during the TEMI congress.

In this report, we will not describe the result of each evaluation step or tool separately, but combine them to produce a set of results organised according to the evaluation objectives.

357 teachers from 15 sites (all 9 countries and Switzerland, as one training was done in Geneva at CERN) out of the about 480 (74%) teachers that had participated to completed cohorts in period 3 (1st August 2015 to 30th June 2016) could fill in the final teacher questionnaire (Doc 4 from the evaluation toolkit). Complete answers can be consulted at the following address: https://fr.surveymonkey.net/results/SM-YFWFSQ8M/ . As in D7.3, the number of teachers answering the questionnaire is not evenly distributed across the countries, a fact that should be kept in mind while interpreting the data. In comparison with an even distribution, for this reporting period, and due in most cases to purely practical or schedule reasons, partners such as UMIL or CUNI are overrepresented; partners like UL or Leiden are underrepresented.

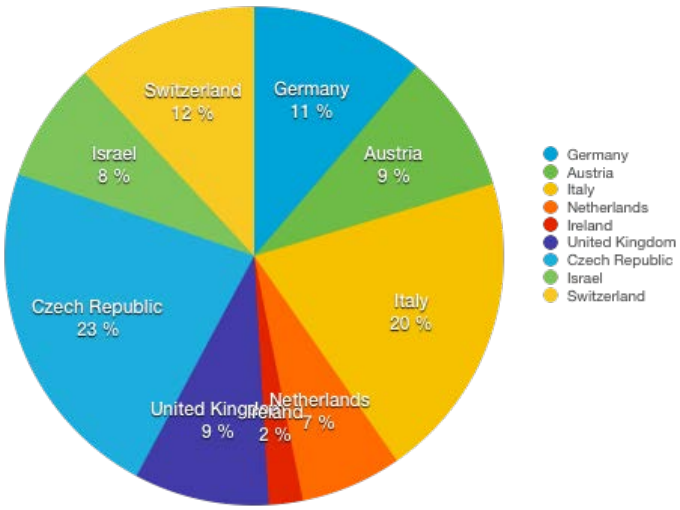


Figure 1: Final teacher questionnaire. Distribution of answers by country

2075 answers to the satisfaction questionnaire (Doc 3 from the evaluation toolkit) from all 9 countries were collected (complete results can be consulted at the following addresses: version 1 (used by UniVie and UniHB) – https://www.surveymonkey.net/results/SM-WJP7RQ8M/ ; version 2 – https://www.surveymonkey.net/results/SM-K2GBRQ8M/ .

2.2. Nature of the participants

About 480 teachers participated in the TEMI cohorts during this last reporting period, from 01/08/2015 to the end of the project. The teachers had once again different backgrounds, with diverse levels of experience in teaching and in IBSE, even though the majority of teachers have already used IBSE at least once (78%), as illustrated in figure 2 and 3. Compared to the previous cohorts, the teachers are much more experienced, as almost half of them had been teaching for more than 15 years (only 26,7% in the previous period). A majority of the TEMI teachers are women (72% in this period), which is consistent with the previous periods, as well as with the statistics of teachers in Europe (cf. Eurostat 2012).

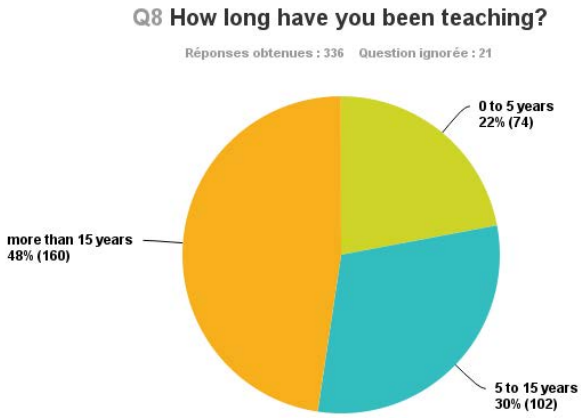


Figure 2: Final teacher questionnaire. Distribution of the years of experience of teachers participating

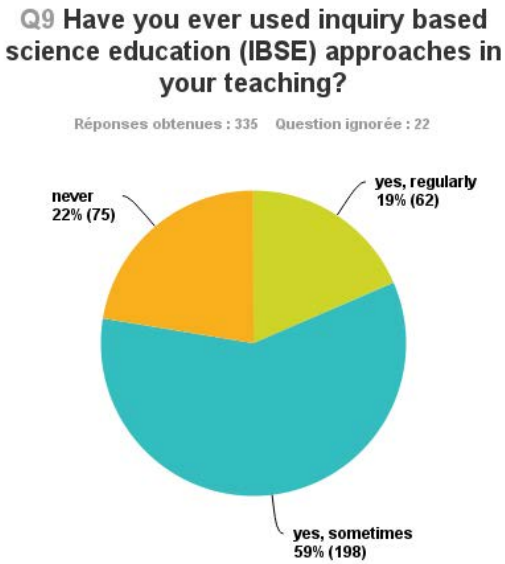


Figure 3: Final teacher questionnaire.
Distribution of the level of experience of teachers with IBSE

No specific correlation was found between how long teachers have been teaching and their experience with IBSE. The teachers that use IBSE regularly have almost the same proportions of experience teachers as the one that never use IBSE. This indicates that projects like TEMI renewing interest in IBSE and equipping teachers for using IBSE are still necessary, as we have not yet reached a situation in which all teachers would naturally progress toward a more inquiry based approach to science teaching.

2.3. Satisfaction of the participants

Teachers are still very satisfied with the workshops, as one can see in the results of the "satisfaction questionnaire" filled in by teachers. The high level of satisfaction regarding the trainings has been sustained throughout the whole TEMI project.

Around 95% of the teachers identified the interest of the training as satisfying ("++" or "+"), and no partner seems to be significantly lower than the other ones. Extremely positive comments are very frequent, as can be seen on the following word cloud generated using the 455 comments.

Figure 4: Word cloud from the comments answered in the teacher satisfaction questionnaire, period 3.

Many positive comments testify from the overall satisfaction of teachers in various countries.

"Variation makes the school lessons more exciting and fascinating. I learned more options to plan and make my lessons varied. thanks!"

(a teacher from UniVie)

However, rates and comments show that the applicability of the TEMI way is still a challenge for some teachers.

« Very interesting looking at the applicability of the TEMI methodology and how it transfers to the classroom. »

(a teacher from SHU)

« Great applicability of the contents, great ability in creating curiosity and in maintaining the attention, in stimulating questions and discussions. »

(a teacher from UMIL)

"Applicability is still a mystery."

(a teacher from Leiden University)

It is noticeable that 90% of the respondents stated that the training tackled aspects of the curricula, both in this report and the previous one. However, even though specific attention has been also paid to the practical implementation of the activities and methods presented, the applicability rate has not improved, though it remains above 80% (rated "+" or "++").

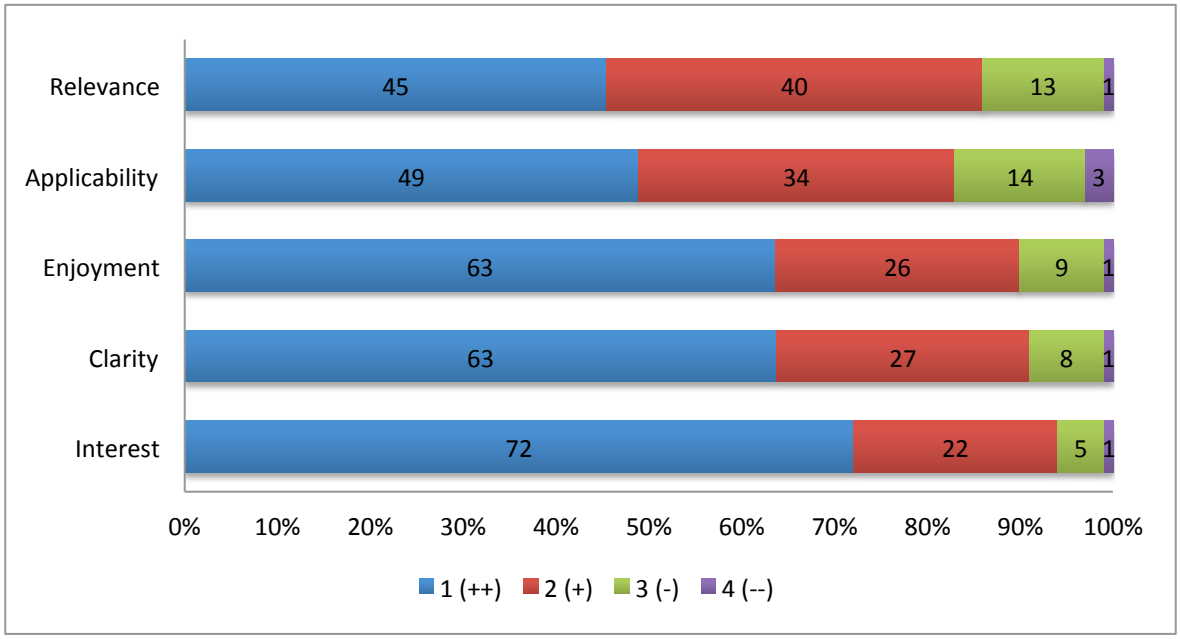


Figure 5a: Satisfaction questionnaire. Averages for period 2.

