Report

S-TEAM

WP 7 Report

Argumentation in Europe and P4CM Teacher Manual

October 2010

Deliverable 7b

The S-Team project has received funding from the European Community's Seventh Framework Programme [FP7/2007-2013] under grant agreement n°234870.

Contact details:

Project Coordinator: Professor Peter van Marion

Peter.van.Marion@plu.ntnu.no

Deputy coordinator: Professor Doris Jorde

doris.jorde@ils.uio.no

Work package 7 Leader: Professor María Pilar Jiménez-Aleixandre

marilarj.aleixandre@usc.es

Project Manager: Dr Peter Gray

graypb@gmail.com

Project Administrator: Hilde Roysland

hilde.roysland@svt.ntnu.no

S-TEAM website: www.ntnu.no/s-team

Postal address:

S-TEAM

Program for Teacher Education

NTNU

Dragvoll Gård

N-7491 Trondheim

Norway

Published by NTNU (*Norges teknisk-naturvitenskapelige universitet*),

Trondheim,Norway

The S Team project has received funding from the European Community's

Seventh Framework Programme [FP7/2007 2013] under grant agreement n°234870

Published under an open-access agreement with the European Commission

Citation:

S-TEAM (Science Teacher Education Advanced Methods) (2010), *Report on Argumentation and Teacher Education in Europe*. Trondheim, S-TEAM /NTNU.

Report coordinated by

María Pilar Jiménez-Aleixandre

Blanca Puig Mauriz

Juan Ramón Gallástegui Otero

(University of Santiago de Compostela, Spain)

Contributors

Ayelet Baram-Tsabari (Israel)

Allan Blake (Scotland)

Gultekin Cakmakci (Turkey)

Nijole Ciuciulkiene (Lithuania)

David Cross (France)

Jens Dolin (Denmark)

Margareta Enghag (Sweden)

Sibel Erduran (England & Wales)

Robert Evans (Denmark)

Liselott Forsman (Finland)

Michel Grangeat (France)

Neil Ingram (England & Wales)

Doris Jorde (Norway)

Berit Kurtén-Finnäs (Finland)

Esther Laslo (Israel)

Loucas Louca (Cyprus)

Anni Loukomies (Finland)

Anja Olsen Moberg (Norway)

Kai Pata (Estonia)

Silke Rönnebeck (Germany)

Matthias Stadler (Germany)

Iva Stuchlikova (Czech Republic)

Andrée Tiberghien (France)

Peter van Marion (Norway)

Wan Yee (England & Wales)

Preface

This document will ultimately form part of a comprehensive package of materials for teacher education and professional development in argumentation. The initial deliverable 7a from Kaunas University of Technology described the rhetorical basis of argumentation theory for pre- and in-service teachers, whilst this state of the art report sets out the current and rather unsatisfactory status of argumentation in curricula, initial teacher training/education and teacher professional development, across the fifteen S-TEAM partner countries. We believe that this is a representative sample and that the report can be taken as a reliable snapshot of the situation in Europe generally.

In addition to the report, we have appended product 7.6, which is the first S-TEAM contribution specifically directed at inquiry in mathematics. Using a radical, philosophically grounded approach, our colleagues at the University of South Bohemia have provided an innovative approach to investigative activities in mathematics, which may also resonate with science teachers who have to engage pupils in mathematical activity as part of the scientific method.

The next phase for Work package 7 will be the production and piloting of teaching sequences building on the theoretical foundations established in the current and preceding deliverables. We are confident that these will strengthen the ability of teachers to encourage effective argumentation practices in the classroom. This is a major factor in the wider adoption of genuine inquiry-based methods across Europe.

Table of contents

Introduction: Purpose of the report

This purpose of this report on argumentation and teacher education, according to the S-TEAM technical annex, is to review the state of the art about argumentation in Europe, particularly in the countries involved in the project, and to draw on published research to suggest lines of improvement.

The report is intended for policymakers and other stakeholders in education, with the goal of sharing information about the development of argumentation in the European countries.

In order to distinguish different stages in the introduction of argumentation, we have identified three dimensions, which, if combined, could describe the status of argumentation in the S-TEAM partner countries:

- Policy documents
- Initial Teacher Education (ITE)
- Teacher Professional Development Programs (TPD)

The focus of the S-TEAM project, on teacher education, called for an exploration of the situation, in both ITE and TPD. However, we deemed it necessary to include the status of argumentation in European curricula, through an examination of policy documents.

The information was gathered through an open questionnaire completed by the National Liaison Partners in each of the 15 countries involved in the project (for the purposes of the project, England & Wales and Scotland are considered as two countries). The countries are listed according to their order in the S-TEAM project.

Once the national reports were received, it was apparent that 'argumentation' was given slightly different meanings in different countries. Therefore an additional section was added, and the report is structured in five sections as follows:

1. The meaning of argumentation;
2. Argumentation in policy documents;
3. Argumentation in Initial Teacher Education;
4. Argumentation in Professional Development Programs,
5. Discussion and suggestions for future developments.

Section 1: The meanings of argumentation in European countries

The reports completed by each country showed that 'argumentation' was used with different meanings in the different policy documents. This is not surprising, given that in the literature about argumentation it is frequently used with different meanings (Jiménez-Aleixandre & Erduran, 2008). For Jiménez-Aleixandre and Erduran, argumentation is understood as the evaluation of knowledge claims in the light of available evidence, and they highlight its relevance to science education, as it is part of the appropriation of scientific practices. A second aspect of argumentation is persuasion: convincing an audience of a given point of view. Argumentation related to the use of evidence (and framed in scientific competence), is the meaning more frequently expressed in the policy documents. There are other meanings, which can be characterized as argumentation related to reasoning and critical thinking, and argumentation related to communication. We see these four meanings as complementary and overlapping, rather than as contradictory.

1.1 Argumentation and use of evidence framed in scientific competence

The coordinators of this report take as a starting point that argumentation and the use of evidence can be framed within scientific competence. Scientific competence, or 'basic competence in science and technology' is, together with mathematical competence, one of the eight key competences recommended in 2006 by the European Union as a central core of lifelong learning (EU, 2006). This reference framework is being translated into policy documents in European countries. In it, scientific competence is defined, among other things, as follows:

> Competence in science refers to the ability and willingness to use the body of knowledge and methodology employed to explain the natural world, in order to identify questions and to *draw evidence-based conclusions* (EU, 2006, p. L 394/15, our emphasis).

Scientific competence has been emphasized in the Program for Indicators of Student Assessment (PISA) framework (OECD, 2006) since 1999. As Jiménez-Aleixandre et al. (2009) point out, three dimensions of the scientific competence are given priority in PISA (OECD, 2006, p. 29); these include the abilities to:

- Identify scientific issues and questions that could lend themselves to answers based on scientific evidence.
- Explain or predict phenomena by applying appropriate knowledge of science.
- Use scientific evidence to draw and communicate conclusions, and to identify the assumptions, evidence and reasoning behind conclusions.

So, in summary, if 'drawing evidence-based conclusions' is one of the dimensions of scientific competence, and this 'evaluation of claims on the basis of evidence' is a key component of argumentation, it might be expected that this would be one of the intended meanings of argumentation in the relevant European policy documents. Moreover, references to argumentation can be found in the sections and general recommendations devoted to scientific competence.

Argumentation with the meaning of 'evaluation of claims, hypotheses and conclusions on the basis of evidence' is found in the policy documents of nine countries[1]: Norway, France, England & Wales, Czech Republic, Denmark, Spain, Finland, Sweden and Turkey. In some of them the references are explicit, in others implicit. In the cases of the Czech Republic and Spain these references are found as part of the characterization of scientific competences. Some quotations from each country illustrate this meaning (our emphasis):

[1] References to documents and pages are provided in section 2

Norway: Pupils should be able to “assess and argue for the validity and quality of one’s own observation data and those of others”.

France: “The pupil should be able to know how to observe, question, *formulate and validate a hypothesis*, *argue*, design elementary models."

England & Wales: "They [*the students*] communicate findings and *arguments*, showing their awareness of the degree of uncertainty and a range of alternative views. They *evaluate evidence critically* and give reasoned accounts of how they could collect additional evidence."

Czech Republic: "such thinking that requires *verifying expressed hypotheses on natural facts* through several independent methods; assessing the importance, reliability and correctness of collected natural-science data *in order to confirm or refute previously articulated hypotheses or conclusions*."

Denmark: "Developing skills in technical *justification* (argument and evidence); [...] understand the logic of arguments; *assess arguments critically*; [...] *assess whether there is evidence* in texts and statements."

Spain: "This competence makes possible to identify questions or problems and *to draw conclusions based on evidence*."

Finland: "pupils learn to *make conclusions about their observations* and measurements and recognize the causal relationships" [...] "pupils will learn to *evaluate the reliability of the information* they have obtained from different sources."

Sweden: Of central importance is the view that scientific knowledge is a human construction and that it provides a basis for evaluating views, decisions and measures[2].

Turkey: Students should be able to: "Understand that science has a *structure that is based on evidence* and it allows questioning and falsification." [...] "Explain *the role of evidences*, theories and/or paradigms on how scientific knowledge changes." [...] "Realize that *when new evidence appears, current scientific knowledge is tested*, limited, corrected or renewed."

1.2 Argumentation as part of reasoning and critical thinking

Argumentation framed in reasoning and critical thinking is found in the policy documents of two countries: Israel, where it is explicitly connected to higher order thinking skills, and Cyprus, where is somewhat more implicit:

Israel: "Biology: expand thinking strategies in the new biology curriculum, especially *argumentation and meta-cognition*." There are similar recommendations in other science subjects.

Cyprus: Argumentation is not explicitly included in the objectives, goals or content of the national curriculum. At kindergarten level there is an emphasis on scientific thinking and reasoning skills, without explicit reference to argumentation[3].

[2] This is not a quotation from the policy documents but a summary from the country representative.

[3] Summary from the country representative.

1.3 Argumentation as communication

References to argumentation framed in communication, debate and discussion are found in the policy documents of four countries, although in Lithuania, Scotland, Germany and Estonia this meaning overlaps with reasoning:

> Lithuania: “Students should be directed towards the acquisition of *scientific communication skills* based on description and argumentation“
>
> Scotland: "They [*young people*] will also demonstrate evidence of progress through their abilities and skills in reasoning, *presenting and evaluating their findings through debate and discussion*, expressing informed opinions and making decisions.”
>
> Germany: “The students present results and methods of biological experiments and *use them in arguments*” [...] “Students are able to *argue and debate autonomously*, with regard to the appropriate facts and recipients and provide explanations for possible solutions.”
>
> Estonia: "Communicative competency: an ability to clearly and adequately express yourself, considering situations and communication partners, *presenting your point of view and argumentation (reasoning)*."

We could summarize the meaning of argumentation in the European policy documents by saying, firstly, that in a majority of cases it is related to the evaluation of claims, hypotheses and conclusions on the basis of evidence. Secondly, other meanings are connected to reasoning strategies and critical thinking, on the one hand, and to communication on the other. These three meanings are complementary and overlapping in many policy documents.

Section 2: Argumentation in policy documents in Europe

2.1 Overview of argumentation in policy documents in Europe

In order to gather the required information about argumentation in policy documents, the National Liaison Partners[4] were asked the following questions:

a) Are there references to argumentation in the policy documents in your country?

b) In which documents? (provide references)

c) At which level, general recommendations or identified science subjects?

d) Is argumentation included in the objectives, goals, etc or in the content?

e) Is argumentation (and the use of evidence) related to scientific competence? Please provide some examples.

