PROMOTING INQUIRY
IN MATHEMATICS AND SCIENCE
EDUCATION ACROSS EUROPE

CAPACITIES

The PRIMAS project: Promoting inquiry-based learning (IBL) in mathematics and science education across Europe

PRIMAS report on the results of the internal evaluation

The objective of the 'internal' evaluation, or more precisely a formative evaluation along the course of the project, is to provide particular insight into: the professional development (PD) process; the impact of the PD courses; the dissemination process; the impact of the dissemination actions during the lifetime of the project; and factors that either support or hinder the widespread uptake of inquiry-based learning. WP8 informs in particular the ongoing working process.

www.primas-project.eu

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

Project Information
Project no. 244390
Project acronym: PRIMAS
Start date of project: 01/01/2010
Duration: 48 months
Project title:

Promoting inquiry-based learning in mathematics and science education across Europe

Dissemination level
Thematic Priority: Science in Society
Funding scheme: FP7/ CSA/ Capacities

Information about the deliverable
Deliverable N° 8.3
Due date of deliverable: Month 48
Actual submission date: 20/12/2013
Deliverable title:

Report about results

Contact Information
Coordinator: University of Education Freiburg, Prof. Dr. Katja Maaß
Lead partner for this deliverable: University of Education Freiburg, Prof. Dr. Katja Maaß

Website: http://www.primas-project.eu/

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

TABLE OF CONTENTS

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

1. Executive Summary

1.1 Background

Regrouping 14 teams from 12 different countries, PRIMAS aims to effect change across Europe in the teaching and learning of mathematics and science by supporting teachers to develop inquiry-based learning pedagogies (IBL) so that in turn, students gain first-hand experience of scientific inquiry. Ultimately, our objective is that a greater number of students will have a more positive disposition towards the further study of these subjects and the desire to be employed in related fields.

1.2 Aims and purpose

The objective of the 'internal' evaluation – WP8, or more precisely a formative evaluation along the course of the project, is to provide particular insight into: the professional development (PD) process; the impact of the PD courses; the dissemination process; the impact of the dissemination actions during the lifetime of the project; and factors that either support or hinder the widespread uptake of inquiry-based learning. WP8 informs in particular the ongoing working process.

1.3 The theoretical background and method

Our activities are aimed at a variety of target groups and thus, the evaluation instruments must reflect this variety in order to measure the overall impact of PRIMAS. Therefore, as part of our multi-faceted evaluation approach, we developed different types of target-group specific questionnaires and a case study approach. This mixed method approach allowed for valuable feedback within the lifetime of the project without neglecting the cultural background of the individual partners. The use of this approach furthermore allowed us a process-accompanied and demand-actuated adaption of the evaluation concept, which was the main intention of the latter.

On the one hand, our questionnaires are based on the stages of concerns underlying the concerns based adoption model (Fuller, 1969, Bailey & Palsha, 1992). On the other hand, items from other dissemination projects were adapted (Swan, 2007). Conducting case studies – which comprise interviews with teachers, PD and classroom observations, and formative questionnaires – is a well-known methodological approach which allows the collection of in-depth information.

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

For the analysis of the formative data, a framework has been provided by the WP leading institution. The framework was supposed to be used as the basis for documenting key evidence across cases. The WP8 evaluation framework is robust and at the same time flexible enough to assess situations and implementation measures that involve a broad range of actors and actions across partnership nations. To allow for national differences, each country team could also include additional data it deemed relevant and of interest.

1.4 Summary and conclusions of the results of the internal evaluation

From the case study research it can be deduced that PRIMAS made a number of essential contributions to a widespread implementation of IBL in schools. At the same time, the case study research showed that systemic factors, biographical-background and deeply-rooted believes and behaviour patterns can impede a broad unfolding of innovative pedagogies like IBL in mathematics and science teaching.

Looking at supporting factors for teachers' successful engagement in PRIMAS activities, it becomes visible that their willingness to be engaged and to accept IBL as a means to improve their teaching and the learning of their students is of high importance. Teachers were aware, and this awareness improved throughout the PD course, that adopting an IBL perspective is demanding and requires much more preparation time and resources, and less 'teacher authoritarianism' during the lessons. Not everything was easy to be implemented, but the fact that students' results were rewarding was a strong motive for them to keep working on better IBL approaches and pedagogies during and after PRIMAS PD. Furthermore, the design of the PRIMAS PD emerged as the second factor that seemed to have a positive impact on teachers' progress. Particularly the possibilities to exchange with other teachers and try out IBL tasks in the PD modules encouraged teachers to reflect about their practices – and do so away from their usual, hectic routines at school. Putting themselves in the student's position also helped the teachers to appreciate the difficulties that students may experience when assessing each other. Further, peer-support within school supplemented the PRIMAS PD in some countries and emerged to be very supportive for a widespread implementation of IBL. Last but not least, the case study research also provided strong indications about the importance of other key placers, namely: competent and committed multipliers; dedicated school directors; and concerned and interested parents. These key players can provide

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

crucial support to teachers who are exploring the implementation of IBL in their classes, and further, these groups also influence teachers' and the uptake of IBL.

Within the case study research, teachers and the multipliers also reported a number of impediments to implementing IBL in day-to-day classroom practices. These include time; available materials; the required curricula/syllabus; and teacher pre- and in-service training on IBL. Such feedback from teachers and multipliers is not unexpected. For example, teachers do have limited time for working through the required curricula – and this time is often not sufficient for them to adopt extracurricular activities, such as the PRIMAS IBL approaches and activities. Therefore, many teachers struggle when it comes to implementing IBL on a regular basis. Another factor here is that, according to teachers, IBL-based lesson planning requires much more time and effort than more traditional approaches. This is an additional burden on teachers. The case study research also provided strong indications that helping teachers – and students – accustom themselves to these new and somehow different roles and become acquainted with the essential skills for IBL based approaches and activities may take a long time. This is particularly true because IBL is a new approach for most teachers.

However, these challenges can be overcome, if: a significant number of teachers act with the same passion (as the teachers accompanied within the case study research are doing) and systemic and structural challenges (like teacher professional development systems or curricular integration of innovative pedagogies) are addressed by policy-making bodies. Here, thinking of professional development as being long-term and the willingness to commit resources to teacher PD are key areas that will need to be addressed in policies. This is necessary to reach the overall aim: more students in Europe benefitting from the learning outcomes of well-delivered IBL lessons. Finally, dissemination activities for out-of-school-target groups may support the widespread implementation and promotion of IBL.

1.5 Recommendations

We are convinced that the three years of work within the PRIMAS project has helped make great inroads towards achieving the goal of implementing IBL in maths and science classes on a wide-spread basis in the European Community. However, we are also well aware that there remains much to be done before IBL becomes an accepted, practised and 'normal' way of teaching and learning in our classrooms. Therefore, based upon our work in, and analysis of the PRIMAS project, we feel confident in making seven recommendations to help inform future projects and achieve the most successful and wide-spread IBL

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

implementation possible in maths and science classes. Our recommendations appear both within this report in pertinent sections – and we speak to them in more detail in the last chapter. To keep in mind while reading the remainder of this report, here are the areas our recommendations concern: IBL classroom materials; PD modules on IBL; Education of multipliers; Importance of peer-support within PD courses and/or schools; Time for reflection; Overcoming barriers to implementing IBL – a task for future projects; Curricula and the assessment strategies – Necessity to integrate IBL processes; and School-context as influencing factor.

2. Report and results of the internal evaluation of PRIMAS

Within this chapter, we present the background and objectives of WP8, outline the theoretical framework and methods and then move on to provide the results of the formative evaluation.

2.1 Background and objectives of WP8

The main objective of the internal evaluation of PRIMAS – or more precisely the formative evaluation along the course of the project – is to investigate the extent to which the project has met its overall aim of a more widespread uptake of inquiry-based learning at schools within the partnership countries. The analysis of evaluation instruments which already have proven efficiency informed the development of the PRIMAS evaluation framework and instruments. The evaluation approach we developed is formative in nature. It aims at monitoring the ongoing processes of PRIMAS initiatives and informing these processes during the lifetime of the project in order to improve PRIMAS activities and materials. This allows us to tailor teaching materials, professional development courses, and other dissemination activities to the needs and concerns of the participating teachers and respective target groups. The investigation of different kinds of data - including process data (on the basis of case studies), promises to help us gain insight into factors that either support or hinder the uptake of inquiry-based learning in maths and science classes.

The main aim of the formative evaluation is to evaluate project activities as they are/were being carried out. This provides for immediate corrections. The formative evaluation thus gives a deep insight into the process and allows for quality management. It ensures that PRIMAS will be successful by helping to

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

improve activities and materials and by tailoring them to the needs of the target groups.

The relevant questions identified for formative evaluation are:

- To which extent can the approach of inquiry-based learning be implemented in day-to-day school practice?
- How do the teachers' beliefs about IBL and effective teaching evolve?
- How does the teacher's teaching practice evolve?
- What impact does the context have?
- Which supporting factors of implementation can be identified?
- Which inhibiting factors of implementation can be observed?
- What benefits, expectations and interests of those involved in the project can be identified?
- Which success is linked to the implementation of the multi-level dissemination plan designed in the project?

In order to ensure the widespread uptake of inquiry-based learning, the following target groups have been identified as key for PRIMAS activities and are thus included in the formative evaluation.

- Teachers and students involved in the in-service teacher training: Is inquiry-based learning actually implemented in lessons, and are changes perceived positively by teachers and students?
- Teachers and students not involved in the in-service teacher training: Did dissemination actions reach these teachers and students? Do they know about the project?
- Other stakeholders such as parents, school authorities, industry etc.: Do stakeholders know about IBL? How many people have been informed?
- Prospective teachers taking part in pre-service training: Are they willing to implement IBL? Do they see the advantages?

2.2 Theoretical framework and methodology

The formative evaluation comprises all important aspects the project tackles, including: dissemination through materials; the success of the continuous professional development approach applied to the project (as efficiency is not

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

proven in all countries, WP4); impact of supporting actions for teachers (WP5); dissemination to, and influence from, various stakeholders (WP6 and WP5); success of the informing policy (WP7); and most of all, the success of combining these actions. As a theoretical guidance model, an elaboration of Stufflebeam's CIPP-model (context, input, process and product information) was selected (Gusky 2000) that includes further facets and layers, as they are relevant to the PRIMAS project (see in more detail the introductory text to the WP8 deliverable 8.2.).

In order to meet the **different (evaluation) cultures in different countries**, the evaluation concept was designed to be as flexible, adaptable and applicable as possible to national backgrounds. Some countries, for example, have a strong tradition in quantitative evaluation. Others are more qualitatively oriented.[1] Thus our evaluation concept includes the following options:

1) Questionnaires (for different target groups, see also below): these have the advantage of being quick to administer and easy to analyse; they provide quantitative data;

2) Case studies: these provide rich data and a deeper insight into peoples' thinking and the relationship between different aspects;

3) Combination of questionnaires and case studies (This aspect is the focus of WP8).

In our **formative questionnaires**, items of the so called 'stages of concern-scale' and items for analysing the atmosphere, the relevance and the quality of the dissemination activity are used (see in more detail Deliverable D8.2).

The different kinds of scales are combined to analyse the success of the dissemination process. Therefore, the different target groups will be investigated with different questionnaires, but in all questionnaires the same relevant key items and key scales are used.

[1] This proved to be true within the work of WP8. Due to the different evaluation cultures, each country has set a different focus in the formative evaluation. Therefore, in countries with a strong tradition in quantitative evaluation, there was a great willingness to implement the questionnaires and pass them on to the teachers. Countries with a strong tradition in qualitative evaluation abandoned a full scale implementation of the formative questionnaires and collected more qualitative oriented data, such as interviews, PD and classroom observations as foreseen in the case studies.

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

The students' questionnaires need to be brief for reasons of feasibility. They are supposed to reflect only the used pedagogies in a lesson in order to mirror and compare what the teacher says about their lessons.

For prospective teachers who take part in a lecture course or similar activities, we cannot use the same questionnaires as for in-service teachers, as the former group is not yet teaching. Thus, the questionnaires for the prospective teachers contain scales about their concerns regarding inquiry-based learning, their intentions for the future and remarks on the course.

The questionnaires for the one-day-dissemination activities (different target groups) must be short for reasons of feasibility and acceptance.

- For teachers, these questionnaires contain scales about the activity, teachers' concerns in relation to IBL and their current engagement with IBL.
- For parents, the questionnaires contain scales about the activity, parents' concerns and hopes in relation to IBL, and their knowledge about IBL.

In addition to the formative questionnaires, a detailed overarching **concept of the case studies** was developed and finalised so that the quantitative and qualitative parts of the formative evaluation are used in the process of the project implementation, most importantly in the area of the PD courses for teachers. Conducting case studies – which comprise interviews with teachers, PD and classroom observations, and formative questionnaires – is a well-known methodical approach which allows the collection of in-depth information.

In order to make the case studies comparable, we committed to a common framework with a common research question. A definition of cases that should be covered within every country was constituted as well. One teacher and their evolution during the lifetime of PRIMAS comprise one case.

- Guiding research question: How does a teacher in their different communities of practice evolve during the lifetime of PRIMAS (in relation to their beliefs, pedagogies, knowledge)?
- Case study definition/kind of cases that should be dealt with in every country: At least two cases with specialist teachers (trained in subject), one in mathematics and one in science.

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

Data collection for the case studies involves interviews with teachers, PD observations and classroom observations to further contribute to the formative evaluation. According to the **mixed method design**, the formative questionnaires are additionally considered in the context of the case studies.

For the evaluation, a **common evaluation framework** – including common interview and observation schedules for offered PD and lessons – was developed. The common framework is to be used as the basis for documenting key evidence across cases. It factors both qualitative and quantitative data. The common frame is general enough to be used in each national context. It involves the work in other WPs and the underlying theory (cf. Annex I (DoW): spiral model – analyse, implement, reflect). Furthermore, the observation grid for PD courses and classrooms, as well as the interview questions, were developed with due consideration of the dimensions and categories that had already been established in the formative questionnaires (cf. teaching practice, teacher's beliefs, professional development). Within the evaluation, the principles of the PRIMAS professional development approach and the four phases in PRIMAS PD have been considered (cf. WP 4). Following the Participatory Intervention Model, there is the possibility of adapting the common framework according to national needs (Nastasi et. al., 1998). Within an international study, the utilisation of the Participatory Intervention Model seems to be expedient in order to be responsive to country-specific circumstances.