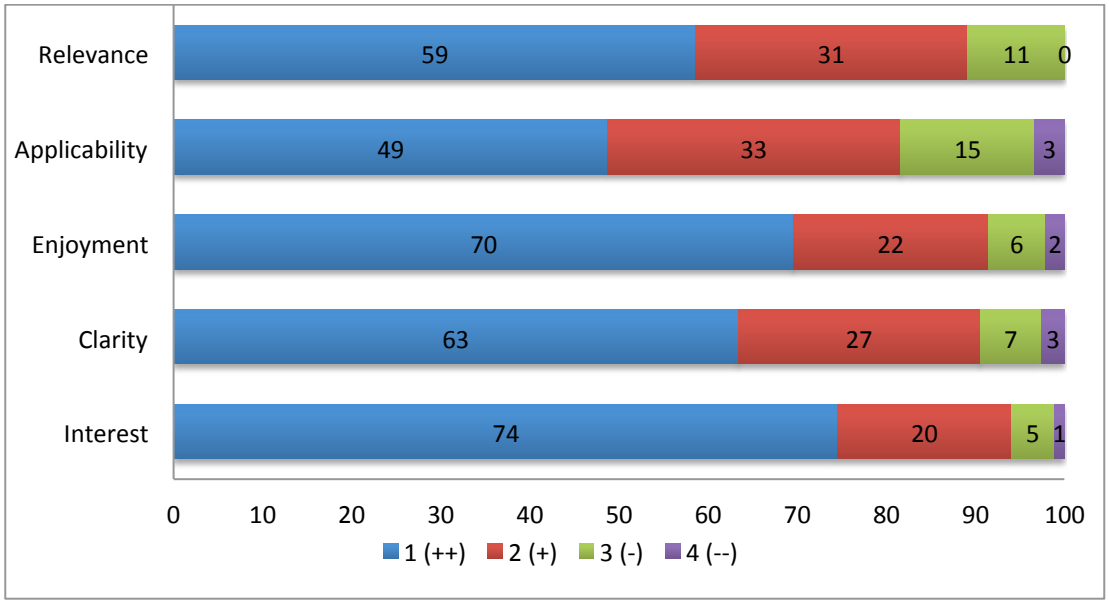


Figure 5b: Satisfaction questionnaire. Averages for period 3.

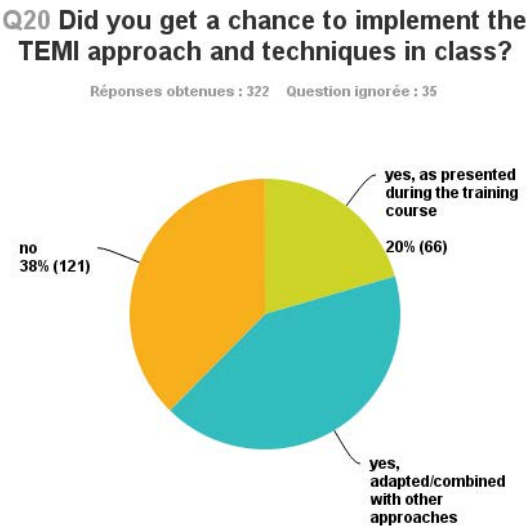


Figure 6: Final teacher questionnaire. Distribution of the number of teachers who applied the TEMI approach & techniques, period 3

62% of the teachers were able to apply the TEMI approach in the classroom (see figure 5 above), two third of those declared to have adapted it to fit their own needs. These numbers do not differ significantly from the previous period, and once again they could be a hint that a large part of the teachers had a good appropriation of the TEMI materials, and embedded them in their own practice.

Still, a stable 38% of the respondents did not get a chance to apply the TEMI approach. The previous report even showed a lower percentage (32%) and already identified the main obstacles: lack of time, wrong timing or difficult circumstances, topics, or other pedagogical approaches currently in use. However, some comments regarding the applicability criteria show that some teachers would have needed more help in bridging the gap between the trainings and the classroom. Again, the efforts of the partners did not obtain an overall increase in numbers of application with students.

If no change was noticeable in the numbers, the comments show that the efforts from partners were noticed and well appreciated by the teachers. Many testimonials stress the link with the classroom situations. Even though between the last two periods the same percentage of teachers did consider the TEMI approach as applicable and did put it in practice, It seems that the teachers who applied it were feeling more supported and carried the activities in the classroom with ease. Rather than a quantitative amelioration, the partners may have enabled a qualitative one.

"Nice practical examples of different disciplines. He told a bit more about how to use the 5E's in practice and how to evaluate this with students."
(a teacher from Leiden)

"Passionate and clear, giving practical suggestions on how to implement in the classroom."

(a teacher from UniHB).

It is noticeable that teachers who already use IBSE were more inclined to apply TEMI in the classroom. In the attached figure are represented once again the percentages of teachers who declared they applied the TEMI approach:

- as presented during the training course (green)
- adapted/combined with other approaches (blue)
- who did NOT apply TEMI in the classroom (orange)

However, these answers are now separated in three groups. Group 1 (on top) has regularly used IBSE in the classroom. Group 2 (middle) has used it sometimes. Group 3 (bottom) has never used IBSE.