In this section the results are presented, first, through a table summarizing the responses to the questions. The second column in table 1 lists references to argumentation, either in general policy documents, in the countries where such documents exist, as for instance *The common base of knowledge and skills* in France, or in the common introduction to the National Curriculum, as for instance in Denmark, Spain and other countries where all subject matters are collapsed in a single document. References to argumentation in subjects other than science, e.g. mathematics, languages or citizenship education are also placed in this second column. The third column lists references to argumentation in the science curricula. The fourth column summarizes the place of references to argumentation in these science curricula: in the goals, in the contents, in the evaluation criteria, or in the examples.

Then the situation of argumentation in the policy documents is discussed country-by-country, drawing on the reports from each one. The section ends with a summary of the state of the art of argumentation in this dimension.

[4] National Liaison Partners (NLP) are the institutions representing their respective countries within S-TEAM.

Table 1. Argumentation in policy documents in the European countries

Country	General guidelines in policy documents	References in Science curricula	Place: goals, contents, examples
Norway	National curriculum – Scientific competence	– Science curriculum: Inquiry, communication	– Learning goals
France	*The common base of knowledge and skills* – Science & Technology culture: validate hypothesis – Other subjects	– Physics & Chemistry curriculum (Grades 6 - 9) – Earth & Life Science / Physics & Chemistry curricula (Grade 10)	– Goals: connection to inquiry – Construct arguments about particular examples
England & Wales	No explicit references	– Science curriculum: Sections 'Ideas & evidence' and 'How science works'	– Goals about evidence evaluation
Lithuania	National Education Strategy – Implicit in communication	– Science curricula: Frame in communication	– Learning goals
Czech Republic	National curriculum – Part of key competences – Other subjects	– Curricula of Physics, Chemistry, Natural Sciences, Geography	– Goals about evaluation of claims
Denmark	National curriculum – Methodological skills – Other subjects	– Physics curriculum	– Learning goals
Scotland	*Curriculum for Excellence* – Reasoning skills	–Science curriculum guidelines: debate	– Learning goals
Germany	National standards – Competence areas: Communication & evaluation – Other subjects	– Biology, Chemistry & Physics curricula: competence in communication	– Learning goals
Country	**General guidelines in policy**	**References in**	**Place: goals,**

	documents	Science curricula	contents, examples
Spain	National curriculum – Scientific competence: draw evidence-based conclusions – Other subjects	– Science curricula: particular discourse – Biology & Geology (Grades 9-10): argue	– Learning goals – Evaluation criteria
Finland	National curriculum – Implicit in argue, justify	– Science curriculum: evaluate information	– Learning goals
Estonia	National curriculum – Communicative competence	– Science curriculum: implicitly in inquiry	– Skills
Israel	*Pedagogical Horizon* – Higher order thinking skills Government directive – Argumentation skills	– Science curricula: Argumentation explicitly incorporated in all	– Learning goals – Evaluation criteria
Sweden	National curriculum – Connection to Socio-scientific issues	– Science curricula Biology, Physics Chemistry	– Learning goals
Turkey	No explicit references	– Science curricula: Role of evidence	– Learning goals
Cyprus	National curriculum – Reasoning skills	No explicit references to argumentation	

2.2 How argumentation is addressed in each country

2.2.1 Norway

Argumentation is mentioned explicitly in the science curricula, and implicitly in the general policy documents. We discuss examples from four documents.

– General Policy document: Since the 2006 reform, the policy documents emphasize basic skills and competence. Basic skills in this context means “the ability to express oneself orally; the ability to read; the ability to do arithmetic; the ability to express oneself in writing and the ability to make use of information and communication technology” (Norwegian

Ministry of Education and Research[5] 2006, 7). The emphasis on basic skills does not mean that pupils are to learn these skills at a basic level, but rather that these skills are essential for learning and development within all subjects at each grade level [6].

– Science Curricula: With the Knowledge Promotion reform of 2006, two important changes were made in the Norwegian science curriculum: the introduction of the subject area “the budding researcher” and the strengthening of “basic skills”.

The “budding researcher” deals with “Natural Science methodologies for developing knowledge which involves the formulation of hypotheses, experimentation, systematic observation, openness, discussions, critical assessment, argumentation, grounds for conclusion and presentation” [7].

The Natural Sciences curriculum states that “*Being able to express oneself orally and in writing* in the natural sciences means presenting and describing one's own experiences and observations from nature. In the Natural Sciences, written reports from experiments, fieldwork, excursions and technological development processes are an important part of the work. This includes the ability to formulate questions and hypotheses and to use natural science terms and concepts. Arguing for one's own assessments and giving constructive feedback is important in the natural sciences”[8].

With the introduction of “the budding researcher” and the emphasis on basic skills, argumentation seems to be referred to in policy documents on the Knowledge Promotions

---

[5] Ministry of Education and Research (2006), *Knowledge Promotion. Information for pupils and parents/guardians: What is new in the 10 –year compulsory school and upper secondary schools from the autumn of 2006*? URL: http://www.regjeringen.no/en/dep/kd/Documents/Brochures-and-handbooks/2006/kunnskapsloftet-.html?id=88432

[6] Norwegian Directorate for Education and Training (2010), *Grunnleggende ferdigheter i naturfag – for læring og utvikling*: URL: http://www.skolenettet.no/Web/Veiledninger/Templates/Pages/Article.aspx?id=64165&epslanguage=EN

[7] Norwegian Directorate for Education and Training (2009): Natural science subject curriculum, p.2: URL: http://www.udir.no/Artikler/_Lareplaner/_english/Common-core-subjects-in-primary-and-secondary-education/

[8] ibid.

reform in general and more specifically in the Natural Sciences curriculum and in the guidelines to the Natural Sciences curriculum[9]. The latter is primarily available as an online resource.

However, when we look more closely into the natural sciences curriculum for grades 1-11, we find that argumentation does not seem to be emphasised as strongly in the competence aims as the introduction of "the budding researcher" and the strengthening of basic skills would suggest. For the most part, the competence aims listed in the curriculum emphasise the ability "to describe", "to talk about" or "to explain", more than the ability to argue based on evidence. Argumentation or the ability to argue is however mentioned in some instances. The examples below are taken from the natural sciences curriculum:

> After year 4, pupils should be able to "argue for appropriate behaviour in nature".
>
> After year 10, pupils should be able to "explain the importance of looking for relationships between cause and effect and explain why argumentation, disagreement and publication are important in natural science".
>
> After year 10, pupils should be able to "observe and provide examples of how human activities have affected a natural area, identify the views of different interest groups on the effects and propose measures that might preserve nature for future generations". This competence aim does not mention argumentation explicitly but indicate that the pupils need to be skilled in argumentation.
>
> After year 11, pupils should be able to "assess and argue for the validity and quality of one's own observation data and those of others".
>
> After year 11, pupils should be able to "assess information about, and elaborate on, ethical issues in connection with biotechnology"

As far as argumentation may be considered as part of the basic skill "the ability to express oneself orally", argumentation is included in the competence goals of all subjects. However, researchers from the University of Oslo and the Research institute NIFU STEP have carried out an evaluation of the Knowledge Promotion reform where, amongst other things, they look at basic skills. Their evaluation indicates that the emphasis on basic skills introduced into the curricula with the Knowledge Promotion reform, has not led to any particular changes in schools as yet (Møller et al 2009, p.14). The work done in schools with regards to pupils' oral skills and writing skills seems to be carried out in the same manner as before the reform (ibid).

As a concluding remark, it seems that argumentation has been introduced into the Norwegian curricula as a part of the basic skills agenda and into the Natural Sciences curriculum through the strengthening of basic skills and the introduction of "the budding researcher". To what extent argumentation is emphasised in practice seems more uncertain.

[9] Skolenettet (2010): *Veiledning til læreplan i naturfag*. URL: http://skolenettet.no/Web/Veiledninger/Templates/Pages/Area2Dim.aspx?id=66364&epslanguage=EN

2.2.2 France

Argumentation is proposed both in general policy documents and in the curricula of science subjects. We discuss examples from three documents.

1) General policy document: *The common base of knowledge and skills* [10] lists the skills that should be acquired by pupils at the end of their compulsory education. It undertakes to educate children, "provide them with a living knowledge which passes on major aspects of legacies, opens them up to the reality of their time and prepares them to succeed in life." (p. 7). In it, argumentation is mentioned, for instance:

a) In the section about general skills: to write argumentative texts (page 27);

b) In the section about Science and Technology culture:

The pupil should be able to:

- Use a scientific approach;
- Know how to observe, question, formulate and validate a hypothesis, *argue*, design elementary models (p. 39)

c) In the sections about Mathematics and Citizenship Education:

> Studying mathematics allows pupils to grasp the existence of logical laws and to develop respect for rationally established truth; [to take an] interest in reasoning based on arguments which are to be proven (p. 37).
>
> Citizenship Education: Pupils must be able to make up their own judgment and have a critical mind, which implies: being able to assess the subjectivity or partiality of a speech, a story or a report; knowing how to distinguish between a rational argument and an argument of authority (p. 42-43).

d) The Physics and Chemistry curriculum for *Collège* (intermediate secondary school, grades 6 to 9)[11]. In it, argumentation is mentioned, for instance, in the introduction to the part entitled "Inquiry" (*démarche d'investigation*) when the text proposes seven main points of the inquiry process, one of them is:

> The exchange with argumentation around worked out proposals:
>
> Communication within the class of worked out solutions, answers and results; questions that remain open; exchanging of proposals, debating their validity, seeking arguments. In

[10] Ministère de l'Éducation nationale (2006), *École et collège, tout ce que nos enfants doivent savoir. Le socle commun des connaissances et des compétences*. Paris: Centre National de Documentation. Pédagogique. http://www.cndp.fr/archivage/valid/83722/83722-13351-16900.pdf

[11] Ministère de l'éducation nationale (2008), 'Programmes du collège programmes de l'enseignement de physique-chimie', *Bulletin officiel spécial, 6,* 28 Aout.

> mathematics, this exchange can be completed by the finding that there are several ways to achieve the expected results and by the collective working out of evidence (p. 4).

e) In the objectives of Physics and Chemistry (for all grades), it proposes again the goals of the General Policy Document *The common base of knowledge and skills* (see above):

> Chemistry and Physics teaching should allow students to be able to practice a scientific approach, that is to say to observe, question, formulate a hypothesis and validate it, argue, make simple models and understand the link between the phenomenon studied and the mathematical language that is applied. In this approach, qualitative reasoning has its own place (p.9).

It also proposes the development of autonomy and initiative:

> From the 7th grade, and certainly the 8th and 9th Grades, physics and chemistry teaching should help students acquire a certain autonomy related to accountability and creativity that takes place particularly during experimental activities. Teamwork requires listening, communicating, expressing his/her point of view, arguing and respect for others (p.10).

Argumentation is also mentioned in the sections dealing with specific content, for instance: electrical circuits (p.15); gas (p. 17); gravitation and mechanical energy (p. 26).

f) Curricula for Earth & Life Sciences / Physics & Chemistry (Grade 10)

In the Earth and Life sciences,[12] argumentation is introduced in the section for all grades at *lycée* level (grades 10,11, 12) in a global way in relation to inquiry:

> In order for inquiry to be a real training tool, a qualitative rather than quantitative view is preferred: it is better to argue correctly and slowly than incorrectly and too quickly. This approach is the appropriate intellectual framework for the implementation of activities in laboratories, including essential manipulative and experimental activities for constructing knowledge of the discipline (p.3).

