

Primas

PROMOTING INQUIRY
IN MATHEMATICS AND SCIENCE
EDUCATION ACROSS EUROPE



Guide for supporting actions in promoting inquiry-based learning in out-of-school target groups



















PRIMAS stands for Promoting inquiry in mathematics and science education across Europe. PRIMAS is an international project within the Seventh framework Program of the European Union. Fourteen universities from twelve different countries are working together to further promote the uptake of inquiry-based learning (IBL) in mathematics and science.

Guide for supporting actions in promoting inquiry-based learning in out-of-school target groups

PRIMAS has developed this guide of actions to promote inquiry based learning (IBL) aimed at so-called 'out of school' targets. It goes beyond initiatives that directly target teachers and focuses on groups such as parents, extended family, students, stakeholders and the wider community. This guide introduces key concepts in addressing such target groups and presents a range of case studies which illustrate concrete actions that can be conducted.

	University of Education Freiburg Germany
	University of Geneva Switzerland
	Utrecht University Netherlands
	University of Nottingham United Kingdom
	University of Jaén Spain
	Constantine the Philosopher University in Nitra, Slovakia
	University of Szeged Hungary
	Cyprus University of Technology Cyprus
	University of Malta Malta
	University of Roskilde Denmark
	University of Manchester United Kingdom
	Babeş-Bolyai University Romania
	Sør-Trøndelag University College Norway
	University of Kiel Germany

Lead partner: Prof. Nicholas G. Mousoulides,
Cyprus University of Technology

PRIMAS Project
University of Education Freiburg, Germany
(Pädagogische Hochschule Freiburg),
Coordinator
www.primas-project.eu
Contact: Katja Maaß,
University of Education Freiburg, Germany

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1. EXECUTIVE SUMMARY

Promoting Inquiry in Mathematics and Science Education across Europe (PRIMAS) project aims to effect a change in the teaching and learning of mathematics and science by supporting Inquiry-Based Learning (IBL) pedagogies and practices across Europe.

While in today's technology-based society and economy mathematics and science are essential, as they provide knowledge tools and the foundations for more advanced training either in higher education or through lifelong learning. Nevertheless, several studies indicate the lack of mathematical and scientific competences of a considerable proportion of both adult and student population around Europe (IALS, PISA, TIMSS). Among the reasons identified, is that the majority of initiatives tend to focus on formal education systems and to underestimate the significance of other key players such as parents, community, stakeholders, and media. Among other activities, PRIMAS targeted these key players, with an emphasis on parents and the community, by running a number of activities in the partner countries that focused on engaging these important to students' learning key players.

Following recommendations from researchers and the EU policy levels that suggest that effective partnerships between schools, parents, and community are important area to be considered by policy makers, PRIMAS identified and included a number of factors which fruitfully engage parents and the community in the school mathematics and science in its activities. In this regard, PRIMAS objectives focus on: (a) analysing out-of-school target groups' relations and impact on current teaching practices and learning in mathematics and science; and (b) developing guidelines and practices to extend and improve parental as well as community involvement in IBL teaching in mathematics and science, as a means to enhance student learning.

The purpose of this guide is twofold; first, to provide teachers (and prospective researchers) with an essential reading on the philosophy and vision of parental engagement in mathematics and science education and second, to present a number of guidelines for successfully designing and implementing an activity that involves out-of-school target groups. These guidelines have revealed from a number of case studies that have been conducted in the PRIMAS partner countries. These case studies aim to inform involved key players and specifically teachers with successful strategies in setting an environment for engaging parents, community and other groups in an IBL framework for improving mathematics and science education.

This short version of the international guide is organised in three sections: (a) a short explanatory framework for the guide with a brief introduction to inquiry based learning in science and mathematics; (b) a brief presentation of the sociocultural framework for parental involvement; and (c) guidelines for teachers on how to design and implement an activity for engaging parents and the community in an IBL perspective of mathematics and science education. Three case studies (out of the 22 studies presented in the longer version

of this guide) that appear in the appendix present some concrete examples of good practice that took place in various PRIMAS countries.

A more detailed version of this guide, along with a larger variety of case studies contacted in all partner countries, can be retrieved from the project's website (www.primas-project.eu).

2. INTRODUCTION

2.1. About this guide – Aims and purpose

The Dissemination Guide for Out-of-School Target Groups aims to fulfil the requirements which teachers face when involving parents and the community in the education of children in mathematics and science. The purpose of the guide is twofold; at first, to provide teachers and researchers with some background information on the philosophy and perspectives of parental engagement in mathematics and science education and second to provide teachers and researchers with concrete guidelines on how to successfully design and implement activities to engage out-of-school target groups. These guidelines are recommended in a number of resources in the related literature and have been refined after the implementation of various activities that have been conducted under PRIMAS. The case studies aim to inform involved key players and specifically teachers with successful strategies in setting up an environment for engaging parents, communities and other groups in an IBL framework for improving mathematics and science education.

The guide is organised in three strands, namely:

- A short introduction to inquiry based learning in science and mathematics (a more detailed analysis of IBL can be also found in other PRIMAS reports);
- A framework for analysing and understanding the involvement of parents and community in school practice (as important groups providing the ‘general climate’ to support the use and uptake of IBL) and for improving this interaction;
- An analysis of the case studies conducted in the PRIMAS countries that involve activities for engaging out-of-school target groups, under the theoretical framework of parental and community engagement in mathematics and science teaching and learning. The analysis resulted in a set of guidelines for teachers for designing and implementing their own activity for engaging parents and the community in an IBL perspective of mathematics and science education.

Further to the three strands, three case studies (out of the 22 studies presented in the longer version of this guide) are presented in the appendix of the guide, as some concrete examples of good practice that took place in various PRIMAS countries. It should be clarified that the dissemination actions presented in this guide refer to event-based strategies, while publications-based dissemination strategies are out of the purposes of this guide.

