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D5.3 Strategies to facilitate innovative education in Science & Technology

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I Summary

In this document, we present results and recommendations or strategies of the project "kidsINNscience. Innovation in Science Education – Turning Kids on to Science", a collaborative SICA project funded under the Seventh Framework Programme of the European Union (see www.kidsINNscience.eu).

After a collection of Innovative Practices (IPs) originating from the participating countries – Austria, Brazil, England, Germany, Italy, Mexico, the Netherlands, Slovenia, Spain and Switzerland – had been compiled, field trials have been performed in all these countries, involving about 100 schools, 180 teachers and 4100 learners during the school years 2010/11 and 2011/12. A set of Quality Criteria for innovative practices produced by the project has also contributed to the collection of IPs and the respective field trials.

The evaluation of the field trials and the experiences of the participating countries have led to an increased understanding of successful ways of teaching and learning science. Discussions and an ongoing process of exchange of experiences of the field trials have resulted in a number of general strategies for innovating teaching and learning science that are applicable to a number of countries. The following patterns of strategies should be in the focus of structural changes:

- Professional learning communities - Strong support should be given to existing professional learning communities or connections should be established in order to create professional learning communities or to foster cooperation between such communities.

- Diversity and inclusiveness / gender - A discussion of diversity and inclusiveness / gender issues should be included in teacher education as early as possible; the regular observation of groups of pupils and identification of problems existing will contribute to raise awareness regarding these issues. This awareness in turn is the basis for improved management of these aspects.

- Teacher education - Teachers are seen as the most important key change agents, therefore teacher autonomy in implementing innovative practices and hands on activities should be fostered strongly. Teacher education is a key aspect and should be supported by educational research results but also by cooperation among educational researchers, teachers and schools supporting each other.

- Sharing of IPs - A selection of innovative and up-to-date practices, well described and documented in the national language, should be available to a variety of key change agents, among them teacher associations and institutions for teacher education and professional development. In addition, access to persons with the necessary content and pedagogical knowledge regarding the IP should be provided.

- Practical work and specialist resources - The creation of a network of schools and research institutions should be strongly supported: schools should be enabled to increase the use of equipment and the related activities in science education, either by purchasing their own new and up-to-date equipment or by sharing resources with others when the needs arise.

- Flexibility & teaching freedom - Curricula should consist of a limited compulsory core curriculum together with other suggested topics, thereby leaving the teacher to choose among different contents and methodologies.

- Authentic context of science education - Teachers and schools should be supported to increasingly include everyday life aspects into science education, enabling learners to benefit from higher motivation and interest.

II Introduction

The Strategies to facilitate innovative education in Science & Technology presented in this document are one of the results provided by the project “kidsINNscience”, funded by the Seventh Framework Programme of the European Commission and carried out by eight European and two Latin American partners: Austria, Brazil, England, Germany, Italy, Mexico, Netherlands, Slovenia, Spain and Switzerland. This workpackage is led by UZH, Switzerland, with FUB, Germany, responsible for Task 5.3 "Strategies to facilitate innovative education in Science & Technology" in all participating countries.

The FP7-project **“Innovation in Science Education – Turning Kids on to Science, kidsINNscience”**, a collaborative SICA action, intends to facilitate the innovation of curricula and teaching and learning of science and technology (S&T) in formal and informal settings in order to enhance the interest of young people in S&T.

Science education is constantly being innovated. However, some countries do better than others in international comparisons. Innovations that work in one country cannot simply be transferred to another country. To secure further development it is essential to find not only single and singular innovations in informal settings, but strategies for innovating the teaching and learning of S&T in mainstream schools (Rocard, Science Education now: A Renewed Pedagogy for the Future of Europe, 2007; Osborne & Dillon, Science Education in Europe: Critical Reflections, 2008; results of TIMSS 2011 and PISA 2009; provisional results of TALIS 2013).

kidsINNscience has analyzed and compared strategies for innovating curricula and for teaching and learning in S&T in different partner countries in order to obtain an overview of innovative practices. The project has established formalized paths for innovative practices to be introduced and facilitated educationalists at different positions in the educational system (from teachers and school leaders to policy makers and administrators) to operate more creatively within the system. It has also helped to generate changes toward more active learning systems.

New about the approach of kidsINNscience was that it used adaptive strategies that enabled countries to learn together how to develop feasible innovation plans, carry out effective pilots to collect evidence and formulate innovation plans that fit their own conditions. This makes national innovation strategies more successful and more cost effective, it also contributes to convince key change agents to participate.

The basic assumption of kidsINNscience was that innovations in science could be transferred but in order to work efficiently they should be adapted to the local circumstances. Accordingly, the main questions that kidsINNscience addresses were:

1) What strategies for teaching and learning in S&T motivate teachers and learners in the participating countries?
2) What similarities and differences are there in innovating S&T teaching and learning in the participating countries?

3) What strategies to innovate S&T teaching and learning would work in my country, considering its characteristics of S&T teaching and learning?

Culture and traditions differ from country to country and even within countries. This is reflected in the various educational systems and policies. Thus a comparative approach that distinguishes between generic and specific conditions, between general conditions that apply to all countries and specific conditions that apply to one country or a group of countries or a target group within a country is appropriate. It enables educationalists from different countries to learn from each other and facilitate the innovation process of S&T education in the participating countries. In each step of the project teacher/school networks in all participating countries have been involved. Thereby communities of researchers, developers of teaching and learning materials and teachers have been created that have worked closely together.