Argumentation is also introduced in the presentation of the three main themes of the curriculum, for instance: theme 1: *The Earth in the universe, life and evolution of life* (10th grade). It aims to show, in the specific framework of life and Earth sciences, that from rigorous methods of argumentation based on observation of the world, science builds a coherent explanation of its state, its functioning, and its history. Beyond the cultural perspective, this line of thinking prepares students for careers in the fundamental sciences, such as research and teaching (p.1). Argumentation is introduced in connection to specific content knowledge, for example about the nervous regulation loop and the energy of the sun:

> Review, extract and exploit historical documents dealing with experimental work to construct and/or argue about the nervous regulation loop.

[12] Ministère de l'éducation nationale. (2010). Programme de Sciences de la Vie et la Terre en classe de Seconde. 29 Avril 2010 Bulletin officiel spécial n° 4.

> Construct an argument (related to experimental work or review) to show the unequal repartition of the quantity of the Sun's energy received according to the latitude and its consequences (p.11).

In the Physics & Chemistry curriculum[13], it is interesting to note that instead of "inquiry approach" (*démarche d'investigation*) the curriculum emphasizes the "experimental approach") (*demarche scientifique*). The idea of argumentation is only mentioned in the sub-section devoted to the "experimental approach", whereas in the introduction. It is not mentioned in connection with specific topics:

> Students should be able to mobilize their knowledge, search, retrieve and organize relevant information, to generate the relevant hypotheses. They also have to reason, argue, demonstrate and work in teams. When presenting their approaches and the results obtained, the students are involved in oral and written communication activities likely to advance their mastery of language skills (p. 1).

2.2.3 England and Wales

Arguments are mentioned in the National Science Curriculum, although the term 'argumentation' is not explicitly used. We discuss examples from one document, the *National Science Curriculum*.

In the United Kingdom, the importance of argument, as the justification of claims with evidence, has been recognized as an educational goal for a number of years, for instance through the *Ideas and Evidence* [14] and *How Science Works* [15] components of the National Science Curriculum. The basic position underlying these components of the curriculum is that students should leave school with a deeper sense of the nature of scientific knowledge, that is, how ideas are produced, evaluated and revised in science. The latest curriculum situates argumentation within the 'How Science Works" component of the national science curriculum:

> How science works" focuses on the evidence to support or refute these ideas and theories. The evidence comes from the collection and creative interpretation of data, both of which need to be considered[16].

[13] Ministère de l'éducation nationale. (2010). Programme de Physique-Chimie en classe de Seconde. *Bulletin officiel spécial, n°* 4 du 29 avril 2010

[14] Department for Education and Skills and Qualifications and Curriculum Authority, England and Wales. (2004). Science. The National Curriculum for England. HMSO.

[15] Qualifications and Curriculum Authority (2007). How Science works. http://curriculum.qcda.gov.uk/key-stages-3-and-4/subjects/key-stage-3/scien ce/Level-descriptions/index.aspx

[16] ibid.

In terms of official curriculum documents, the term 'argumentation' is not explicitly used although 'argument' is mentioned. In the national curriculum component *How Science Works*, argumentation is the process by which exceptional work will be achieved:

> They communicate findings and arguments, showing their awareness of the degree of uncertainty and a range of alternative views. They evaluate evidence critically and give reasoned accounts of how they could collect additional evidence.

Exam boards such as EdExcel and OCR interpret the National Curriculum policy level statements for the design and implementation of teaching. Different exam boards tend to have different interpretations of the 'How Science Works' agenda, hence the varying use of 'argumentation' in teaching. There is a review of some of the key exam board specifications on the "How Science Works" component of the National Science Curriculum in England and Wales in Lavelle & Erduran (2007).

2.2.4 Lithuania

Arguments are mentioned implicitly in the National Curriculum and explicitly in the science curricula. We discuss examples from two documents;

a) *The National Education Strategy*: In the reviewed Lithuanian National Curriculum for secondary schooling the relevance of the use of evidence and of argumentation is emphasized in the *The National Education Strategy* 2003–2012[17]. It is mentioned in the description of the main national education goals, objectives and contents whilst stressing the importance of the development of problem solving skills:

> ...contents of education is related to the provision of values, general skills and competencies that are necessary for the life of an individual and society; targeted development of the main literacy skills, social, cultural and communication competences, critical thinking, problem solving skills and ability to learn.

b) *Science curricula*: This position is further developed in the secondary school curriculum. It stresses the importance of competence based reformed programmes. We may use as an example the renewed mathematics programs for secondary education. Along with the traditional approach towards the learning of mathematics, the programmes stress "the list of statements that the students should be able to prove while relying on the basics of logic." The most argumentation-orientated are the programmes of biology that explicitly mention the development of argumentative competence:

> The revised Biology Secondary Education Programme[18] is based on the development of observation, experimental and problem solving skills. Students should be directed

[17] http://www.smm.lt/en/legislation/docs/Lithuanian%20Education%20Strategy%202003-2012.pdf

[18] http://www.smm.lt/ugdymas/docs/sudp/Informacija%20apie%20projektus.pdf

> towards the acquisition of scientific communication skills based on description and argumentation.

2.2.5 Czech Republic

Argumentation is included both in general policy documents and in the curricula of science subjects.

a) *General policy documents*: Curricular documents are developed at two levels, state and school. In the system of curricular documents, the state level is represented by the National Education Programme (NEP) [19] and the Framework Education Programmes (FEPs) [20]. Whereas the NEP formulates the requirements for education, which are applicable to initial education as a whole, the FEPs define the binding scope of education for the individual stages of preschool, elementary and secondary education. The school level is represented by School Education Programmes (SEPs), on the basis of which education is implemented in individual schools.

Argumentation is an integral part of the general definition of key competences as well as of the description of the goals in the mathematics and science subjects. For instance the *Problem-solving Competency* states that an elementary-school graduate:

> ...thinks critically; makes prudent decisions and is able to defend them; realises the responsibility for his/her decisions; is able to evaluate the results of his/her decisions.

b) *In the section on Mathematics*: The objectives of this educational area state (amongst other things) that the instruction is aimed at forming and developing key competencies by guiding the pupil towards:

> ...developing combinatorial and logical thinking, towards judging critically and argumenting comprehensively and factually by solving mathematical problems (...) developing the confidence in his/her own abilities and potential when solving problems, (...) towards forming the ability to express hypotheses on the basis of experience or experiment and towards verifying them or repudiating them using counterexamples.

c) *Science curricula*: Argumentation is included in the description of goals of Mathematics and the educational area called “Man and Nature” (Physics, Chemistry, Natural Sciences, Geography). This area is intended to support the pupil, through activity and research-based instruction, towards the development of deeper understanding of the laws governing

---

[19] Ministry of Education (2001). Národní program rozvoje vzdûlávání v âeské republice. Ministerstvo ”kolství, mládeÏe a tûlov˘chovy. ÚIV Praha: Tauris.

[20] Rámcov˘ vzdûlávací program pro základní vzdûlávání (se zmûnami proveden˘mi k 1. 7. 2007), VÚP Praha 2005.

natural processes and thus also to become aware of the usefulness of natural-science knowledge and its application in everyday life.

The instruction of this educational area guides the pupil (amongst other things) towards:

- The need to ask questions about the course and causes of various natural processes, to formulate these questions properly and to seek adequate answers to them;
- Thinking that requires the verification of expressed hypotheses on natural facts through several independent methods;
- Assessing the importance, reliability and correctness of collected natural-science data in order to confirm or refute previously articulated hypotheses or conclusions.

2.2.6 Denmark

Argumentation is mentioned both in general policy documents and in the curricula of science subjects. We discuss examples from one document containing the curricula and guidelines for all subjects, the *National Curriculum and Guidelines*[21]:

The Danish Ministry of Education's latest guidelines for curriculum at all levels of education contain specific references to argumentation. Argumentation is a general goal in the social sciences and a specific goal in the secondary Danish language and literature and physics curricula. It can be seen in the curricular goals that the general development of the skills of argumentation are clearly related to 'technical justification', in the sciences and elsewhere. Furthermore the relevant goals for Physics specifically address the 'technical-scientific content' relevance of argumentation.

An instance is found in the common goals for Social Science:

- The development of methodological skills
- Developing skills in technical justification (argument and evidence)

It is suggested that communal efforts are made with technical arguments and evidence, so that students are able to justify statements about social phenomena. Education should therefore give pupils the possibility to:

- Identify different types of arguments in texts and statements
- Understand the logic of arguments
- Assess arguments critically

[21] Danish Ministry of Education (2010) curriculum and guidelines Website. Retrieved on 8-9 2010 www.uvm.dk/Uddannelse/Gymnasiale%20uddannelser/Fagenes%20sider.aspx

- Argue logically and factually
- Assess whether there is evidence in texts and statements
- Distinguish between different types of documentation
- Demonstrate through reference to sources and empirical data
- Create different types of empirical data that can serve for documentation in students' own investigations

The Physics curriculum includes learning goals related to argumentation, specifically:

> Students should work with texts with technical-scientific content and reflect on the content and argumentation, from the perspective of the [scientific] professions

Argumentation is also mentioned in other subject areas including Danish Language and Literature, which includes specific curriculum goals such as argumentation and rhetorical analysis.

2.2.7 Scotland

Argumentation is not explicitly mentioned in the policy documents, which frame notions close to it in 'debate and discussion', on the one hand, and in 'reasoning skills' in the other. We discuss examples from four documents, one about general recommendations and the other three about science education practice.

a) *General policy document*: The curriculum and assessment background to promoting advanced methods in science education in Scotland comprises the *Curriculum for Excellence* (*CfE*) initiative[22]. While still in its infancy, *CfE* is generally supportive and encouraging of investigative science lessons, the range of possible activities that could count as investigative, and the diversity of the ways in which scientists work. Within the accompanying policy documents, a 'totality of experiences [… that put] the learner at the centre of the curriculum' is suggested as the means of developing school leavers as 'successful learners, confident individuals, effective contributors and responsible citizens' [23].

The initiative sets out a number of purposes for learning science, what young people will do, the skills young people will develop, and a statement regarding scientific literacy, as well as the broad features of assessment in science. Unlike previous curriculum initiatives, the *CfE* is less reliant on content in expressing learning outcomes and instead focuses more on learning

---

[22] The Scottish Government (2008) *Curriculum for Excellence: Building the Curriculum 3, a framework for learning and teaching*, Edinburgh: The Scottish Government.

[23] Ibid, p.11; p.7.

experiences, though it does set out the background of scientific content on which these experiences are to be based.

– Policy documents about Science Education: Learning and Teaching Scotland's companion guide, *Curriculum for Excellence: Sciences, Principles and Practice*[24] states that:

> From the early years through to the senior stages, children and young people will demonstrate progress through their skills in planning and carrying out practical investigations, inquiries and challenges, working individually and collaboratively, and describing and explaining their understanding of scientific ideas and concepts. They will also demonstrate evidence of progress through their abilities and skills in reasoning, presenting and evaluating their findings through debate and discussion, expressing informed opinions and making decisions on social, moral, ethical, economic and environmental issues.

This is perhaps the closest the policy documentation comes to openly acknowledging the importance of argumentation as a feature within science learning, though the language does, admittedly, tend towards the less terminologically precise register of 'debate and discussion'. While it is probably accurate to suggest that aspects of argumentation exist implicitly within the ambitions and ethics of the policy documents, it also appears that the closer one moves towards the context of practice, the more indistinct the concept and its attributes become. For example, within the five levels of learning that are outlined in a *Curriculum for Excellence: Sciences Experiences and Outcomes*[25], mention of 'argument' and 'debate' is almost completely effaced in favour of 'discussion'. In this moderately detailed exemplar of scientific competences and experiences (such as might come into existence between pre- and secondary school stages of learning), an example is given as follows: 'By using my knowledge of our solar system and the basic needs of living things, I can produce a reasoned argument on the likelihood of life existing elsewhere in the universe'.