Besides the development of a common evaluation framework, we agreed on a **common method for data evaluation**: The qualitative analysis of content (cf. Mayring 2003). To this effect, coding categories were provided and were centralised within a coding agenda. This coding agenda could be complemented by the participants if categories had not been considered in the provided coding agenda and seemed to be of importance for the evaluation. Due to risk of change in meaning and nuance with data translation, each partner evaluated its own qualitative data – ending in two case studies per country. Results of the formative questionnaires (provided by the WP leader institution) were integrated within the studies.

2.3 Results of the internal evaluation of PRIMAS

To provide insight into teachers' evolvement during their participation in the PRIMAS professional development (PD) and to identify supporting or hindering factors in the take-up of IBL pedagogies, we analysed within each case study different dimensions. These included: teachers' beliefs on IBL; their own

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

teaching; effects of IBL on students; the PRIMAS PD courses; contextual factors; and the impact of dissemination activities on the widespread implementation of IBL. During PRIMAS lifetime, such data was collected and used formatively.
The results of the formative evaluation are built around the experiences and engagement of 24 maths and science teachers who have been involved in PRIMAS PD initiatives. In addition, they include all dissemination activities as reported in our project diary (cf. 2.2.6). Within this report, we present all results in the form of an overview.

2.3.1 Teaching in an IBL-oriented way – from the teachers perspective

Analysing the case studies, it becomes apparent that many of the 'case teachers' have very interesting professional **biographies** that include experience in other fields and/or professions beyond education. These range from previous careers in import/export, the pharmaceutical industry and politics (one teacher is a former mayor!).[2] Some teachers reported about extensive stays abroad, for example working in a foreign country as a teacher, or taking part in an exchange programme like Erasmus.[3] Especially during these stays abroad, many of the teachers first became acquainted with the IBL approach:

> *'I used to work at a school in the U.S.A. […] and that's when I got in touch with IBL and teaching science. [L]earning via IBL is very common in the general U.S. way of teaching'. (Teacher from Germany)*

> *'While teaching in the U.S.A., the book that I had to use was written for a workshop model method that included IBL […]. [A]t that time, I didn't know a lot about it (IBL).' (Teacher from Slovakia)*

Most of the teachers accompanied within the case study research consider IBL as a student-centred approach which involves self-directed but guided exploration, asking questions, making discoveries, and testing assumptions in search of new understanding:

> *'IBL includes discussion, exploration, explanation, reasoning, questioning, reporting and argumentation.' (Teacher from Malta)*

[2] Cf. Case studies from Switzerland, Hungary, Cyprus and Netherlands.
[3] Cf. Case Studies from Slovakia and Germany.

The project PRIMAS has received funding from the European Union
Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

'Firstly, [IBL means] developing and paraphrasing questions, what really is useful and important. This way of hypothesising is most important, as well as developing questions and discussing them with peers.' (Teacher from Germany)

'Inquiry is about giving priority to students to generate explanations and engage in critical discourse instead of not requiring any thinking at all [...] these (activities) include engaging the students in scientific questions, giving priority to evidence as students plan and conduct investigations in solving complex problems, students apply their knowledge to new real world problems, and engage in critical discourse with others about models, solutions and documentation.' (Teacher from Cyprus)

However, the implementation of IBL within class is seen as a **challenging but fruitful opportunity to design lessons in a different way** – in comparison to lessons which are designed in a so-called classical way. The teachers in particular emphasise the value of IBL and highlight the benefits that self-directed and inquiry-based learning has for their students:

'IBL is more challenging, but once you get the students accustomed […] then you have independent individuals who have begun to understand what they are doing. And I think that that is our goal. We do not want to have students who just sit and ask the teacher, "What do we do now?"' (Teacher from Norway)

'From our own experience, we know the value of having found something by ourselves, instead of having simply been taught the solution. When teaching IBL, students really learn an approach, they then have more keys for understanding, and they gain a better distance to the learning.' (Teachers from Switzerland)

The teachers also emphasise the **positive impact of IBL-oriented processes on students reasoning**:

'I have realised that there was an impact on students' inductive reasoning. I was impressed by the ability of some students to make robust conclusions, and support them using mathematical evidence, in the form of models […] students' oral participation has been dramatically increased […] especially the use of correct mathematical terminology, something that is not easy at this age […] students were very engaged to work in IBL tasks, especially those that involve the use of computers.' (Deputy Head from Cyprus)

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

'[There is] a change in the learner and the teacher's role in learning and teaching. The activity of students is put into light. The teacher is not the source of information, they have a minimal management role, they act like a facilitator. A change in the student and teacher behaviour, the individual learning is linked to collaborative learning and to cooperation with colleagues and teachers. The IBL activities overshadow the differences among students, so they support handling individual frustration and increase motivation. They produce a shift towards independent and responsible learning. Students develop skills in research, critical thinking, independent research etc.' (Teacher from Romania)

In this connection, some teachers indicate that in their own school days they loved teacher-dominated lessons – and so do some of their current students. But according to the teachers accompanied within the case study research, **student-centred lessons** (in which open questions and problem-solving tasks are getting implemented and students need to develop their own strategies in order to solve a problem) are more effective than 'classical lessons':

'I liked teacher-centred teaching and I think that students still do like it. But they won't learn that much since they won't have to solve a problem themselves. They will get the problem, the procedure of solution and the solution itself at the end. They won't have to deal with the problem themselves.' (Teacher from Germany)

In this context, the **importance of students exchanging with their classmates** is highlighted by the teachers:

'I discovered how important it is to get students to use that kind of opportunity (dialogue) to start figuring out what they know and what they might be able to learn from others. And then students might notice that they end up with an answer they may have thought they did not have.' (Teacher from Norway)

'Discussion and group work, it's not something I usually do, I will be honest with you. I am enjoying it now. I am still at the very early stage but I think I will do more … but I think it would definitely get better, the more group work one does and the more you are able to find that time to think and that helps your planning as well.' (Teacher from the UK)

Working with IBL involves a **change of roles**, both for teachers and for students: Teachers take up the role of a learning-facilitator and students will be awarded a very active part. The teachers interviewed highly appreciate this

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

change within the classroom but indicate that this was, respectively still is, a challenging process for them. There seems to be a conflict going on within some teachers who are trying to adopt IBL pedagogies and embrace a different role of the teacher in the classroom: from a role where the teacher occupies a central position in the classroom, source of all knowledge, who controls and oversees the learning taking place, to that of the teacher who facilitates learning, who believes that students should be the key-players. It is worth noting at this point that this struggle is even taking place within teachers who already possess several IBL characteristics and show a very good disposition towards it. One can expect a greater struggle and more difficulties in teachers who are less well equipped to accept this pedagogy. By analysing the case studies, it became clear that helping both teachers and students to accustom themselves to these new and somehow different roles and get acquainted with skills needed for IBL based approaches and activities may be a time-consuming process. Some teachers report that they feel like they are at a crossroads: caught between their traditional past and a desire, which is not immune to uncertainties and fears, to move towards an IBL pedagogy in view of its learning and motivational benefits:

> *'I am a rookie in need of more time to get used to this new type of teaching or rather this new type of philosophy.' (Teacher from Malta)*

> *'IBL had an indisputable effect. After a short period of teaching, I thought that at the mathematics lessons, the main role is not the role of teachers; it is the role of students. For this reason I fostered students (and sometimes even forced them) to discover new connections, to formulate properties and hence, to construct their mathematical knowledge (or at least a part of it) on their own work, not on some end product I present to them. This wasn't IBL, but had a few key elements from IBL. In a period my contribution increased and I was too frequently in the position of a scientist performing a lecture. The PRIMAS project somehow revitalised me, it strengthened my basic belief that it is worthy to seek for new (or simply other) ways in teaching classical contents.' (Teacher from Romania)*

> *'My greatest challenge is the fact of giving tasks to students to solve without helping them at all. I have to keep telling myself that whatever happens, I cannot help, otherwise they would not be truly engaging in IBL processes. Due to this, some tasks did not work out or they needed to be continued on other occasions as the students still lacked some basic knowledge that was required to go about the task I had given them'. (Teacher from Slovakia)*

Although IBL is seen as an opportunity to design lessons in a different way and to activate students' thinking and reasoning, most teachers still appear to see

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

IBL as something that can be distanced from normal teaching – teaching that in their view guarantees syllabus coverage and acquisition of skills and procedures. A reason for this might be a number of **impediments** that teachers are confronted with and that – besides deeply rooted traditional beliefs on teaching – **aggravate the implementation of IBL in day-to-day classroom practices**: the mathematics and science syllabi that should be covered; time available to plan and implement IBL activities; available materials; assessment of students and their performances when dealing with IBL tasks.[4]

Teachers emphasise that when IBL is new, they find **preparation time consuming**:

> *'I think the biggest problem is the [class] time and time for planning of it. Especially if you're looking at key stage four (14-16), if you're looking at a very, very heavy amount of content in the syllabus then, fitting in the time to do inquiry-based learning is quite hard. Because you've got so much to cover in a very short space of time, in our case, but also if you want to do it properly, it takes a lot more time to plan than a lesson where they are just getting things done that are required for the specification. So you know, you've got to kind of think, I can't do this all the time because of the volume of time it would take to plan, but we need to fit some in somewhere.' (Teacher from the UK)*

> *'Preparation is also a hard part about teaching physics by inquiry […] it requires so much time outside of the classroom. I need to find appropriate materials, and this is sometimes not easy, as our lab is not well equipped […] lesson design is demanding; I have to take into account many variables, and have everything well planned, if I want my students to actively engage into inquiry, and to actually deliver a student-centred lesson.' (Teacher from Cyprus)*

> *'My problem is that it (IBL) is highly time consuming […] so in many cases, I have to renounce due to other practical problems. […] Three hours is not sufficient for the whole activity if we work with students and we want them to make inquiries, this can create problems in scheduling the activities if we use regular lessons. I think […] my colleagues have the same problems.' (Teacher from Romania)*

This does, however, improve with experience, and the outcomes are more than worthwhile:

[4] PRIMAS research has shown that even teachers who are very experienced in IBL, motivated and engaged, struggle with the named constraints.

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

'Our concern was: Is this going to be something over and above the work that we already have? If so, then it is already difficult to manage to cover everything; but then we realised that this was a normal lesson and then we were not so worried or afraid. I still would say that lessons with IBL are more time consuming. That's definitely so, but I think that at the end, they are worth it because what the student has acquired is a lot better than in a traditional lesson.' (Teacher from Malta)

'Of course it takes a lot of time but it is not something additional. Actually, I learned to use IBL to work on mathematical content. Students learn things in a much deeper way and understand more.' (Teacher from Spain)

Furthermore, **working with IBL tasks** is described as **'unpredictable' in terms of outcomes**, and consequently – according to the teachers accompanied within the case study research – problematic with respect to syllabus coverage, planning and sticking to the plans made. A Maltese teacher spoke at length about these systemic difficulties linked to IBL lessons:

'Within traditional teaching, textbook chapters are covered independently and this results in students not connecting what they have learnt, to solving problems. On the other hand, my main concern with IBL lessons is whether or not I would be able to cover the entire syllabus. Again, when I'm doing an IBL lesson I'm never that sure that I would be covering that part of the syllabus that I had in mind...unlike traditional tasks that target specific parts of the syllabus, IBL tasks can take you in different and unexpected directions as the underlying pedagogy involves a spiral teaching approach which can cover different topics at the same time. As a result, the planning of lessons involves a lot of thinking since you can only guess some of the objectives that the task could cover...students could come up with different ideas and new ways to approach the solution of the task with the result of altering the lesson plans all the time. A related problem is that you cannot prepare beforehand a definite scheme of work, as you cannot say which topics can be covered from the IBL task presented. Also you cannot predict the final result of the IBL task, as students have different abilities and they could deviate from the main aim of the task. But, on the whole, IBL is innovative and fun to do since it encourages students to work independently of the teacher...it is no longer a matter of simply having the teacher delivering the lessons.' (Teacher from Malta)

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

With reference to their lessons, some teachers mention setting non-routine tasks and a number of IBL processes that accompanied students' engagement with these tasks. However, **most teachers seem to be linking IBL exclusively to a particular type of task** – calling it 'non-traditional', 'open' or 'non-routine' – that acts as the catalyst for the students' engagement with IBL processes. The way of seeing this link between 'tasks' and 'IBL processes' was expressed more clearly when a Maltese teacher said:

> *'Basically, I present students with a task and they have to find a way to go about the problem using IBL processes and then they present and discuss their findings with the rest of the class. Obviously, I need to plan ahead to incorporate all this during the IBL lessons...I do an IBL lesson once a week!' (Teacher from Malta)*

This teacher's understanding – as well as the understanding of most teachers accompanied within the case study research – seems to be that IBL processes do not exist outside a teaching approach that is based on the presentation of similar tasks to students. It seems as if IBL is something that cannot be incorporated with a more traditional teaching approach. This explains why the Maltese teacher claims to be doing IBL only once a week. In their view, when not presenting in class what they call 'IBL tasks' that are prepared and discussed during the PD sessions in school, this teacher thinks they are not doing IBL at all. It is as if teachers consider the implementation of IBL in class as either black or white, that there is no space for the varying shades of grey. The dichotomous way of viewing lessons as being either IBL or not emerged clearly when a teacher said:

> *'I have very little experience so far in IBL teaching – a couple of lessons last year and an IBL task each week this year.' (Teacher from Malta)*

Another main concern for teachers when implementing IBL (or not) is assessing student performance. A main priority for interviewed teachers is in helping students to do well in their **external assessments**. According to them, mainly student assessment is counter-rotating to the IBL approach: Examinations in schools mainly focus on students' capacity for memorisation and are not oriented to contextual understanding, key competences and/or process evaluation – like the IBL approach implies. Therefore, teachers are in conflict to prepare their students for the exams or to implement IBL within class, which obviously doesn't go along with the existing requirements:

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

'My primary task is to prepare students for the next external assessment, which gives them a certificate that helps them in their future. They don't want more - and if I did more, well the first thing they would do is rebel. The next step would be that the parents would tell me that it is not my task to do this. That's the point at which I realise I don't want to come up against a brick wall.' (Teacher from Germany)

'I don't have the time to do modelling and IBL. I need to prepare the students for the external assessment.' (Teacher from Malta)