Since the start of the project in autumn 2009 the description and comparison of S&T curricula and methodologies for teaching and strategies for learning in S&T in primary and secondary schools in the participating countries with special attention to active and learner centred strategies have been carried out. An **initial set of criteria and indicators** – the starting point of the project – has been defined and a **scan on the S&T innovative practices and methodologies** (D3.1, Innovative methods in learning of science and technology - National findings and international comparison, 2010) has been accomplished in all partner countries. The scan explicitly focused on innovations and indicates how these innovations relate to S&T education in mainstream schools. The intention of this step was twofold: to get an idea of the state of S&T-education in the participating countries and to test the initial set of criteria. Issues that have been dealt with were, for example, how criteria are interrelated, how they can be grouped into categories and what sort of evidence is useful to indicate performance. The following **comparison of the state of the art** of innovation of S&T teaching and learning in the participating countries included (categories of) quality criteria, amongst them gender and cultural diversity and inclusiveness and activity based and learner centred approaches such as IBTL (inquiry-based teaching and learning). On the basis of the scan and the countries' comparison a **common set of quality criteria** (D.2.1 Common Set of Key Indicators, 2010) has been defined. The criteria have been grouped into categories and descriptors have been added as examples. This common set of criteria has enabled the participating countries to make comparisons and connections between characteristics of S&T-education and to formulate feasible plans for further innovations. It was also helpful to put national activities into an international perspective.

Selected innovative practices (from D3.1, Innovative methods in learning of science and technology - National findings and international comparison, 2010) have been made suitable for national circumstances, according to the national selection and adaptation (D4.1, Adaptation of Innovative Methods in Science Education, 2010). The **adapted innovative practices** in science education (the national adaptations were carried out in close collaboration with the participating teachers) have formed the basic material for the field trials that started in autumn 2010 and lasted until summer 2012, over two full school years. More than 180 teachers and 4100 learners in almost 100 schools have taken part in the field trials that have been carried out in the 10 participating countries. (D4.2, Documentation of field trials, 2012)

On the basis of the outcome and the evaluation of the trials (D5.1, Evaluation of field trials of innovative practices in science education, 2012) the **common set of quality criteria** has been re-evaluated (D5.2, Redefinition of Key Indicators (Revision of Quality Criteria), 2012). This set of quality criteria as well as the outcome of the field trials have contributed substantially to this deliverable, the formulation of strategies for innovating science education in all participating countries. These strategies formulated by kidsINNscience do not claim to represent a completely national approach because in some countries the project has been active only in a region or part of this country, depending on the location and the sphere of influence of the partner institution but also on the huge differences in size of the participating countries.

III Overview about strategies in participating countries

Besides the validation of quality criteria given in deliverable 5.2, the reflections on the different national innovation strategies provide an important insight into the national conditions for innovating science education. In preparation of the feedback modus regarding to the different national innovation strategies a decision to develop a framework for structured feedback has been taken.

For that reason we would like to introduce the different categories we asked for, then we would like to give a short explanation why that framework seems to be usable for gathering data about the national innovation strategies and why we decided to include the answers in the way we have done. This part is followed by an overview into different national feedbacks and a short summary.

Template of National Strategies - Description of Procedures

After a short introduction of questions we asked for developing a deeper understanding of different national innovation strategies, a short summary about the given feedback is added. For explanation of the context of the national innovation strategies partners were asked to describe the constellation of important actors as well as a list of potential key change agents.

The first question was about main trends in educational governance / policy in each participating country. It is about identifying main trends and dynamics within the field of science and technology education. With that question the gathering of important information about educational policy is possible. The second question is more about constellations of actors within the field of science education. In addition to the second question it was necessary to aggregate the list of actors according to their institutional framework in the third question. For identifying different levels of action a multi-level approach was chosen. For a useful differentiation of function and range it asked for allocation of the announced actors as well as for an allocation due to different functions. Last but not least a question about proposed general strategies was added. With that question experiences made in the project kidsINNscience should be carried over in proposed strategies of fostering innovative science teaching (see Annex I for the template / information about purpose and methodology).

Explanation of the template

The developed framework takes into account that national innovation strategies are strongly related to national constellations of potential key-actors. For a deeper understanding of the motivational background of these actors it seems to be important to get an insight into certain national significant main trends in educational governance and policy. With this information the national context is given, in which innovation and its transfer occurs and could be supported (see also Annex to D3.1, National contexts and innovative practices in Science Education. A Comparative Report, 2011).

Heuristic advantage

The simply kept framework allows an easy comparison of different national strategies and their conditions. Common aspects are showing similar conditions and potential regarding to further cooperation. Already made experiences could be exchanged and might provoke learning from other's experience. Differences provide references to innovative potential and could also provoke a trans-national learning process.

Summary: National Strategies

The feedbacks given led to an insight of the various national frameworks of implementing innovative IP's. Its obvious that different perspectives of necessary action are identified. So the reported feedback is based on a) more common national trends and concrete national strategies on b) micro, c) meso and d) macro-level of educational systems. In all given feedbacks we find details of cross-sectional cooperation (horizontal and vertical) and therefore some important argument for science education in spite of further limited resources, like in the case of Italy. Key institutions and actors could be identified on two different levels what leads to the important fact that innovation needs both engagement at the micro level (classroom, school) and meso (e.g. regional actors, networks), or macro level (agencies of teacher education and curriculum development as well as evaluation agencies, ministries) in a supportive way to secure sustainable transfer.

Therefore the provided insight in culturally different represented strategies allows the reconstruction of necessary conditions and constellations regarding the improvement of science-teaching on national levels.

a) The different feedbacks on national innovation strategies within science education lead to different actions of reforming. Centralization like in the case of UK leads to the perspective of the implementation and controlling of quality criteria. Where there is a statutory National Curriculum as in the UK, strategies to implement innovative practice entail, at a micro level, working with teachers within the existing framework. Teachers and researchers can then plan together ways of incorporating aspects of the identified quality criteria. This in turn leads to teachers engaging in professional discourse through Continued Professional Development, to disseminate how innovative practice can be accommodated within a centralized curriculum. However, the centralized National Curriculum is not mandatory in all schools in the UK; many schools at both primary and secondary level have opted out by becoming academies or free schools, which are locally controlled and do not have to follow National Curriculum programmes.