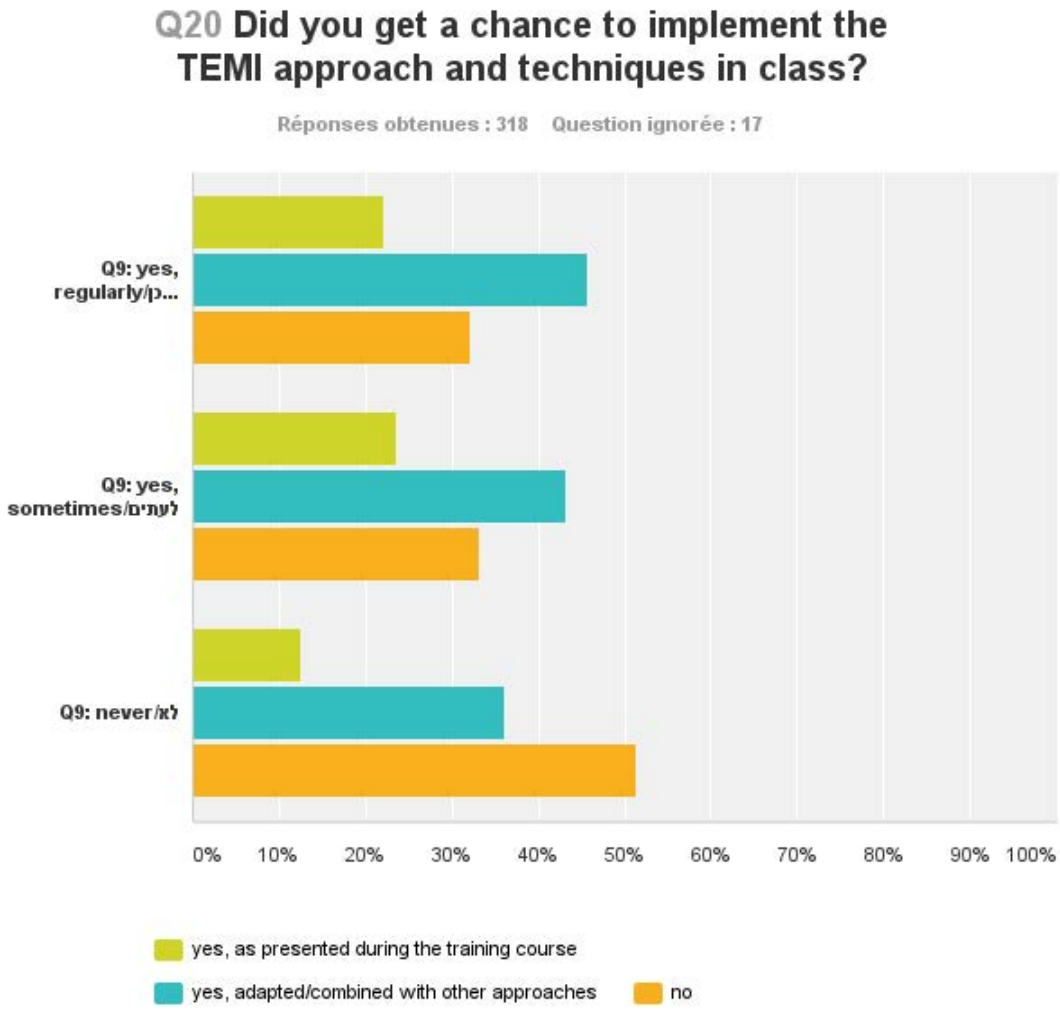


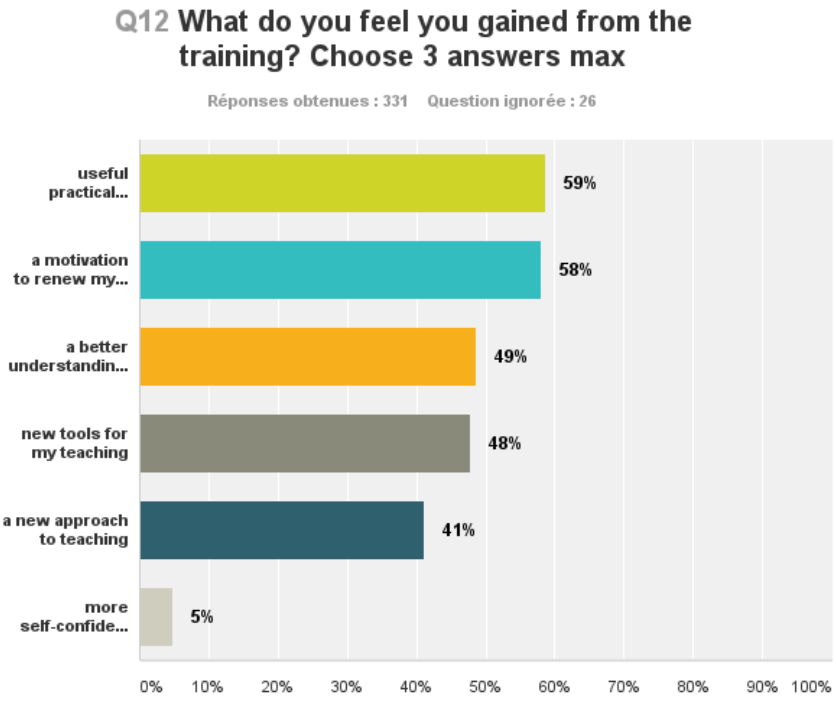
Figure 7: Final teacher questionnaire. Distribution of the number of teachers who applied the TEMI approach & techniques, period 3, separated between those who regularly use IBSE in the classroom (top), those who have used it sometimes (middle), and those who have never used IBSE (bottom).

Group 1 and 2 have the same profiles. Thus, having used IBSE a little bit or a lot does not seem to matter much. There is no need to be an IBSE expert to implement TEMI, which is a good thing! However, the teachers who never used IBSE were less inclined to apply TEMI in the classroom. An experience (even a small one) in IBSE seems to play an important role and foster the implementation with students. Though this data does not tell us the reason, one may identify some possible hypothesis, such as:

- Teachers who had an experience with IBSE had fewer new things to integrate and try for the first time, which made the task easier.
- Teacher who had an experience with IBSE were already convinced of the relevance of the IBSE approaches, so they were more willing to implement it.
- Teacher who had an experience with IBSE were statistically teachers more interested by innovative teaching and improving education, so they were willing to implement the innovations.

The vast majority of the respondents (81%) considered that the trainings matched their professional needs, gaining useful practical examples (59%) and a renewed motivation for their teaching (58%) – these results match with the previous periods. More than 90% of the respondents stated that the "productive mysteries" were appropriate for their context, and also that the activities presented were varied enough to fit all teacher levels of experience.

The amelioration on the information sent to teachers before the trainings is also noticeable: only 5% of the respondents reported that this information was insufficient, versus 10% in the previous period.



useful practical examples	59%
a motivation to renew my teaching	58%
a better understanding of inquiry based science education	49%
new tools for my teaching	48%
a new approach to teaching	41%
more self-confidence/ בטחון עצמי מוגבר	5%

Figure 8: Final teacher questionnaire, period 3. Percentages of votes on what teachers feel they gained from the training in decreasing order.

"I liked the ways in which it showed me how to make science teaching and learning more interesting for both the student and the teacher!" (a teacher from UL)

Even though the general satisfaction is high, the teachers did spot some weak points. These are frequently linked to some parts they experienced as too challenging, so they had difficulties following and understanding them. For example, the training on optics seems to have been difficult for many teachers (especially the polarisation part). In a similar way, the teachers who attended the training at CERN (Geneva) have experienced the part on the Higgs Boson in a very different way, some highlighting it as their favourite part, other stating they struggled to understand the explanations. The theoretical part on the TEMI approach was also challenging for some teachers who classified it as the part they liked the least.

2.4. Which challenges remain?

Interestingly, the fact that the TEMI trainings were aiming for interdisciplinary training seems to have bothered some teachers. If many of them stressed they enjoyed the exchanges, the variety of disciplines was sometimes lived as a weak point, the teachers immediately discarding all activities that were not relevant for their field. Some of them even revealed they would prefer a training focused on their own discipline. However, it is noticeable that teachers from various disciplines (physics, chemistry, biology) all appreciated the TEMI approach and found it relevant for their topic.

« Because we were divided into groups, I didn't see everything. Also I don't teach biology so the biological topics were not useful for me. » A teacher from CUNI

The 5E are extremely appealing to teachers, but some revealed the felt the last E, "evaluation", was not developed enough. Indeed, one of the challenges of IBSE is to find a way to accommodate the very open learning approach with the grades generally required by the school system. Moreover, several teachers asked for more examples using the complete cycle with the 5Es, in order to better understand how they can be articulated.

« I would have preferred practical sessions and more insights on evaluation, an aspect non negligible for a teacher. » A teacher from UMIL

Even though the students enjoyed the freedom and the responsibility, they sometimes struggled with the difficult tasks. Being creative or formulate some relevant hypothesis was sometimes hard for them, especially when they were not used to IBSE. It also appeared that some students who want to achieve a high level sometimes felt frustrated by this novel approach.

« Inquiry based learning (self-dependent) is too difficult for my students ». A teacher from UniVie

« Students were very involved, but a little disoriented by the methodology » A teacher from UMIL

Teachers and students also had to deal with new situations. The Gradual Release of Responsibility is still difficult to achieve for many classes. Moreover, the very experimental approach of TEMI implies that sometimes the experiment presented does not work. Teachers and pupils are used to very clear messages in the classroom, and may be confused or frustrated by experimental failures. An effort on how to work

with failures in IBSE could be a relevant area to explore in order to enhance the TEMI approach. In contrast with classical teaching, the TEMI way and IBSE in general are much more open to unexpected results, which should be seen as a source of engagement and new exploration. Thus, a strong lesson to be learned here is that “dealing with the unexpected” or even “ dealing with failure” are situation for which teachers should be trained. First of all, this will prevent teachers from using TEMI as a “closed” approach – were the expected results would be totally known and controlled by the teacher, which would be in contradiction with the GRR and with the very principle of inquiry. Secondly, having students deal with failure will get them closer to real research, and will encourage new behaviours: rather than on “getting the good result”, they will focus on “how do I react to my results?”. Last, one of the barriers to the GRR could be the fear that the student will not succeed if the teacher is less present. Rather than making sure they succeed, the teacher could make sure they know how to react when they fail.

Another challenge is involving the class as a whole. Some teachers reported that the TEMI way is suitable only for small classes. Even so, they sometimes report that the level of participation was unequal among students. Some participated less or did not cooperate much. Engaging every student is very time consuming, and time still appears as one of the main obstacles to teach the TEMI way.