'Unfortunately, this type of teaching is not supported by the style and content of the final examination.' (Teacher from Romania)

It is true that in many countries, examinations and tests do not directly reward students for their ability to inquire and problem-solve. This is an issue that some governments are aware of and are trying to address. In the current UK proposals for reform, for example, there is a new emphasis on tackling unstructured problems. When teachers have tried to integrate IBL in a sustained way however, they have found that exam results do improve:

'I used to say OK so I'm using IBL then I have to rush the remaining topics … what if my students don't do well in the exams … many people will have something to say about it! Those were my concerns. Once that didn't happen I felt better… you have to think and plan ahead so that this doesn't happen, you need a lot of time management.' (Teacher from Malta)

'Some of my students did not do well in their half-yearly exams – they started to lose heart. However, their self-confidence improved once I used IBL activities with them. Their marks on tests also showed plenty of improvement.' (Teacher from Malta)

Additionally, teachers report that when they have brought themselves to implement IBL within school based tests, they sometimes struggled with **students' performances,** as they **are heterogeneous**. The assessment strategies provided within the PRIMAS PD seem to be a helpful tool for teachers to handle this challenge:

'I had difficulties with different levels of findings and processes that students went through. Some of them had problems even to come up with something. In the lesson, it wasn't the content that was the most important. I wanted to focus the students on the process of finding new things, like the "winning strategy", and describe it. It was quite

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

difficult to introduce this process in a proper way.' (Teacher from Romania)

'When evaluating students' performances, especially relating to IBL tasks, you have to tackle them partly a bit differently. […] I integrated IBL within tests and I assessed the tasks like our multiplier suggested. Also, I created "really normal tests" consisting of a part you can learn by heart and some questions where you have to combine different things. Also there was a question based on inquiry-based learning which was modelled to the lessons topic; this wasn't completely new but simply a similar problem we had within the lesson.' (Teacher from Germany)

A further challenging factor relating to the implementation of IBL in class that was named by some teachers in the beginning of their participation in PRIMAS is related to **student's behaviour**: they feared that working with IBL within a class of 30 students could be problematic in terms of classroom behaviour (noise and disorder). This fear, however, was refuted:

'For the first time, I implemented an IBL activity in a fourth degree class I was really surprised. I thought "it's impossible to do that in my classroom because my students will not be thinking about the activity, they will waste their time, they will talk about something else and the noise will be tremendous" Then, I implemented that activity, and, I was surprised that everyone was involved and engaged, even they were working in groups trying to obtain an answer.' (Teacher from Spain)

'I cannot let them work independently, with the full classroom (about 30 students). I need to take care of the discipline, so I couldn't allow them so much freedom.' (Teacher from Slovakia)

Looking at **students' achievements**, some interviewed teachers indicate that they struggle with differentiating the tasks to take into account students' various levels. In particular in the beginning of their participation in PRIMAS, many teachers feared that students – mainly **low-achieving students** – get lost within IBL working-processes and more guidance would be required for them:

'I found it very difficult to adapt the content and activities of the lessons for all learners. It is almost impossible to prepare for all possibilities that may happen in the classroom. For example, low achieving students need a different approach on specific levels of the understanding than the higher achieving students. For me as a teacher it widens the possible situation that I need to be aware of and react in

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

specific situations with adaptive questioning as well as instruction.' (Teacher from Slovakia)

Also, there were teachers who were concerned whether IBL would be effective for high-ability students:

> *'At first, I was not convinced that IBL would be effective - especially with high-ability students. I was concerned that these students might consider IBL a waste of time and not like it because they are used to explanations followed by many drilling exercises.' (Teacher from Malta)*

However, the concerns of the teachers relating to the adequacy of IBL for high- and/or low-achieving students could be refuted over the course of PRIMAS. Teachers finally indicate that IBL is suitable for all students:

> *'In the beginning I used to think that certain IBL is not going to work with those who are low-achieving but experience has shown me that this is not the case. I think this is something that I have learnt. One can almost say that I felt that with this type of student it works even better…. At first I was sceptical… I used to say: This will work with the good group, but not with the other group.' (Teacher from Malta)*

> *'What I've discovered […] because I have some students who have attention problems, dyslexia, different things. But when it's like let's say cram tests, concepts and stuff like that, then they perform poorly. However, when tests are about understanding, achievements are much better. I think these kinds of tasks are very well suited for these types of students.' (Teacher from Norway)*

> *'[That's] exactly the same experience I have, among other things, from the magic box. Students who otherwise are unable to reproduce and display their knowledge in a traditional test, when they sit and to try to find solutions on how the magic box appears inside, they make it absolutely brilliantly, and are is among the best in class. So there are a lot of the same kind of experiences we have.' (Multiplier from Norway)*

2.3.2 Lessons

It became apparent within case studies that although many teachers would like to have more IBL 'going on' in their classrooms, it can be quite hard for them to get started. Successful inquiry-based teaching requires more than having new learning tasks available which are suitable for the approach. It also requires teachers to develop new teaching repertoires. Changed roles, both for teachers and students, also result from applying the approach. Most teachers who

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

participated in PRIMAS PD courses – and who were accompanied within the case study research – point to the relevance that the above mentioned issues have for them. Considering these aspects within the case study research, more than 24 lessons were observed by the PRIMAS research team. (In most cases, two lessons per participating country.) The lessons were mainly geared towards IBL specific topics. Based on the experiences made during the observations, we would now like to share some insights into class actions. In doing so, we will outline the handling of the requirements that go along with IBL related processes for teachers and students.

Looking at the **arrangement of a lesson**, all interviewed teachers report that due to their participation in the PRIMAS courses they now implement IBL within their classes on a regular basis – more in science lessons than in maths lessons. This also became obvious within the classroom observations. Depending on the context, the target group and the learning aims, IBL oriented lessons took many forms: from mathematical modelling to experimenting to guided exploration. The scope of application also became apparent when PRIMAS staff members observed some of the lessons of the teachers who participated in project courses. One of the physics lessons that was observed in Switzerland was about the 'FriXion Pilot Pen', in which students explored how it is possible to erase pen ink. Another Swiss teacher offered a lesson where students dealt with a mathematical problem called 'the divided square'. In other lessons we observed, students dealt with various problems with titles like 'The measurement of a volume', 'Chemical burn', 'The Vitamin C content of an orange', or 'The bare essentials of polarity'.

Most of the **lessons observed were student-centred**: Students worked together in groups, going through a challenging set of questions that required them to piece together available information and their previous knowledge. Furthermore, most of the tasks involved processes like stating and testing hypotheses, measuring, experimenting, controlling variables and so on. Students were encouraged to think and discuss within their group and to infer. Most of the tasks were related to an every-day life situation, some of them were designed to be more open, others less so.

When working with IBL tasks, in most cases students were asked to provide reasoned explanations for their approaches and results. When they were stuck, some of the teachers didn't help too quickly, but allowed time for thinking before offering help:

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

'I ask students to exemplify or to detail their arguments. In most of these cases they are able to proceed further. If the student can't go on, I try to change the context in order to emphasise the problem. These modified contexts usually are related to everyday life.' (Teacher from Romania)

Within these processes it became apparent that questioning progresses during an inquiry is helpful for students – and teachers, as well. Within the lessons observed, some teachers asked questions like: 'How can you simplify this problem? What assumptions might be made?' Then, after the students had formulated the problem, some teachers continued to ask: 'Can you think of a systematic approach? What is a sensible way to record your data?' As data was collected, others asked their students, 'Can you see any patterns here? Can you explain why these arise?' Towards the end, the teachers' focus was on communicating the findings: 'How can you explain this clearly and succinctly?'

Another important point that surfaced from classroom observations is the **time factor** that was also mentioned several times by the teachers within the interviews. According to the interviewed teachers, carrying out IBL tasks is time-consuming. Most of the sessions observed were devoted mainly to the hands-on part of the lessons. In the case of a traditional recipe type of experiment, all of the experiment can be fitted in a 90-minute session, except perhaps the report-writing. But doing this investigation through IBL uses a lot more time, for example for students' discussions and their research processes. Many teachers feared (and their fears were sometimes were confirmed within their lessons) that all this time spent on one task means having less time to cover other work. This lack of time has influenced the teachers' actions as they tried to guide students in a designated direction:

'Three hours is not sufficient for the whole activity if we work with students and we want them to make inquiries, this can create problems in scheduling the activities if we use regular lessons.' (Teacher from Romania)

One of the important aspects in using the IBL approach that became apparent during the observations was that teachers wish to **create a classroom environment where students feel safe to speak out, even to make mistakes**. Students would feel that they were listened to, and that their opinion mattered. The classroom management supported by such a view of classroom culture is thus an important factor which needs attention when a teacher works with the IBL approach. The students not only need to feel safe in asking

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

questions, making mistakes and stating their opinion, they also need clear signals about which behaviours are acceptable. This turned out to be a relevant aspect with respect to positive student-teacher interaction and interaction between students:

> *'For example, I make mistakes too and students call my attention to it and calculate the task properly. I praise them for doing so and they like it. I think that is something that supports communication, too. Handling it this way: "Oh yes, I did it wrong. Sorry. You're right." I show students that mistakes are nothing bad. So they have the courage to show mistakes and to admit them. If they find the right answer afterwards, then they actually learned much more. They probably won't make that mistake again.' (Teacher from Germany)*

Closely related to this, the **importance of students' active participation** within lessons and providing them the freedom to make their own discoveries emerged during the observations. This attitude seems to be strongly influenced by teachers' participation in PRIMAS:

> *'After PRIMAS PD, I see the major difference in my interaction with my students. I was not that encouraged to talk to students and provide them such freedom to work on their own […] I used investigations and modelling problems, but I was rather in favour of a guided discovery, rather than a truly IBL approach. Now, I know that students can, and should be able to ask questions about the modelling procedures, set their own pace of working, and do much writing and documentation and less drill and practice.' (Teacher from Cyprus)*

A further aspect that emerged within the case study research is that there is a **difference relating to the implementation of IBL in maths and science classes**. According to the teachers interviewed, a reason for this is the nature of the subjects, which means that science subjects generally are more oriented towards the IBL-approach than maths. Even teachers who value the use of IBL seem to have concerns about a comprehensive use of IBL in maths lessons. They fear that when using IBL in mathematics classes, students won't learn enough mathematical strategies:

> *'In science, probably 90% of the lessons start with a question in the beginning or students do have to compile something. In maths it's a bit different. The time pressure is a bit greater: at the end of a school year, several things have to be done. Also in maths it's more difficult because students are on very different levels. In science you have a new topic again and again, which you can check off and afterwards*

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

there is a new one. In comparison to that, in maths topics are more connected. That makes it more difficult for me. It's the aim to bring the students to almost the same level. That's the reason why in maths it's more difficult for me and IBL is used maybe in 40% of my lessons to say it in numbers. […] In science we have more time. For example an experiment can last over a longer period of time. In maths there is less time. There is a task or question, for example, and based on that students can learn something new and come to a solution.' (Teacher from Germany)

However in the end of PRIMAS, an increased implementation of IBL could be assessed.

Looking at students' handling of IBL, teachers indicate that **students like to work in an IBL-related way** as these types of tasks are closely connected to their daily life, which is – according to the teachers accompanied within the case study research – different to non-IBL related tasks:

'The students are very open to these types of activities, they enjoy them because most of the problems are usually based on real life situations, and this is quite different from the usual tasks. The fully open problem situations usually create difficulties because they do not know how to start.' (Romanian Teachers)

Also teachers emphasise that their students like this method as they experience firsthand how maths and/or science work(s):

'Inquiry-based learning is the scientific approach, really, that students should get an understanding of through school, so that they know how science or maths works. I think that is interesting for students. How does a chemical experiment work, for example? What's in the beginning, what stands in the end, and how do I get there in single steps? Always by using problem-solving strategies.' (Teacher from Germany)

In accordance with the impressions reflected above, teachers commented on the **impact PRIMAS had on students' cognitive and affective developments** as follows:

'Alex (the teacher) has noticed a significant progress in students' achievement and attitudes. After a year in working with PRIMAS activities, Alex feels that inquiry-based activities have much to offer to students […] not only the high ability students, but also average and below average students. In fact, I have the same impression, although

The project PRIMAS has received funding from the European Union
Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

I am not very familiar with IBL and modelling […] Alex managed a balance between student-centred teaching, rich and world based activities, and progressed with regards to the syllabus. This is not an easy task for a teacher […] A teacher needs a lot of preparation and willingness in successfully implementing such an approach; this is not easy, but it is rewarding when you see the positive impact on your students' progress. Students not only improve their abilities, but they also develop positive attitudes to physics, and in other disciplines.' (Deputy Head from Cyprus)

'I also see the unique opportunities that come from implementing such teaching. Exploratory tasks allow students to use their own experience and logical thinking to a greater extent.' (Pre-service teacher from Norway)

Apart from the learning aspects of the IBL approach that are mainly linked to students' agency. Most teachers interviewed are particularly impressed with how **this pedagogy introduces the important element of fun for students** during mathematics and science lessons. Teachers talk about how IBL links learning with fun:

'In my opinion the students look forward to the IBL tasks as they find them fun to do and are different from a normal traditional lesson. Through IBL students are given the opportunity to discover, present their findings and have their say during a mathematical lesson whilst before the teacher was doing everything in class.' (Teacher from Malta)

The teachers accompanied within the case study research furthermore emphasise that **IBL makes substantial demands on students** as well, and they need time to adjust. Students need time to acclimatise themselves to the new classroom environment and to IBL challenges. Teachers report they felt that while an IBL lesson is taking place, students need a lot of support because they are used to being spoon-fed by the teacher who provides all the knowledge and the instructions so that all students need to do is to follow. The teachers also admit that motivating students to become active learners is not easy because a number of students remain passive, but add that one has to keep trying. Teachers report that within the lifetime of PRIMAS, students started to get used to the IBL-related working method:

'Students are more acquainted with traditional, transmissive lessons, so they have to learn to work in an IBL-oriented way. They have to

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

learn working in groups, but then, when they get used to it, they are very proud of what they find.' (Teacher from Switzerland)

'Initially it was difficult until the students got used to it. However, (I don't know whether I should have done this). But I had a quick look at the students' answers to the questionnaires and I was pleased with what they wrote, i.e. that they could talk, they could give their ideas, that they were not always the usual lessons where they just sit down and listen. So I think … at first it was difficult… they found it strange … saying "so I can just stand up and discuss…?" Because they were used to sitting down and listening.' (Teacher from Malta)

Some students, particularly those that have succeeded under traditional, transmission - oriented approaches, may take time to get used to the new, more active roles that are required of them:

'They struggle with such tasks and keep asking, "Why should I do that? Why can't you just explain it to us?" They sometimes don't concentrate on the task and therefore don't understand why they are supposed to do certain things since the teacher knows exactly how it works.' (Teacher from Germany)

'I met also some […] students who didn't like the IBL tasks, they think that they could progress faster if the teacher just transmits information.' (Teacher from Romania)

Teachers emphasised that it is important to explain to students the new expectations that they have of them: that they should learn to actively ask questions, seek answers, compare approaches and pursue their own lines of inquiry – without continually asking for help. They should also know how important it is to learn to work collaboratively, just as professional scientists and mathematicians do in the world around them.