In a different connotation the feedback from Spain gives an insight into the "competence-turn" of recent strategies educational governance as in many European countries caused by several comparative studies about educational efficacy.

b) At the micro level the experiences made in UK are drawing the proposed strategy of enabling teachers to modify their curricula and taking part in a professional discourse about pedagogical innovations of teaching science as mentioned in the feedback from Switzerland as well. In Mexico it was emphasized, from some of their results in the field trials, that local school authorities might influence in fostering or blocking innovative engagements. Strategies in general are the continuing education of professionals (e.g. in the case of using new teaching methods like ICT, as communicated the in Slovenian feedback) and the establishing of cross-sectional subjects within schools.

c) At the meso level we know that publishers and providers of teaching material are important actors of transferring innovative knowledge about teaching science. Regarding to that strong professional communities of practice (and knowledge) are situated in the need of network-based distribution of experience and expertise, Germany proposed.

d) At the macro-level teacher education must be organized in that way, that the "culture of innovation" (regarding to the feedback of Slovenia, Switzerland and Germany) must be an important aim at universities and educational training centres. Last but not least, financial support of such activities must be provided. It seems that the case of Italy strongly shows an urgent need for innovation in the educational system although it seems to be a more general problem within the whole fiscal system of Italy.

IV kidsINNscience general experiences and strategies

The evaluation of the field trials has shown some patterns among a number of participating countries regarding successful ways of teaching and learning science (D5.1, Evaluation of field trials of innovative practices in science education, 2012). Discussions about experiences of the partners in kidsINNscience, the results of the evaluation of the field trials and the national strategies summarized in the previous chapter have led to a number of general strategies or categories of strategies that have a high degree of overlapping in the participating countries. The strategies evolving also reflect the ongoing discussions of the consortium and the structured feedback by the partners (previous chapter).

The experiences of kidsINNscience showed the following patterns of strategies to be important:

- Professional learning communities
- Diversity and inclusiveness / gender
- Teacher education
- Sharing of Innovative Practices
- Practical work and specialist resources
- Flexibility & teaching freedom
- Authentic context of SE

These patterns of strategies relate to the specific experiences of partners during selection and adaptation of IPs, preparation of field trials and selection of schools, motivation of participating teachers and classes as well as ongoing support for teachers and schools during the project / the field trials. They always apply to a number of participating countries and have been agreed on by all partners. According to the different situation and context in these countries some strategies are of more or less relevance. Country specific strategies in relation to these general strategies will be presented in the following chapter.

1) Professional learning communities

The field trials of kidsINNscience showed that within a number of countries teaching and learning arrangements could be very successful if professional learning communities (PLC) were formed. This accounted for teachers as well as students, but also scientists or education researchers and families or whole school environments.

Teachers could cooperate at the same level (e.g. among primary schools) or at different levels and benefit from the exchange of experiences regarding the implementation of one or more innovative practices. The cooperation of teachers meant added value and appreciation for their work, the building of professional learning communities led to increased knowledge, skill and fun. The evaluation results revealed that in some specific cases teachers who participated in these groups enjoyed working with their colleagues for the first time. Teachers in these communities more easily reflect about their own practice and try to improve this practice until changes are generated and positive learning outcomes can be observed.

Pupils / students could also cooperate at different levels, within the same class (e.g. group work or general discussion) or between different classes. One of the goals of these learning communities is to enable pupils to become autonomous learners within a classroom. In order to achieve that teachers have to be autonomous themselves and this condition can be obtained to a large extent by forming and supporting professional learning communities.

In some countries the regular and ongoing support of cooperation between scientists and teachers or education researchers and teachers proved to be of great importance for outstanding project results. With the help of scientists and education researchers teachers were better able to form learning communities that again contributed to the implementation and the success of innovative practices.

In some countries the same accounted for the families of the pupils and for the whole school environment - including as many stakeholders as possible into the implementation of such practices can greatly increase the learning experiences.

General strategy: Strong support should be given to existing professional learning communities or connections should be established in order to create professional learning communities or to foster cooperation between such communities.

2) Diversity and inclusiveness / gender

kidsINNscience showed that the inclusion of cognitive / cultural / behavioural diversity is for teachers easy to accept (one of the reasons is that in the majority of kidsINNscience countries strategies for this kind of inclusion already exist) while gender issues are generally not considered as important by teachers. Gender issues are often not reaching out to the teacher's perception because of other apparently more pressing educational problems or issues or simply because at first sight they think there is no difference between boys and girls.

In a number of countries engaged in kidsINNscience the first step was to involve teachers in accurate observation of their own class in order to identify any existing problem. When teachers have become aware of a problem as such they have been able to propose strategies and methodologies to deal also with gender difference. The discussion of gender issues should therefore be included in teacher initial education and the observation of different behaviours and attitudes should be a component of the practical education of teachers. An important step in this direction is the handbook for teachers from Austria (Gender_Diversity_Kompetenz im naturwissenschaftlichen Unterricht. Fachdidaktische Anregungen für Lehrerinnen und Lehrer, IMST_Gender_Diversity-Kompetenz Netzwerk (ed.)

(2012): Amon, H., Bartosch, I., Wenzl, I., Alpen-Adria Universität, bm:ukk) directed to in service teachers.

Working in groups is one of the strategies to face the issue of inclusion but kidsINNscience shows that in some of the participating countries the basic competencies of managing group-work is not mastered by teachers and that there is a need in teachers initial education and in teachers in service education for a good training on methodologies and techniques of collaborative work. TALIS surveys (OECD Teaching and Learning International Survey 2008) show that on average science and math teachers are not working in a constructive way; on the other hand, teachers who regularly undertake professional development are used to a wider array of teaching practices and are more likely to co-operate with other teachers.