Even though the approach is open and inquiry-based, students are still expected to reach some specific conclusions foreseen by the materials and the teachers. In a number of cases, the students did not reach them. Even though this is perfectly acceptable for IBSE outside the classroom, teachers found difficult to manage such situations.

3. The learning outcomes

3.1. Teacher learning outcomes

« 5E was most relevant for my teaching. » A teacher

"The practical example of Explore, that gave me the possibility to experiment directly the method." A teacher from UMIL

The teachers report several learning outcome through the questionnaires and the feedback wall of the TEMI Congress:

- First of all, teachers faced a new approach for teaching, which gave them new perspectives, and an awareness of their current approach.

"Overall my experience of the TEMI training was a very positive and productive one and gave me new insights to a different teaching method. Well done to all concerned. » A teacher from UL

- The trainings renewed the teachers' motivation, excitement and engagement.

« It was a very encouraging day! » a teacher from UniHB

- The teacher felt empowered to experiment with the approach in the classroom, and to adapt it to their own needs.

« During the current year I would like to choose a topic for each class and to develop that topic, following the TEMI approach. It will be a first experiment. » A teacher from UMIL

- The teachers took advantages of the exchanges with their peers, and developed a community of practices.

« Very relevant, especially in the context of the new curriculum specifications in Ireland. Great ideas and great professional contacts made. Feeling empowered to implement. » A teacher from UL

- Teachers started to transfer part of the responsibility of the learning process to their students. Though it is still challenging for many teachers, the gradual release of responsibility has been identified as an important tool. It requires some time: as most students are not used to such responsibility, they need a transition period to adopt the new attitude.

« They were a bit wary of the independence at first but then they embraced it. » A teacher from SHU

"TEMI reminded me to make my lessons more of an engaging performance that lets the students teach themselves" A teacher at the TEMI Congress

Teachers decided to devote more time and energy to areas that are not directly related to the field they are teaching, nor part of usual didactics. In particular, they started spending some efforts on storytelling or showmanship, increasing the emotional power of their teaching. The mix of all innovations enabled those specificities that are sometimes absent from other IBSE approaches. Several teachers report storytelling as a very effective tool in the classroom, combined with the experiments.

"The story inspired the students, it made them laugh and intrigued them."
A teacher from Weizmann

"I invest more on storytelling, with special love for the live stories about how the topic really started."

"[TEMI] has made me think again about excitement and showmanship - it has made me think more consciously about these skills. "

Two teachers at the TEMI Congress

- Teachers gained a better awareness of the way to get students' attention, and of the cognitive process at work while learning.

"I'm aware of it that sometimes small riddles at the end of a lesson are more important than my "real" lesson". A teacher at the TEMI congress.

Several other learning outcomes can be identified, such as:

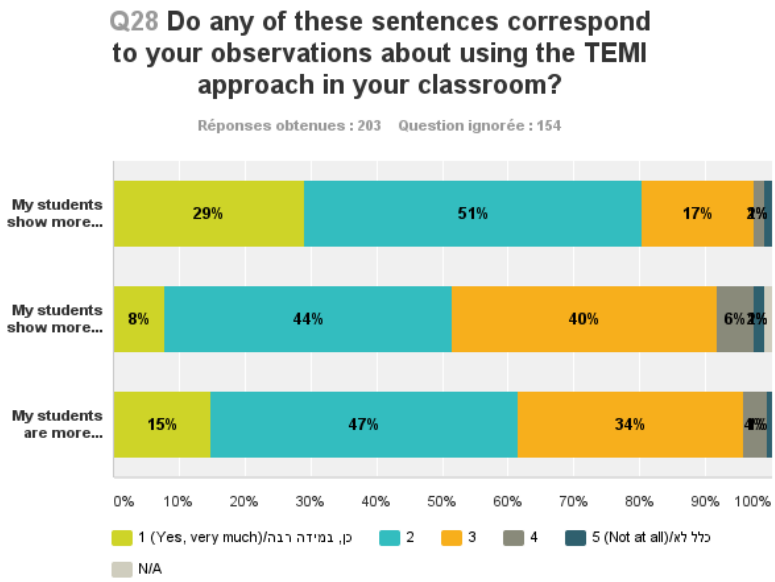
- being able to use many new practical examples. One of the main strength of TEMI is the richness of its materials and all the various practical examples it may offer. A large number of teachers appreciated the examples, and many even asked for more of them.
- being able to be more creative.
- becoming aware of the student scaffolding that is necessary for implementing IBSE.

The TEMI approach is particularly efficient at the beginning of a lesson, to ignite curiosity and generate engagement. Several teachers report its relevance for opening a new subject.

3.2. Students learning outcomes

As stated in D7.1, the direct interaction with the students through questionnaires or interviews proved to be too challenging, in particular for legal reasons. Thus, the learning outcomes of students have been evaluated through the eyes of the trained teachers, who were asked in the final questionnaire about what the students liked and disliked, what worked well and what worked less well in the classroom. The teachers present in the TEMI congress could also write publicly on a feedback wall what impact TEMI had on their students. The fact that teachers and not the students themselves evaluate the students learning outcomes should be taken into account during the interpretation of the data in this chapter.

First of all, 81% of the respondent teachers report that the students overall motivation increased, confirming that TEMI is a valid approach to renew the students motivation. About half of the respondents report a gain in students self-confidence. Teachers reported many other effects – we will now review the more salient ones.



	1 (Yes, very much)/כן, במידה רבה	2	3	4	5 (Not at all)/כלל לא	N/A	Total
My students show more motivation	29% 58	51% 102	17% 34	2% 3	1% 2	0% 0	199
My students show more self-confidence	8% 15	44% 85	40% 78	6% 11	2% 3	1% 2	194
My students are more autonomous and work more independently	15% 28	47% 89	34% 65	4% 7	1% 1	0% 0	190

Figure 9: Final teacher questionnaire. Roll-out phase, period 3. Percentage of votes on what teachers feel their students gained from the training in decreasing order.

TEMI is extremely efficient to stimulate the students' curiosity. A huge number of teachers report the engagement and interest of students as the thing that worked best. The excitement and curiosity they gained through the TEMI activities are then also transferred to the other subjects, and strengthen their motivation. The use of mystery is widely reported as very efficient.

« Students were curious, they sudden started with connections to similar phenomena, with posing questions and so on. » A teacher from UMIL

TEMI fosters other behaviours in the classroom, and the students showed more cooperation and reflexion than usual. Their interactions increased, facilitated by a playful atmosphere, which students enjoyed. Students are also much more encouraged to ask questions than with traditional lessons.

« Some children cooperated and thought things out more than usual. » A teacher from CUNI" A teacher from UniVie

« TEMI approach is excellent for teamwork. » A teacher at the TEMI Congress

Students have gained autonomy thanks to the TEMI approach, and in particular the Gradual Release of Responsibility. This autonomy is sometimes reported in terms of autonomous learning, of organisation

among the group, or of choice of the direction of inquiry. Of all respondent teachers, 61% reported a gain of autonomy and independence of their students.

"[The students liked the] new way of working, independent designing of experiments »

« New, practical, they found out everything themselves »

Two teachers from CUNI

This autonomy also led to independence of thought and increased the critical thinking among students.

"They had to start thinking on their own" a teacher at the TEMI Congress

4. The training methodology

4.1. Implementing IBSE and the 4 innovations in class

The confidence that teachers have in implementing the innovations of TEMI is almost the same during period 2 and period 3, in the roll-out phase.