Also within the case study research, it became clear that dealing with **IBL requires a lot of energy and self-confidence from students,** especially when they fail in the beginning of working with these types of tasks. Summing up – according to the teachers accompanied within the case study research – handling IBL-tasks remains a challenge, as well as a continuous learning process for the students:

'It is difficult for students if they have an idea of how the experiment should work and then it doesn't. They need to understand that this is no reason to give up, but try again with another hypothesis. They need a lot of energy, self-confidence and so on in order to say "Okay, I

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

accept that and walk on". But I think if they have experienced that this strategy worked a couple of times they might draw their self-confidence from those experiences and won't struggle too much with failures.' (Teacher from Germany)

With regard to the **data collected through students' questionnaires**, the results revealed a significant contribution of PRIMAS activities on students' cognitive, affective and behavioural gains. Depending on each PRIMAS partner country's evaluation culture, the questionnaires were administered twice. The first time was before implementation of PRIMAS in the class used for the case study, and again after completion of PRIMAS activities' implementation. Students were provided twenty statements in which they were invited to comment on the frequency of the occurrence of each statement in their classroom. Results were coded from *1: Almost never* to *4: Very often.*

The results revealed some significant differences between the data collection at the beginning and the end of students participation in PRIMAS. Quite interestingly, almost all students' answers improved between the first and the second administration. At the same time, students' results that are more connected to the concept and the process of PRIMAS and the IBL perspective have revealed significant differences.

Specifically, students feel much more comfortable asking the teacher questions and choosing which questions to work with. Also, it became apparent that students were keener to ask the teacher questions and had more opportunities to talk to and explain their ideas to the teacher. Interestingly, in the statement 'I choose which questions to do, or which ideas to discuss', the difference in students' answers average was 0.86, while the difference in the question 'I look for different ways of doing a question' was 1.00! (cf. Table No. 1)

Students changed their answers significantly with regard to the frequency they discuss their ideas in a group or with their partners. Students also reported using less time in memorising questions, instead spending much more time on discussions with their peers and their groups, and on working with real problems. (cf. Table No. 1)

Additionally, the analysis demonstrates that there is a strong correlation between students' confidence and their activity during a lesson. Students who have problems with their self-confidence do not fill an active role in the classroom. They stay very passive especially during the communication with the teacher.

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

Also it became apparent that during research processes, students gave up less often if they could chose the task. (cf. Table No. 1)

Table No. 1: *Means and standard deviations of students' statements with regard to their classroom behaviour before and after PRIMAS implementation (Country Case Cyprus)*

Statement	Pre test		Post test	
	Mean	s.d.	Mean	s.d.
I listen while the teacher explains.	3.41	1.33	3.36	0.79
I ask the teacher questions.	2.77	1.02	3.67	0.53
I am silent when the teacher asks a question.	3.64	0.66	3.41	0.67
I explain while the teacher listens.	3.00	1.07	3.27	0.77
I only do questions I am told to do.	3.72	0.32	3.32	0.72
I choose which questions to do or which ideas to discuss.	2.09	0.87	2.95	0.95
I copy down the method from the board or textbook.	3.55	0.91	3.09	0.87
I look for different ways of doing a question.	2.32	0.89	3.32	0.72
I practice the same method repeatedly on many questions.	3.73	0.46	3.50	0.67
I work on my own.	3.82	0.50	2.86	1.08
I discuss my ideas in a group or with a partner.	3.27	1.03	3.77	0.53
My partner asks me to explain something.	3.23	0.92	3.55	0.60
I make up my own questions and methods.	2.86	0.94	3.23	0.81
I do easy problems first to increase my confidence.	3.55	0.67	3.50	1.44
I memorise rules and properties.	3.86	0.35	3.45	0.74
When work is hard, I don't give up.	2.41	1.26	2.91	1.02
I try to connect new ideas with things I already know.	3.09	0.97	3.86	0.47
We design experiments to test out our ideas.	2.95	0.95	3.45	0.74
We work on problems that seem real.	3.09	1.02	3.82	0.50
We discuss our mistakes so that we can learn from them.	3.45	0.74	3.59	0.59

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

In conclusion, students seemed to agree that the PRIMAS impact was significant, and changed the classroom setting and practices in mathematics and science teaching and learning.

Furthermore, during the observations **students were asked how they personally judge IBL lessons**. Some of the answers obtained were:

- I like it better than other lessons.
- We learn more.
- I remember more in an exam.
- At first we found it difficult, now it's OK.
- It makes us think.
- In exams when we have a question that is more difficult and requires thinking, we say: OK so here we must think like we do during the Biology lesson to try to come up with the answer…
- We really enjoyed working as a group when we had visitors in class.
- This year I had a lot of fun during my maths lessons. I really loved doing different tasks rather than normal lessons because I found it easier to understand the point of the lesson…Some tasks were quite challenging too, but we had teachers to help us figure it out. I'll never forget these experiences and I hope that the following years will be the same!!! We have a lot of fun tasks…Apart from the tasks, I also like the lessons when the teacher lets us talk and share our ideas. I really liked these lessons.
- This year in the maths lessons we've done a lot of tasks, discussions and fun activities…It was a bit challenging but we succeeded as a group. To me, being in a group is better than being by yourself. Throughout the lessons, I've learnt a lot…
- I wish that next year we'll keep learning in this manner.
- I liked the tasks because I could participate instead of sitting down and just working on my own.
- Thanks to IBL I'm understanding mathematics better!!!
- This year I liked mathematics because we were using a new system […] I liked working with tasks because we could hear each other's opinions. Maths was not easy this year but bit by bit I began to understand…Overall I like the new system!!!
- This year maths was very special for me. I learn by seeing and doing things…that's why I liked the tasks and the experiments…I also liked

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

the idea that after doing the task, we go out of our place to present our ideas and to talk about how we dealt with the challenge.

- This year was a new experience because instead of copying notes, I had the chance to show my intelligence by working on different tasks […]. These tasks helped me to better understand maths.
- Thanks to the tasks, we covered a lot of topics at once. So for some topics we already had an idea about what they were.

The above excerpts from students' feedback reveal that they had already acquired some understanding of what an IBL-pedagogy entails and how this differs from the traditional transmission method of teaching mathematics. Indeed, their responses indicate awareness that mathematics can be learned through an integrated approach as opposed to an atomised one. They also appear to recognise the important role of learner autonomy in learning as opposed to being a passive receiver of knowledge. Moreover, the students comments reveal that they know how this active mode of learning is characterised, for example, by group work, discussions and presentations (all of which are ingrained in an IBL approach of teaching). It seems that these students were acquiring an understanding of this 'new' pedagogy through being exposed to specific lessons that promoted this way of approaching teaching and learning. The students not only appreciated the difference of IBL pedagogy from traditional teaching, but also saw its educational benefits and made requests to have more IBL-oriented lessons in the coming years. This is not to say that they saw no negative aspects to IBL. The following student comments present their main concerns:

- I found no problem with the tasks, but I would've liked more explanations. Then again, I understand that the teacher has a lot of topics to cover.
- …sometimes we could not really agree among ourselves.
- I did not really like the fact that not everyone used to participate when doing the tasks.

The rare instances that recorded students' 'discontent' with IBL activities in class were largely indicative of a level of unease that seems to be caused by the shift in how they perceive their 'new' role as learners of mathematics and science. For instance, some of them found it disconcerting that they could no longer rely completely on information being dished out by the teacher. Again, being more active as learners meant that different students were now reaching different

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

conclusions instead of simply regurgitating back teacher methods to reach the one prefixed correct answer. It is also interesting to note that possibly for the first time, students were realising that what other students do in class could affect their learning – this social dimension of learning is not an issue when teaching is teacher-driven and students are expected to work on their own/ work alone. Most significantly though, although some students did express a level of concern about IBL lessons, this was generally confined to getting accustomed to the 'uncertainties' that this new way of learning brought with it – and none argued outright against it. On the contrary, the students appeared very receptive to the idea and generally concurred that they want more of it in the future.

Finally, when reflecting on **students' development,** one teacher described as follows:

> *'By the end of their first school year, […] the students have a much higher understanding of the interplay between theory and experiment. They are now very familiar with the idea that one can dream up a model which subsequently can be made probable by experiments. They are also familiar with the idea that one can try out simple relations (proportionality and inverse proportionality) first, and then replace the relations with more complex relations if the former do not function well enough. The many games on variable control, which the class has played, have given them a much better understanding of this issue […]. Moreover, they have a really good understanding of how to fit real data with the program Logger Pro – using both the usual equations of mathematics, as well as their own equations. […] Finally, I succeeded in getting the students to understand that in some situations, we are content with a calibrations curve – without any deeper understanding of the relations behind the experiment (e.g. determination of rest metabolism) – while in other situations, we can introduce simple mathematical models in the description.' (Teacher from Denmark)*

2.3.3 Context: Supporting and hindering factors

Based on the results of the case study research, it becomes apparent that the context in which teachers' work does have an eminent influence on the distribution of IBL. Particularly, support from school administration and the head of school, cooperation with colleagues, existing learning and teaching materials as well as the backing from parents, are significant when it comes to IBL use in the classroom.

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

We would now like to look at **school-level factors that support or hinder the uptake of IBL**. In some countries, like Malta and Norway, the respective directorates for education arranged to provide PRIMAS participating teachers with a reduced teaching load during the two scholastic years of the PD courses. The school administration also made arrangements to ensure that the participating teachers had a common, class-free time during the week so they could meet. Meetings with multipliers occurred in the school, during school hours. This arrangement greatly facilitated the organisation and ensured that teachers could dedicate time to the meetings, preparation of new or modified lessons, and reflect on their performance and preparation:

> *'For me it was important that the principal had put time to it. Said that 1.5 hour each week is going to this, and you could sort of place it wherever you want, but you HAVE to meet. So, it was not just me offering them some sort of help, but it was time […] for it. It was important.' (Multiplier from Norway)*

This, however, wasn't the case in all participating countries – and could even change in countries which led by example due to shifts in school administration or the appointment of a new school director. Many teachers claim to receive **little support on school level**. They point out how the necessary changes in culture and beliefs require time, perseverance and support in order to achieve the aim of broad-based IBL implementation. Especially when looking at **allocating time for teachers' participation in PD** and **providing time for peer-work**, there seems to be little support on school level:

> *'In most schools it (PD) ends, as a principal believes that they have no time for it. They can't allocate any time for it. This is the first school I have found that has a good framework on doing professional development, because they spend time on it.' (Teacher from Norway)*

> *'When we were talking to the Head this morning, she wasn't sure that there will be her full support with regards to timetable […] obviously I hope that there is support from leadership, including higher up. Because on one side in the Science Vision document it's all about IBL, but then we need to provide situations that make it easier not more difficult because after all, the teacher benefits, the students benefit.' (Teacher from Malta)*

> *'I think it is partly the PD, but I think it is a general emphasis we have this year anyway, it is why we decided to take part in it. We knew we wanted to do more problem-solving activities, so it fitted in nicely. Whether we would have done some of this work anyway, I am not sure, but I think what it has done is it has given us the structure and*

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

the time to focus on it in a way that we might not have done had we not got these session built in. Part of all of our department meetings are meant to be CPD and teaching and learning activities, but nine times out of ten, we have got five minutes at the end.' (Teacher from the UK)

This is an important point: Good intentions must not only appear on curriculum descriptions, they must be followed up with the appropriate support, and include support at school level, otherwise, it will never go beyond good intentions.

Also, within some case studies it emerged, that the **school director's conviction relating to the importance of IBL implementation** within class was crucial for teachers' participation in PRIMAS PD. Some school directors did not support teachers' participation in the PD. This meant, for example, that some directors did not accept PRIMAS PD participation as a grounds for a teacher being absent from school. In some participating countries, this factor influenced when PRIMAS PD could take place. In these countries PRIMAS PD courses took place during school-free time (afternoons, weekends, school holidays). However, in other cases directors highly welcomed teachers' participation in the PRIMAS PD and indeed, this was often the reason for a teacher taking part in the PD:

'Mrs. XY was my mentor during my studies. That was the main reason for me to attend the PRIMAS PD and I knew it'd be fun and I'd like to learn about IBL.' (Teacher from Germany)

'I joined the PRIMAS project because my Head of Department motivated me to join the group. He truly believes in this IBL approach and has been trying to convince us about the benefits of adopting this teaching approach...I am also glad to say that my Head of Department has been an excellent mentor for us all at school.' (Teacher from Malta)

Furthermore, it turned out to be important that for the success of a project like PRIMAS, the school directors not only have to agree to participate, but that they include doing so in their school year priorities, i.e. in their 'action plan'. Written agreements about participation terms should also be reached between the school head and participating teachers (and signed by both parties).