In fact working in groups is essential not only for science education and for the development of a scientific attitude of debating and comparing hypotheses and results, but also as basic ‘citizenship European competencies’ (2006, European key competencies, 2003 DeSeCo Oecd document).

General strategy: A discussion of diversity and inclusiveness / gender issues should be included in teacher education as early as possible; the regular observation of groups of pupils and identification of problems existing will contribute to raise awareness regarding these issues. This awareness in turn is the basis for improved management of these aspects.

3) Teacher education

The experiences gathered in kidsINNscience offered many ideas on what could improve teacher education, pre-service as well as in-service. One general consideration is the lack of methodological and pedagogical preparation of secondary school teachers: in many countries this preparation is reserved to primary school teachers while secondary schools teachers are mainly prepared on disciplinary contents and on disciplinary ‘didactics’. kidsINNscience offered the possibility (e.g. in Italy) to compose these 2 characteristics in a useful way: the cooperation of teachers from different schools and different grades allowed a useful exchange with primary school teachers offering their methodological expertise while secondary teachers and schools could help with their disciplinary knowledge.

Another important result of kidsINNscience is to present and explain the importance of educational research results to teachers. In some countries these results seem not to be taken notice of by the majority of teachers or the relevant teacher education institutions. In a number of field trials teachers benefited greatly from these results, especially when a strong and ongoing cooperation between education researchers and participating teachers existed.

kidsINNscience also showed the utility of a participatory action research approach in teacher education - action research is a useful strategy for professional learning communities and for teacher professional and personal development.

General strategy: Teachers are seen as the most important key change agents, therefore teacher autonomy in implementing innovative practices and hands on activities should be fostered strongly. Teacher education is a key aspect and should be supported by educational research results but also by cooperation among educational researchers, teachers and schools supporting each other.

4) Sharing of IPs

In some countries the presentation and dissemination of a large number of innovative practices from many different countries and educational systems (see D3.1, Innovative methods in learning of science and technology - National findings and international comparison, 2010) contributed to increased interest of teachers in innovative science education. For example in Germany the catalogue of more than 80 innovative practices has been distributed to a number of teacher education seminars, but also found its way from teacher to teacher and thereby influenced a large number of schools. Many teachers appreciated the overview and the short, unified presentation of each IP, leaving enough freedom to develop their own methods to implement a number of IPs or only parts of an IP.

General strategy: A selection of innovative and up-to-date practices, well described and documented in the national language, should be available to a variety of key change agents, among them teacher associations and institutions for teacher education and professional development. In addition, access to persons with the necessary content and pedagogical knowledge regarding the IP should be provided.

5) Practical work and specialist resources

kidsINNscience showed that there is a demand for specialist resources / technical equipment for implementing a number of innovative practices into everyday school life. By sharing specialist resources and information through professional learning communities schools could be helped to facilitate these field trials and thereby to reduce costs of equipments and technical support personnel. At the same time, better equipment and higher numbers of equipment allowed to specifically foster gifted or talented students or to give girls more access to science equipment and investigation.

General strategy: The creation of a network of schools and research institutions should be strongly supported: schools should be enabled to increase the use of equipment and the related activities in science education, either by purchasing their own new and up-to-date equipment or by sharing resources with others when the needs arise.

6) Flexibility & teaching freedom

In order to develop and implement innovation, a variety of learning contexts is essential as well as teachers' freedom in the choice of contents and methodologies. Curricula should clearly distinguish between a very reduced core curriculum – that is compulsory – and many other suggested topics that are left to the teachers' choice. In many countries the curriculum is theoretically free, but the lack of this distinction and the proposal of ‘encyclopaedic’ text books lead teachers to stick closely with the book proposal limiting their freedom.

The kidsINNscience experiences have shown that bureaucracy for the implementation of innovation should be reduced to a minimum, and the single school should have (as it is already allowed in many kidsINNscience countries) the possibility to decide autonomously about the innovations to be implemented during the school years (e.g. projects, collaboration between school and external institutions as universities etc.) without the need of formal approval by local/regional authorities.

General strategy: Curricula should consist of a limited compulsory core curriculum together with other suggested topics, thereby leaving the teacher to choose among different contents and methodologies.

7) Authentic context of science education

Innovative practices with a strong relation to the everyday life of pupils resulted in very good experiences within the kidsINNscience field trials (D5.1, Evaluation of field trials of innovative practices in science education, 2012). Pupils / students may work on the production of their own food, on the understanding and simulation of everyday technology or create their own energy out of renewable resources: to deliver an authentic context within science education creates high motivation and interest among learners and teachers as well. Many innovative practices gathered and compiled in the catalogue (see D3.1, Innovative methods in learning of science and technology – National findings and international comparison, 2010) relate to these everyday experiences of learners.

General strategy: Teachers and schools should be supported to increasingly include everyday life aspects into science education, enabling learners to benefit from higher motivation and interest.

V Experiences and strategies related to participating countries

Austria:

1) Professional learning communities

The cooperation of teachers of various classes implementing all the same innovative practice was important and contributed to the success of the implementation, especially in one school. The whole school participated at the end and the feedback of the teachers was that they learned as a community.

3) Teacher education

Teacher education: improvement of teaching and informing teachers about

- learner centred approaches
- hands-on-activities (teacher students have scarce possibilities to do hands-on-activities during their professional training
- the awareness for gender-aspects and diversity and inclusion should be fostered more in teacher education

6) Flexibility & teaching freedom

The more flexible the organisational structure within a school is, the easier is innovation in teaching and learning in schools.

The higher the freedom in terms of topics, methodologies and timeframe is for teachers, the more successful and satisfying was the implementation of an innovative practice for the teachers an the students. Both, teachers and students (and in the case of Science in Family and Potatoes don't grow on trees also parents) acquired ownership and dedication towards the innovation.