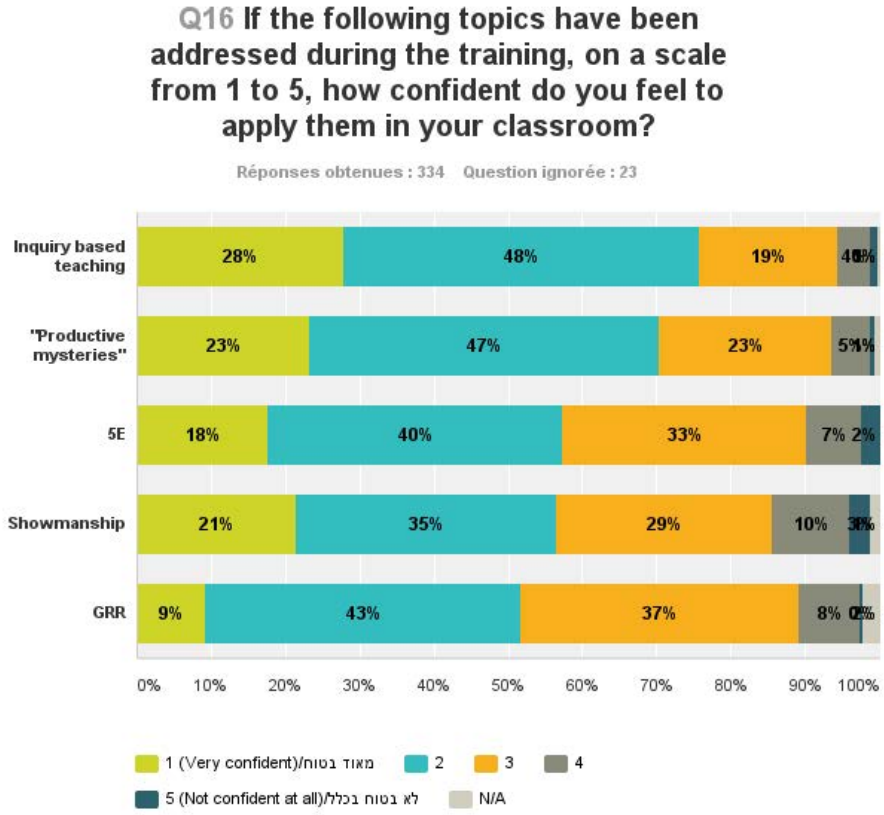


Figure 10: Final teacher questionnaire. Roll-out phase, period 3. Percentages for each level of confidence with the 4 innovations

First of all, this last year confirms that TEMI is a great way to approach IBSE. Not only does it provide appreciated hooks through the mysteries and practical cases, it also gives a fresh approach for a sometimes disorienting or frightening practice.

" Inquiry-based learning has been there for 30 years. You need a new wave of enthusiasm, and TEMI is contributing, with the mystery" (Veronica McCauley, lecturer in Science Education, National University of Ireland, Galway)

TEMI can also be used to investigate new directions for IBSE. First of all, the TEMI methodology is not aimed only at the good science students, but towards every one of them. Ron Nurit (Director of the Products Implementation in the R&D Division) and Dorit Taitelbaum (Chief Inspector in Chemistry Studies) from Israel underlined the need to measure the influence of TEMI on non-scientific minded students, or on the students that will not study science afterwards. TEMI may foster critical thinking among students, which could be beneficial to all of them.

In that direction, the University of Leiden received a large number of non-science teachers in a TEMI training (cohort 4). Although this happened initially by accident, most of these teachers stayed until the end of the training and were very enthusiastic. The challenge for them was to adapt the TEMI resources – or to build their own resources. For example, an art teacher decided to add some mysteries to a course focused on *camera obscura*. She introduced her students to the TEMI approach, and then asked them to find and bring some relevant mysteries linked with the *camera obscura* theme. The teachers trained were convinced after they saw the effects of the TEMI approach on their students, and the University of Leiden decided therefore to open the training to all kinds of disciplines. This also fits with a general trend in the Netherlands, where many schools wish to apply IBSE to new topics.

Many stakeholders appreciated the shift offered by TEMI: less focused on the facts and figures, TEMI teaches a specific approach. Martin Hruby, chemist involved in science education in Czech Republic, insisted on the fact that TEMI teaches "independent thinking", and should be used in combination with other approaches. Ron Nurit (Director of the Products Implementation in the R&D Division) and Dorit Taitelbaum (Chief Inspector in Chemistry Studies) from Israel also stressed that point: instead of conveying the idea that scientists know "the truth", TEMI conveys the scientific approach – which is a new message for students.

4.1.1. Productive mysteries to create curiosity

Secondly, the mysteries were widely appreciated by the teachers. Numerous comments show that the idea of productive mystery was the one teachers liked best, and 70% of them feel confident implementing it. Generally speaking, they were recognized as the main asset of TEMI. Indeed, the mysteries do not only refer to a specific approach, they are also linked with a collection of practical situation to experiment in the classroom, which means they were the simplest aspect to implement. Moreover, the "WOW" effect produced by the mysteries on students is valuable in the classroom. It immediately attracts students' attention, but also triggers their long lasting curiosity and engagement.

"[What worked best was] the introduction of the ideas of mystery and illusion".

(a teacher from Leiden)

Many teachers outlined that the mysteries are particularly useful to open a new topic or start a lesson. Even when the teachers are not using the other innovations or IBSE, the mysteries are great "hooks" that can be used quite easily.

The mysteries can also be applied in other contexts than school. Wendy van den Putte (Senior Project Manager at Nemo Science Centre) confessed that she was extremely impressed by the mystery approach, and would like to use it in the science centre. She considers that having a TEMI training for the science centre staff would be extremely valuable.

4.1.2. 5Es

The 5Es were often perceived as giving a frame to IBSE, allowing the approach to be clearer and easier to implement. Several teachers outlined it as their favourite aspect of the training. Other ones, however, struggled with an excess of theory, and had difficulties understanding the transfer in the classroom. In particular, some teachers regretted that they did not apply the whole 5E cycle on one mystery during the training. Implementing the whole 5E cycle is still perceived as a challenge.

As a result, the most difficult E, Evaluation, was sometimes not treated enough. Several teachers would have preferred spending more time on the evaluation. First of all, teachers are usually required to evaluate their students, and IBSE makes evaluation more complicated: the student may search in an unexpected directions, one cannot state they were "wrong". Thus, many teachers were interested in having a frame to evaluate the student while using IBSE, and the training on the 5Es could focus more on this aspect. Secondly, the 5Es being student-centred, there was sometimes a confusion between an evaluation led by the student and an evaluation led by the teacher, which should be clarified.

"[What was missing was] something more about Evaluation. It's the weakness of the approach presented. » (a teacher from UMIL)

However, the 5Es fit easily in a variety of educational set up. Wendy Cox, from Ogden Trust (United Kingdom), stresses that the 5Es would be perfect for actions in primary schools. As an example, the University of Limerick (Ireland) implemented with good results the TEMI approach in primary schools. Wendy van den Putte from NEMO Science Centre considers that the 5Es would be valuable for the activities her institution is offering in schools.

4.1.3. GRR

Although more than 50% of the trained teachers feel confident implementing the GRR, this result is lower than the previous innovations. GRR is the only innovation that got a significant lower score in period 3 compared to period 2, the roll-out phase. Indeed, GRR is attractive but delicate to handle for teachers. It requires building a strong trust with the students, and is a progressive process of scaffolding that requires time. Even though some teachers spotted GRR as a strong point, others noted the lack of time, making it extremely challenging.

The GRR is reinforcing the active role of the student, and offers a frame to have students lead their own learning. Claudio Fazio, Associate Professor in Science Education at the University of Palermo, sees a link between the GRR and spontaneous learning, which is an important process nowadays.

Like other TEMI aspects, the GRR can be applied in new situations. Kirsten Fiskum, University lecturer at the Norwegian Centre for Science Education, takes home from the TEMI Congress the idea to make teachers responsible of innovation by scaffolding their capacity to work in network -defining it as a sort of application of the GRR to teacher training. Indeed, a recurrent challenge for IBSE is to sustain in the school system, even when the projects that brought it to schools (like TEMI) ends. Using a kind of GRR process with teachers may be a way to have them carry on with the innovation, develop new materials and exchange resources as well as good practices with their peers.

4.1.4. Showmanship

Showmanship has generated very opposite reactions. Acclaimed in some training, it has provoked some frustrations in others. The main complaints were about the difficulty to replicate or apply it in the classroom. Some teachers also regretted that this part was very passive for them, that they had to sit still for a too long time. They considered this part should be more practical.

"Showmanship was least easy to take away and replicate" (a teacher from SHU)

The first element we can conclude from the results is that showmanship is highly relevant for teachers. They liked the fact that the training tackled showmanship, and wanted to improve in that skill. The trainings succeeded in raising awareness about the importance of showmanship. However, actually improving the teachers' showmanship skills would require much more time: for example, they would have to prepare and present shows, work on theatrical aspects, on the body and voice, on suspense effects… This could be a lead towards a continuation of TEMI – in a new project – as the Showmanship aspect was understood but not necessarily acquired yet.

5. The mysteries and the training materials

The teachers appreciated the TEMI resources. A very large number of comments point out their clarity, and their very easy use in the classroom. As many of them wrote, the documents were “ready to use”.