Also, it turned out that in some countries – like in Romania – teachers are not treated as autonomous professionals. This means they always expect to have some central guidelines – and implementing IBL is not (normally) included here. Such conditions hinder the widespread implementation of IBL within these countries. Furthermore, in some countries **social conditions** – meaning social

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

problems on students' side or the lack of needed resources – **hinder implementation of the IBL approach**:

> *'In this school we have classes with only a few students, but most of the students have social problems at home (very low income, most of them from Romany families, etc.) so they need extra care and attention.' (Teacher from Romania)*

> *'"The teacher must teach" approach (is a problems we are dealing with), which suggests that students can be passive observers in school activities, the responsibility is assumed to the teacher's and is not shared between students, parents and teachers.' (Teacher from Romania)*

The implementation of IBL within class was relatively new to most teachers and their colleagues. Using these methods, and thus, IBL implementation, was a challenge for everyone. Therefore, most teachers emphasise the importance of having someone to lean on and someone who gives advice – like **peer-support and/or on-site help**. Teachers appreciated the opportunity of being able to share with other teachers the difficulties they experienced when trying to carry out IBL-related tasks that had been suggested during the professional development sessions:

> *'During our PD sessions, we have been made aware of how we can teach some topics and it has been a great development, met everyone's challenges. Given the idea you had there, it was good, and others can come up with some ideas about it, and might become a little more confident that they will manage this.' (Teacher from Norway)*

> *'So the fact that every fortnight we were able to meet and talk about our difficulties and discovering that we were experiencing similar problems helped a lot […] working against isolation.' (Teacher from Malta)*

> *'I love when we are working together. I think it is efficient and I enjoy it. The different ideas are very helpful for the teaching materials. Moreover, there are no hang-ups, jams that frequently appear when I work alone. I really like working like this.' (Teacher from Romania)*

> *'I think it has been nice to say the whole of these department meetings have been given over to looking at a particular issue and a particular topic. So I think it has given us the freedom as well as structure to talk about it a lot more and to talk about it as a team. We have our office, and there is a lot of discussion that goes on at lunchtime and a lot of swapping of ideas and sharing of resources and discussion of things that have worked and things that haven't worked.*

The project PRIMAS has received funding from the European Union
Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

And people sharing problem-solving activities. I think that is the effect of it, we have done more of that sort of activity with more confidence and we have discussed it more as a department because the CPD has made us devote the time to it; which we might not have done in the normal madness of a term.' (Teacher from the UK)

Another important topic that we found in the case studies is that existing **learning and teaching materials** do not support a more widespread implementation of IBL in school if these are (as is often the case) not oriented towards IBL. This is because such materials do not leave much space for students to make discoveries on their own. Teachers highlight the important role of textbooks and materials and that these can be either a lever for – or hindrance to – the dissemination of innovative pedagogies:

'Indeed I met the IBL approach during my studies at university, but afterwards as a teacher in school, I followed the methodical book, which is mainly content-focused and instruction-oriented.' (Teacher from Slovakia)

'I liked the idea (IBL) a lot, but unfortunately the approach was rather at a theoretical level […] I would like to work in that direction, but I had no materials […] when I first tried to do an open investigation in my class, I found great difficulties to provide students with freedom, to ask open questions, and to organise a whole class discussion […] I was not sure if that method (inquiry) could work.' (Teacher from Cyprus)

'Some teachers find even one of them (PRIMAS sample task) totally discouraging. Let us say, on the video clips we have watched, there is an abundance of coloured paper sheets, pens, pencils. One teacher may think that IBL is for those countries where teachers do not have day-to-day problems with living expenses, and, to turn back to the video clips, where the presence and use of stationery in the classroom is no problem (in terms of financial resources). But on the positive side, there are many enthusiastic colleagues who seem to be even motivated by the difficulties raised by the lack of resources. And a third problem is the permanently changing policy environment. Many teachers feel that completely new things may enter the curricula in every two or four years.' (Teacher from Hungary)

When implementing IBL in class, some teachers furthermore report on **challenges that are caused by students' environment**, for example by their **parents.** When implementing IBL, there is an understandable fear that parents and others will misinterpret teachers' intentions and believe that they are abdicating from their responsibility to tell students how to perform scientific techniques:

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

'After really nice lessons, where students were investigating the different approaches to figure out the area of a shape on a grid paper, some parents complained that the students do not have enough grades from mathematics. Experiences like this do have a negative influence.' (Teacher from Slovakia)

In teachers' experiences, however, this challenge has not been problematic when IBL has been carefully explained at parents' evenings and other events. Parents are reassured to find that students are still being taught the techniques:

'At the beginning, the parents of the 5th graders were a bit sceptical relating to the open questions. They would have preferred (it) if I dictated contents to their children which they could learn by heart. Therefore, I tried to explain to the parents what IBL is about. Practically, I gave each of them different stripes of chewing gum. I asked them to find out which of the chewing-gum stripes has the highest sugar-percentage. First the parents were just sitting there and were looking desperately for the wrapping of the chewing gums. Then most of them used their web-compatible mobile phones to solve the task. But I told them that their children aren't allowed to use their mobile phones within lessons, so parents aren't allowed too, either. Also I told them that we don't have a computer in the classroom to check possible solutions; so they have to think of how they could find out the sugar-percentage. [...] In using this task, I tried to explain to the parents what inquiry-based learning is about, simply trying to solve everyday questions with materials that surround you. And also to think about if the results you got make sense or not; or if you made some mistakes.' (Teacher from Germany)

'The feedback of parents is always positive because students enjoy the non-traditional activities and they share their experiences with their parents. I think we should use a comprehensive way of informing the parents, as well as involving them in our activities.' (Teacher from Romania)

Another challenging aspect that emerged from the case study research is that in most PRIMAS partner countries, the syllabi were not designed with IBL in mind. Consequently, the teachers accompanied within the case study research indicate that when teaching, the time they have available for completing the syllabus is not sufficient for them to adopt extra-curricular activities, like the PRIMAS IBL approaches and activities. In most cases, the **density of the syllabus** forces them to adopt the lecturing method in order to cover the required content – and leads them to limit the amount of hands-on practical work, problem-solving and IBL used in class. The excerpts quoted below also show the dilemma experienced

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

by some teachers who believe in, and want to, adopt IBL and yet feel that they need to ensure that they cover the entire syllabus:

> *'A difficulty is time and the syllabus […] we always complain about the syllabus. Our syllabi were designed ages ago, I don't think that they were designed with the IBL approach in mind, so if you want to use that type of lesson, you end up rushing through the syllabus … I wish that these activities can be incorporated, the way they are in the Form 1 and 2 syllabus, incorporated as part of the syllabus … so you won't feel that you won't be able to cover everything because of the time you are taking to cover a particular IBL lesson.' (Teacher from Malta)*

> *'Fulfilling the curriculum and finding enough time to prepare the students for IBL is really difficult. It's nothing you can introduce and complete within one year.' (Teacher from Germany)*

Even if teachers are greatly concerned that implementing IBL will result in failure to cover the whole syllabus, instead of giving up, at the end of PRIMAS they want to try to learn how to implement IBL better so that syllabus coverage will not be an issue:

> *'I have learned that through IBL, that with one task you can cover more than one topic and sometimes you even cover topics that you did not plan to cover. It offers a new way of how the teacher goes about covering the syllabus. So what I need to continue to learn is how to improve my implementation of this whole IBL process.' (Teacher from Malta)*

2.3.4 Professional Development

The professional development meetings between the multipliers (respectively the national PRIMAS-teams) and the teachers participating in the project mainly started in the beginning of 2012 and finished in the end of 2013. Depending on the arrangement of the PD courses within each participating country, the courses were designed in different ways. For example, teachers met for weekend courses, met several times a year for a day, or even met every fortnight. The meeting places varied, too. Some courses were run at a university, others were designed and held on-site, meaning they took place within school.

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

During the PD courses, the multiplier and/or the national PRIMAS-teams carried out the PRIMAS PD modules tasks. As foreseen within the PRIMAS spiral model[5] and similar to the arrangement of an IBL-lesson, in most cases, a discussion followed that most often focused on a challenging problem from day-to-day teaching. Teachers participated in these discussions, gave their views and described their experiences. Usually, the task to be implemented by the next session was introduced. Teachers also brought and discussed feedback related to the implementation of earlier tasks. During the PD meetings and in addition to working with the PD modules, teachers were encouraged to report on their difficulties, problems and dilemmas that they encountered during the process of being instructed to use the PRIMAS IBL approaches and materials in their classrooms – and to reflect on possible ideas on how to overcome these difficulties. In some countries – like Malta, the Netherlands and Cyprus – teachers were also encouraged to keep reflective diaries. During the PD, teachers were also asked to report on their feelings, observations and reflections on the workshops in which they participated. Therefore, the PD sessions not only provided teachers with food for thought, but it also gave them the possibility to air their concerns and to try to find solutions.

Teachers seemed to enjoy the working method, as evidenced in the interviews carried out and in other teachers' comments during the PD. Especially at the beginning, teachers were not confident about implementing IBL in their classrooms. This belief changed, however, during the PD courses. Gradually, teachers felt comfortable sharing their concerns, ideas and solutions to the provided problems, and about reflecting on their teaching approaches. When it came to the classroom implementation, most of the multipliers encouraged all teachers to try out various IBL activities in their classes, because according to them:

> *'Unless we try something in our classrooms, we cannot claim that this is appropriate or not [and] inquiry based activities need not only a lot of thinking and good preparation but also many cycles of implementation.' (Multiplier from Cyprus)*

[5] Visually, PRIMAS thinks about teachers' growth using a spiral model. The fact that the spiral is infinite, encapsulates the idea that teachers are continuously growing. Because the spiral progresses in a circle and somehow revisits old 'places', but at a higher level, encapsulates the idea that several cycles of implementation and reflection are needed. This process of growing could be described, in a very simplistic way as cycles of 'analysis – implementation – reflection'. (Cf. PRIMAS guide for professional development providers)

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

Looking at the arrangement of the PD, the teachers were satisfied with the PRIMAS PD courses. This was in respect to all aspects, including preparation, organisation and content. Teachers reported that workshop preparation workshops was good, and the objectives and procedures in general and the activities carried out and discussed in particular, were precise and clearly structured. Teachers mentioned in various cases that the provided resources were appropriate and with rich examples on how IBL could be used in teaching various concepts from sciences and maths. Teachers also commented on the content of the PRIMAS PD:

> *'The content of the workshops was very interesting, leading from existing problems in teaching physics to the potential alternative methods, like inquiry […] the activities were very challenging, based on real world problems, and required group work to be appropriately completed.' (Teacher from Cyprus)*

Looking at the **training time**, there are some teachers who claim that the PD courses could have lasted longer in order to achieve a much more fruitful implementation of IBL within class, and in order to give the teachers the security to deal with related challenges like: (a) limited resources and lab equipment, which make it difficult to use real world problems and interdisciplinary projects, (b) limited teachers' preparation in inquiry and problem solving methods, (c) high density of the syllabus forces the teachers to adopt the lecturing method in order to cover it, and (d) teaching time is not adequate for adopting a student and inquiry oriented approach:

> *'In our case we have done one year so far … I wish it was longer to be honest … because the first year you will meet certain difficulties and during the second year, you can work on them so that then you can improve even more during the third year … I would say that a three year span would be ideal.' (Teacher from Malta)*

According to the teachers interviewed, participation in the **PRIMAS professional development courses is highly rewarding** and they find that their efforts to implement IBL in class are worth it. Teachers state that their participation in the PRIMAS courses facilitated their use of IBL pedagogies in class and furthermore, helped them to get new perspectives on their roles within the classroom:

> *'Due to the PD, I became more comfortable in terms of open tasks and the implementation of IBL and I became more open-minded.*

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

Furthermore, the PD helped me to reflect on my lessons.' (Teacher from Germany)

'I am very happy with what I have learnt in this course. I have now so many ideas to try out in my classroom and I enjoy so much the way students are engaged […] working so productively with my colleagues has also opened new perspectives to my work.' (Teacher from Cyprus).

In the same manner teachers indicate that the courses **supported** them in their **professional development** and they also say it helped them **to better interpret the in-class activities and processes**. As one of them states in the interview:

'Not only do the PD courses give you ideas about how to implement lessons, but they give you the keys to interpret what happened and therefore the possibility to change and improve your teaching.' (Teacher from Switzerland)

'My participation in PRIMAS […] has really been a fruitful experience for me - both professionally and personally. It was very inspiring to see and discuss different ways of organising inquiry based teaching and to engage in practical inquiry activities yourselves. It was great fun!' (Teacher from Denmark)

In the teachers' own words, **collaboration, sharing and debates held with other colleagues attending the professional development course were helpful** because:

'While working on your own, you think that certain difficulties are only being experienced by yourself – and perhaps at that point you can't see a solution. When you discuss them with others, first of all you say: ah, so it's not just me … And from other people you may get an idea of how they are tackling a particular situation, from which you can learn. You may learn a solution, or you may accept that there is no solution to this particular problem'. (Teacher from Malta)

Most teachers' also value the **importance of reflection** during the PRIMAS PD – which is an essential component of the PRIMAS spiral model:

'Reflection during the PD is pretty useful because it makes you think about how you have done things in the past. So, otherwise it is just too easy to sit in the course and come to the next course a month later and in between... You intend to do something with it, but you are so busy that you forget actually to implement what you've done. By giving you an assignment you implement this and report on it during

The project PRIMAS has received funding from the European Union
Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

the next meeting and this really helps you to actively think, "Well..how am I going to do it?" and then after you've done it, "How did I do it?" or "What came out of it".' (Teacher from the Netherlands)

Working with students' tasks was furthermore pointed out as very helpful by the teachers accompanied within the case study research. Supporting students to find individual ways of conclusions without giving any concrete hints in advance was very interesting for most teachers. The teachers accompanied within the case study research emphasise as well that all PD participants developed **various solutions of IBL tasks.** This experience taught teachers about many new aspects which they would not have considered themselves. Additionally, working with students' tasks within the PD was helpful for teachers as participants were supposed to make mistakes within a **safe and encouraging environment**:

'As a teacher, that gives you security to try things out. You have the possibility to say: "Okay that didn't work". To find that out I think that makes sense.' (Teacher from Germany)

'This PD course strengthened my beliefs that it is useful and essential to look for new methods, approaches, viewpoints in teaching and also dissolved some of my concerns. I got acquainted with IBL activities that I can use in my daily practice. This course encouraged me to design new activities, to plan, perform and reflect on teaching materials, lessons and to have a process oriented perspective.' (Teacher from Romania)

Within these discussions, it turned out that **some teachers encountered some difficulties in acquiring the skills to adopt their new roles in the classroom**. As a result, some measures were taken to ensure that teachers would be capable of implementing an IBL approach in the classroom. For example, they were asked to collaboratively plan their lessons during PD sessions, and teach these lessons in their classrooms:

'While working on your own, you think that certain difficulties are only being experienced by yourself – and perhaps at that point you can't see a solution. When you discuss them with others, first of all you say: ah so it's not just me. And from other people you may get an idea of how they are tackling a particular situation, from which you can learn. You may learn a solution or you may accept that there is no solution to this particular problem.' (Teacher from Malta)

The project PRIMAS has received funding from the European Union
Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

Furthermore, teachers positively evaluate the **receipt of classroom materials which are well suited to use in class**. Particularly with regard to IBL, teachers point out that it is often difficult to obtain adequate materials:

> *'The materials developed in this project (and the collection realised) enrich my teaching toolbox.' (Teacher from Romania)*

> *'The PRIMAS materials are very good; you could really use them well in class. For example, within the PD we got a task relating to fractions. I could use it immediately in my class. That worked perfectly and that was really nice. […] Additionally, the IBL materials have a better clearness than materials from our school books. […] To find appropriate material is difficult. A lot of the material that is offered seems to be fine at first glance. But it turns out to be horrible at second glance. So you can just advise everyone: "If you want to do something like IBL, try it yourself before you implement it in class."' (Teacher from Germany)*

In this context, teachers rated the **PRIMAS material data base** positively; it helped them to increase their teaching repertoire. The tasks are of special significance for teachers because, based on their own assessment, there is not enough time to develop their own tasks during the school year:

> *'It definitely helped me. I saw there is a pool of tasks I can have a look at and get some helpful suggestions. It's always a problem to develop such a task by yourself; because often ideas are missing or even time. So the database is definitely helpful.' (Teacher from Germany)*

Nevertheless, some teachers claimed that the PRIMAS materials were not explicitly related to the content of the curricula and asked that PRIMAS materials be adjusted accordingly. Hence, at various times the multipliers decided to make changes in PRIMAS PD modules, so as to better fit their teachers' needs. The PRIMAS team responded to this demand and tried to design appropriate tasks covering topics like operations with natural, integer and rational numbers, symbolic calculations and representations, and operations with sets.[6]

Besides receiving materials and gaining insight into colleagues working practice, teachers hoped that by attending PRIMAS PD, they would receive **support with, and ideas of, how to combine different subjects in order to teach in a cross-curricular way**. They say that it is the teacher's responsibility to ask and

[6] Cf. Case Study from Romania.