Moving closer still to the environment of practice, *Science: A portrait of current practice*[26] by HMIE (Her Majesty's Inspectorate of Education) reviews the extent to which contemporary practice in science teaching is successfully promoting the four capacities of *Curriculum for Excellence* (namely *successful learners, confident individuals, effective contributors and responsible citizens*). This report is clear that practical, inquiry or investigative learning activities are 'key to developing successful learners in science'. However, drawing on

---

[24] The Scottish Government (2009a) *Curriculum for Excellence: Sciences, Experiences and Outcomes*, Edinburgh: The Scottish Government.

[25] The Scottish Government (2009b) *Curriculum for Excellence: Sciences, Principles and Practice*, Edinburgh: The Scottish Government.

[26] HMIe (2008) *Science: A portrait of current practice*, HM Inspectorate of Education.

the evidence of the inspection of primary and secondary schools between 2004 and 2008, the report is reserved about the depth or breadth of argumentation in Scottish schools. The report does, however, provide case studies of a small number of 'Ethical Debates' that inspectors did observe. For example:

> Young people in S1 carried out a survey of other young people's views on the use of stem cells. They then researched the topic and presented arguments for and against stem cell use in a public debate. Using voting tools to gather the views of the audience, they analysed the results to determine if opinions had changed following the debate. The young people said that they enjoyed the task because it was challenging and fun and made them realise that it could affect all their lives. (p.19)

Interestingly, the investigation by HMIe is somewhat conservative in its interpretation of informed debate in the classroom as residing within the moral life of the responsible citizen, whatever reasoned argument for the existence of life in the rest of the cosmos might, for example, be possible. In sum, the report concedes that 'Across all sectors, the use of debates and class discussions to help children and young people develop informed, ethical views of topical issues in science was **not** a common feature of learners' experiences'.

2.2.8 Germany

Argumentation is explicitly mentioned in the National Science Education Standards, while in general policy documents and in the curricula of science subjects there are references to communication competence. We will discuss examples from seven documents.

a) *General Policy document*: In Germany educational policy is regulated by the federal state authority. This results in different curricula and different structures for the educational systems in each of the 16 German federal states. One ramification of the PISA 2000 results is, however, that the Standing Conference of the Ministers of Education and Cultural Affairs of the Länder (federal states) in the Federal Republic of Germany (*Kultusministerkonferenz*, KMK) agreed upon the development and implementation of national educational standards. These standards are output-oriented and define what knowledge and which competences students should have achieved at different stages in their educational careers[27]. The standards distinguish four competence areas, namely content knowledge, achieving knowledge (epistemology), communication and evaluation – and three proficiency levels ranging from low (level I) to high (level III) proficiency.

b) *Science National Standards*: In Germany, secondary school (i. e. beginning in 5th grade) science is usually taught in separate subjects – namely biology, chemistry and physics.

---

[27] KMK (2005a). *Beschlüsse der Kultusministerkonferenz: Bildungsstandards der Kultusministerkonferenz. Erläuterungen zur Konzeption und Entwicklung. Beschluss vom 16.12.2004*. München: Luchterhand.

References to "argumentation" can be found both explicitly and implicitly, within the educational standards in biology [28], chemistry [29] and physics[30] for the intermediate school leaving certification (*Mittlerer Schulabschluss*). In all three documents, these references belong to the competence areas "communication" (exchanging and extrapolating information subject-oriented and with respect to the underlying facts) and "evaluation" (identifying and evaluating subject-specific facts).

In the educational standards for biology, argumentation is explicitly mentioned in competences K1: "The students communicate and argue in different social contexts", and K6: "The students present results and methods of biological experiments and use them in arguments" (KMK 2005b, p. 14). In both cases, argumentation is at proficiency level III – "Students are able to argue and debate autonomously, with regard to the appropriate facts and recipients and provide explanations for possible solutions". In the document, several examples are given, e.g. a role play of a town hall meeting is conducted in which students take over the roles of different stakeholders arguing and debating for or against building a planned holiday resort (KMK 2005b, p. 31).

Similarly, argumentation is mentioned in the educational standards for chemistry as part of the competence area communication:

> Students can present their position in a subject-specific manner, they can reflect on their opinion, find arguments or eventually change their opinion based on presented objections (KMK 2005c, p.9).

In chemistry, argumentation is moreover part of the competency area evaluation:

> Considering issues that are relevant from a social point of view, students realize that solutions for problems might depend on shared or accepted values. They should be able to test arguments with respect to their subject-specific and ideological content and thus to make subject-specific, autonomous and responsible decisions (KMK 2005c, p. 9).

A discussion of the carbon cycle is mentioned as an example (KMK 2005c, p.31).

In the educational standards for physics, argumentation is explicitly mentioned only in the examples (e.g. "Which arguments are in favor of [...]/Which arguments do you think are

[28] KMK (2005b). *Beschlüsse der Kultusministerkonferenz: Bildungsstandards im Fach Biologie für den Mittleren Schulabschluss. Beschluss vom 16.12.2004*. München: Luchterhand.

[29] KMK (2005c). *Beschlüsse der Kultusministerkonferenz: Bildungsstandards im Fach Chemie für den Mittleren Schulabschluss. Beschluss vom 16.12.2004*. München: Luchterhand.

[30] KMK (2005d). *Beschlüsse der Kultusministerkonferenz: Bildungsstandards im Fach Physik für den Mittleren Schulabschluss. Beschluss vom 16.12.2004*. München: Luchterhand.

correct? ”). Implicitly, however, argumentation is also part of the competence areas communication and evaluation (KMK 2005d, p.10):

> The ability to communicate with respect to the appropriate facts and recipients is an essential part of physics literacy. [...] Communication requires students to master the rules of discussion [...] [and] to demonstrate the willingness and ability to contribute their knowledge, ideas and beliefs to the discussion, to meet their discussion partners with respect and trust and to give them insight into one’s own knowledge.

c) *Science curricula*: In the context of this analysis we looked at the science curricula from Bavaria, Brandenburg and Schleswig-Holstein. Although curricula in Germany principally depend on the school track (*Hauptschule, Realschule, Gymnasium*), a general tendency to focus primarily on content can be observed. Argumentation is not explicitly mentioned in these curricula. They do, however, refer to the competence areas of communication and evaluation as defined in the educational standards. Implicit references can for instance be found in the physics curriculum for Brandenburg [31] where it is stressed that:

> The ability to communicate subject- and recipient-related [...] is an important aspect of scientific literacy (p. 13).
>
> Based on their physical knowledge, students should be able to personally take a stand that is subject-related and open to criticism (p. 11).

Implicit references to argumentation can also be found in the science curricula for Bavaria[32] (2009) and Schleswig-Holstein[33] (1997), although, they seem to be related more to general thinking abilities, logic and reasoning (for instance, to reason about an observation by drawing on knowledge about molecular structures). We give some examples from the biology curriculum for Schleswig-Holstein. The curricula for chemistry and physics differ only marginally regarding competences related to argumentation.

One aim of biology teaching is to:

> ...develop an understanding of nature and the environment [...] by fostering perception, thinking and judgement (Schleswig-Holstein 1997, p. 15).
>
> Biology education [...] aims at introducing students to scientific working and thinking. The students have to experience that scientific statements have to be separated from normative statements. Therefore, biology instruction has to counteract false conclusions

[31] Brandenburg (2008). Ministerium für Bildung, Jugend und Sport Land Brandenburg. *Rahmenlehrplan für die Sekundarstufe I, Jahrgangsstufen 7-10, Physik*.

[32] Bavaria 2009. Staatsinstitut für Schulqualität und Bildungsforschung. *Jahrgangsstufenlehrplan Chemie Gymnasium*.

[33] Schleswig-Holstein 1997. Ministerium für Bildung, Wissenschaft, Forschung und Kultur des Landes Schleswig-Holstein*. Lehrplan für die Sekundarstufe I der weiterführenden allgemeinbildenden Schulen*.

drawn from biological facts especially when the peaceful coexistence of the people is at stake (Schleswig-Holstein 1997, p. 16).

Biology instruction should enable students to follow the technical applications of biological knowledge in an open and critical way and to make judgements about them. (Schleswig-Holstein 1997, p. 16).

Biology instruction develops the following skills:

- To get acquainted with methods of biological work, especially […] analysing, interpreting [..]
- To differentiate between observations and interpretations
- To develop simple hypotheses in order to explain phenomena (Schleswig-Holstein 1997, p. 17)

Biology teaching supports

- Oral and written skills through the adequate verbalization and the logically consistent description of biological facts
- The ability to realize the limitations of scientific evidence" (Schleswig-Holstein 1997, p. 18)

In biology instruction, students learn to […] communicate in a group of peers, to evaluate the conceptions of others and to change their own opinion if necessary (Schleswig-Holstein 1997, p. 19).

To sum up, argumentation does not seem to be very prominent in science curricula in Germany. Because we did not analyse a comprehensive sample of documents, we cannot be sure about the situation in other federal states, although there is no indication that there are substantial differences. Argumentation seems to play a role in other school subjects, especially first language, ethics and mathematics, for the latter e.g. in the notion of constructing a proof for a statement.

2.2.9 Spain

Argumentation is mentioned both in general policy guidelines and in the curricula of science subjects. We discuss examples from one document containing the curricula and guidelines for all subjects, the National Curriculum (MEC, 2007)[34] general guidelines.

In the Spanish National Curriculum for secondary school, the relevance of the use of evidence and of argumentation is emphasized both in the general definition of two (out of eight) key competences, namely scientific and mathematical competences, and in the

[34] Ministerio de Educación y Ciencia, Spain (MEC). (2007). Real Decreto 1631/ 2006 Enseñanzas mínimas educación secundaria obligatoria. Boletín oficial del Estado, 5 January, 677-773. Retrieved at http: //www.boe.es/boe/dias/2007(01/05/pdfs/A00677-00773.pdf

description of goals in the science subjects. The key Scientific Competence (literally "Competence about knowledge and interaction with the physical world") states that:

> This competence [...] enables [pupils] to engage in rational argumentation about the consequences of one or another way of life, and to adopt a stance towards a healthy life both physically and mentally [...] This competence makes it possible to identify questions or problems and to draw conclusions based on evidence, with the goal of understanding and making decisions about the physical world and about the changes produced by human activity in the environment, the health and people's quality of life (MEC, 2007, p. 687).

The description of the contributions of science to the basic key competences also highlights "a particular way of constructing discourse, aimed towards argumentation" (MEC, 2007, p. 692) and includes the skill of argumentation amongst the general objectives of science education for compulsory secondary school (*Enseñanza Secundaria Obligatoria*, ESO), from the ages of 12 to 16 years.

Argumentation is mentioned also in the definition of Mathematical competence:

> The ability to interpret and to express clearly and accurately information, data and arguments is part of mathematical competence. This increases the possibility of carrying on learning throughout life […] These processes enable [pupils] to apply that information to more situations and contexts, to follow argumentative chains identifying the main ideas, and to estimate and judge about the logic and validity of argumentations and informations (MEC, 2007, p.687).

– *Science curricula*: Argumentation is mentioned in several headings of the sections of the National Curriculum devoted to science curricula, for instance in the objectives, content and evaluation criteria.

Introduction to the sciences, an implicit reference, mentions hypothesis evaluation:

> The construction of these explanatory and predictive models is carried out through methods of search, direct observation and experimentation, and through the elaboration of hypotheses that need to be tested." (Ibid, p. 690).