The present guide can be considered as a stand-alone product, and it can be used in this manner. However it is highly recommended to be used in conjunction with the materials and guidelines (especially the guide for supporting actions for teachers) provided in PRIMAS website and in coordination with PRIMAS consortium members.

2.2. About the PRIMAS project

PRIMAS is the acronym of the European project *Promoting Inquiry in Mathematics and Science Education across Europe*. Founded under the 7th Framework Programme, PRIMAS brings together mathematics and science educators from 14 universities in 12 different European countries.

PRIMAS aims to:

- Provide insights into approaches to mathematics and science teaching that are motivational and enjoyable for learners;
- Support teachers with inquiry-based learning (IBL) pedagogies in mathematics and science;
- Provide resources and coordinate professional development for teachers and teacher educators;
- Support teachers, students and parents in their efforts to better understand the nature and importance of inquiry-based learning;
- Develop and work with networks of teachers and professional development providers in participating countries;
- Analyse and understand current policies in relation to inquiry-based learning and inform and work with policy makers to support improved practice.

Our aim is to reach the critical amount of teachers, students, parents and policy makers that will ensure a real and perceivable impact on daily teaching practices, students' learning, parental perception of school mathematics and science, and current and future policies.

Among the different actions PRIMAS is promoting, the successful implementation of a wide scale and long-term professional development (PD) programme in every country is absolutely crucial. Teachers are probably the most important actors in promoting a change in the way mathematics and science are conceived and taught across Europe. And together with the support they will get from students, parents and policy makers, they are the only ones capable of making this change really happen.

In order to support teachers during this challenging and fascinating journey, the PRIMAS site offers a wide variety of professional development resources and exemplary classroom materials.

2.3. Inquiry-based learning in mathematics and science education

According to the National Research Council (2000), inquiry in education is *'a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in the light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations and predictions; and communicating results.*

Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations' (p. 23).

In a narrow sense, IBL may be defined as a teaching approach which intends to promote learning by engaging students in any of the processes or activities typically involved in scientific research. These include: making observations, formulating hypothesis, defining problems and key guiding questions, designing and performing experiments and communicating results and evidence-based conclusions.

Within the PRIMAS project, there is a multifaceted understanding of IBL which does not only focus on the processes related to scientific inquiry but on other key aspects considered essential for an efficient IBL implementation. These characteristic IBL features are briefly outlined below:

Student activity

Inquiry based learning is a student-centred methodology which stresses the importance of the active construction of learning. Therefore, students are expected to pose questions, make decisions, design plans and experiments, discuss, collaborate, communicate results and provide justified answers and explanations when engaged in the inquiry process.

The teacher's role

Teachers are not considered as knowledge providers, but as motivators and facilitators of students' learning. For this purpose, specific teaching competences are required to subtly guide students and help them work in profitable ways. The use of questioning is one of the key teaching competences in inquiry methods. Appropriate questions can enhance students' reflection, critical and logical thinking and self-regulation. To this end, the ability to prompt constructive interaction between students when holding a discussion is crucial for ensuring the social construction of knowledge. Teachers should also know how to design and use unstructured tasks which offer appropriate challenges and provide rich contexts and scenarios to facilitate learning.

The classroom atmosphere

The classroom atmosphere is considered to be a key feature in the efficient implementation of IBL. It is important to establish a culture where there is not a knowledgeable authority but instead, ideas are respected and accepted according to their foundation and how they are supported by evidence and logical thinking. In this atmosphere, mistakes are considered to be learning opportunities and there is a shared sense of ownership and purpose.

The expected learning outcomes

Students are expected not only to acquire conceptual understanding of science topics and mathematical tools, but also to develop process skills and competences. Since IBL requires a student-centred, approach it encourages autonomous and life-long learning.

PRIMAS considers IBL as an essential ingredient to successful education. The following diagram shows five key aspects of IBL and highlights specific features that are characteristic of each perspective (Figure 1).

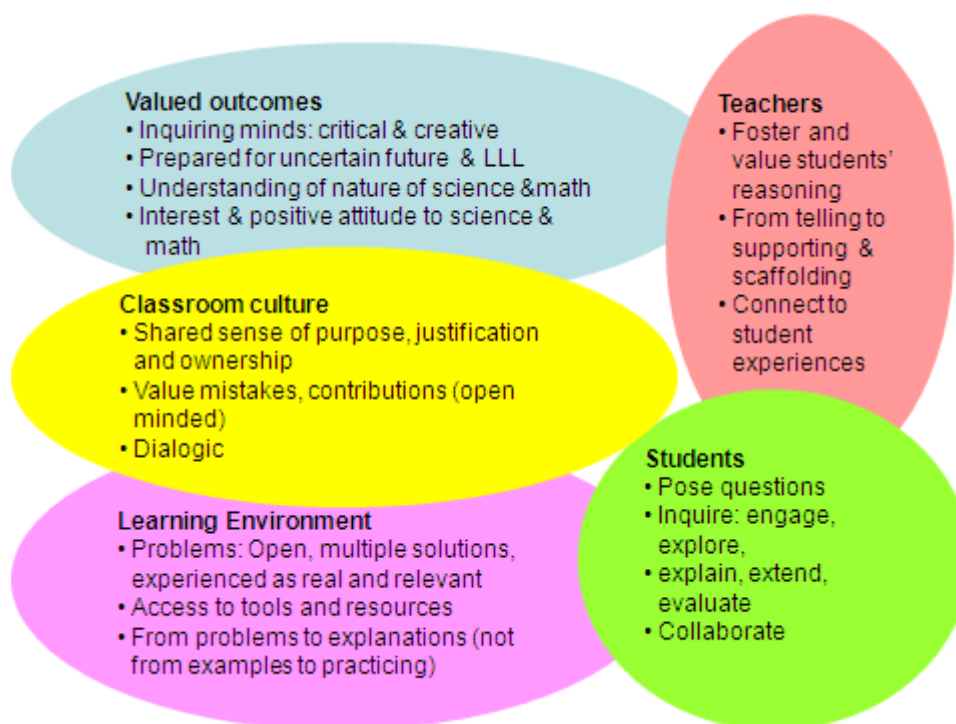


Figure 1: The key aspects of IBL

2.4. What are dissemination activities for out of school target groups?

PRIMAS points to the importance of intervening at more levels than the teacher/teaching level, by including interventions on the learning climate within families and communities and underpinning streams in our society at large. These attempts also include actions to involve media and policy-makers, as these are also identified as key players for the successful implementation of *Inquiry* in mathematics and science classrooms.