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

train students to think in an interdisciplinary way. According to them, many teachers do not emphasise clearly enough during class how closely linked several disciplines are:

> *'The students are used to the attitude of doing two lessons of maths and then e.g. two lessons of chemistry afterwards. But they won't get how closely linked both topics actually are. One reason might be the teachers, too: We hardly ever show them the links between all the different scientific disciplines and maths. This deeper understanding is one of the most important things I've learnt during the PD. I want to teach my students that science is not only about learning stuff by heart. That is really important to me.' (Teacher from Germany)*

This request, however, was fulfilled over the course of the PRIMAS PD. Teachers expressed enthusiasm about using IBL and modelling in teaching science and maths in their classes, and in adopting a more interdisciplinary approach:

> *'At this workshop, I had an opportunity to think about some teaching problems and possible solutions, especially using a more interdisciplinary approach. Linking physics to other disciplines in solving real problems can provide a rich learning and teaching environment.' (Teacher from Cyprus)*

Additionally, teachers state that the PD was very useful for **updating their knowledge of new trends in the teaching of mathematics and sciences**. Getting access to new and contemporary approaches is quite rare, considering that there seems to be a weakness in teachers' preparation and support relating to the use of IBL in classrooms, which means teachers continue to adopt traditional learning approaches. Looking at the time when the case teachers were students, most of them emphasise that in their own schooldays, lessons were mainly designed in a teacher-centred way – which is frequently known as the classical method, respectively classical teaching behaviour:

> *'As a pupil and at university, I was taught predominantly in a traditional, instructive way, and haven't experienced IBL by myself. Today, if something is going wrong during my lessons, for me it is a challenge not to run back to traditional teaching and teach as I was taught. I try to transform my traditional believes into constructivist believes, but I know that I am not completely there yet.' (Teacher from Slovakia)*

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

Therefore, teachers highly appreciate the update of their knowledge within the PD:

> *'The impact PRIMAS has on my work is huge! Perhaps I cannot mention everything […] I have confirmed and extended my initial ideas that mathematics is evolving, and is changing all the time […] if you want your students to see the richness and beautiful nature of mathematics, you have no other option but to adopt an inquiry and investigative approach […] my confidence has been improved and I feel capable of designing my own activities […] I like what I see in my students' eyes.' (Teacher from Cyprus)*

> *'The course has helped me to learn about this methodology (IBL) which was previously unknown to me. So, I think that, although the first activities I implement will not be as good as I would like, over time I hope to increase self-efficacy.' (Teacher from Spain)*

Furthermore, teachers rate the **homework** they received within the PD as very positive for their acting in class. They highlight that the tasks animated them to find the courage to use IBL more often within class. In addition, it became clear to them that – especially relating to the use of IBL within mathematics – the use of this approach is reasonable for students, even though it seemed to be very time consuming in the beginning:

> *'What we felt most useful was to work with our own "homework tasks", share experiences on meetings, comment on each other's tasks, this has been the best.' (Teacher from Norway)*

> *'You know that within two weeks we will be meeting to discuss the homework thing, so you had to work on it … you had to find time and do it … rather than procrastinate and say: OK I'll do it some time.' (Teacher from Malta)*

With regard to the **data collected through formative teachers' questionnaires**, the results revealed a significant contribution of PRIMAS activities on teachers' cognitive, affective, and behavioural gains. We will now give insights into teachers' development based on the country case Norway. In doing so, we provide the most interesting answers teachers gave in the pre- and post-test questionnaire. We mention post-test-answers only when interesting differences appeared from the pre-test, i.e. we list only the most important changes. Here is a summary of the Norwegian teacher's answers from the first survey:

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

- Students *never* perform experiments where more than one right answer or method exists.
- Only in few lectures are students given the possibility to try out their own ideas or design their own experiments.
- In most lectures, Mr X gives his students precise instructions.
- IBL is not a part of his teaching practice, but he wants to increase the amount of IBL.
- He doesn't like his present teaching practice.
- He doesn't know how to assess students' efforts when using IBL.
- Students must undergo assessment schemes that do not value IBL.
- He agrees that IBL doesn't exist in textbooks.
- He has only very positive comments/answers to the PRIMAS-course.
- He would very much like to cooperate with colleagues who use IBL.

Here is a summary of the teacher's answers from the second survey (where these showed significant change from answers provided in survey 1):

- *In most lectures,* students perform experiments where more than one right answer or method exists.
- IBL is now a large part of his teaching practice, although not yet a part of his daily practice and he still wants to increase the amount of IBL.
- He is even more positive about the importance of IBL now than before the course (e.g. he strongly agrees instead of agrees that students benefit from IBL, that he wants to use more IBL, that he wants more support to integrate IBL).
- He now knows how to assess students' efforts in IBL.

Looking at the statements above, the teacher's progress through the PRIMAS PD courses was significant – this also became apparent in reactions and feedback during the interviews, the PD observations and the classroom observations. The teacher started sharing materials and ideas with other colleagues, initiated various discussions with other teachers in his school and within the PD courses,

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

implemented IBL within class on a regular basis and can explicitly state students development caused by the implementation of IBL.

The survey results are consistent with all the **final feedback teachers gave us about the PRIMAS PD**. In conclusion, the PRIMAS PD courses appear to be effective and appropriate:

> *'The PRIMAS PD model is probably the most impressive thing I have studied and worked with thus far! In my future mathematics and also science instruction, I will definitely want to implement this model because I believe it functions as an incredible tool to engage students in mathematics and science inquiry.' (Teacher from Cyprus)*

> *'It (PRIMAS programme) forces you to think in a different way, it forces you to see other opportunities and particularly evaluate yourself for what you are doing.' (Teacher from Norway)*

Additionally, some teachers **linked the PRIMAS PD model to contemporary teaching and learning of mathematics and sciences** – which also turned out to be very positive. Teachers explained:

> *'After the courses and the opportunities I had to run a few modelling activities in my classroom, I see that the focus today is on providing students with opportunities to think more critically and guide their learning, rather than just providing them with the information […] In parallel, that was how I was engaged in the PD course […] a teacher has to create opportunities for their students to gain a much deeper understanding of the concepts, and PRIMAS provides an ideal example on how to do so […] I try to make the students in the class feel capable […] not done through insincere praise, or inflated grades, but through the ways in which I try to interact with the students.' (Teacher from Cyprus)*

> *'With your courses, I have learnt that it is possible to design one kind of activity in order to obtain higher students' engagement. Usually, for students this means something that arouses interest and motivation.' (Teacher from Spain)*

> *'I think that my personal perspective on teaching has changed. I am not convinced that applying IBL methods will solve my problems, but I will focus on finding suitable IBL activities for my students and I will try to organise additional activities both for my students and for younger pupils (from the elementary school). Anyway, I will select my materials with far more care.' (Teacher from Romania)*

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

2.3.5 Multipliers

By means of the PRIMAS long-term PD courses, the project aimed to reach a target amount of more than 1200 teachers – this means educating around 100 teachers per partner country. We followed a cascade model to: guarantee the best possible education of the participants and also cope with the financial and/or practical feasibilities which go along with educating such a large a number of teachers. The PRIMAS team instructed the multipliers (teacher educators) and in doing so, pursued a consistent strategy comprised of three strands: learning-off-job; learning-by-job; and learning-on-job.

Most of the multipliers involved were teachers who had their own classes. This meant that multipliers had access to a class and were able to try out some of the things discussed with their own students. In some countries – like Hungary and Malta – Education Officers and NCP members were involved as multipliers, too. This was also beneficial as they may be in a good position to influence or advocate changes in policy, syllabi and assessment as a result of their first-hand experience with IBL in PRIMAS.

Multipliers' experiences with IBL varied. Some multipliers were already acquainted with the use of IBL in class even before they took part in PRIMAS. For others, PRIMAS was their first experience with this method. Especially the IBL-inexperienced multipliers indicate that the **PRIMAS PD not only had a huge influence on their teaching within PD, but also within their school classes.** Their manner of teaching seems to have changed from 'presentation style' to 'listening to students':

> *'I [realised] […] that […] just planning one lesson or one activity is, that there are much more aspects to think about […] than I did before. But in a way […] it gets more and more automatic, too. So it takes less and less time in a way. […] I plan differently, and I think my teaching is better, that the children learn more. … before, I think I planned just lesson by lesson, and that I […] sort of decided on the progression in advance, in a way, (say) for a month, or for a period of time. […] But now I have some problems or activities that I want to do […] So if we use more or less time, I just change the progression when we are working with it. So we have more of a, when I plan for a period or topic, I have other things ready […] and I am not using the book. Almost not. And I organise the children differently. […] and pose different questions.' (Multiplier from Norway)*

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

But even multipliers who are experienced with the implementation of IBL within class do report on challenges that have to be overcome when using IBL:

> *'The conception is very good. My problem is that it (IBL) is highly time consuming (for a new material the cycle is: invent, design, develop, plan, perform, analyse and repeat the last three), so in many cases I have to renounce due to other practical problems. I think some of my colleagues have the same problems.' (Multiplier from Romania)*

> *Even if I'm trying to use IBL tasks in my lessons, I know there is much more to learn. There are many topics without specially designed IBL tasks, and because of the lack of time (and sometimes the lack of a "good idea") I can't design such tasks for every lesson I want to.' (Multiplier from Romania)*

Looking at the **PD courses for multipliers**, most of them were designed in a way similar to the PD courses for the participants. Within all participating countries, regular meetings were held between the university project teams and the multipliers. Some of the courses were designed as weekend sessions, others as daily sessions which took place, for example, four times a year or even every fortnight. Within these meetings, sometimes PRIMAS PD modules were covered and tasks tried out, discussed and, when necessary, adapted. In addition, expected teacher difficulties and concerns were discussed (learning-off-job). On other occasions, the meetings or part of the meetings were used to gather feedback about what was happening in the schools, challenges encountered within the PD, tasks being used, and videos of the PD sessions were generally analysed (learning-by-job). The multipliers then adopted the same method with their group of teachers: introducing a topic, discussing it, doing the tasks suggested in the modules, trying things out in class and reflecting about the outcome (learning-on-job).

Encouraging the multipliers to start a self-regulated process, focusing on adapting PRIMAS materials and preparing their participation as trainers in the courses resulted in different reactions. This depended on the multipliers' background and prior experience. Some multipliers felt really confident about their capacity to run PD activities based on the PRIMAS materials. They felt comfortable with the PD materials and familiar with IBL pedagogies. For their courses, some of them even created extra materials and included activities of their own. Therefore in this case, the 'learning-by-job' phase was mainly focused on organisational issues and resulted in PD actions within a relatively short period of time. On the contrary, other multipliers felt insecure about their own capacity to run PD activities, and therefore demanded very detailed information on how to run a PD. They asked for a deeper reflection about IBL, as well as for a

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

deeper understanding of the PRIMAS PD modules. The 'learning-by-job' period in these groups was structured around study seminars. These focused on the PRIMAS modules and lasted much longer.

Closely connected to this, within the case study research it became apparent that **multipliers' beliefs on IBL influence the course of the PD**. This means that multipliers who are more open-minded and experienced with IBL create their PD courses in a different way than multipliers who are less open-minded and/or less experienced. At first glance, this factor might call the quality of the cascade model used into question.