The flexibility is also linked to resources in terms of time, rooms and material available and accessible in school. As realized in some field trials, more flexible regulations would facilitate the implementation of innovative practices, a flexible curriculum allows for even spontaneous implementation of innovation.

Brazil:

1) Professional learning communities

We have observed that the interaction between academic researchers, research students and practicing teachers was welcomed by all involved. Different participants were able to bring their experiences and perspectives to the analysis of teaching problems and to the proposition of solutions. It seems that mutual acknowledgement of the validity and scope of knowledge produced in universities and schools can be consolidated through greater integration between research and practice.

3) Teacher education

Early exposure of beginning teachers to curriculum innovation programs and research results should help make teachers aware of the potential benefits of adopting an investigative approach to teaching practice. It also helps with keeping teachers up-to-date with knowledge generated by the educational community, including teaching resources and their evaluation.

Apart from strengthening content-based approaches, teacher education curriculum reforms should value disciplines such as:

- Philosophy of Science, for a better understanding of the nature of science – a category that was very much emphasised in the IP adaptations but the understanding of which proved to be problematic during implementations;
- Science Studies, for a better understanding of socio-scientific issues and of the possible interfaces between Natural Sciences and Sociology;
- Humanities in general, especially those subjects concerning the bases of education for citizenship.

6) Flexibility & teaching freedom

It would be very important to create new career plans that allow teachers to work at one school (as opposed to having hourly contracts). This would create conditions for the necessary interaction to the development of interdisciplinary practices and more time for teachers to participate in educational innovation projects. Moreover, curriculum recommendations should privilege guidelines to the planning of classroom work as opposed to the presentation of strict syllabi to be followed within the academic year.

England:

Individual learners: It is valuable when trying to introduce innovative strategies to focus on individual learners in the class or school. Looking specifically at misconceptions or alternative conceptions which learners may have developed can help teachers to enhance real learning towards more accepted scientific concepts. When teachers see the need to focus on what learners really think and understand, they gradually begin to see the importance of inquiry based learning and its associated techniques, such as increased dialogue in the classroom, helping learners to frame their own investigative questions, making abstract ideas more approachable, etc.

1) Professional Learning Communities

These communities were enhanced in one of our trial schools, working across both stage 1 and stage 2 of the field trials. We managed to make contacts with parents and carers of very young children in stage 1 and by cooperating with teachers in different year groups, maintained the same links with some of the children and their parents/carers into the second year of field trials. This supported the idea of Science in Family, an IP originating in Mexico and also supported the wider notion of the importance of parents and the home life in children's education in science as well as in other curricular areas.

2) Gender

Another important issue is the "problematizing" of certain questions. Often teachers have been unaware of the individual needs of learners or the ways in which male and female learners approach scientific knowledge, ideas and understanding. Researchers have needed to focus teachers' attention on aspects of learning, such as gender, so that they can look more deeply at ways in which boys and girls are motivated towards science learning.

2) Inclusion

The inclusion of learners with special educational needs is also an area where innovative science projects can be valuable. Often, learners who do not fit in well in the social parts of lessons, can be supported through innovative science to express their ideas and to join in with others. One case we encountered was with boys who were reluctant to engage in drama activities when modelling invisible structures. A way to deal with this was to change the groupings of children in the class, so that the reluctant boys were grouped with girls who were more motivated. This helped the introverted boys to take a more active role in the communication aspects of science learning.

Germany:

4) Sharing of IPs

In Germany the presentation and dissemination of a large number of innovative practices from many different countries and educational contributed to increased interest of teachers in innovative science education. The catalogue of more than 80 innovative practices has been distributed to a number of teacher education seminars, but also found its way from teacher to teacher and thereby influenced a large number of schools. Many teachers appreciated the overview and the short, unified presentation of each IP, leaving enough freedom to develop their own methods to implement a number of IPs or only parts of an IP.

5) Practical work and specialist resources

A number of kidsINNscience field trials carried out in Germany (e.g. Science on Tour / mobiLLab) offered good access to technical equipment for implementing innovative practices into everyday school life. The structure of the innovative practice - a mobile laboratory in a bus with a number of experiments, capable of visiting up to 3 schools per day - allowed for a significantly reduced costs of equipment and technical support personnel per school. The high quality equipment and experiments on different levels allowed to specifically foster gifted or talented students and to give girls more access to science equipment and investigation.

6) Flexibility & teaching freedom

The field trials of kidsINNscience have shown that schools that open up their learning environment and teachers that have the freedom to use and also make use of educational landscapes contribute to an increased interest of pupils / students in science education. For example Research - Education- Cooperation (e.g. Science on Tour / mobiLLab) offer a good possibility to regularly leave the traditional classroom and experience "real" science and hands-on activities in a new, usually motivating environment.

Italy:

1) Professional learning communities

Some of the key agents (teachers associations, local authorities entitled of the education system on a regional scale, groups of teachers from different schools, teachers educators, and so on) should organize events where the invited teachers can work as a community of learners directly experiencing what innovation is about. They should be given a problem to work on as if they were students in order to get a direct experience of the related methodology. The hosts should lead an extensive discussion about pros and cons, difficulty and efficacy of innovation regarding the learning outcomes.

It is our opinion that when scaling up innovation on a local or national basis the key change agents should give teachers the opportunity of making their own personal opinion on innovation.