In the Common *objectives* of all the Science areas, including Biology, Geology, Physics and Chemistry, we find:

> Objectives: Science education in this stage [secondary school] has as a goal to develop these abilities:
>
> [...] To understand and to communicate messages with scientific content using oral and written language appropriately; interpreting diagrams, graphs, tables and basic mathematical expressions, as well as to communicate to others arguments and explanations in the field of science." (Ibid, p.693).

Contents of the subject Natural Sciences in the first theme of the 9th and 10th Grades (14-15 and 15-16 years), including Biology, Geology, Physics and Chemistry:

> Interpretation of scientific information and using this information to develop one's own opinion, to talk and write accurately and to argue about problems related to nature. (Ibid, p. 696).

Evaluation criteria of different science subjects, for instance Biology and Geology in the 9th Grade:

> To collect information from various documentary sources about the influence of human activity on ecosystems: effects of pollution, desertization, decreases in the ozone layer, resource depletion and species extinction. After analyzing this information, to engage in arguments about potential actions, in order to avoid degradation of the environment, and to promote a rational management of natural resources. They [the students] should also value the environment as human heritage, and to be able to argue reasons for individual and collective actions in order to avoid its degradation (Ibid, p. 698).

References to argumentation are also found in other subjects, such as Social Sciences, Citizenship Education or Mathematics. For instance, an evaluation criterion in Social Sciences in the 9th Grade mentions:

> To evaluate the use of oral language and of argumentation, as the compliance with norms regulating dialogue and group discussion." (Ibid, p. 708).

The introduction to Citizenship Education mentions the relevance of "knowing how to reason and to engage in argument." When discussing the contributions of this subject to the key competences, it is stated that:

> The curriculum pays special attention to argumentation, to the construction of one's own thinking, to case studies involving taking a stance about a problem and its solutions […] The systematic use of debates contributes to linguistic communicative competence, because it requires the exercise of listening, presentation and argumentation [skills] (Ibid, p. 717).

Argumentation is also included in the goals and in the evaluation criteria of this subject, as for instance:

> To justify their own positions using in a systematic way argumentation and dialogue [...] This criterion seeks to assess the appropriate use of argumentation about dilemmas and moral conflicts (Ibid, p. 721).

2.2.10 Finland

Argumentation is not mentioned explicitly in the policy documents, although there are implicit references to argumentation skills. We will discuss examples from one document containing guidelines for all subjects in the National curriculum.

In the Finnish *National Core Curriculum for Basic Education*[35] (2004) (FNCC) there are no explicit references to argumentation. However, there are some aspects that can be interpreted as the implicit promotion of argumentation skills. In the FNCC, within the aims of many subjects, pupils are supposed to argue their points reasonably and explain their decisions. This aim of arguing for one's opinion is emphasised for example within the aims of Finnish language study (FNCC, 2004, e.g. pp. 27 and 29). Also, in mathematics, pupils are guided to explain their conclusions, from the first grade onwards (FNCC, 2004, p. 105 Finnish, p.158 English). Pupils are also supposed to argue their understanding and give justifications for their decisions about social, environmental and ethical issues, for example within social studies, health education and ethics, and within various cross-curricular themes that are presented in the FNCC. Thus, argumentation is considered indirectly within many subjects.

– *Science curricula*: From the point of view of science education, there are no explicit aims of teaching argumentation. Some goals about learning causal relationships and critical thinking can be interpreted as implicitly encompassing argumentation as well. For example in grades 5 and 6 it says:

> ...pupils learn to make conclusions about their observations and measurements and recognize the causal relationships associated with the properties of natural phenomena and objects (FNCC, 2004, p.124 Finnish, p.186 English).

In grades 7-9 it states:

> Pupils will learn to evaluate the reliability of the information they have obtained from different sources (FNCC, 2004, p.126 Finnish, p.189 English).

Furthermore, some goals about developing justification skills in the FNCC are very content-bound, like the aim of 7-9 grades biology that states:

> ...pupils know how to justify the importance of biodiversity from the standpoint of ecological sustainability (FNCC, 2004, p. 121 Finnish, p.181 English),

which means that students learn a ready-made justification, without reasoning about the issue for themselves.

2.2.11 Estonia

The role of argumentation and reasoning practices is minimal in the main policy documents. We will discuss examples from four documents, two about general guidelines for primary and secondary, and two about science education for the same levels.

[35] Finnish National Board of Education (2004). Finnish National Core Curriculum for Basic Education. URL http://www.oph.fi/english/publications/2009/national_core_curricula

a) *General policy guidelines*: Argumentation is mentioned in the general part of the National Curriculum[36], both at the basic school and gymnasium level in the section about communicative competence, defined as "an ability to clearly and adequately express yourself, considering situations and communication partners, presenting your point of view and argumentation (reasoning)".

b) *Science Curricula*[37]: The subject curricula are currently being restructured. The working versions of the science education curricula for basic school and gymnasium do not emphasize argumentation and reasoning as the key competences to be acquired during this school level.

Argumentation practices and reasoning are implicit in the suggested problem-solving and inquiry learning approach; in decision-making and role-play activities (e.g. making inferences, solving problems considering ethical, moral, economical and legislative dilemmas).

In the science, biology, geography, physics and chemistry curricula for basic school the skills of formalizing hypotheses and making inferences based on experiments and observations are emphasized, starting from grade 4. The science education curricula ignore collaborative learning and discussions, and mainly highlight individuals as knowledge constructors in inquiry learning, using ICT based technology and empirical experiments.

In the current subject curricula, inquiry learning is even less emphasized, and argumentative practices and skills are not emphasized at all. The new curriculum will start from 2011.

2.2.12 Israel

Argumentation is proposed both in general policy documents and in the curricula of science subjects. We will discuss guidelines from four documents.

[36]Vabariigi Valitsuse 28. jaanuari 2010 määrus nr 13 "Gümnaasiumi riiklik õppekava" (National curriculum for gymnasium level, general part)

Vabariigi Valitsuse 28. jaanuari 2010 määrus nr 14 "Põhikooli riiklik õppekava" (National curriculum for basic school level, general part)

[37] Vabariigi Valitsuse 28. jaanuari 2010. a määruse nr 14 „Põhikooli riiklik õppekava" lisa 4 (National curriculum for Basic school, annex 4, science education)

Vabariigi Valitsuse 28. jaanuari 2010. a määruse nr 13 „Gümnaasiumi riiklik õppekava" lisa 4 (National curriculum for Gymnasium, annex 4, science education)

a) *General policy document*: The Director General's Code of Bye-Laws[38] published by the Ministry of Education in 2008 contains instructions to school system employees. It was distributed to all formal and informal educational settings (K-12). In it, the Ministry of Education set a new goal called "Pedagogical Horizon" [39] which was defined as a prime pedagogical target. This new policy was defined as a shift "from repetition- focused learning to the development of thinking processes". The new target was integrated into all subjects. It incorporated the teaching of reasoning strategies such as decision making, argumentation, problem solving, and comparison, identifying hidden assumptions, drawing conclusions, etc.

The new policy was guided by the principle that in the 21st century the Israeli educational system must address new cultural, economic, scientific and technological challenges. This will call for the teaching of higher order thinking skills to enable students to acquire knowledge through creativity and critical thinking [40]. Knowledge needs to be significant and relevant to life. These reasoning skills should help students make informed decisions and to function in a changing world. As citizens of a democratic state they need the ability to weigh moral considerations, apply critical thinking skills and argumentation skills. Thus reasoning skills are clearly the foundation for all types of pedagogical activities in school.

This policy is comprehensive and involves three components: (1) Evaluation (matriculation exams, growth and effectiveness measures for schools) which leads to (2) the need for in-service teacher education (continuing education program) and (3) development of curriculum standards and new criteria to assess teaching material [41],[42]. School textbook publishers are now required to include reasoning assignments in new books.

---

[38] The Director General's Code of By-Laws, Israeli Ministry of Education, September 1, 2008. Retrieved from: http://cms.education.gov.il/EducationCMS/Units/Bitachon/ChozreyMankal

[39] Zohar, A. (2009). Thinking Education Report "Pedagogical Horizon" 2006-2009": Description, Insights and Further Recommendations. Israeli Ministry of Education, Pedagogical Secretariat, Jerusalem. (In Hebrew) http://cms.education/gov/il/EducationCMS/Units/Mazkirut_Pedagogit/OfekPedagogi

[40] Orad Y. & Ravid, S. (2008) Thinking and Information Management, Israeli Ministry of Education website.
http://cms.education.gov.il/EducationCMS/Units/Mazkirut_Pedagogit/OfekPedagogi/Digmy_Horha/Yessodi/Tyon.htm

[41] Levi, Binyamin (2009). Approval Process of Textbooks for Thinking Education. In Zohar, Anat (Ed) Thinking Education Report: "Pedagogical Horizon" 2006-2009: Ibid.

b) *Science curricula*: Each field was called upon to define the way in which argumentation, as part of high order thinking skills, should be incorporated into the curriculum, learning materials and testing[43]. In the sciences for example, this has been concretized as follows:

- Biology: expand thinking strategies in the new biology curriculum, especially argumentation and meta-cognition.
- Chemistry: Integrating high order thinking skills with a focus on meta-cognition (see for instance, Zimrot, 2009).
- Physics: Development of learning materials and teacher continuing education courses, which integrate argumentation skills as part of physics teaching.
- Science for all: development of teaching materials by teachers, which integrate reasoning skills such as argumentation (see for instance, Shtessel, 2009).
- Electronics and computer engineering and Energy Conservation: Projects implementing argumentation skills.
- Science and technology in elementary school and in junior high school: developing books that integrate argumentation activities in all grades.
- Science in kindergarten (age 3-6): developing activities requiring argumentation.

Furthermore, a government directive[44] dated June 30, 2007 to all school principals made the teaching of argumentation skills obligatory as part of scientific skills.

2.2.13 Sweden

Argumentation is included in the National Science curriculum for compulsory school. We discuss examples from one document. In it, argumentation is mainly mentioned in connection to socio-scientific issues.

– *Common Syllabus for Science*[45]: The Swedish school system is in an on-going process of changing the curriculum. The 2011 curriculum has not yet been finalised, but focuses on core

---

[42] Yoad, Z. et al. (2009). Higher Order Thinking Skills. A Guide for Curriculum Designers. Israeli Ministry of Education, Pedagogical Secretariat, The Department of Curriculum Design and Development. (In Hebrew)

[43] Zohar, 2009, op cit.

[44] Zohar, A. (2007), Changes in the Status of Basic Science Education in Theoretical Areas. A Letter to School Principals. Israeli Ministry of Education, Pedagogical Secretariat. (In Hebrew)

content, without instructions on how to teach in the classroom. Argumentation is included, for instance, within the subjects and their role in education:

> At the same time education aims at an approach to the development of knowledge and views, which resonate with the common ideals of the natural sciences and democracy on openness, respect for systematic investigation and well-founded arguments.

In the 'structure and nature of science' section:

> A critical and constructive attitude to one's own and others' arguments, as well as sensitivity and respect for the reasoning of others and their views are important ideals for a democracy, and are also central principles for dialogue and discussion in the sciences. Of central importance is the view that scientific knowledge is a human construction and that it provides a basis for evaluating views, decisions and measures. It is also important that the education *gives prominence to a wide spectrum of arguments, covering ethical, aesthetic, cultural and* economic aspects, which are of relevance in discussions concerning Man's ways of living together and using nature.