« I liked the clearness, transparency and adjustability » (a teacher from CUNI)

As on can read on figure 11, the teachers’ guide and the students hand out were the most used resources. Some teachers had some minor difficulties accessing the document through Dropbox. Other pointed out that even though the resources suggest clear and easy experiments, these could still fail! Thus, teachers should be reminded to prepare and try out the experiments before using it in class.

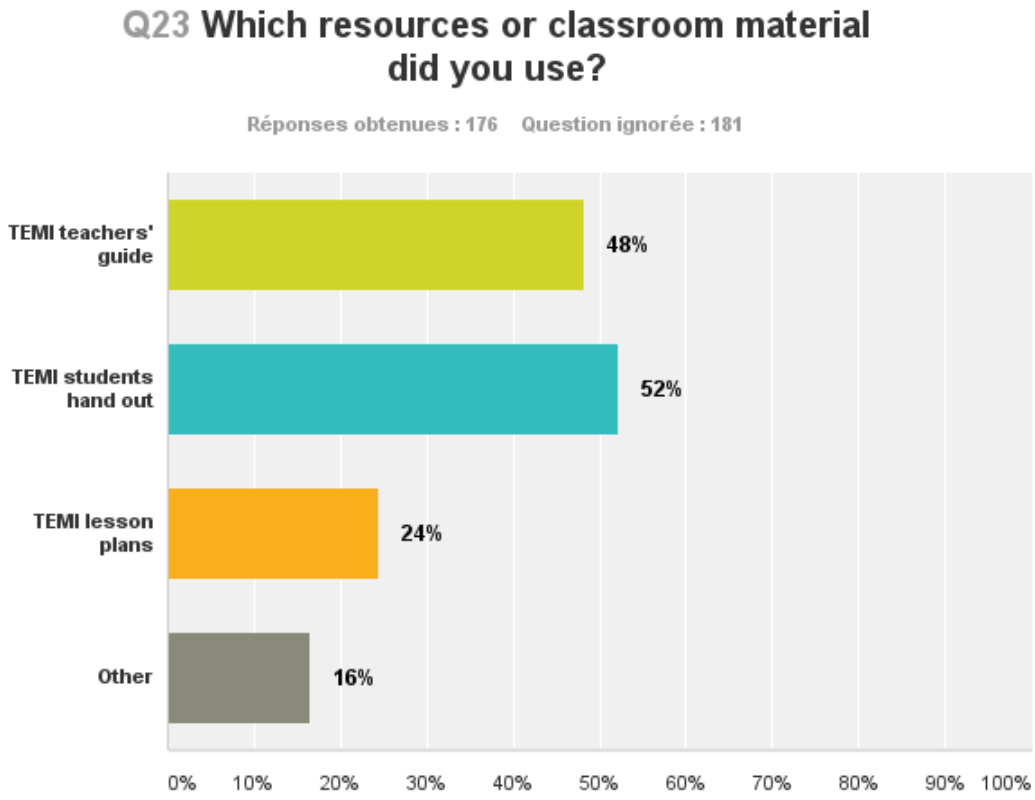


Figure 11: Final teacher questionnaire, roll-out phase, period 3, resources used for implementing TEMI in the classroom, as declared by teachers, in decreasing order.

5.1. Teachers and mysteries

Once again the mysteries were in line with the curricula. The results are similar to the ones obtained from period 2: 90% of the teachers estimated that the training helped them tackling aspects of the curricula. However, several comments underline the difficulty of interdisciplinary trainings. Biology teachers were not really interested in mysteries related to physics, and vice-versa. A wider reflection should be opened here among partners:

- Is it preferable to build disciplinary trainings that fit better with teacher actual needs?
- Is it preferable to keep interdisciplinary training that fosters links between disciplines, encourages interdisciplinarity and build bonds between teachers of often-separated matters?

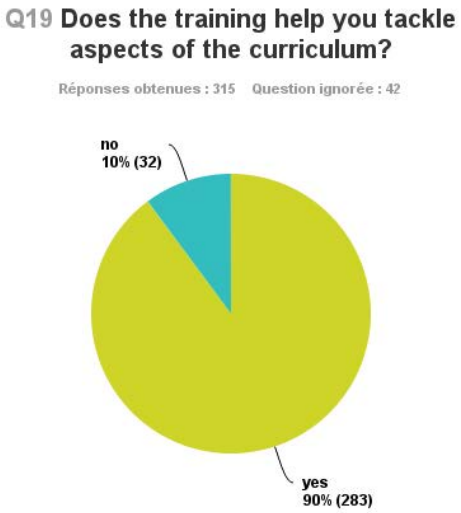


Figure 12. Final teacher questionnaire, roll-out phase, period 3. Distribution of the opinion of teachers concerning whether or not the training helps them tackle the curriculum.

Even though the teachers concentrated themselves on a smaller number of mysteries, 90% of them considered that the mystery presented were appropriate for their context.

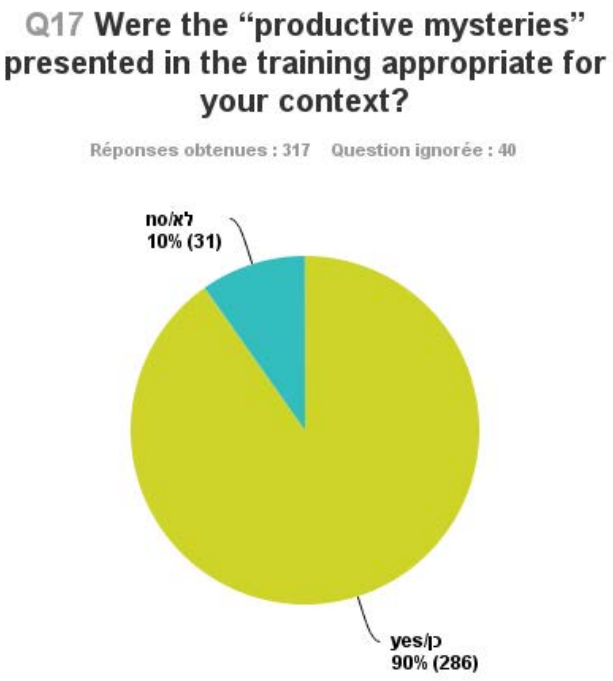


Figure 13. Final teacher questionnaire, roll-out phase, period 3. Distribution of the opinion of teachers concerning whether or not the training was appropriate to their context.

Below is the list of mysteries that that were applied at least in two classrooms. One should note that, out of 357 teachers answering the final questionnaire in period 3, 301 ignored this question. Thus, the numbers below enable to identify which are the preferred mysteries, but they do not reflect the actual number of times the mysteries were used. The low numbers and the variety of context do not allow to make particularly relevant comments on this aspects: qualitative appreciation of the different mysteries expressed by teachers locally remain more meaningful.

Name of the mystery	Number of times used
Sand Of Overseas	8
Genie In A Bottle	7
Disapearing Ink	6
Bottle with holes	5
Cola Mentos Fountain	5
A Lot Of Guts	2
Colour Changing Pens	2
Floating Egg	2
Lung Capacity	2
Never Wet	2

Figure 12: Final teacher questionnaire. List of mysteries most used by teachers.

The variety of mysteries used is lower than during period 2. It is possible that the teachers concentrated more on the most successful mysteries, already identified during period 2. One could be surprised that the large amount of productive mysteries resulted in an apparent small diversity of mystery used in the classroom. Teachers did concentrate on the mysteries that were relevant for curricula, efficient with students, reliable and easy to use. This narrowed to the list to a dozen of mysteries.

Regarding the presentation method, demonstration is still the main way used, with a rather strong use of storytelling as well. A small portion of the teachers also appreciates video. Proportionally, more teachers dared to use theatre during period 3 than during the previous period. These results may indicate that Showmanship was appreciated and sufficiently integrated by some teachers to lead them to use stories and even theatre.