5) Practical work and specialist resources

To have laboratory facilities and equipments in the school (or in a network of schools) is surely very important if only because it is a requirement for many quantitative experiments. Nonetheless many qualitative experiments or simple measurements made by comparison can be performed in much simpler environments like the classroom itself. What makes the difference is not the equipment but the approach. Experimental work is not good because it can be performed with sophisticated apparatuses. It can have useful outcomes in learning if it is performed with an inquiring attitude and students work together to answer their own questions. To organize a very elegant experiment or precise measurement just to demonstrate that something is as it is reported in books or scientific papers cuts off any discussion and can paradoxically lead to a completely different outcome: instead of raising a critical attitude towards scientific knowledge it could contribute to a more passive acceptance of experimental data which are taken for granted pushing in the background some of the most important characteristics of scientific thoughts like inference and argumentation. Maybe because its undeniable positive effect in raising students' motivation practical work is often considered helpful in learning without any further investigation. A clarification should be made about this because many teachers or key change agents could consider practical work as a sort of cure-all for science teaching and learning problems.

Mexico:

1) Professional learning communities

Teachers being considered as key agents for the effective innovative practices' (IP) implementation played an important role also by engaging themselves in a learning community. Learning communities among teachers, researchers and even between schools allowed them to share experiences, ideas and giving support to improve the IP's implementation. For example, the cooperation of teachers implementing the innovative practices in the first cycle helped them to build themselves, in the experience, as specialists in the IP. Later these "specialists" teachers contributed to create a learning community with the researchers and the new teachers participating in the second cycle of IP implementations.

5) Practical work and specialist resources

Some of the implemented innovative practices required specialized materials and equipment to perform certain activities or experiments; for this reason it is highly recommended that schools and teachers build a communication channel with research institutions that could provide facilities and specialized equipment that often schools lack. For instance, in Mexico, Cinvestav provided specialized equipment and spaces (visits to the building) when it was necessary or suggested by the teachers; all the students participating in the "Maíz, maíz, maíz" IP came to work in the lab of Cinvestav, the teachers' workshops were set in these facilities as were and other activities like visits from the students to the other laboratories.

6) Flexibility and teacher freedom

The recent adding of problem-based learning (PBL) in the Mexican classrooms gives teachers the opportunity to have a space/flexibility in the curricula, in order to work or go deep into specific topic of interest.

Slovenia:

1) Professional learning communities

Collaboration of parents seems very important. We observe very good response when IP Science in Family (source CINVESTAV) was adapted and carried out. Crystallization (sugar) was chosen which can be carried out at home and discussed with parents. Results (crystals) were brought from homes to school and discussed there too. Primary school ages are especially convenient for involving parents into science issues. Key change agents and policy makers should implement this issue in the curriculum.

2) Gender

In spite of the opinions of teachers that there is no difference between boys and girls regarding carrying out experiments we observed this difference. Girls had lower level of practical experiences in technical matters or they were disposed to leave some techniques to boys when experimenting in groups. In most of our field trials our researchers were engaged as tutors in carrying out attractive experiments. So we were able to give girls more chances in experimentation in mixed groups. The result was very promising in that girls overcame their keeping back when in groups with boys. There is a need for special strategies to work on this issue in schools at subjects where experimentation is important. Policy makers in education should have this issue in mind. We also suggest that from time to time tests should be carried out about technical experiences of boys and girls to have a tool to observe any progress in this issue.

5) Practical work and specialist resources

In most of the field trials in Slovenia collaboration of a research institute (IJS) with schools and school teachers was used. Teachers were mostly interested in attractive experiments, which cannot be carried out regularly at schools (lack of equipment and/or experience) and which pupils and students enjoyed. For this to achieve two IPs were adapted: Science in Tour and NATLAB. The program of experiments was defined in collaboration with teachers such that it can be used in the frame of curriculum (chemistry, physics).

Another issue regarding practical work vis a vis e-presentations of experiments is that in spite of the usefulness of e-presentations of some experiments (from YouTube or other sources) practical work gives much more technical feeling and competences to be used throughout one's school career and later at university and in science research institutions. Pupils and students (in primary and secondary schools) should gain as much practical experiences as possible (materials, equipments, phenomena, etc.) at these ages.

The result was very promising in the direction of better collaboration of science research institute and schools in future. There is neither a regular basis nor financing for such a collaboration in Slovenia. Therefore policy makers (government) should allow such activities on a systemic way.

Policy makers should also give teachers (and pupils and students) more time in the curriculum for carrying out experiments.

Spain:

1) Professional learning communities

A new approach to Teachers' Professional Development (TPD): All strategies would require supporting Professional Learning Communities (PLCs), an alternative approach to TPD, involving teachers in long-term critical reflection about their own practice and in the generation of alternatives and changes (Mena, Sánchez & Tillema, 2009; Stoll et al., 2006), rather than in receiving top-down courses. An example of such community is the group TORQUES, the pre-school teachers involved in the Potatoes IP.

3) Teacher education

- support teachers in a teaching that promotes students development of scientific competencies

4) Sharing of IPs

- make teaching resources, IPs and other resources available for teachers

6) Flexibility & teaching freedom

- increase teachers' autonomy and capacity to teach a competency-oriented curriculum
- support teachers in generating their own teaching resources or modifying existing resources, and reducing the dependence from published textbooks, which usually embody a traditional, teacher-centred approach

7) Authentic context of SE

- support teachers in generating or using teaching units and resources based on real life situations and framed in authentic contexts

Switzerland:

1) Professional Learning Communities

In the majority of the Swiss field trials, two or more teachers from the same school collaborated and formed Professional Learning Communities. These PLC took many different forms: teachers teaching pupils/students from the same class or year, from different classes or years, teaching different subjects or taking different functions such as regular teacher and special education teacher. In the field trials where there was only one teacher involved the collaboration between the teacher and the science education researcher/teacher educator can be seen as another successful form of PLC.

3) Teacher education

Teachers profited most for their professional development when

- they were involved actively in each step of the field trial (selection, setting objectives, adaptation, implementation, evaluation)
- the science education researcher/teacher educator actively addressed methodological issues and discussed them with the teachers, e.g. inquiry-based learning and teaching (IBTL) in pre-primary and early primary years
- the collaboration between the teachers and the science education researcher/teacher educator stretched over a longer period of time, e.g. several months

6) Flexibility & teaching freedom

Teachers have much freedom concerning the choice of methodology and – esp. on pre-primary and primary level – the choice of the topics. This freedom facilitates the implementation of new practices and enhances the teacher's commitment and ownership for the innovation. The teaching freedom is also very pronounced in the setting of classes for high achieving learners.