Research has shown that children at all grade levels do better in school, feel more confident about themselves as learners and have higher expectations for themselves when their parents are supportive of and involved with their education. There are various ways to engage parents in their children mathematics and science education, but this engagement and appropriate communication between school and family is not easy to maintain. To this end, this guide not only presents various guidelines on engaging parents in school

mathematics and science, but also provides concrete suggestions to enrich and maintain this involvement and interaction.

Dissemination activities that have been directed to students are also included in this guide since students are among the target groups as well. This is important for a number of reasons, including that Inquiry Based Learning is new to many students and may not fit into their beliefs about mathematics and science education. In consequence they may react negatively on teachers' efforts to include inquiry-based learning and thus prevent teachers from further efforts. Carrying out activities that directly target students, especially in out-of-school settings and with the participation (in some cases) of their parents has been identified as an effective mean to improve student attitudes towards mathematics and science in general and towards IBL in these subjects in particular.

Policy-makers are also a target group, since they are not only a key player in the adoption of research recommendations (from a project like PRIMAS) at the policy level, but they also have the potential to offer important insights into each phase of project or curriculum planning, implementation and evaluation. Policy-makers also have the potential to illuminate issues and needs during the course of programme implementation, and consequently, eliciting on-going feedback and keeping lines of communication open are crucial to programme success. PRIMAS activities that have targeted, among others, policy-makers include conferences and press releases, both at a European and national levels.

3. MAIN GUIDE

Acknowledging the central role of parents and community in children's learning, PRIMAS project aims to involve parents and other out-of-school target groups as a means to cultivate underlying home and community cultures as springboards for student learning in mathematics and science. Towards this aspect, the project has the following objectives:

- Developing materials for teachers to involve parents and other community members in IBL activities and pedagogies;
- Developing and implementing intercultural activities for parents, representatives of parent associations, and others involved in training activities for parents, as a means to facilitate the integration of IBL in mathematics and science teaching and learning;
- Developing and implementing intercultural IBL related activities for other out-of-school target groups, including community members and policy makers.

As parental involvement has been recognised as a key element to a child's achievement, parents, families and communities are among the groups PRIMAS targets for a comprehensive, holistic, and successful integration of IBL in school mathematics and science. To this end, parents are empowered to understand and collaborate in implementing IBL, providing a home environment that enhances children's scientific development and prepares them to meet the challenges of the 21st century.

The guide starts with a focus on research findings that support the crucial role of parental engagement in their children's mathematics and science education and the importance of communication and collaboration between school, families, and the community in improving mathematics and science teaching and learning. Building on these findings, the guide is not narrowed to activities and actions, but it rather builds on successful activities that took place in the various PRIMAS countries and presents some case studies that involve the targeted groups. The analysis of these case studies resulted in a refined set of recommendations for teachers for designing and implementing dissemination activities for the groups mentioned above. Therefore, the case study part opens up a broader range of actions to be carried out to improve the learning climate in favour of IBL and it can also be seen as exemplifying the vast array of options available (e.g., target students and parents in science days, invite parents to actively participate in IBL related activities, disseminate IBL to media).

3.1. Theoretical background

The research literature indicates a very strong positive relationship between school performance and a conducive to learning home environment (Downey, 2005). However, the majority of parents do not have the needed knowledge and skills to create a home learning environment that fosters children's development and is coordinated with school activities. Even worse, when is related to IBL related activities, the great majority of parents encountered school mathematics and science as drill-oriented subjects, made up of rules

and procedures to be memorized, and they consequently might not be in favour of inquiry activities in mathematics and science.

To face the challenge raised above, parent education, considered an “essential component” of successful parental involvement, is highly needed (DiCamillo, 2001). To spur IBL related reform in mathematics and science education, parents should be provided with guidance and support on how to enhance their children’s learning experiences. The next session outlines one of the prominent theoretical pedagogical premises of parental education and provides a framework for best practices in involving parents and community in promoting IBL in school mathematics and science.

Parental Involvement Theory

A school culture that supports active family engagement in the school relates positively with the child’s school performance and attainment in terms of fostering learning and high achievement scores, increasing pupils’ motivation, participation and competence during lessons, augmenting their expectations from themselves and improving their homework habits (Epstein, 1992).