A specific goal in science subjects is that the school in its teaching of science should aim to ensure that pupils, concerning the use of knowledge:

> develop a critical and constructive attitude to reasoning of their own and others, showing respect and sensitivity to the views of others

Argumentation is seen as a goal in itself, for instance, by the end of the fifth year, pupils should:

> ...have insight into how arguments over daily environmental and health issues can be constructed through the use of personal experiences and scientific knowledge.

By the end of the ninth year:

> Pupils should, concerning the use of knowledge, have an insight into the difference between scientific statements and statements based on values; *be able to use their knowledge of nature, Man and his activities as arguments on issues* concerning the environment, health and inter-personal relations.

– *Science curricula*: Argumentation is included in the curricula of Biology, Chemistry and Physics for compulsory school. The example of biology is quoted, as the goals are worded in a similar way in Physics and Chemistry:

> Pupils should be able to use not only scientific but also aesthetic and ethical arguments on issues concerning the conservation of habitats and diversity of species and the use of genetic engineering. Pupils use their scientific knowledge to examine the arguments concerning issues of environmental, resource management, health and technology and the interests and values that underlie different positions.

[45] Swedish Syllabus for science (English version):
http://www3.skolverket.se/ki03/front.aspx?sprak=EN&ar=1011&infotyp=23&skolform=11&id=3878&extraId=2087

2.2.14 Turkey

Argumentation is mentioned in the Science Curriculum. We discuss examples from two documents:

a) Secondary school science programmes [46] (grades 9 through 11). These programmes have been recently renewed (in 2007). According to them, physics, chemistry, biology, astronomy, and geology form the "physical sciences" and they use mathematics as a tool of thinking and language. Science is seen as a dynamic way of understanding that provides the most accurate explanations of the universe and life based on observations and experiments, with the capability of changing these explanations based on developing observations and experiments. In their objectives related to argumentation and scientific literacy, these programmes[47] state, for instance, that students should be able to:

> Understand and accept the nature of science; develop skills for conducting experiments and evaluate experimental data to reach generalizations; become aware of the importance of scientific approach and critical thinking to interpret the world; realize that scientific knowledge is not always absolute truth, but valid under certain limits; realize that many men and women from different cultures contribute to science and technology.

More specifically about the role of evidence, that they should be able to:

> ...understand that science has a structure that is based on evidence and it allows questioning and falsification; explain the role of evidences, theories and/or paradigms on how scientific knowledge changes; realize that when new evidence appears, current scientific knowledge is tested, limited, corrected or renewed; evaluate the role of continuous testing, reviewing, and criticizing in the development of science and technology.

About science and technology issues in the context of society:

> Realize that technology is not good or bad in itself, but [that] decisions on the use of technological products and systems may result in wanted or unwanted consequences [and gives examples for these situations]; join contemporary discussions about science and technology that may influence the future of individuals, society or environment; evaluate the economic, social and environmental costs of technological benefits; realize that there may be different opinions in the society about the adoption of ideas and applications in science; give examples of cases when today's knowledge in science and technology is insufficient for solving problems related to individuals, society and environment; understand the responsibilities of individuals and societies for conservation of environment, wild life and natural resources.

---

[46] MEB (Turkish Ministry of National Education) (2010). *Biology, Chemistry and Physics Curricula*, Retrieved 25 August, 2010, from http://ttkb.meb.gov.tr/ogretmen/

[47] MEB (Turkish Ministry of National Education) (2008). *Turkish 10th Grade Physics Curriculum (pp. 22-28)*, Retrieved 25 August, 2010, from http://ttkb.meb.gov.tr/ogretmen/

2.2.15 Cyprus

There are no formal references to argumentation in the national curriculum documents at any education level.

There is a clear reference, however, (especially in kindergarten and elementary grades) to the development of scientific method skills (observation, design experiments, carry out experiments, making predictions etc). Additionally, at kindergarten level there is an emphasis on scientific thinking and reasoning skills, again without explicit reference to argumentation. In summary, argumentation is not explicitly included in the objectives, goals or content of the national curriculum.

2.3 The state of the art of argumentation in policy documents in Europe

The state of the art of argumentation in policy documents through Europe, in particular in the national contexts of the 15 countries involved in the project, can be summarized by saying that argumentation is addressed, in most cases explicitly, in the national curricula of all but one of the national contexts examined.

Argumentation is explicitly emphasized, either in the common guidelines of the national curricula or in the science curricula, or even in both, in 11 countries: Norway, France, England & Wales, Lithuania, Czech Republic, Denmark, Germany, Spain, Israel, Sweden and Turkey. In most of them argumentation has a meaning related to knowledge evaluation and justification, and to the use of evidence (France, England & Wales, Czech Republic, Denmark, Spain, and Turkey), in a second case in connection to inquiry and inquiry based science teaching (Norway and France), in a third, framed mainly in communicative competence (Lithuania, Germany, Sweden), and in a fourth as part of higher order thinking skills (Israel). Moreover, it should be noted that in Israel the teaching of argumentation skills has been compulsory since 2007.

Implicit references to argumentation are found in the policy documents of three countries: Scotland, with meanings closer to debate and communication, Finland, with meanings closer to justification and data evaluation, and Estonia, where they are framed in inquiry approaches.

In the Cyprus policy documents there are no references to argumentation.

Regarding how it is situated in the official documents, argumentation is part of the learning goals of the national curricula or guidelines in twelve countries. In two cases at least, Spain and Israel, it also forms part of the evaluation criteria. This is relevant, as evaluation is a driving force behind educational changes introduced in the classrooms.

Sometimes, when the guidelines are at the level of science curricula, the meaning of argumentation as evaluation of evidence shifts to debate and discussion, as, for instance, we have noted in the reports about Norway and Scotland.

The introduction of argumentation in policy documents can be related to the European recommendation about eight key competences (EU, 2006). In some of the policy documents argumentation is framed in one or more of the key competences, in most cases scientific competence, in others communicative competence.

It should be noted that there are three relevant modes of knowledge circulation, namely the academic mode, the practical mode and the mode of governance. This section addresses the mode of governance, where knowledge circulates through guidelines, regulations, standards, meetings and policy statements. Research shows that the presence of a given dimension, recommendation or orientation in national standards or in guidelines does not ensure its implementation. In fact, as some country reports note, changes at school level as a result of policy statements etc. are not apparent (e. g., Møller et al., 2009), although it is known that some time is needed before educational recommendations are translated into classroom practice.

The presence of argumentation in the policy documents is, however, a first step, for it is clear that, without it, this implementation would not take place. Therefore, the current situation provides an appropriate context for the integration of argumentation into European science education classrooms. This integration depends critically on factors such as the availability of teaching resources, which will be produced as future deliverables by S-TEAM work package 7, and the preparation of teachers, both during initial teacher education/training and during in-service professional development, issues addressed in the next sections of this report.

Section 3. Argumentation in Initial Teacher Education in Europe

3.1 Overview of argumentation in Initial Teacher Education programmes

In order to gather information about argumentation in Initial Teacher Education (ITE) programmes, the National Liaison Partners were asked the following questions:

a) Is argumentation included in the programs of Initial Teacher Education?

b) For all student- teachers or in particular for science teachers?

c) Which is its status (e.g., part of the Science Education program, part of a course / seminar about scientific competences?)

d) Which is its weight and format (a lesson out of...; a few lessons; a workshop)?

Please provide some examples

It needs to be noted that there are some differences between the data collected from the policy documents, and the information about ITE, which, being the responsibility of different universities across each country, is dispersed and not always easy to ascertain. In the case of some countries there is higher homogeneity, due for instance to guidelines issued by the educational authorities, or to common contents agreed upon by universities. The available data are complemented in the country reports through some inferences based, for instance, on the role of argumentation in National Curricula, which will call for its presence in teacher education programmes.

In this section the results are presented, first, through a table summarizing the responses to the questions. The second column in table 2 presents argumentation lessons in general courses or seminars, or in any seminars different from science education in the ITE programs. The third column lists argumentation lessons in the science education seminars (which in almost all countries except UK are named *Science Didactics*). The fourth column summarizes the weight and format of argumentation in these seminars.

Then the situation of argumentation in ITE is discussed in two contexts, where respectively argumentation is explicitly and implicitly taught. The section ends with a summary of the state of the art of argumentation in this dimension. Throughout the section the focus is primarily on Secondary Teacher Education.

Table 2. Argumentation in Initial Teacher Education (ITE) in European countries

Country	General seminars in ITE programs	Science methods	Format and weight
Norway	Not explicitly mentioned in ITE programmes	Indirectly included in the competence goals	Not specified
France	Evidence based reasoning in Mathematics education	Currently in process of change	– 6 hours
England & Wales	Argumentation (ideas & evidence) part of the training of other subjects	SEP: "Science Enhancement Programme" from several universities	– One or two 3-hour sessions
Lithuania	Argumentative reasoning Critical thinking	Not explicitly	– Series of workshops
Czech Republic	Integrated in general pedagogy courses	Subject didactics for secondary Primary science and mathematics courses	– Two lessons science – One lesson per general course
Denmark	Science Communication	Advanced science teaching methods course	– One-day interactive role- play
Scotland	Argumentation implicitly included.	Emphasis on evidence and explanations	Online environments, mobile technologies
Germany	No explicit references	Courses about scientific methods and thinking in some universities	SINUS module 'scientific work'
Spain	Reasoning	Explicitly included in the Science Methods program in some universities and texts	– Workshops from 3 to ten hours – Master thesis
Country	**General seminars in ITE**	**Science methods**	**Format and weight**

	programs		
Finland	Implicitly included within the aims; not in the course descriptors	Aims of science education courses (e.g. in: *Structures and processes of schools physics*)	Not specified
Estonia	Minimal status; it may be part of some seminars	Taught as part of inquiry learning and problem-solving	Role-plays with SSI computer simulations,
Israel	Thinking strategies	Academic courses for ITE including thinking strategies	– Part of a 28 hours course on thinking
Sweden	Integrated in general pedagogy courses	Integrated in Science Education	– Concept cartoons
Turkey	Partly addressed in Nature of Science courses	Partly addressed in Science Methods	Not specified
Cyprus	No explicit references	Some aspects of argumentation are taught	Not specified

3.2 The state of argumentation in Initial Teacher Education in each country

It has to be remembered that, in European countries, universities are responsible for ITE. In most cases the Ministries of Education establish a common frame with the total number of credits and the type of seminars, but contents and programmes are decided upon by individual universites. There is, therefore, a certain amount of diversity, not only between different countries, but also within countries, making it difficult to draw a common picture.

Contexts where argumentation is explicitly addressed

Argumentation, use of evidence or knowledge evaluation are explicitly addressed, with different emphases, in the ITE programs in nine countries: France, England & Wales, Lithuania, Czech Republic, Denmark, Spain, Estonia, Israel and Sweden. As each university is responsible for its own ITE programmes, it is difficult to establish the extent to which argumentation is addressed. In a few countries it seems to be generally addressed, while in others the available data suggest that it is addressed in some, but not all, universities. Several country reports suggest that, as argumentation is part of the national curricula, it could be assumed that it forms part of teacher education programmes.

3.2.1: France

The programmes and organisation of Initial Teacher Education are currently in a process of change. Thus, time is needed before reliable data can be collected for the whole country. Nevertheless, as argumentation is part of national programmes for schools, as well as inquiry based learning and teaching, it can be assumed that it is included in the programmes of ITE. For instance in some universities, such as Grenoble, three lessons (6 hours) are devoted to "evidence-based reasoning" within a course about "Inquiry based methods in mathematics".