7) Authentic context of science education

A common, everyday object such as a potato turned into an object worth to be studied for several months. Following an IBTL approach, i.e. taking up the pupils' questions and their ways to find answers, also very young learners from pre-primary and early primary years kept a high degree of interest and motivation.

VI kidsINNscience Quality Criteria

The quality criteria developed by kidsINNscience - originally compiled in order to facilitate a scan of a number of innovative practices in the participating countries - have evolved in the course of the project to a more general description of innovative practice in science teaching and learning. The strategies presented in this document refer to this set of quality criteria and descriptors (see Annex II Table "kidsINNscience Quality Criteria" for the full list of quality criteria).

Perception of quality often depends heavily on context and local culture, making the development of wide-ranging quality criteria difficult on a trans-national scale. Specific quality criteria and indicators may not be appropriate in new situations or different countries. Therefore the quality criteria have been compiled from the substantial overlapping of the national criteria of all partners. In order to produce a framework that could be applied to all partner institutions and countries the consortium decided to shift from a common set of indicators to a common set of general quality criteria that could be applied to all different national environments in science education practices. Therefore quality criteria within all relevant categories have been compiled. If applicable, descriptors have been added to all quality criteria as examples. The different categories are grouped as:

three basic categories (general quality criteria on practices in science education), the innovative practice should be:

- **scientifically sound**
  (e.g. Correct use of scientific content/ knowledge according to the context; Raise awareness of the Nature of Science)

- **pedagogically and methodologically sound**
  (e.g. The design, learning materials, learning activities and teaching methodology take current theories about science learning into account; Motivation / interest in science is stimulated, Interdisciplinary approach)

- **fostering scientific competencies**
  (e.g. Include practical work (hands-on activities, lab-work, experiments etc.); Include decision-making activities; Stimulate collaborative work)

three more specific categories (for innovative practices in science education), the innovative practice or its implementation could be:

- **socially relevant**
  (e.g. Promote public understanding of science; Promote actions, reflections and debates concerning science responsibility towards health, environmental and sustainable development issues)

- **supporting teacher participation and professional development**
  (e.g. Teachers are involved in designing or adapting the innovation to their own specific situation; Research attitudes in the teachers are supported)

- **considering developments in science education and science education research**
  (e.g. An implicit reference to science education research is existing; The innovation

contributes to research on science education)

two categories relevant for this international project (for a potential transfer of an innovative practice to another region / country), the innovative practice should be:

- **sustainable**
  (e.g. Is solidly based on evidence; Can be applied by averagely trained and willing teachers)

- **transferable (within a country / to other countries)**
  (e.g. Is flexible enough to be adapted to different national/regional circumstances; Has simple, short but clear documentation (preferably in several languages))

The three basic categories should appear in the description of every good practice in science education, be it basic or innovative, because they describe the indispensable quality characteristics. The other five categories could be present, as they add quality (and under certain circumstances 'innovation') to the good practice. The progress of kidsINNscience has shown remarkable differences in the educational environments of the participating countries, therefore performance of criteria is strongly dependent on the context (e.g. what may be a good or extraordinary level in one country could be normal school life in some other countries).

For the identification and selection of innovative practices in science education in all participating countries within the framework of kidsINNscience the criteria on sustainability and transferability were given an "imperative" status that had to be applied to all practices in order to maintain a high number of potentially usable innovations for all countries. Mostly innovative practices that meet all or the majority of the sustainability and transferability criteria have been selected for the international pool of innovative practices and have subsequently been used for the adaptation of practices and the field trials.

The attached table (see Annex II kidsINNscience Quality Criteria) consists of all categories and quality criteria with added descriptors for each criterion. The descriptors given are general examples of all partners - on a national level a much higher number of more in-depth descriptors have been compiled and adopted.

VII References

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ANNEX I Template "Compilation of National Innovation Strategies"

Partner (Please mark)
□ AIE □ UZH □ IJS □ SLO □ RM3 □ LSBU □ USC □ CINVESTAV □ UFRJ

Compilation of National Innovation Strategies
Main trends in educational governance / policy
remark: Please report about the main trends in educational governance / policy in your country. Which dynamics / movements of reformation and innovation can be observed?
- - -
Key actors
remark: Please compile a list of key actors relevant for the strategies. (e.g. teachers, curriculum developers but also publishing companies for school books, E-learning companies etc.)
- - -
Institutions for key actors
remark: According to your previous list, please give institutions that are relevant for these key actors. (e.g. in Germany: for teachers - teacher associations and unions, for curriculum developers – federal state institutions for curriculum development, teacher training and media etc.)
- - -

Actors on local / regional / national level
remark: Please mark and explain the level in your country where innovation strategies will have the highest impact on the learning system. The key actors should be listed according to the level and their function should be defined. Each key actor has to be marked with a, b, c etc. according to the following list: a) multiplier by setting political conditions and frameworks b) multiplier by in-service training c) multiplier by information management (learning portals, websites etc.) d) multiplier by political counselling e) multiplier by research and development
Key actors on local level: - - - Key actors on regional level: - - - Key actors on national level: - - -
General remarks (by each partner): - - -
Innovation strategies
remark: Taking into account the national evaluation-results of the IPs and the identification of the most important actors within the multi-level systems described above: Which innovation strategies do you suggest for your country?
- - -

ANNEX II Table "kidsINNscience Quality Criteria"

Quality Criteria for Innovative Science Education Practice (IP)