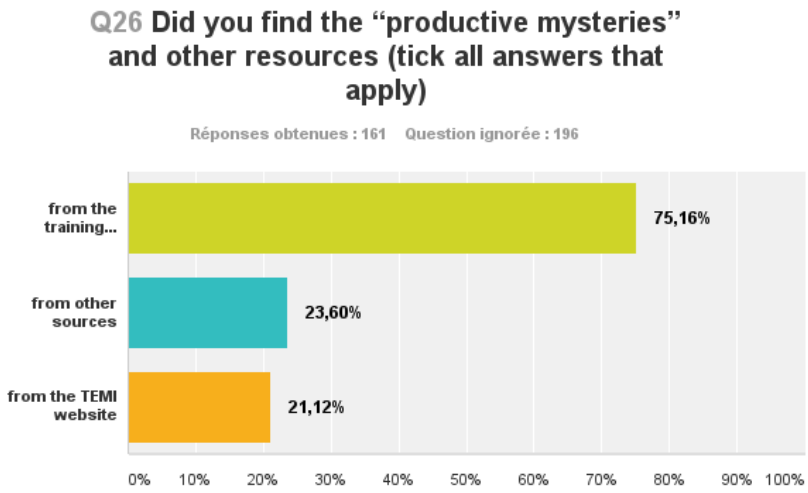
Presentation method	Number of times used
Demonstration	37
Story	23
Theatre	6
Video	6

Figure 14: Final teacher questionnaire. List of methods most used by teachers to present mysteries.

The main reason to choose a mystery remains its relevance to the curriculum and to the lessons the teacher intended to teach. However, some teachers also mentioned they chose the most easy to reproduce mysteries, or the ones that would have the stronger effect on the students.

"'[These mysteries were] leading into the topic of density and pressure which I was starting to teach to my class at the time" (a teacher from UL workshops)

Some teacher also developed their own mysteries, or found other sources. Figure … shows that only 75% of teachers did use the mysteries they discovered during the trainings. Though a significant number of teacher (21%) also used the TEMI website, a remarkably high number of them (24%) found mysteries from other sources. The most commonly mentioned external source of mysteries is the internet, but some teachers also mention their peers, some dvd or personally owned materials, or they even developed themselves the resources.



from the training workshops		75,16%	121
from other sources	Réponses	23,60%	38
from the TEMI website		21,12%	34

Figure 15. Final teacher questionnaire, roll-out phase, period 3. Sources of productive mysteries used by teachers, as declared by the teachers, in decreasing order.

6. The minimum thresholds and quantitative indicators

The minimum thresholds announced in the DOW and those agreed upon by the consortium are not particularly high neither binding. Without giving too many constraints to partners, some more minimum thresholds were set to ensure equal weight of partners in the project and general improvement of the TEMI brand.

As a reminder, the minimum thresholds agreed by partners were based on the achievements during the pilot phase, and on a set of important features highlighted in the literature about CPD success. The main sources used to elaborate them are mentioned below.

- Literature review by Working Group "Professional development of teachers" of Education and Training 2020 section of the LLP of the EC
- *Understanding What Enables High Quality Professional Learning*, Centre for the Use of Research Evidence in Education (CUREE)
- Benefits, status and effectiveness of Continuous Professional Development for teachers in England', Opfer, V. Darleen and Pedder, David (2010), Curriculum Journal
- "*Continuous Professional Development Among Primary Teachers in Ireland*" report, Joanne Banks and Emer Smyth's , ESRI, on behalf of The Teaching Council, Maynooth, 2011.
- *The Effects of Professional Development on Science Teaching Practices and Classroom Culture*, Jonathan A. Supovitz, Herbert M. Turner, University of Pennsylvania, Journal of Research in Science Teaching.
- Creating Effective Teaching and Learning Environments: First Results from TALIS 2009 (and 2013 results).

The most important points to watch for the success of TEMI were already highlighted in D7.3:

- Level of sharing with school
- Invited experts
- Time span
- Balance of programme
- Safe spaces to try, application, adaptation (in multiple contexts)
- Teaching of the TEMI methodology and cognitive strategies
- Materials and workshops fit teachers real life needs, links to local priorities
- Spaces for discussion between teachers, with staff
- Space to try mysteries, teachers as students
- Curriculum match
- 5th E (evaluation)

We will present below the results obtained as to June 2016 regrouped in three categories, represented in green (above threshold), orange (slightly below threshold) and red (well below threshold). We will then discuss upon the recommendations that were stated in D7.3 to see which of them were actually followed – and did lead to an improvement.

People concerned by criterion	Name of criterion	Figure to reach	Figure reached by beginning of June 2016
partners	Teachers answering questionnaire	> 90%	75% for the whole project
teachers	Level of confidence with showmanship	70%	59% total, 56% in the last period
teachers	Adapted the TEMI approach	75%	43% total, 42% for the last period
teachers	Application of TEMI lessons	> 80%	65% total, 62% in the last period
partners	Time between 1st and last workshops	4 weeks	Only one partner kept the duration under 4 weeks during the last period
partners	Hours of training per group of teachers	> 16	In the last period, all partners except one increased to be above 16 hours of face to face training.
partners	Cohorts per partner	6	All partners implemented from 6 to 8 cohorts
partners	Presence of all 4 innovations	All partners	All partners
partners	Communication to teachers before the trainings insufficient	<15%	5% in the last period
partners	Participation of partners to exchange of good practice (April 2015 meeting or video conference)	1	100%
teachers	Teachers taught the TEMI way with different levels	Mentioned by teachers in more than half the countries	
teachers	Satisfaction with applicability	75% ticked 1 or 2	81% in the last period, 81% in the whole project
teachers	Teacher feeling helped to tackle curriculum	> 75%	90%
teachers	Teachers declare that the training fits their professional needs	60%	82% total, 81% in the last period
teachers	Sharing the experience with colleagues or	> 50%	63% total, 62% in the last period

	management		
teachers	Teachers declare "productive mysteries" presented in the training are appropriate for their context	85%	88% total, 90% in the last period
teachers	Level of confidence with 5Es	30%	60% total, 58% in the last period
teachers	Level of confidence with GRR	20%	55% total, 52% in the last period
teachers	Level of confidence with IBSE	60%	77% total, 76% in the last period
teachers	Level of confidence with mysteries	50%	71% total, 70% in the last period
teachers	Lower rated satisfaction criterion of the 4 criteria	75 % of total number of respondents ticked 1 or 2.	Above 80%
teachers	Average of all satisfaction grades	75 % of total number of respondents ticked 1 or 2.	Above 80%
teachers	Teachers feel a higher motivation in their students	> 80%	Above 80%
teachers	Teachers feel that they mostly gained a motivation to renew their teaching	55%	59% total, 58% in the last period

The first remark would be that results between period 2 and 3 are almost identical, apart for a slight decrease in the level of confidence of GRR. A few improvement are however to be noted:

- All partners achieved the minimum of 6 trained cohorts, some went further up to 8 cohorts,
- Most of the partners increased the number of hours per training session to reach the minimum of 16 hours.
- The information sent to participants before the trainings was sufficient for a larger proportion of the teachers (95%)

Some difficulties remain, and in particular:

- The level of confidence of teachers in GRR and showmanship decreased,
- Most partners did not maintain the time between the first and the last workshop below four weeks. This led to a rethinking of the agreed time intervals, leading to the conclusion after collective discussion that is necessary to leave more flexibility to this parameter, in order to adapt to practical local issues, and to extend it in general.
- Application of the TEMI lessons were less frequent in period 3 than in period 2, and none reached the 80% threshold,
- Although a good number of teachers experimented the TEMI way in the classroom (65% in total), less than half of the teachers used it AND actually adapted TEMI to their own need.

The DOW indicates that each country should reach 60 to 90 teachers in total, adding up to 540 to 810 teachers for the whole consortium. At the end of the project, all partners reached those thresholds, and some of them even went way further.

The total number of trained teachers is 924.

7. Insights from other stakeholders

In order to understand the impact of TEMI on other stakeholders such as policy-makers, science centres, science education researchers or science education trusts and project managers, TRACES conducted semi-structured interviews during the TEMI Congress and through teleconferences.

The interviewed stakeholders were the following:

First name	Last name	Role	Institution
Nurit	Ron	Director of the Products Implementation in the R&D Division	Israeli Ministry of Education
Dorit	Taitelbaum	Chief Inspector in Chemistry Studies	Israeli Ministry of Education
Veronica	McCauley	Lecturer in science education	National University of Ireland, Galway
Claudio	Fazio	Physics Ed. Associate prof	UNIPA
Kirsten	Fiskum	University lecturer	Norwegian Centre for Science Education
Günter	Ruff	teacher and TEMI alumni, regional STEM in-service teacher education coordinator	GGS Schwarzenbek
Sotiriou	Sofoklis	Head of Research and Development Department	Ellinogermaniki Agogi
Jeff	Wiener	Teacher Programmes Manager	CERN
Martin	Hruby	Scientist, researcher on chemistry	Institute of Macromolecular Chemistry
Martinkova	Marketa	Vice Dean for students	Charles University in Prague
Wendy	Cox	National Primary Science Consultant	Ogden Trust
Wendy	van den Putte	Senior Project Manager	NEMO Science Centre

In the following sections, we will summarize the main insights from the interviews.