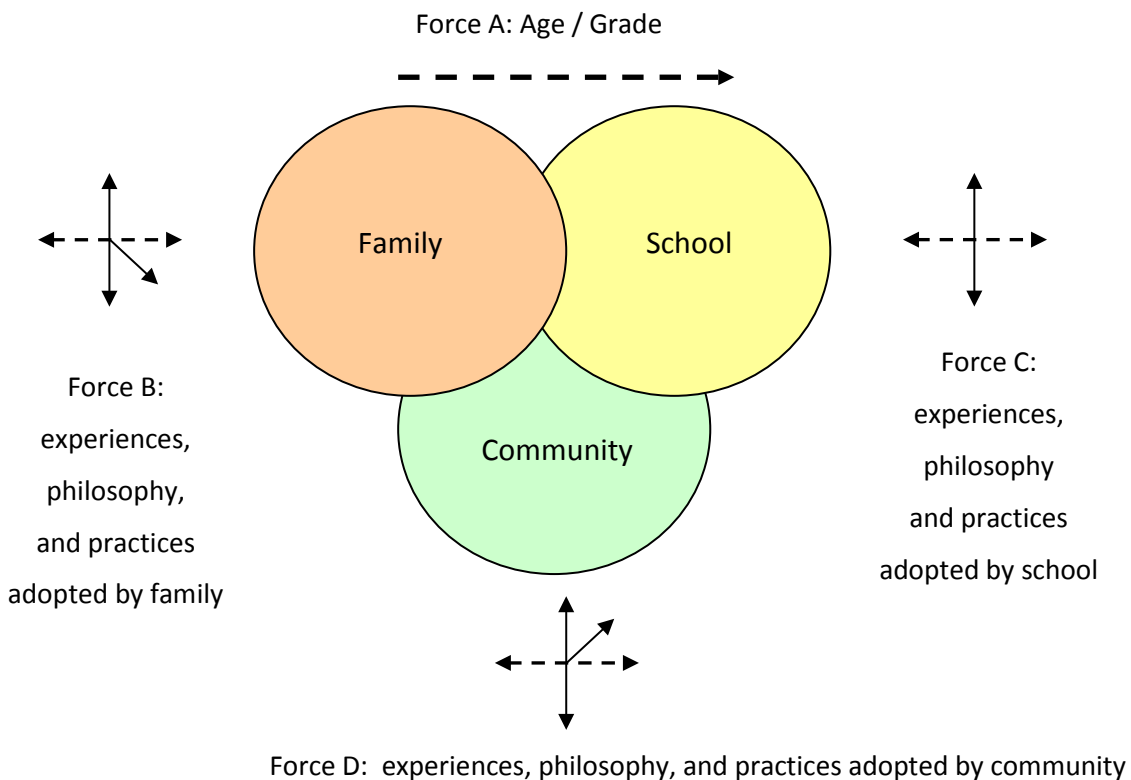


Figure 2: The theory of the overlapping spheres

One of the proposed theoretical constructs for parental involvement, proposed by Epstein, is the theory of the overlapping spheres (see Figure 2). Interaction between the spheres is at a maximum when school, families, and communities function as genuine partners within an overall programme that includes a number of shared activities. The model emphasizes reciprocity among teachers, families and students and recognizes students as active agents in school-family relations. The model assumes that the children's development and learning processes will benefit from an exchange of skills, abilities and interests between parents and teachers that is based upon mutual respect and a sharing of common goals (Epstein, 1996, 2001).

Various researchers reported on partnership activities that can promote a rich interaction between schools, community and families (e.g., Epstein & Sanders, 2002; Desimone, 1999). Joyce Epstein and her colleagues (1995, 1997, 2002) proposed six types of parents' involvement in their children's education. This model of the six types of parents' involvement is now accepted by the majority of researchers and found in several studies. These six types of activities, slightly modified (for the purposes of this guide) to better meet the requirements of mathematics and science education, include:

- *1st, Basic obligations of parents:* Parents provide a safe and stable family environment that encourages learning and good behaviour in school. The schools provide information and training for parents to understand children's development and to "deal" successfully with the changes they observe.
- *2nd, Basic obligations of schools:* The parents get informed from relevant school programmes and the progress of their children. This can be done via telephone, email exchanges, the use of social media (like Facebook and Twitter), written notes, and meetings.
- *3rd, Voluntary participation in school activities:* Parents can voluntarily participate in school activities and programmes. These programmes can explicitly focus on mathematics and science teaching and learning, like workshops for parents and other community members, information days, mathematics and science fairs, and student competitions and project activities.
- *4th, Participation in learning activities at home:* With the guidance and support of teachers and family members (parents and family), students are assisted in their assigned work, school homework and other related to school activities. This participation is more needed when it comes to IBL related activities because students might encounter difficulties in solving complex real world problems. Inquiry problems sometimes require more than 1-2 teaching periods. Consequently parents and family have time at home with their children during the implementation of inquiry activities, and therefore have great opportunity to become involved in their children's learning. This interaction can be moved even a step further; trained parents can serve as 'learning facilitators' at home and inquiry activities are implemented both at school and at home.

- *5th, Participation in Decision-making in education:* Schools can provide parents with an important role in decision-making. The representation and participation of parents in school governance should be open to everyone. Furthermore, parents and community members can have an active role on which research projects, initiatives, and curricula the school adopts and participates in, and therefore have a strong voice.
- *6th, Cooperation with other entities:* Schools can help families in cooperation with other agencies (e.g., health care, cultural associations, teacher associations) and provide access to services and programmes (recycling, childcare and after-school mathematics and science related activities).

Epstein and her colleagues underline that any parental training should aim at supporting families to establish home conditions which facilitate children's learning. Sample practices they propose (Epstein, Sanders, et al., 2002) include:

- Suggestions for home conditions that support learning at each grade level;
- Workshops, videotapes, computerized phone messages on parenting and child rearing for each age and grade level;
- Parental courses and workshops (might include specialized workshop on Inquiry in mathematics and science, home based science activities etc.);
- Family support programmes to assist families with health, nutrition, clothing, safety, swap shops, food co-ops, parent-to-parent groups and other services;
- Family room or family resource centre for parent meetings, volunteer activities, videos, publications, and other information for parents;
- Home visits at transition points; neighbourhood meetings to help families understand schools and to help schools understand families;
- Annual surveys for families to share information and concerns with schools about their children's goals, strengths, and special talents, and their willingness to be involved in extra-curricular activities (like research projects);

As researchers suggest, the challenges for the successful design and implementation of parental training are to provide information to all families who want it or who need it, not just to the few who can attend workshops and meetings or meetings at the school building. Parental education also needs to enable families to share information about culture, background, and children's talents and needs, and make sure that all those information are clear, usable, and linked to children's success in school. In describing these challenges researchers clarify that when referring to parent training and workshops, this should mean more than a meeting about a topic held at the school building at a particular time; it should also mean making information about a topic available in a variety of forms that can be viewed, heard, or read anywhere, at anytime.