3.2.2: England and Wales

Argumentation skills form an integral part of the training of other subjects than science (e.g. history, geography, English) in initial teacher training, although these skills may not be formally recognized as such. Each uses a different type and range of evidence. History is very much evidence-based. Schools do not tend to explicitly use argumentation as part of study skills training, although this may well be coming in because these kinds of critical thinking/problem solving courses are becoming established in some schools at Key Stage 3 level. In pre-service teacher training courses, typically one or two 3-hour sessions are dedicated to issues of argumentation and nature of science, accompanied by some observational and teaching experiences.

The Department for Education[48] has highlighted the importance of ideas and evidence in initial teacher training. For instance, they have highlighted the Science Enhancement Project (2004), which involved a set of universities working with trainee teachers and mentors, and is funded by the Gatsby Foundation, as a case study. Simon and Maloney (2006) review some of the recent ITE initiatives in training pre-service science teachers in argumentation.

3.2.3: Lithuania

Argumentation is included in the programs of Initial Teacher Education for all student-teachers. The majority of teacher training modules include the development of critical thinking and problem solving skills. The methodological basis of lectures reflects the possibility of discussions, disputes and debates. In all teacher-training institutions there are modules of business communication including learning to create argumentative texts. There are optional modules of rhetoric that address the essence of argumentation, reveal kinds of arguments and features of argumentative reasoning. The prevailing pattern is a series of workshops.

3.2.4: Czech Republic

There is great variability in teacher education programmes, as the universities are quite autonomous and there are no national frameworks, except for recommendations concerning the content of the programme provided by the Accreditation Commission for Higher Education. Standards for the Teacher Professional Development System are currently being developed and will be implemented in 2012-2015. An obligatory ITE curriculum should then be derived from the standards – at the moment it is regulated by the Accreditation Commission.

Argumentation is integrated in general pedagogy courses (e.g., general didactics, critical thinking) for all students. Prospective science teachers also have argumentation skills development emphasized in their subject didactics courses. Primary teachers have compulsory mathematics and primary science courses, where argumentation is embedded as well.

Nonetheless, argumentation is rarely presented as a separate topic; it is usually introduced in relation to instructional practices. Student teachers practice argumentation on their own so that they realize its importance and master the skill of facilitating pupils' argumentation. Unfortunately, the time devoted explicitly to argumentation is rather short: on average it could be about two lessons per science course and one lesson per general pedagogy course.

[48] http://nationalstrategies.standards.dcsf.gov.uk/node/97653

3.2.5: Denmark

Denmark has a long national tradition of dialogue in education, but not a national standard for argumentation in education. Instead, each teacher education programme decides how and where to include argumentation in its syllabus, either for all students-teachers or for prospective science teachers.

At the University of Copenhagen, argumentation is a significant part of two courses, Advanced Science Teaching Methods and Natural Science Communication, taken by some pre-service teachers. The main reference used is the Jiménez-Aleixandre et al. (2009) booklet produced as part of the European Project *Mind the Gap*.

In the Science methods course, one entire day is given to participation in an argumentation interactive role-playing activity, *Dreams of the Universe*[49], at the Danish National Museum. Pre-service science teachers actually participate in a special programme designed for pupils in which they learn about argumentation and then are given one of three perspectives to defend about the structure of the solar system, based on historical documents in the museum (Copernican, Ptolemean or Tycho Brahe's).

During the role-play the students have to solve tasks, detailing their argumentation roles. They are supplied with the allegations in each round after a brief introduction. The tasks aimed at pupils must find evidence and a legal basis for the allegation. This is done either in a session or in the physics room. Pupils have solved a problem when they have *formulated* a justification and a basis that supports the Toulmin argument model[50].

3.2.6: Spain

The programmes for Secondary Teacher Education have been changed in 2009 into a Masters degree. To enter it, students should possess a previous four-year degree in Biology, Geology, Physics or Chemistry. There is a common frame, specified in guidelines from the Ministry of Education, but each university is responsible for the development of the programmes. Reasoning and critical thinking form part of the general seminars.

These new programmes have only been running for one year, and it is therefore too early to assess the extent of the presence of argumentation in the 30 public universities in Spain offering ITE programmes. There are two sources of data pointing to a progressive introduction in science education courses: on the one hand the emphasis on competences in

[49] http://www1.ind.ku.dk/drommeUniverset/

[50] See S-TEAM deliverable 7a

the National Curriculum, calling for particular modules addressing scientific competence, argumentation and use of evidence. On the other hand, two textbooks by a major educational publisher, which are intended as manuals for the courses about Biology and Geology Education (Cañal, 2010), and Physics and Chemistry Education (Caamaño, 2010), part of the Master program, include one chapter (out of eight) about argumentation, alongside with topics such as inquiry, pupils' ideas on science or laboratory work.

A questionnaire about the presence of argumentation in ITE in the new programs was sent out to 15 Spanish science educators. According to their answers, about half of the universities – among them the ones with stronger science education research programmes, as the Universities Autónoma of Barcelona, Barcelona, Extremadura Santiago de Compostela or Valencia – explicitly address argumentation. The format, typically, would include, on the one hand, from one to three lectures and from three to ten hour workshops. On the other hand argumentation is a topic addressed by part of the students in their final research project or Master thesis in these universities.

3.2.7: Estonia

The same pedagogical competences are offered as the teaching module for all students teacher in Tallinn University. The status of argumentation is minimal; it may be part of course activities in some seminars without particular emphasis on argumentation skills. Argumentation practices or reasoning skills are not explicitly emphasized in the curriculum goals. The curricula emphasize the ability to initiate and participate in discussions related to the subject domain and teaching in general. The ability to present research results and discuss about them is another required competence. No competences in leading student discussions, argumentation and reasoning practices are mentioned.

Argumentation is taught as part of inquiry learning, problem-solving and decision-making activities, especially through role-plays with socio-scientific and technological dilemmas, computer simulations etc. Collaborative learning activities are part of the Teaching Methods in Pre-service teacher education.

3.2.8: Israel

There are three types of academic courses for initial teacher education which integrate thinking strategies:

- Specialized courses in education dealing with the development of thinking during the teaching of various subjects.
- Courses related to each discipline combining ways to develop thinking through instruction.

- Integrating thinking development in pedagogical training.

Beside these courses there are continuing education courses on thinking development for teacher trainers in teacher training institutes. In 2009, 74 courses on thinking development were held in teacher training institutes. Twenty-six of these courses took place at seven universities and 48 courses at 14 colleges. Ten of the courses were intended for academic lecturers.

Argumentation is usually part of a course on thinking. An example is: "Cultivation of Dialogic Thinking for Significant Learning", a 28 hours course at Ben-Gurion University, taught by Amnon Glassner (2008). It focuses on managing information, which requires intensive development of thinking skills. The use of critical skills, in particular argumentation skills, is designed to enable the participants to control and regulate information. The course practises these skills in the context of learning concepts, texts, ideas and issues from the disciplines learned at school. It provides experience in activities and strategies of recognition, mapping and evaluation of arguments, as well as using arguments in discourse.

3.2.9: Sweden

Argumentation forms part of both general seminars and science education courses. An example of the first is a new book for teacher educators (Andersson, 2010), which includes a chapter about argumentation.

Concerning science education, at Karlstad University, for instance, argumentation tasks within two teacher education courses are based on Concept Cartoons (Keogh & Naylor, 1999), and on-line materials (www.collaborativelearning.org). At Kristianstad university there is a programme for developing argumentation resources[51] and also for using puppets and concept cartoons. At Linköping University argumentation is included, mainly in courses that address socio-scientific issues. There are also students working on research projects about argumentation.

Contexts where argumentation is implicitly addressed

Argumentation is implicitly addressed in the ITE programmes of six countries: Norway, Scotland, Germany, Finland, Turkey and Cyprus. This could mean that it forms part of competence goals or contents, or that there are some lessons within these programmes, including lessons on how to develop arguments.

[51] See e.g. http://www.sisc.se/ESERA09/MR_BL.pdf

3.2.10: Norway

Initial teacher education is the responsibility of universities and university colleges. It is up to each institution to prepare programmes and to define the content of each subject, practical training, and organization. However, regarding teacher education directed towards primary and lower secondary school, programmes need to be in accordance with Regulation on General Plan for Teacher Education, Grades 1-7 and 5-10 [52], and National Guidelines for Teacher Education for the Compulsory Levels, Grades 1-7 and 5-10 [53] (Aasen et al. 2010a; Aasen et al. 2010b).

In these National Guidelines for Teacher Education for the Compulsory Levels, Grades 1-7 and 5-10, argumentation is not mentioned explicitly, either in the general description of the education programme or in the parts specific to science teacher students. The competence aims for science teacher students, however, recommend that the student should be able to adjust the teaching of Natural Sciences in a way that emphasises the basic skills (Aasen et. al 2010a, p. 66; Aasen et. al 2010b, p. 67). These National Guidelines also stress that the students should have knowledge about how to develop pupils' basic skills (Aasen et.al 2010a; Aasen et.al 2010b).

Thus, argumentation may be said to be included indirectly in the National Guidelines through the emphasis on basic skills, but these guidelines do not specify how this emphasis should be translated into practice. Considering that basic skills is a vast subject area which comprises many competence aims, an emphasis on argumentation does not seem to have been communicated well enough in the National Guidelines for us to conclude that argumentation is included in programmes of Initial Teacher Education.

Regarding initial teacher education, there are no national guidelines for upper secondary level. The structure and content of these programmes are decided by each university.

---

[52] Ministry of Education and Research (2009): *Forskrift om rammeplan for grunnskolelærerutdanningene for 1.-7- trinn og 5.-10. trinn*. URL http://www.regjeringen.no/en/dep/kd/dok/lover_regler/forskrifter/2010/Forskrift-om-rammeplan-for-grunnskolelarerutdanningene-for-17-trinn-og-510-trinn-.html?id=594357

[53] As of autumn 2010 there are two teacher education programmes in Norway for primary (grades 1-7) and lower secondary school (grades 8-10), respectively Teacher Education for the Compulsory Levels, Grades 1-7 and Grades 5-10.

3.2.11: Scotland

As an example, in the Professional Graduate Diploma in Education, Sciences (PGDES) at the University of Strathclyde, argumentation is not offered as a discrete component of the course, but is spread throughout the learning in that year. The emphasis place upon argumentation depends, therefore, on individual lecturers' views as to its relevance. At a minimum level, argumentation is regarded as a provisional element of the programme, beyond the more immediate concerns of initial teacher education. Even so, student teachers are encouraged to foster those skills which lead to a critical analysis of data, as well as scepticism about the so-called truth value of knowledge, to better reflect aspects of real-world science. As an example, students undertake an evaluation of the science in newspaper articles as part of a wider look at 'Science in the News'. The programme also includes an examination of the role of estimation in science, which involves some of the same skills as argumentation. By dealing with pupils' false impressions (as well as the student teachers' own misconceptions), students are encouraged to test their own misconceptions 'to destruction'. To further promote a view of science as involving 'constructed' rather than 'given' knowledge, the PGDES students are rotated between physics, chemistry and biology topics, in order to deliberately remove them from pre-existing, subject-specific 'comfort zones'.

Overall, there is an emphasis on evidence and explanation. Experiments and investigations are certainly guided, but hypothesis development is also promoted. Following experiments and small investigations, students are asked for explanations based on what they see rather than on what they know, and to discuss ideas about constructs and analogies. There is also recognition that advances in information and communication technology (ICT) present an opportunity for new kinds of pedagogy and learning experiences in the science classroom. For example, podcast and web-based artefacts are promoted within the ITE programme as presenting learners and practitioners with the capacity to act creatively and flexibly in the presentation of knowledge development. This occasional disavowal of a 'formal writing frame' is indicative perhaps of a more innovative form of pedagogy, in which the emphasis on print literacy as a prerequisite of learning might even be seen as a constraint on pupil development (Carrington, 2008). It perhaps reflects the view that what twenty-first century citizens appear to require is a 'broad, qualitative grasp of the major science explanations […] ideas [that are] integrated into an overall explanatory account or picture, rather than […] fragmented pieces of knowledge' (Millar, 2007, p. 1507). The effect of working in online environments or with mobile technologies may, therefore, provide the PGDES cohort with the opportunity for a deeper reflection on science explanations, as distinct to the somewhat tabular or atomistic learning offered by more traditional paper-based methods.