7.1. TEMI teachers to change the school system

The strength of TEMI is that it did not only rely on its approach and resources, but also on new networks of engaged teachers. Many partners and stakeholders noted that teachers involved in TEMI are usually highly motivated teachers, and their motivation was reinforced by the trainings. Moreover, the TEMI teachers built links together, and the training partners fostered the emergence of an active community of practice, first in their countries, and then at national level. This movement was reinforced by the TEMI congress, which can be considered as a great success in terms of teachers' engagement and community building.

In several countries such as Israel or Czech Republic, the TEMI teachers will act as "leaders", "specialists" or "guides". Their role will be to spread the science education innovations and to support other teachers in implementing them. Although they are not experts in the academic field of science education, their experiences in the classroom and their strong commitment are recognized by their peers and will help them "guide" other teachers towards new approaches.

"TEMI is great for highly motivated teachers, which will be the leading teachers for the following ones" (Martin Hruby and Marketa Martinkova)

Motivated teachers are also integrating new skills and behaviours. Veronica NcCauley from Ireland stressed that teachers are now becoming used to a variety of approaches and techniques, so they can now teach with mixed approaches to adapt to different situations, or to make sure that all students in a group got a way to "get in" the learning. Kirsten Fiskum from Norway recognized the emergence of more engaged teachers, who are feeling responsible for using innovations in the classroom. In other words, TEMI had its own Gradual Release of Responsibility process towards teachers. The trained teachers are not only implementing the TEMI way, they are now looking for science education innovations in a more autonomous way.

7.2. Education for the 21st century

During the last years curricula have started to evolve in Europe, in order to support students in building the skills that are necessary for the "knowledge economy" and the labour market of the 21st century. Some of these skills include creativity, autonomy, investigation skills or social skills. TEMI is well suited to build those skills, and has contributed in the partners' countries. The stakeholders identified TEMI and its resources as a very valuable asset: TEMI could play a major role in the evolution of science education in Europe.

The TEMI project has a variety of strengths to make change happen. First of all, it is recognized by all stakeholders as very practical and hands-on. Veronica McCauley underlined that the TEMI approach may be implemented in the next days following the training. Moreover, TEMI is based on already existing theories, which are well established in the academic field. One of the major successes of TEMI, as spotted by Günter Ruff from GGS Schwarzenbek, is to have succeeded in getting those theories finally reach teachers. Being built for an easy and immediate application, TEMI is linking the underlying theories with the actual education field (teachers in particular) and policy-makers. The TEMI project is seen as well-designed and well-positioned to make change happen.

TEMI is well-suited with many new teaching approaches that are now experimented in classrooms. The need for a new kind of teaching, in which the teacher does not know the whole answer, has been claimed by several stakeholders from Czech Republic, Israel or Germany. Claudio Fazio saw a link between TEMI and spontaneous learning, while Wendy Cox considered that TEMI was contributing to increase the confidence and autonomy of students.

TEMI has not developed new theories, everything is there already, but is difficult to take it to the teachers and TEMI is very helpful for this. (Günter Ruff)

In several countries such as Ireland, the curricula are changing and are more open to IBSE. This change will enable teachers to keep using the TEMI way even after the end of the project. These institutional changes are making TEMI much more sustainable. Wendy ven den Putte even expressed that the new "skills for the 21st century" now promoted in the Netherlands are interdisciplinary, which makes TEMI even more relevant.

7.3. Using the TEMI approach in new settings

Although TEMI was primarily built for secondary school teachers and students, many stakeholders identified new settings for which TEMI could be adapted. A large number of training situations, including informal education, university courses or non-scientific training could make use of the TEMI way, and apply the innovations to enhance the training process.

7.3.1. Formal education

The first of this new setting that has been spotted is primary schools. Wendy Cox from the Ogden Trust stressed that the 5E pattern and the student-centred methodology of TEMI fits will primary schools. Moreover, primary school teachers often have more freedom to experiment IBSE and the other innovations. Some of the qualities developed by primary schools teachers are also very relevant to the TEMI way.

"Primary school teachers are usually good as showmen" (Wendy Cox)

Some experimentation has been done in that direction during the project. For example, a two-hour TEMI workshop for primary school teachers has been implemented by UL, with a selection or an adaptation of the TEMI resources.

The TEMI way can also be relevant for adult training, from university and higher education to teacher training. There is sometimes a lack of connection between University teachers and science education. Claudio Fazio, from the University of Palermo, stated that using TEMI can be a way to link them and foster the use of science education results in university courses. Moreover, many university students will later teach in their own career. Claudio Fazio emphasized that today most of the science teaching in University is done in a traditional manner, whereas the more engaging pedagogy are taught separately. TEMI could enable students to learn science directly through these engaging pedagogies, thus changing the relationship that students have with scientific knowledge.

"TEMI materials and the 5Es are very relevant for teachers in their capacity to link real life classroom needs with something bigger. " (Kirsten Fiskum)

Kirsten Fiskum, from the Norwegian Centre for Science Education, explained that one of the challenges in science education was to keep teachers researched-informed – TEMI is directly tackling that issue: while TEMI is research-oriented, it also exemplifies how changing and improving teaching is possible in practice. Some TEMI elements will be integrated in new teacher trainings, for example in Israel, in the new training deleoped by the Be'er Sheva science centre.

7.3.1. Science Centres

In the course of the project, several partners established or made use of a relationship with science centres and museums. Institutions such as Science Museum London or Espace des Sciences Pierre-Gilles de Gennes

in Paris were involved in the training, and actors of the informal education field, such as Paul McCrory from Learn Differently, were active in the development, the implementation or the dissemination of TEMI. Science centres often have a variety of activities: towards students, teachers or other audiences, on-site or off-site. While science centres may use the TEMI way as a whole, many professionals stated they were more interested in choosing some specific elements to be integrated to some specific kind of activities. Their goal is not necessarily to apply TEMI as it is, but to steal some parts and make their "own mix".

"I am particularly interested in the way TEMI engages students through the use of mysteries". (Wendy van den Putte)

As mentioned above, Ron Nurit and Dorit Taitelbaum detailed how the TEMI materials will be used in the new Be'er Sheva science centre for activities and teacher training. Wendy van den Putte, from NEMO science centre, discovered the approach during the TEMI congress, and is now foreseeing to use some elements from TEMI in the science centre activities. First of all, Wendy van den Putte revealed that the 5Es would be the most relevant for classroom activities, i.e. activities offered by the science centre in classroom settings. The principle of mystery, and the mysteries themselves, is a powerful tool to engage students during the activities handled in the science centre. Wendy van den Putte also identified some elements of showmanship that could be useful for the science centre staff, and would perceive a TEMI training for NEMO's teams as very valuable.

7.3.2. Non-scientific settings

As detailed in the 4.1 section, the Leiden University had a conclusive experience in training non-scientific teachers to implement the TEMI way. Teachers in arts or other disciplines had to be motivated enough to build their own resources and classroom dynamics, but this effort was very rewarding.

TEMI can have a crucial impact on non-scientific students. Using IBSE, it may give them a sense of the way research works and science knowledge is built. Ron Nurit and Dorit Taitelbaum believe that TEMI can change the relationship that non-scientific students have with science, it may increase their understanding of what science is and what science is not. TEMI appears here as a valuable tool to enhance the dialogue between science and society, by conveying an understanding of the scientific approach.

"What we need to measure now is the impact of TEMI on students that don't study science" (Ron Nurit and Dorit Taitelbaum)

TEMI is also built upon independent reflexions and experimentations of the students, gradually giving them more and more responsibility. Thus, it is an efficient approach to build critical thinking skills among students, which are essential not only for scientists – but for all citizens. In some countries such as the Netherlands, the trend is now to use IBSE not only in STEM but in many other disciplines, to build a stronger engagement, a better learning experience, and to foster transversal qualities such as autonomy and critical thinking.

Last, TEMI can be used to get back students who are about to leave school. With a very engaging and student-centred approach, based on curiosity and observation, TEMI appears as a possible way to offer an alternative learning way for those who were about to give up school.