Parents' Beliefs

In strengthening the communication between parents and teachers Barr and Parrett (2003) identified the importance of taking parents' beliefs into account. As Miller (1989) stated, "the most effective source of attitudes toward science and mathematics is the family. The family can socialize either a very positive or a very negative attitude toward science. Parents want their children to study science and mathematics and encourage that through ... talk about topics and problems that involve science and mathematics. (p. 177).

It is necessary that teachers consider parents as partners in their children's learning, and do not keep a professional distance from them, since this sometimes creates a feeling of teachers not caring about their children. This lack of understanding can lead to miscommunication and misunderstanding. The beliefs and expectations between families and educators have to be shared collectively, in building strong school and home relationships.

Technology

Technology is providing a growing variety of methods for school leaders and teachers to connect with parents anywhere and anytime. Contemporary technological tools can be used to facilitate appropriate communication between schools and families. Such tools include Twitter feeds, Facebook pages, Wikis and other blogs, and text messages. These communication texts can be sent in multiple languages, giving parents instant updates, news, and information not only about their children's progress in general, but also insights at a personal, day-to-day level. Further, providing parents with access to Web portals and other similar platforms can assist parents by engaging in day-to-day teaching practice, in innovative approaches, like inquiry, in mathematics and science (among other subjects), and in bridging the gap between school and family.

Policy makers and other stakeholders

Policy makers and other stakeholders (like country, state and city officials, business owners, sports figures, out-of-school youth, and health and social service providers) can also play an important role in successfully implementing an IBL approach in mathematics and science education. Especially policy makers and other officials can offer important insights into many phases of the planning, implementation and extension of an innovation. Policy makers and stakeholders can support both schools and families in meeting the requirements of implementation an innovation like IBL by also providing their resources and knowledge in making the innovation or project sustainable. Policy makers and stakeholders may be involved in multiple roles and various functions, including focus groups, volunteer opportunities, advisory committees, and participation in hiring processes, programme committees, and various other means.

In involving policy makers and other stakeholders schools and teachers might consider which community organisations and businesses are already tied or can be tied to school, both directly (e.g., financial or in-kind contributions, internship programs) and indirectly (e.g., parents' employers). Schools might also consider other community entities that could possibly be a partner in implementing innovative teaching and learning methods, like IBL. Such entities might include non-profit organisations, government entities, and outreach programmes provided by companies, and universities.

In summary, PRIMAS project acknowledges that parents', families' and communities' engagement in students' education are valuable and should be respected when planning parent educational programmes (Carter, 2003). Indeed, the most promising opportunity for student achievement occurs when families, schools, and community organisations work together. However, in order to be effective, school programmes must be individualized to fit the needs of the students, parents, and community (Moore et al., 2003). Effective programmes, like PRIMAS, assist teachers and parents in creating an environment that fosters learning and provides support and encouragement for students' success in mathematics and science.

3.2. Case study analysis

A number of case studies that the PRIMAS consortium has been involved in and which are related to dissemination for out-of-school target groups, are presented in the longer version of this Guide (see project's website). More than twenty case studies have been collected and analysed. These case studies present activities and events that have taken place in various countries, which can provide information and engage parents, students, community, policy makers and other stakeholders in the implementation of IBL in day-to-day teaching in mathematics and science.

The case studies' presentation aims to inform and advice teachers (and researchers) on how to design and support activities that will facilitate the teachers, parents, and other community members in developing family-community-school partnerships, to assist them in reflecting on their existing practices related to the teaching and learning of mathematics and science and to reflect on existing practices for improvement.

Case studies include conferences and meetings open to parents, community members, and policy makers, science days and science fair events, talent competitions, technology based activities for students with parent and community members support, school activities and lessons involving parents, activities aiming to positively impact student affective domain, meetings with curriculum designers, web resources that promote parent participation in science and mathematics teaching and learning, and collaboration with stakeholders in education. The various case studies can be categorized in the following categories: (a)

activities for parents, (b) activities for parents and students, (c) activities for students, (d) activities for policy makers, stakeholders and media, and (f) activities for teachers.

Three case studies are presented in the appendix, providing some concrete examples on how the PRIMAS consortium adopted the related literature framework and guidelines in designing and implementing good strategies for engaging parents and other out-of-school target groups in IBL.

3.3. Planning a dissemination activity

In planning a successful dissemination activity it is essential to build on the interests and concerns of the targeted group (e.g., parents) and to design the course through discussion with the participants, if possible. A dissemination activity might take the form of several actions, varying from one-day activities to much longer action plans. At first, we can think that there are two main ways to get parents involved in dissemination actions that support their children's learning in mathematics and science: (a) learning at home. Parents should receive information and support to help their child's learning at home, in the community and at school; (b) Home / School partnership. School and teachers should be open to the engagement of parents and consider ways of providing appropriate information, resources, and communication.

The following recommendations for activities can serve both ways. Among the possible activities that teachers and schools can design and implement for parental involvement in order to support IBL related pedagogies are the following:

- Workshops for parents to explain new mathematics and science standards and pedagogies like IBL, and to demonstrate and discuss how inquiry in mathematics and science is taught to students.
- Articles for parents in school or class newsletters by pupils and mathematics and science teachers on interesting mathematical topics and skills. Articles on the role of inquiry in problem solving mathematics and science could attract parents' interest and facilitate the integration of IBL teaching and learning.
- Volunteer mathematics and science tutors to assist students who need one-on-one tutoring and extra help with specific skills.
- Weekly interactive homework assignments for pupils to demonstrate mastery of a mathematical or scientific skill for family partners. Parents can discuss with their children how inquiry skills are used in everyday problems and other situations.
- Family Mathematics and Science Nights for fun and learning.
- Mathematics and Science Fairs.
- After school programmes funded by business and community partners to provide students with extra help and enrichment activities in mathematics and science.
- Parents' participation in curriculum and textbooks discussion in school.