Category: an I P	Criteria	Descriptors
1. should be scientifically sound	a. Correct use of scientific content/ knowledge according to the context	a. e.g. pupils use scientific concepts or models and transfer them to different situations and contexts
	b. Raise awareness of the Nature of Science	b. e.g. pupils search for influences / dependencies / relations (big, small, none, statistic) on which phenomena are based on
	c. Provide insight in the way scientific knowledge is constructed	c. e.g. tentative nature of scientific knowledge and concepts

2. should be pedagogically and methodologically sound	a. The pedagogic basis/background is clearly described and learning activities are consistent	a. e.g. materials used with cultural focus, such as food from the local area used in chemistry experiments; activities are based on modelization, IBL or socio-constructive approach
	b. The design, learning materials, learning activities and teaching methodology are clearly described and consistent with the pedagogical basis	b. e.g. formative assessment, assess pupils progress
	c. The design, learning materials, learning activities and teaching methodology take current theories about science learning into account	c. e.g. science education is a combination of technical training, theoretical education, and general knowledge
	d. Allow for diversity in learning materials and teaching methods in order to meet a variety of pupils' needs and interests	d. e.g. variety of teaching and learning methods and styles; incorporate thinking skills of various types; pupils can choose out of several subtopics
	e. Take gender- and (multi)cultural issues into account	e. e.g. gender equal learning and cultural independent teaching and learning
	f. Include all pupils, including those with special educational and physical needs	f. e.g. medial, methodical, thematic, social differentiation to meet the requirements of individual learning needs
	g. Motivation / interest in science is stimulated	g. e.g. examples of students´every day life
	h. Interdisciplinary	h. e.g. several disciplines of S&T or other areas like social sciences are

		involved in the issue addressed, in solving the problem given, in teaching

3. should foster scientific competencies	a. Foster scientific literacy (identify scientific issues, explain phenomena scientifically, use scientific evidence)	a. e.g. use of the specific vocabulary of science; multimodality; use argumentation structures to explain
	b. Include practical work (hands-on activities, lab-work, experiments etc.)	b. e.g. lab work, field work, design of inquiries
	c. Offer inquiry based learning activities	c. e.g. students formulate research questions, design projects and experimental procedures
	d. Stimulate argumentation and critical thinking	d. e.g. exercises, presentations, discussions, mimic symposiums
	e. Include decision-making activities	e. e.g. problem solving and decision making exercises
	f. Stimulate collaborative work	f. e.g. group work
	g. Use ICT-skills (information and communications technology)	g. e.g. pupils depict data graphically; pupils use various presentation techniques

4. could be socially relevant	a. Raise the awareness of social, ethical and cultural influence and implications of science and technology	a. e.g. work on positive and negative effects of science and technology on society
	b. Address national problems in science education	b. e.g. improve attitudes towards science, promote science vocations/careers, improve levels of achievement in science, inclusive education
	c. Promote changes or improvements in educational contexts	c. e.g. involvement of parents / carers in the education of their children
	d. Promote public understanding of science	d. e.g. empowerment, links between science & technology and everyday life
	e. Promote actions, reflections and debates concerning science responsibility towards health, environmental and sustainable development issues	e. e.g. work on historical cases of scientific-technological developments and their impact on social development
	f. Use resources and teaching contexts from outside the school	f. e.g. regional offers like museums, research institutions, companies
	g. Promote global citizenship	g. e.g. work on the dilemma between open scientific discourse and commercial interests (like patenting)

5. could support teacher participation and professional development	a. Teachers are involved in designing or adapting the innovation to their own specific situation	a. e.g. flexibility in applying methods according to the abilities, interest and individual learning needs of the children
	b. Teachers engaged in peer reviews and line reviews of the innovation	b. e.g. teachers have access to and make use of time slots and offers where they can reflect their teaching and exchange their insights and discuss their questions with fellow teachers as well as teacher trainers and coaches
	c. Training opportunities are offered within and/or outside school	c. e.g. preservice and inservice teacher training is offered
	d. Stimulate peer reviews and visits to classes of other teachers inside and outside school(s) to give each other professional feedback	d. e.g. feedback to teachers about their science lessons
	e. Innovation has a clear teacher manual	e. e.g. sufficient documentation of the practice is available
	f. Research attitudes in the teachers are supported	f. e.g. offer real situations of communication and cooperation between school level and research level

6. could consider developments in science education and science education research	a. A science education innovation should be backed up by evidence in educational research and/or educational practice	a. e.g. national or international research journal reports available
	b. An implicit reference to SE research is existing	b. e.g. problem based science education
	c. The innovation contributes to research on science education	c. e.g. partnerships and collaborations with institutions for science education research and science communication

7. could be sustainable	a. Is solidly based on evidence	a. e.g. try outs and practice are well documented
	b. Has been implemented for several years in a regular class (or school).	b. e.g. survey / evaluation / feedback is available
	c. Does not involve substantial costs or extensive infrastructure	c. e.g. in-classroom practice
	d. Does not require a substantial system change	d. e.g. can be performed by regular teachers
	e. Can be applied by averagely	

	trained and willing teachers	

8. could be transferable - within a country	a. The core of the innovation is clearly described and easy to implement	a. e.g. critical points for transferability are clearly highlighted
	b. Is flexible enough to be adapted to different national/regional circumstances	b. e.g. use local materials and environments; cheap and locally available resources, no or limited system change needed
	c. Includes dissemination materials for internal and external school audiences	c. e.g. PowerPoint presentations available (addressed to the school staff/parents)
- to other countries	d. Is flexible enough to be adapted to other countries with different socio-cultural conditions	d. e.g. does not depend on distinctive regional or cultural features
	e. Has simple, short but clear documentation (preferably in several languages)	e. e.g. website material is offered in different languages
	f. Has supportive graphic and/or multi-media materials	f. e.g. photos, videos, interactive materials