Asking the multipliers to rate the **overall conception of the PRIMAS PD**, as well as the quality of their **education as a multiplier**, they rate it highly positively:

> *'This is a very good conception. This style of work should be mandatory and all participants should involve their colleagues. In our system, the whole IBL conception can be used regularly only if teachers are working in small groups, because no one can invest a very large amount of time and energy to develop material that is used once and is not tested in several contexts. In this way, the whole IBL implementation is in danger if these small, local communities are not formed and are not strong enough. The localisation of groups is very important because of the travelling expenses (especially time). The successful implementation of this method requires an active participation and a series of regular meetings in order to discuss the obstacles, difficulties or even for improving the successful ideas.' (Multiplier from Romania)*

Looking at multipliers' **preparation in terms of being a teacher educator**, most of them highly appreciate the support of the PRIMAS national teams. But there are some multipliers who wished for a more precise preparation relating to teaching methods which can be used during the PD and one (or a few) who it seems also expected to be instructed during the PD using traditional methods:

> *'I learned a lot at PRIMAS trainings. I analysed a lot of IBL tasks, I realised that standing at the desk and being a student is different than teachers imagine it. I think I can use this experience for my lessons.' (Multiplier from Romania)*

> *'I have never taken part in such a poorly organised PD program. I had to develop the equipments I used; I had to decide which instructional method to use.' (Multiplier from Hungary)*

Closely connected to the multipliers' preparation, the multipliers positively emphasise the **continuous mentoring on the part of the national PRIMAS**

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

teams. In most participating countries, multipliers were educated within **long-term courses** over a period of more than 13 months in, among others: IBL; formative assessment (e.g. questioning, feedback on students' written work, etc.); analysis of textbooks and analysis/amendment of mathematics and science tasks to keep/build-up cognitive demands; and using video as a tool for professional development. These long-term courses/mentoring gave multipliers time to reflect and evaluate their own practice and can be seen as a crucial ingredient for the success of the courses:

> *'I don't think I could have started something like this without going to this multiplier course. That was very essential for me, trying out everything first and […] It felt a bit, I was a bit insecure when I wanted to start, because I didn't feel I was, maybe qualified enough at the moment.' (Multiplier from Norway)*

In terms of the **commitment to the multiplier courses**, it appeared important to have a clear agreement with those teachers (i.e. that they would be expected to work as multipliers with colleagues), and it also seemed essential to have selected face-to-face sessions:

> *'I think I need to meet because it makes it more committing, in a way. You meet face-to-face.' (Multiplier from Norway)*

A further benefit of the PD multipliers highlight is the creation of **communities of practice**, in which multipliers supported and encouraged each other:

> *'It (collaboration and exchange within the PD) is very useful, especially in the planning of activities and in developing teaching materials. All different individual experiences and viewpoints are somehow concentrated and used to produce a better lesson, a better teaching material. I usually learn a lot from my colleagues at these sessions.' (Multiplier from Romania)*

Also the multipliers highly rate their **active involvement in the PD courses** and appreciate the experiencing parts of the sessions:

> *'I had the opportunity to try, explore, analyse and evaluate new, non-traditional teaching methods.' (Multiplier from Romania)*

Looking at the **venue of the PD courses,** the multipliers state that conducting them – both for multipliers as well as for teachers – in their own schools was really positive. This was the case, for example, in Malta and Norway. Many multipliers state that this helped them to link/shape the sessions according to their school context (aims & focus areas of the school) and their pedagogic practice. In doing so, the courses gained relevance for the work in their own environment.

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

Out of the participants' perspective, the multipliers felt that very important components of the PD course were the **PRIMAS PD modules**. Many multipliers reported on 'success stories' due to the well-developed modules within the interviews. Two multipliers specifically commented that they have used knowledge from PRIMAS modules in their further work, in terms of a) guiding their colleagues and b) teaching a new subject with focus on basic skills:

> *'I really like the clear structure of the modules, and the high quality of the materials, although there is weakness in relation to primary school and science.' (Multiplier from Spain)*

> *'From being a reluctant group of teachers, it has developed into very good meetings, and I understand that the involved teachers think that this has been helpful and good. Many have used the problems from modules we have discussed in their teaching and find it exciting. During the last year, we have focused on colleague guidance in our educational development. This matched very well with the work of PRIMAS, and we have brought with us a lot of PRIMAS into colleague guidance. (Multiplier from Norway)*

Within the PD, multipliers (just like the teachers) were given '**homework tasks'** which included trialling IBL and selected teaching strategies in their classes. From what some of them said, this provided opportunities for them to 'trial out' what they would teach as multipliers later. According to the multipliers, they adapted this strategy in their own PD sessions with teachers. Hence, they felt that this was a successful aspect. From conversations with multipliers we know that teachers were given tasks to trial out which included practising IBL and different teaching methods in their classes, before reporting back from their experiences and discussing these in the PD sessions. Despite the benefits that are connected with the homework, multipliers criticise the **high amount of it they had to do within their PDs**. They express that teachers generally have a large amount of tasks in their day-to-day teaching. It seemed difficult for them to fulfil the PRIMAS tasks on top of their regular work schedule, especially if the tasks needed a large amount of time for either preparation or practise. Since homework and reflections around teachers' own practice is an important aspect for the success, it is important to establish good and clear contracts with school owners and principals before the start of the project.

In terms of **what they, as multipliers, learnt most from the PD sessions**, multipliers said that it was mainly connected to the ways of 'planning' and 'thinking' about mathematics and science:

> *'Well, a lot of things really. But […] I think I learned more […] for me personally that there are a lot of elements in, or many more elements*

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

in teaching maths than you usually have time to think about because you are so short of time. So, it opened my eyes for […] thinking differently about it. And that what we learned in the sessions, it doesn't necessarily take more time. […] it's just another way of thinking in a way. Or another way of planning.' (Multiplier from Norway)

'I think with IBL it's […] at first I thought that I really had to change everything, but after a while I could see that these things I learned in the sessions are more elements to include in the maths teaching. And of course you already do a lot of those things from before, but it is another way of thinking when I was planning and acting in the classroom, than […] yes.' (Multiplier from Norway)

Additionally, the multipliers emphasise that the PD had a huge influence on their beliefs and/or strengthened them:

'This PD course strengthened my beliefs that it is useful and essential to look for new methods, approaches and viewpoints in teaching, and also dissolved some of my concerns. I became acquainted with IBL activities that I can use in my daily practice. This course encouraged me to design new activities, to plan, perform and reflect on teaching materials and lessons, and to have a process oriented perspective.' (Multiplier from Romania)

Looking at the PD sessions that were run by the multipliers, multipliers report that at first they had to get used to the **preparation for the PD courses**. Also the **new way of working** within the PD was challenging both for themselves and the participants. In line with this, multipliers indicate the most important experience of the multiplier education was the fact that IBL must be taught using IBL:

'It was challenging I think, because it is a different way of having sessions than I had experienced earlier. Because usually, teachers go to courses and they just sit down and get lots of information, tips and hints, and maybe smart things to find on the internet, but here we sort of […] it felt like we created it more … As a group. So it was more challenging.' (Multiplier from Norway)

'I felt really disappointed after the first session in combinatorics at lower-secondary mathematics course. I prepared a very nice lecture with interesting examples. Attendees, teachers, were […] how to say it […] did not agree with work like that. Only four teachers from the group of 25 tried to solve given problems individually. They told me, my lesson was not suitable for their daily teaching.' (Multiplier from Slovakia)

The project PRIMAS has received funding from the European Union
Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

> *'The main challenge for me is to create a very deep cooperation climate with the teachers I am working with in order to make possible the common work in designing, performing and analysing our activities. Most teachers are not comfortable when they have to teach in the presence of other teachers, and this can create an extra tension.' (Multiplier from Romania)*

In the beginning of PRIMAS, teachers apparently were not used to these kinds of activities in professional development, but more to lectures in connection with 'tips and hints.' Instead, in the PRIMAS course they felt they had to commit and work together as a group – which was evaluated positively, both by multipliers as well as by participants:

> *'When you just get information and sit like in a [lecture], it is more difficult to find time to try it out later. But it felt more committing in a way.' (Multiplier from Norway)*

The multipliers were strongly motivated and became more and more confident with their work during course implementations:

> *'In the beginning, (I) was a bit insecure. But it changed over time. After a few PDs, it became normality.' (Multiplier from Germany)*

According to the multipliers, the **participants of the PD are willing to implement IBL within class, but face many challenges**. Also, there seems to be a difference between the implementation in lower and upper school levels. This also became apparent within the teacher interviews:

> *'The majority of teachers react with open minds and actively participate in the sessions, but the main difficulty comes only afterwards, when they try to implement IBL activities in their own classrooms. The curriculum and time framework is very tight, especially in upper secondary school, so in most of the cases they cannot afford the luxury of IBL activities. The main challenge for us as trainers is to convince teachers that it is worth it to include IBL activities into their practise even if the environment is hostile, neither the construction of the curricula, the textbooks, nor the assessment is supporting IBL. In such conditions, for most of them the first reaction is that IBL can be used as a 'festivity', but not as a regular/casual activity. Most of them feel that it needs too much energy, because the general climate is against it.' (Multiplier from Romania)*

Due to these hindrances, multipliers report that a **main challenge was to convince the participants to implement IBL on a regular basis** within class – this however could be overcome over the course of PRIMAS:

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

'The general experience is that most teachers welcome the IBL activities. The consequence is that most teachers involved in CPD try to implement some of the IBL activities they saw/experienced at the PD courses. On the other hand there are only very few teachers wanting to experience something new, or develop new materials. For this reason, I believe we need to develop a series of new materials, even try to give a series of activities related to the same chapter. It is also important to give detailed descriptions and to organise more frequent meetings in order to support them when they lose their motivation. It is also important to ask them to bring their colleagues to our courses, because working in groups is more effective and one sip does not make spring.' (Multiplier from Romania)

'I think that the major result of training teachers in Romania is that the participants realised the importance, the possibilities and some practical tricks of using IBL. This training also emphasised a natural viewpoint in teaching and learning mathematics.' (Multiplier from Romania)

Out of the user perspective, the **multipliers also appreciated the PRIMAS modules and the handbook** as they felt it supported their work, in the sense that they were building their sessions on research-based theories and activities:

'The courses were useful for the participants. We have tackled a series of tasks that can be used with students. There were some activities that can be classified as being rarities (they were necessary in order to emphasise some major ideas), but especially for lower secondary school, we used a lot of materials that can be used directly in their classrooms. In order to increase the effectiveness of our courses, we should try to treat one or two major topics from the beginning to the highest level. I think our materials structured in accordance with a Van Hiele[7] levels type framework will be even more welcome.' (Multiplier from Romania)

'The theory input is important as well. I think for my group of teachers, it wasn't something I had created, but […] it was something that I had been taking a course in. It gave it a bit of authority. […] because ok this is research, these are things we know will help learning, and not just something that [the multiplier] has read and fancied or found out.' (Multiplier from Norway)

Asked about what **teachers/participants seemed to have learnt and appreciated most**, one multiplier said:

[7] The Van Hiele model describes how students learn geometry and emphasises students at early levels analysing properties and classifying shapes.

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

They discussed that a lot. (First)What the children learned to this question. Not just having a list of questions to choose from, but what will they learn? I think they also lifted […] [up from sort of the details. The details and the planning, and saw it in a bit broader perspective, about 'What are we actually learning when we are working with' […] 'I think they hadn't thought about it before, so […] I think for them it was just letting go of the book. It was just […] they had used it as a […] support […]because I think they felt a bit insecure about their own maths knowledge, and teaching maybe […]?I think they felt more confident leaving the book, or making problems, or modifying problems from the book maybe. (Multiplier from Norway)

In conclusion – and highly important – most of the multipliers said that they **would be ready to continue working as a multiplier**. They seemed to enjoy the 'multiplier role' of working with teachers on PRIMAS tasks. Multipliers describe their experiences as:

'A learning experience for all … in which one can develop and grow professionally.' (Multiplier from Malta)

'That [to be a multiplier again] I would certainly do again.' (Multiplier from Germany)

2.2.6 Implementing IBL on a widespread basis

PRIMAS aims to promote the widespread uptake of inquiry-based learning techniques. Fundamental to such a promotion are 'supporting actions' for teachers and out-of-school target groups. IBL professional development and classroom materials, together with the PD courses themselves, are core measures to fostering IBL classroom practices. Additionally, though, we carried out **various supporting actions in order to enhance the dissemination of IBL and its core ideas and concepts**. These actions need to involve and address the several layers of the pyramid model. This had already been established in the proposal, but our experience has fundamentally underlined this need. Without targeted supporting actions involving different systemic levels, the direct measures offered to teachers (such as PD courses), may not unfold their potential as they meet unsupportive, uninformed or even hindering climates. This could lead (in the worst case) to a costly investment with very little return on the long-term.

The supporting actions for teachers and out-of-school-target groups that have been carried out by the PRIMAS project therefore **covered a broad range of activities.** The scope of these included: information sessions for the offered PD courses; experiential acquaintance with IBL; large-scale dissemination events;

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

and online and print publications). All such activities are/were used and implemented depending on purpose and context (cf. dissemination activities listed in ECAS). In doing so, the National Consultancy Panels have proven to be invaluable panels as they provided advice and support in effectively reaching and addressing teachers and other groups. In order to carry out the actions in a concerted way and to provide for knowledge exchange during the project, actions needed to be documented and shared. This was done continuously with the help of the so-called **'project diary'**, an internal document and knowledge exchange platform. This continuous work fed into the collection of dissemination activities and the international guide for supporting actions for teachers, based on prior analysis done.

During the first stages of the project, a **broad range of dissemination activities were performed** in order to create knowledge and interest for IBL and to 'recruit' teachers, multipliers, schools and other key stakeholders for the professional development courses offered in PRIMAS. While certain supporting actions were directly addressed to teachers, many targeted other groups key to education that could support the work of teachers and the more widespread use of IBL. Such groups range from parents or students (see WP6 that targets these groups in particular) to teacher training providers, educational authorities and policy (see WP7 targeting the latter in particular), curriculum designers, textbook publishers, etc.

Supporting actions for teachers as they were carried out can be split into two areas:

1. They were directed to teachers and were designed to:
    a. help motivate teachers to participate directly in the project activities (e.g. informing and convincing teachers to become multipliers in the project or attend the IBL PD courses);
    b. reach a wider audience of teachers to benefit from the project results and to use IBL materials and teaching strategies (e.g. by publishing information about the PRIMAS IBL classroom resources available to anyone for free in a teachers' journal).
2. They were directed towards 'supportive groups' for teachers in their uptake of IBL teaching strategies – these are groups closely connected to the school system that have a significant role in supporting teachers' use of IBL. Groups included here are: head teachers, teachers' networks and associations, school authorities, curriculum & assessment developers, and teacher trainers.

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

Over the course of the project, the focus on dissemination activities directly supportive of the teacher training (category 1a) gradually shifted towards dissemination activities and supporting actions that had the potential to further link, strengthen and extend existing knowledge, networks and initiatives relating to IBL (that have been formed in- and outside PRIMAS) in order to create long-lasting effects and sustainability.