At a more practical level, a teacher could consider the following questions, in designing an activity for engaging parents and community in school mathematics and science:

- Are parents involved in deciding what issues and topics will be discussed and developed during their engagement?
- Do parents choose issues that are most important to them? Are all parents involved in this process in ways that are accessible to them?
- Do all parents and community members have the opportunity to contribute?
- Is information available in the languages used by parents of children at this school or living in this area?
- What arrangements are there to include parents in meetings who live a distance away and/or work during afternoon or weekend?
- Do parents know they can contribute in many different ways – such as text, email, letter, phone, leaving comments and suggestions at the school, as well as through meetings?
- How are people who are less confident or less experienced getting encouragement to take part?
- How will people know if their ideas and views have led to changes?

A third strand teachers should consider in designing a dissemination activity are the expected outcomes, and the impact the activity might have on parents' and families' beliefs, attitudes, knowledge, and interactions with their children. Among others, successful dissemination activities can assist parents to:

- Encourage their children to observe, ask questions, experiment, tinker, and seek their own understandings of natural and human-made phenomena.
- Foster children's creative and critical thinking, problem solving, and resourcefulness through authentic tasks, and other everyday activities.
- Provide frequent opportunities for mathematics and science learning at home and in the community through outdoor play, participation in summer programmes, visiting museums, zoos, nature centres, and other interesting science and mathematics rich sites in the community.
- Take advantage of not knowing all the answers to their children's questions, and embrace opportunities to learn mathematics and science together.
- Encourage their children to participate in extracurricular opportunities focused on science, technology, engineering, and mathematics, such as clubs, field trips, after-school programmes, and science and mathematics research competitions.
- Advocate for organisations that support schools, including museums, libraries, and other science and mathematics-rich non-profit organisations.
- Reach out to policy makers to impress upon them the value of mathematics, science and technology learning and its importance to their children's future.

- Encourage their children to disbelieve negative stereotypes about scientists, and help them understand that anyone can have a career in science and technology.

Parents, community and policy makers have a critical role to play in encouraging and supporting innovative IBL pedagogies in day-to-day teaching in mathematics and science. Teachers also play an important role in this effort and can be highly valuable in designing and implementing activities that engage these groups in cultivating mathematics and science learning confidence and skills, through an inquiry approach.

4. CONCLUSIONS AND RECOMMENDATIONS

The results from PRIMAS support the expectation that inquiry-based approaches will likely affect teachers-parents' partnership in mathematics and science and possibly students' outcomes (Epstein, 2001; Sheldon & Epstein, 2003). In line with previous research findings, we have argued in PRIMAS that the inclusion of IBL activities in school mathematics and science as a means to engage students in creative and innovative problem solving and to increase students' awareness of the different aspects of mathematical problem solving and modelling in real world problems is greatly beneficial. The PRIMAS activities successfully demonstrate that parental engagement can be achieved by designing challenging, meaningful, and worthwhile problem solving activities. The implementation of the activities has the potential to develop a rich environment in which students, their parents and teachers established appropriate communication and collaboration venues, which resulted in improved students' learning outcomes.

Parental engagement is essential if we want to make *inquiry* a core element in school mathematics and science. At the same time, inquiry might serve as an appropriate means to engage parents in their children's mathematics and science education. We need to design an interactive environment in which school mathematics and science teachers refocus their teaching to incorporate and respond to students' ideas and needs, and in which parents respond positively to their new roles as engaging partners in their children learning, and welcome initiatives, like IBL. Technology can also be a core element of the interactive environment that could be developed for the communication between teachers and families (see for instance the Twitter® activity in the appendix). Results from research studies have revealed that such tools can assist teachers in generating a safe, shared knowledge space in which parents gained insights into their children's learning. It is important that teachers realise that there are appropriate methods to engage parents, beyond traditional classroom observations and formal meetings with parents. Students and their families can have access to new space and interactions, and facilitate the design and implementation of innovative IBL practices and pedagogies in mathematics and science classrooms.

Results from our case studies showed that teachers can share the importance of IBL related approaches in mathematics and science instruction with parents and communities, using a variety of activities. There are of course challenges and demands in teachers' knowledge and other institutional constrains, but engaging out-of-school target groups have the potential to enrich IBL. Clearly, teachers can play a significant role in bridging the gap between home and school. Both teachers' and parents' beliefs are important in determining parental engagement, while positive teachers' beliefs and attitudes are needed to maintain the best possible parental engagement and to build mutual understandings and collaboration for the improvement of mathematics and science teaching.

PRIMAS related research employs a longitudinal design to examine the long-term impact of using modelling activities in an inquiry based approach to mathematics and science teaching

and learning and to engage parents in the learning process of their children. Our continued research examines the extent to which dissemination activities for out-of-school target groups and especially activities focused on parental engagement can become manifest in the teaching and learning of mathematics and science. The analysis of the case studies presented here, not only unveiled traits of effective parental engagement from the perspective of parents and teachers but the research has also revealed traits that schools and communities must possess to help strengthen and sustain parental engagement. Moreover, case studies show that teachers and parents explicitly shared a common understanding of the necessity to further work towards parental engagement and communication between parents and teachers. Unquestionably, students need high-quality instruction to improve mathematics and science learning. If schools, teachers, and parents work together in creating appropriate, collaborative environments, they are more likely to see higher students' learning outcomes. Furthermore, the more intensely parents are involved, the more confident and engaged their children are as learners and the more beneficial the effects on their achievement.

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6. APPENDICES: CASE STUDIES

6.1. Appendix 1: Science Fairs Case Study

Science fairs are well-known events that normally involve a whole school, even pupils from different schools. There are different versions for this kind of events. In some of them, students compete in order to get a prize, whilst in others the idea is to engage as many students as possible and to let them work as far as they can. Also, in some fairs students will choose the project they will work on and inquiry about it whilst, in others, teachers provide students with a set of experiments and they have time to learn about the science and/or mathematics involved and also to prepare their stand.

We will not discuss the possibilities of science fairs to promote students' inquiry-based learning here. We will focus on the opportunities they give for parents to get involved in the education of their children.

As it has been discussed in the guide, science fairs can be effective events to push together the "family", "school" and "society" spheres. The key issue is in what extent families and school work together in order to organise the science fair. The closer this partnership is, the more likely it is to produce a positive impact on parents.

We can think about the situation from too ideal and opposite cases. One option is that parents are involved in the organisation of the fair, in the selection of experiments and projects, and in the preparation of the stands of their children. They are first actors in the whole process and share the responsibility with their children.

The opposite option is that the whole science fair is organised within the school, inviting parents to the event where students show their experiments. Although getting parents involved in the process might be powerful, there are obvious obstacles (like parents' lack of time, parents' involvement, or their lack of scientific or mathematical background) that potentially might lead to inequalities.

In the case of PRIMAS in Spain, the second option has been chosen. PRIMAS, together with experienced teachers, has been actively involved, in the organisation of several science fairs in which students have been working closely with their teachers in order to select their experiments and demonstrations and to prepare their stands.



Science Fair in Úbeda in 2011



Science fair in Úbeda in 2012



Science fair in Atarfe in 2012

After the preparation of the experiments and stands, two science fairs have been successfully conducted in the city of Úbeda (province of Jaén) and another one in the Atalaya primary school (city of Atarfe, province of Granada).

In the case of the science fairs in Ubeda, several schools (both primary and secondary centres) from different cities have been working together. The fair resulted in a wide event opened to pupils and society. In the morning, pupils coming from different cities and villages near to Úbeda visited the fair. In the afternoon, the fair was opened to the general public. That was the opportunity for parents to learn about different ways of doing and learning science and mathematics in school. According to the data provided by the organisers, around 5000 people visited the fair in the afternoon.

In the case of the science fair in Atarfe is slightly different. First, because it was restricted to a single school and it took place within the school itself. Second, because it was restricted only to primary school. The smaller dimensions of the event lead to closer collaboration of parents. Indeed, the “parents association” was actively involved in the organisation of the fair, leading to a better insight about science and mathematics education. The fair was opened to parents, but not to the public in general. They could visit the fair in the morning, talk to pupils and share the experiences with them.

As a conclusion, science fairs are powerful events to promote of different way of doing and learning science. Particularly, it is an effective way of pushing together “school”, “family” and “social” sphere. Considering that most of the parents think about science education in a traditional way, related with their learning experiences in the past, science fairs are motivating event that could lead to changes towards an inquiry-oriented understanding of science and mathematics education.

6.2. Appendix 2: Twitter in Mathematics Teaching Case Study

This activity focused on exploring teachers' and parents' beliefs on parental engagement in mathematics and science, with an emphasis on implementing an inquiry-based approach in complex mathematical problem solving. We hypothesized that the rich interactive learning environment that could be formulated while working with a real world problem, would have a positive impact on both teachers' and parents' beliefs and that it could further inform good practices on parental engagement in school mathematics and science. During the activity: (a) we investigated teachers' beliefs about inquiry-based mathematics and parental engagement, (b) we investigated parents' beliefs about inquiry-based mathematics and their engagement in inquiry based complex problem solving, and (c) we explored the impact of the inquiry based environment that was created, comprising of the activity and Twitter[®] on teachers' and parents' beliefs, as they mentioned above.

This activity follows three of the teachers who participate in PRIMAS, who work in two sixth grade classes from a public K-6 elementary school in Cyprus. One class of 22 and one class of 19 eleven-year old students, their parents and the three teachers worked on the *Water Shortage* activity. The activity was implemented during the second year of PRIMAS (2011-2012 academic year). The *Water Shortage* activity that has been implemented in this study was part of a sequence of four modeling activities. All activities required students to develop models for solving engineering based real world problems. However, parents participated in only two of the four activities (Water Shortage and House Temperature activities).

Teachers and parents attended two three-hour workshops on afternoon or Saturday sessions. An additional workshop on the use of Twitter[®] in general and in the mathematics classroom in particular and on parental engagement good practices and discussion, also took place. Out of the 41 parents that were invited to participate only 28 accepted the invitation and participated in the two workshops. The workshops were designed and conducted by PRIMAS project personnel, with the guidance of the author, with expertise in science and mathematics, and in cultural issues in education. Teachers were actively involved as they shared questions, suggestions, and examples of their own practices and beliefs. Teachers also shared their thoughts about similarities and differences in teaching and learning environments among the schools. A number of teachers who had participated in our previous research project Compass (www.compass-project.eu) (and who continued to participate in PRIMAS) demonstrated how to implement model-eliciting activities in elementary and secondary classrooms. Similarly, parents expressed their willingness to learn more on IBL and how such an approach might improve both students' achievement and attitudes towards mathematics and science. They also welcomed the invitation to participate in the project and explore with researchers and teachers appropriate ways to be involved in their children's learning in mathematics and science.

The activity's aims and objectives were presented to participants and a number of extra resources were also presented. Teachers and parents were then asked to formulate groups and work on the activity. The three teachers then built one group and discussed ideas on how to implement the activity, while parents formulated their own groups, trying to find

possible ways of being involved, during the implementation of the activity. During the second part of the activity parents (and teachers) familiarised themselves with Twitter[®]; they created accounts, shared tweets (messages) among them, followed others, sent direct messages, and created lists. Parents and teachers were also introduced to a free service for shortening website links (urls) (as tweets are limited to 140 characters, users often have to shorten long urls).