Within the lifetime of PRIMAS, we realised **more than 350 dissemination events** with **more than 35 000 face-to face contacts** with key target groups. The project diary reports the fact that every month of project lifetime saw us carrying out project activities. If the duration of the activities as reported under WP5 is considered, these were predominantly of a one day nature. This feature is reasonable for the WP5 activities, which are mainly aimed at piloting and advertising actions for teachers. Reported target groups are mainly teachers, but also teacher educators, school, university and graduate students, school authorities, and also policy makers. The activities realised cover short professional development days (not long-term, continuous PD as provided by WP 4) for teachers and students, evening meetings, summer schools for school and university students, competitions based on PRIMAS materials and partnerships such as Mathematical B-day, workshops for teachers, workshops for academic staff, colloquiums for university students, presentations and talks for teachers' networks and meetings with prospective teachers. Several one-day and long-term science and/or maths fairs were reported, too. It is noteworthy that there were several bilateral visits on various dissemination activities between partners (cf. WP5 dissemination activities reported on ECAS; esp. dissemination activities of the PRIMAS partners D, ES, GB, NO and RO).

Thanks to the internationally recognised professional work of the PRIMAS project partners, PRIMAS and IBL pedagogies were promoted at more than 25 conferences, congresses, symposiums and other international activities. PRIMAS IBL ideas have not only reached PRIMAS partner countries, but also other EU countries, including: Czech Republic, Belgium, Bulgaria, Ireland, Scotland, Greece and Turkey. Furthermore, PRIMAS was promoted on other continents: For example in the context of the ISDDE Conference in Boston, USA, the ICMI 2012 in Seoul, South Korea, the PME 2012 in Taipei, Taiwan and at a conference in Lima, Peru.

Venues for the reported events were not only universities, schools and conference facilities, but also public places such as museums, national science centres (Space Centre Leicestershire, STEM Centre in York, NEMO in Amsterdam) and also shopping malls. The project partners from Nottingham were also invited

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

to give their presentation at a meeting of the Joint Mathematical Council, held at the Royal Society in London.

PRIMAS also used existing media channels and publications to reach even more target groups. In order to promote PRIMAS and to benefit from other experiences, the PRIMAS partners were also in intensive contact with other EU projects, for example 7FP Fibonacci, Comenius DynaMAT and Comenius Math2Earth. This close link to other FP7 projects was also institutionalised within the ProCoNet education (Project coordinators network – founded by the coordinator of PRIMAS, Prof. Dr. Katja Maaß and Peter Gray from S-Team).

Taken as a whole and looking at the widespread implementation of IBL, PRIMAS has received good coverage at local and international levels.

3. Summary and conclusions of the results of the internal evaluation

From the case study research, it can be deduced that PRIMAS made a number of essential contributions to a widespread implementation of IBL in schools. At the same time, the case study research showed that systemic factors, as well as biographical-background, deeply-rooted beliefs, and behaviour patterns can hinder a broad unfolding of innovative pedagogies like IBL in mathematics and science teaching. In the following, we summarise supporting and challenging factors for teachers' successful engagement in PRIMAS activities and draw conclusions.

Supporting factors for teachers' successful engagement in PRIMAS activities

The **most important factor** for teachers' successful engagement in PRIMAS activities was their willingness to be engaged and to accept IBL as a means to improve their teaching and the learning of their students. Most teachers claim that IBL enables students obtaining deeper insight into the topics which cannot be provided by simply teaching in a traditional way. Most teachers have already implemented many different aspects of IBL in their daily lessons. Their students build hypotheses, develop questions, experiment and reflect on what they have done. By encouraging their students to discover, explore and critically reflect on several topics individually or in groups, teachers try to activate their students during lessons. Hereby, it is most important for them that the students cooperate and also state and discuss their opinions and ideas. Besides this, it became

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

visible that most teachers focus on providing meaningful lessons which are as true-to-life as possible in order to emphasise the topic's relevance for everyday life and young peoples' futures. Teachers seek to achieve this by teaching cross-curricular topics and aspects whenever possible. Teachers were aware, and this awareness improved throughout the PD course, that adopting an IBL perspective is demanding and requires increased preparation time, more resources, and less 'teacher authoritarianism' during the lessons. Not everything was easy to implement, but the fact that students' results were rewarding was a strong motive for teachers to keep working on better IBL approaches and pedagogies during – and after PRIMAS PD.

A **second factor** that seemed to have an impact on teachers' progress was the design of the PRIMAS PD. The supportive climate that was developed in the PD definitely had a positive impact on teachers' progress. Furthermore, most teachers highly appreciated the discussions with other participants and claimed these are very useful when it comes to implementing IBL in class. Trying out the tasks during the PD modules also encouraged teachers to think and reflect about their practices, which was not always possible in the usual daily hectic school routines. Then trying out tasks in class, receiving materials (i.e. IBL tasks developed for PRIMAS), and putting themselves in the position of the students also helped the teachers to appreciate the difficulties that students may experience when assessing each other. Peer-support within the school – which supplemented the PRIMAS PD in some countries – emerged to be very supportive for a widespread implementation of IBL. This last point is worth emphasising: Teachers who have no peer support either because they teach in small schools and are the only ones teaching a particular subject, or because they are the only ones interested in trying the new pedagogies, may give up trying to implement IBL due to isolation and lack of support.

As a **third point,** the case study research also provided strong indications about the importance of having competent and committed mentors – which in the PRIMAS project are referred to as multipliers – as well as committed school directors and parents that support teachers who are exploring IBL implementation. All these key-players influence teachers' actions and the uptake of IBL. For example, when there was an IBL-oriented attitude at school level, this 'positive climate' further enriched the teaching and learning environment that was generated. Looking at the mentors/multipliers, during the PD they were very keen on discussing, learning from each other and showed a great deal of interest in the professional practice of participants. They shared their experience and know-how gained throughout the PD. Especially noteworthy is that a lot of

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

teachers who took part in the PRIMAS PD are willing to continue exploring the use of IBL in class primarily because of two factors: (i) the reassuring presence and constant support of their multipliers and their head of school and (ii) the support they received from colleagues within the community of reflective practitioners that was evolving both among the PD participants, and the peer groups within school. From what teachers said, one may speculate that the more competent and supportive the multiplier and school environment are, the more 'courage' teachers have to advance in their teaching. These two characteristics may form the basis of future IBL implementation efforts.

Last but not least, it became visible that in addition to the PRIMAS PD courses, supporting actions for teachers and out-of-school target groups positively influenced the widespread implementation of IBL, and its core ideas and concepts. In doing so, more than 350 dissemination events with more than 35 000 face-to face contacts with key target groups were realised during PRIMAS lifetime.

Challenging factors for teachers' successful engagement in PRIMAS activities

Within the case study research, a number of impediments for the implementation of IBL in day-to-day classroom practices have also been reported by the teachers and the multipliers. These impediments mainly included time, available materials, the syllabus that should be covered, and teacher pre- and in-service training on IBL. Teachers are expected to encounter the following difficulties in implementing IBL pedagogies and modelling activities, when teaching:

First, teachers say that the time available to them for completing the syllabus is not sufficient for extracurricular activities, like the PRIMAS IBL approaches and activities. However, when technique is underpinned by deep understanding, it is retained for much longer and re-teaching becomes unnecessary. In addition, as students become more independent in their learning, they begin to learn new material for themselves and to help one another. In the long run, IBL approaches have considerable benefits – but this needs persistence. Also it is imperative that activities adopting an IBL perspective should be linked (to the maximum possible extent) to existing concepts and processes that should be covered in the specific class, according to the grade's curriculum.[8]

[8] Cf. PRIMAS Final Publication, p. 77.

The project PRIMAS has received funding from the European Union
Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

A **second factor** that seemed to have an impact on teachers' progress is, that IBL-based lesson planning requires much more time and effort than with the more traditional approaches. The teachers' burdens are increased. Especially when working with IBL related tasks, many teachers identified the diversity of students' solutions and the lack of prepared materials (which hardly exist in schools) as one of the biggest problems. This shows how important the role of textbooks and materials is as a lever to the dissemination of innovative pedagogies, or as an obstacle to it. Also it became clear that teachers are going to think of IBL as doing a special type of task. If this is (or remains) the case, they will only be able to afford to assign such tasks a couple of times a year. Teachers need to be encouraged to think of IBL in terms of shorter tasks, in terms of the development of a classroom culture, development of skills that they can work on in their everyday lessons with their students, rather than to associate IBL only with one-off, longer activities or projects. Teachers may need to learn how to decide when IBL is the appropriate pedagogy and when it is less appropriate in the planning of particular lessons. They also must consider when to provide more – or less – support to students. This factor depends on the material and concepts to be learnt – especially when students are still at an early stage in their development of inquiry skills.

A **final factor** we would like to point to again here is the amount of time teachers – and students need to get used to IBL. The case study research also provided strong indications that helping both teachers and students accustom themselves to these new and somehow different roles and acquaint themselves with the essential skills for IBL based approaches and activities may take a long time. Allowing this needed time may come at the expense of the syllabus, particularly since this is a new approach for the majority of teachers. It is not easy for teachers to change their role and position in class from that of a traditional teacher to that of a facilitator of learning, supporting inquiry. We may assume if a teacher who has the right knowledge and attitude is experiencing difficulty with changing their role in IBL situations – as became clear within the case study research –, it will be a lot more difficult for teachers who lack these attributes (prior knowledge, less positive attitude, and less conducive beliefs) to adopt IBL. This is indeed something that we need to think about if IBL is to be introduced. How will teachers who have no wish to embrace IBL pedagogies, who do not believe in IBL and who hardly know anything about IBL, fare when they are 'forced' to use it because the curriculum expects them to use IBL? How will their students fare – especially as the case study research showed that students need time to acclimatise themselves to the new classroom environment and to

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

IBL challenges. If students experience IBL very early in their science/maths lessons, preferably right from primary school, they will regard it as 'how science/maths is usually learnt', rather than something that they need to start doing differently at some stage. This implementation strategy provides students time to learn and internalise inquiry skills over several years of schooling.

However, we believe that all these challenges can be overcome if:

- a significant number of teachers get on board with passion (as the case study teachers are doing)
- policy-making bodies address systemic and structural challenges (like teacher professional development systems or curricular integration of innovative pedagogies)

Thinking about professional development as being long-term and committing appropriate resources to it are key policy areas that need to be addressed in order to reach the overall aim, namely: more students in Europe benefitting from the learning outcomes of well-delivered IBL lessons.

In conclusion, we would like to take this opportunity to thank the teacher educators, the pre and in-service teachers and their students who participated in PRIMAS. Their contributions enabled us to gain fruitful insights into their work practices – and were the basis of the project's success. Together, we will continue to promote inquiry in mathematics and science education across Europe – and in doing so, welcome your own feedback and involvement to help further our goal of preparing our students for their lives beyond our classrooms.

4. Recommendations

We come now to the **seven recommendations** that follow from our analysis of the PRIMAS project. Most of them have been made along with the presentation of our results in separate sections. In this final chapter, we would like to give a general overview of recommended future actions and initiatives our research has shown which are needed to further the work of PRIMAS and lead to the most successful and widespread implementation of IBL in maths and science classes.

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

IBL classroom materials

It became apparent that there is a lack of IBL classroom materials. To facilitate a widespread implementation of the IBL approach in science and maths classes, we recommend creating a wider basis of these materials. The PRIMAS material platform already provides a wide range of IBL-related materials and tasks. A further important contribution was made with the PRIMAS Final Publication.[9]

PD modules on IBL

In order to guarantee the most widespread implementation of the IBL approach possible, multipliers were educated within the PRIMAS project. This proved to be highly successful in facilitating their work and ensuring an effective and comparable transmission of the IBL-approach. We therefore strongly recommend developing and making available further PD modules that can be used by the multipliers when holding PD courses on IBL.

Education of multipliers

From our analysis it appears that the education of multipliers proved to be successful. However, when educating them, it needs to be considered that just as with the teachers they will teach, multipliers also need time to get acquainted with the IBL approach, and furthermore need support and guidance to learn to identify IBL in classrooms. We therefore highly recommend that sufficient time and resources be committed to educating IBL multipliers.

Importance of peer-support within PD courses and/or schools

Furthermore within the case study research it became visible, that for both, teachers and multipliers, peer-support is a crucial supportive factor for a wide-spread implementation of IBL. Due to this fact, we recommend facilitating opportunities for peer-support within schools and/or as an integral part of PD courses.

Time for reflection

Closely related to the latter, from our analysis it also appears that reflections of teachers relating to their implementation of IBL within class are of high importance. In order to facilitate these processes, we recommend using videotapes of participants' lessons as a resource for reflection and analysis.

[9] The PRIMAS Final Publication is available on the PRIMAS Website.

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

Overcoming barriers to implementing IBL – a task for future projects

From our analysis it also appears that there are several barriers which hinder a wide-range implementation of the IBL-approach. For future projects we therefore recommend increased focus on these barriers, e.g. assessment, and exploring ways of overcoming these.

Curricula and the assessment strategies – Necessity to integrate IBL processes

IBL does not seem to be considered within European assessment strategies on a regular basis. This is one main reason why many teachers struggle or even neglect to implement IBL within class. IBL is still often seen as an extra-curricular aspect, although it is included in many curricula. This might be due to the fact that many teachers consider the curricula to be too overloaded to include IBL. To counteract this and to enable a more frequent implementation of IBL within classes, we recommend connecting IBL to subject matter.

School-context as influencing factor

From our analysis, it also appears that the school-context, in particular the support from school directors and administrations, and parents, has a tremendous influence on the implementation of IBL within class, as well as on teacher/multiplier participation in the PD. We therefore recommend making firm agreements with schools before teachers take part in PD courses. Such agreements make processes most transparent, define mutual obligations, and furthermore, integrate PD courses as an integral part of schools' action plans.

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.

5. References

Bailey & Palsha (1992). Qualities of the stages of concern questionnaire and implications for educational innovations. Journal of Educational Research, 85(4), 226-232.

Fuller (1969). Concerns of teachers: A developmental conceptualisation. American Education Research Journal, 6, 207-226.

Garcia Garcia (2013): PRIMAS guide for Professional Development Providers.

Guskey (2000). Evaluating Professional Development. Thousand Oaks: Corwin Press, Inc.

Mayring (2003). Qualitative Inhaltsanalyse. Grundlagen und Techniken. Weinheim: Beltz.

Nastasi, Varjas, Schensul, Silva, Schensul, & Ratnayake (1998). The Participatory Intervention Model: A Framework for Conceptualizing and Promoting Intervention Acceptability. School Psychology Quarterly, 15(2), 207-232.

PRIMAS Final Publication (2013): Inquiry Based Learning in maths and science classes.

Swan (2007): The impact of task-based professional development on teachers' practices and beliefs: A design research study Journal of Mathematics Teacher Education. 10(4-6), 217-237.

The project PRIMAS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380.