The *Water Shortage* model eliciting activity was implemented by the teachers. Activity implementation lasted three weeks. Specifically, working in groups of three to four, the children spent five 40-minute sessions on the activity. Two sessions took place in the first week, two in the second, while the last session took place in the third week of implementation. Implementation in the two classrooms took place in parallel. During the first two sessions the children worked on the newspaper article and the readiness questions and familiarize themselves with the Google Earth and spreadsheet software. Specifically, during the first session students were asked to read the newspaper article in individual and answer the corresponding questions (see Appendix). Students then discussed the importance of the problem presented in the article and submit a relevant tweet (one Twitter[®] account was created for each group of students and not for individual students) within their groups. Twelve parents commented on students' tweets, by agreeing that this is among the country's most important problems and by providing additional sources of related information. During the second session students reviewed their parents' comments and suggestions, which were provided through Twitter[®]. They visited the provided resources and reached a conclusion on the importance of the water shortage problem. Students were then introduced to Google Earth. Core functions and commands of the software were presented and discussed with students, with a focus on commands like "Fly to" for visiting a place, "Add Place-mark" and "Ruler" for calculating the distance between two points, and "Path" for drawing a path between two points. In contrast to regular maps, Google Earth can help students in making accurate calculations, being more precise in drawing the tanker routes, in "visiting" the different countries for exploring their major ports and finally in observing country's landscape. Since the great majority of students were familiar with Excel no specific introduction took place.

In the next two sessions students worked on the problem. They developed a number of appropriate models for solving the problem, which they shared with their teachers and parents. During model development students were prompted by the teachers to share their initial ideas with their parents and later their model documentations, their Google Earth and Excel files. For these purposes a small public Wiki was created, in which students quite easily uploaded their files. Students then shared the links of their files with their parents, using appropriate tweets. The great majority of parents (26) followed their children's tweets and provided feedback and suggestions to their models. In total, parents and teachers send more than eighty tweets during the model development. However, a significant number of these tweets just encouraged students to continue the good work, while few actually provided constructive feedback and identified weaknesses in students' models. In the last session

students wrote letters to local authorities (as indicated in the activity), explaining and documenting their models/solutions.

6.3. Appendix 3: Scientific Market Case Study

The “Scientific Market” activity took place in Nitra, Slovakia and involved parents, students and the community in general.

The main idea of the event was to present natural science and mathematics in a non-traditional way and to model the inquiry process of scientists to the public. Eight departments of the Faculty of Natural science prepared interesting programmes from their discipline that should present the beauty of science in the way to interest the wide public. There were seven separate stations for each of the discipline: Mathematics, Physics, Chemistry, Biology, Informatics, Ecology, Geography and the Presentation stage. The Presentation stage was mainly about presenting some interesting physical experiments, for example liquid nitrogen showing levitating magnets. Each station presented several experiments and activities from several branches. There was included always only a brief description.

Biology presented experiments in dactyloscopy, trichology, osteology, DNA, gemology microbiology and ornithology. Geography focused on work with information in cartography and usage of ArcGIS system for map production. In ecology station participants could get known their region and its environment. In physical station participants could become a Mac Gyver and learn how to use things in their surroundings using scientific knowledge. In chemistry station participants could predict results of several experiments and understand the misconceptions of the old alchemists. Informatics station focused on robot programming and solving mathematical puzzles with computer using algorithms. Last but not the least was the mathematical station. In this station we presented geometrical thinking, graph theory and Nim games, and algebraic thinking and demonstrating the mathematical inquiries.

From seven stations, partners had to choose one that was to be described in detail. The main reason why we choose algebraic group was due to the fact that I was a group leader, so the activity was about algebraic thinking and mathematical inquiry. At the end I realised that there were two different target groups. The first one was from the participants (main target group) during the “Scientific Market day” and the second group were team members during the preparation of the programme. In our team there were two university employees (one was a PRIMAS team member) and four PhD students in mathematics education. At the beginning there were only a few common understandings on how our station should look like. We decided that every group member should come up with ideas and problems that could be used. We also discussed whether these problems are suitable for presentation in the scientific market and how our target group will then cope with them. There was a dichotomy in opinions what kind of problems we should use. Mostly we talked about traditional problems with only few simple steps to solve. Later I posed the question about

how could we show to participants, who face these problems, how mathematical inquiry works? Then we focused on bigger idea “How do the mathematicians work?”

In our preparation we used framework based on PRIMAS project and work of (Brown & Coles 2008). At the beginning we mostly communicated via e-mails individually, but about two weeks before the action we met four times where we set up a time schedule and we shared our presentations. The aim was to investigate the problems, formulate questions, suggest the way of how to solve a problem and verify our own solution. We spent a few nice afternoons with discovering answers for ourselves. For all of us it was very exciting and one of the PhD students asked: “Why didn’t they show us such way of mathematical work in schools? It is so interesting.”

On the Scientific market day we were organised in groups of two – three. When the market started the ages of the participants were from 2 to 60+ years. We couldn’t present all the activities that we were talking about during our group meetings so we synthesized them and decided to use only a few catchy “bits” of it. We called it “Can you read minds? We do. And we can show you how.” In about 5 to 10 minutes we based on a few mathematical operations that could figure out the mathematical principle behind the “mystery”.

Based on these activities we presented the mathematical reasoning, making conjectures, proofs and we interpreted our results. We mostly found other participants amazed by the results that they could predict and proof the things. The participants were mostly confident with simple calculations but were not self-confident with prediction making conjectures and proving them. Of course during the “Scientific market Day” there were different groups of students and adults that were interested in the problems after finishing of the prepared engaging bits so we could encourage them to continue in the inquiry and ask them or let them ask themselves new and more open questions.

There are several factors why this project has been successful. The main thing that positively influenced the activity was highly motivated people that were interested in the presenting of their work. Each department of the faculty was very well prepared and interesting scientific content was modified to the form that could be presented in popular way. Another factor that positively influenced the outcome was the cooperation between the Faculty and the Shopping centre as well as the good propagation of the activity in advance. We used several big billboards, sent information letter to schools and informed about the activity in local as well as national media in advance and after the action.

There were several limitations that we observed during the preparation process and the realisation of the activity. Because of the wide range of ages of the target groups (kindergarten to seniors) it was challenging to interest all the target groups. We were also limited by the time and the space so it was hard to establish an environment that could lead students, parents and all other participants to the longer inquiry process. We managed this challenge by adapting our activities to the bits of inquiries that aimed to be finished in a shorter period of time.