3.2.12: Germany

Teacher education is offered exclusively by universities. There are general requirements concerning educational and subject-oriented knowledge and skills for prospective teachers but the universities have considerable freedom concerning the actual content and organisation of their teacher education programmes. This analysis is based on information from physics teacher education programmes[54] available on the Internet.

There is no explicit reference to argumentation in any of the programme descriptions. These are mostly about subject matter, with a smaller part dedicated to educational studies. These are usually considered from a general perspective (history of education, educational theories, educational, psychological and sociological aspects of schooling). Within their science education programmes, some universities have courses about scientific methods and thinking as well as teaching and learning. The former seem to refer to science related activities like observing, comparing, forming hypotheses and testing them, collecting and interpreting data, communicating and discussing as described in the SINUS module ‘scientific working’ (Duit, Gropengießer, & Stäudel 2004).

3.2.13: Finland

The general goal of Finnish research-based ITE is to impart reflective teaching that will help new teachers to solve problems that they may face in practice, through autonomous thinking and logical argumentation. The use of argumentation in everyday practice is recommended. A teacher should be able to interact and communicate with others and argue for the decisions that she or he makes regarding her or his own teaching.

Specifically, the study of argumentation skills is not explicitly included in the programmes of Teacher Education. There are aspects in the descriptions of the aims of science teacher education courses that can be interpreted as having the aim of developing students’ argumentation skills. The concept of argumentation is not used in the course descriptions, but the issue is implicitly discussed. The aim of reflective and critical thinking can be interpreted so that it also promotes students’ argumentation skills. For example within the course *Structures*

[54] http://www.kfp-physik.de/fachbereich/details; 2.8.2010

and processes of school physics, students are asked to present their ideas concerning the structural relationships between certain fields of physics as graphical network representations, and they are asked to give justifications and rationales for their solutions. This aim of explaining one's solution refers to developing one's argumentation skills, but the word 'argumentation' is not used specifically.

3.2.14: Turkey

Universities are responsible for pre-service teacher education. National frameworks for teacher education are developed by the Council of Higher Education. Ideas about argumentation are not particularly addressed in specific courses, but these ideas are partly addressed in "*Nature of Science and History of Science*" course and "*Science Methods Courses*" in science teacher training programmes. Since teaching and learning objectives about argumentation are not clearly specified, the use of these ideas in the pre-service science teacher education programmes vary between different universities. Explicit teaching about argumentation might be useful for pre-service teachers. In addition, exploring how argumentation can be embedded into the teaching of science and practicing these ideas in teaching can be quite useful for Turkish pre-service science teachers.

3.2.15: Cyprus

The structure of the education system is very different within the various levels of education. At the pre-primary and primary level, teachers need to have a BA in Educational Sciences, acquired from a (public or private) University in Cyprus, in Greece, or another non-Greek language University (sometimes with additional courses from a University in Cyprus). At the secondary level (middle and high school) science teachers need to have a BA in the specific discipline that they will be teaching (e.g., physics, chemistry, biology, mathematics, etc.) and an additional year of pedagogical studies as part of their pre-service education at the University of Cyprus.

Due to the large number of Universities that offer degrees for teachers, we do not have a clear picture about the teaching of argumentation as a tool for science education. In education degrees (pre-primary, primary and middle school) that are offered by public and [the three] private Universities in Cyprus, argumentation is not included as a formal priority of study in their official courses related to science and science education. However, various faculty members may teach aspects of argumentation, such as what constitutes a good argument, how to help students develop arguments or how arguments can be identified in discourse through the analysis of videotaped science lessons.

2.3: The state of the art of argumentation in Initial Teacher Education

The state of the art of argumentation in Initial Teacher Education through Europe, in particular in the national contexts of the 15 countries involved in the project, can be summarized by saying that argumentation is explicitly addressed in the Teacher Education programmes of nine countries, although with various degrees of homogeneity within countries, as well as with a diversity of weighting and formats. According to the national reports, argumentation is implicitly included, to some degree, in the remaining six countries.

Claims about ITE programmes need to be qualified. It is difficult to draw a common picture, not only from the different European countries, but also from the various ITE programmes within each country, due to the fact that Universities are fully responsible for these programmes. Therefore, even in countries where some steering documents or recommendations about teacher education have been issued, such as England and Wales, Czech Republic, Spain, Norway or Turkey, there is much variation in the presence of argumentation in goals, contents or teaching activities. Israel seems to be the country where programmes have greatest similarity within the country, and where argumentation in connection with higher order thinking has a stronger presence.

It should be noted that, in a number of countries, Initial Teacher Education programmes for secondary teachers are in a process of change, caused in part by the need for alignment with the Bologna Framework. This is the case, for instance, in France, Czech Republic or Spain, where ITE programmes have recently changed, or are being transformed. This poses further difficulties for ascertaining the status of argumentation in these programmes.

Notwithstanding these caveats, it seems that argumentation has made its way into ITE programmes over the last few years. Some S-TEAM national reports relate its presence to the inclusion of argumentation and scientific competences in the national curricula. The presence of argumentation may take the form of a few lessons and interactive sessions in the general pedagogical seminars, or may constitute longer teaching modules and workshops in Science Methods (Science Didactics) seminars.

An interesting issue, mentioned in some national reports, is the use of resources for the teaching of argumentation produced in other EU countries. This illustrates the potential for the exchange of practical knowledge across Europe.This is, for instance, the case of resources produced in Spain (in the EU funded project *Mind the Gap*), which are also being used in Denmark; or of resources produced in the United Kingdom, which are being used in Sweden.

This supports the need for producing teaching modules about argumentation, as planned within Work Package 7 of the S-TEAM project.

Section 4: Argumentation in Teacher Professional Development Programmes in Europe

4.1 Overview of Argumentation in Teacher Professional Development

In order to gather information about argumentation in Teacher Professional Development (TPD) programs, the National Liaison Partners were asked the following questions:

a) Is argumentation included in the Professional Development programmes? (examples)

b) Are these programmes supporting argumentation a national initiative or are they initiated by some particular [local] instances?

c) Are there training packs, books, or resources about argumentation?

Please provide some examples

It should be noted that, as in the case of ITE, in most countries there is no single framework or institution responsible for TPD programmes. These are carried out by a variety of institutions, from universities and teacher centres to local authorities. Only in some cases, such as England & Wales or Lithuania, are there frameworks at a national level. It is only possible, therefore to present an incomplete picture of the state of the art of TPD in each country, as it is not feasible to examine all, or even the majority of, TPD courses.

In this section the results are presented, first, through a table summarizing the responses to the questions. The second column in table 2 represents the presence of argumentation in national programmes or frameworks (or the absence of such national programmes), and the third its presence in some particular courses or programmes. The fourth column summarizes available resources for introducing argumentation in TPD.

Then the situation of argumentation in TPD is discussed in two contexts, where respectively argumentation has presence in national programmes and in particular courses. The section ends with a summary of the state of the art in this dimension.

Table 3. Argumentation in Teacher Professional Development Programs (TPD) in European countries

Country	**Argumentation in national programs**	**Argumentation in some particular programs**	**Resources**
Norway	(TPD programs not nationally organized)	TPD courses in Biotechnology	Biotechnology Advisory Board
France	In the context of IBST	As evidence-based reasoning	Not specified
England & Wales	Science Learning Centres	*How Science Works*	– Futurelab – *Mind the Gap* resources
Lithuania	Teacher Competence Development Centres	Not specified	– Resources pack
Czech Republic	(No national policy for TPD)	Embedded as part of key competences	Not specified
Denmark	No national standards for argumentation	Numerous local initiatives about argumentation	– Web site resources – Books
Scotland	*Debating in Schools*	*Tasks for Teaching & Learning Science*, Dundee U.	– Web resources: *Talk Science*
Germany	(No common federal policy for TPD)	Embedded in competence-oriented teaching	Not specified
Spain	In the context of competences and IBST	Increasing presence since 2008	– *Mind the Gap* resources & website – Books
Finland	Argumentation not included in TPD	–	–
Estonia	(TPD programs not nationally organized)	Embedded in reasoning	Not available

Country	Argumentation in national programmes	Argumentation in some particular programmes	Resources
Israel	In the context of thinking skills	Workshops about reasoning strategies, including argumentation	– Web site resources – Books
Sweden	In TPD series	Embedded in communication	– Concept Cartoons
Turkey	(Not explicitly included)	Embedded in IBST	– No specific resources
Cyprus	(Not explicitly included)	Not specified	–

4.2 The state of argumentation in Teacher Professional Development by country

In most countries there is no single framework or institution responsible for Teacher Professional Development programmes, which are carried out in diverse institutions. However, in some cases there is either a network of Teacher Centres, for instance the Science Learning Centres in England, or a common framework. These two contexts, representing respectively some degree of a common framework within a country, or argumentation addressed in particular courses, are discussed separately. Nevertheless, there is no clear-cut distinction between these two contexts, which have to be seen as different positions in a spectrum from countries where TPD is highly centralized, as in Israel, to countries where it is difficult to find commonalities. There are also national contexts where argumentation seems to have no presence at all in TPD.

Argumentation addressed in the context of national programs

Argumentation is addressed in the context of national programmes in six cases: England and Wales; Lithuania; Scotland; Spain; Israel; Sweden.

4.2.1 England and Wales:

The Science Learning Centres across England provide in-service teacher education in 'How Science Works', which may include themes on argumentation. For example, a course run by the Science Learning Centre London[55], called "Decision-Making Activities in Science" is described as follows:

> This session explores using decision-making activities in science. In this session you and your colleagues will practise using some decision-making activities that have been developed for small group discussion in Key Stage 2 classes. The activities have been designed to reveal differences in opinion so that children can explore their reasoning and expose their thinking. There are four activities presented in different formats and in the session you will discuss the merits and limitations of the resources for your classes. You will have the opportunity to work in groups to adapt the activities for a science lesson of your choice. The session is designed to enable you to work towards enhancing your children's decision-making and encourage group discussion and argumentation in your lessons.

Resources: There are documents published by key organisations such as *Futurelab*[56] that aim to highlight the importance of argumentation (Wolfe & Alexander, 2008). The *Mind the*

---

[55] https://www.sciencelearningcentres.org.uk/centres/london

[56] http://www.futurelab.org.uk/

Gap Project Resources (Erduran & Yan, 2009) and IDEAS pack (Osborne, Erduran, & Simon, 2004) contain teacher training and teaching resources on argumentation.

Another resource in argumentation is *Talk Science*, funded by the AstraZeneca Science Teaching Trust. This project's TPD activities are confined to primary and secondary teachers in the London Borough of Richmond, though its professional development materials are available to all teachers through the project website[57], where, for instance, it is stated that:

> "The creation of science knowledge is not declarative. Knowledge that becomes part of the canon of science is agreed through processes involving communities of scientists. Understanding how science works is an important part of a science education. Here the process of argumentation is used as the basis for developing children's science knowledge as they transfer from their primary to their secondary education."

4.2.2: Lithuania:

Argumentation is included in Teacher Professional Development programmes. These are programmes supporting argumentation as a national initiative. The institution that provides such programmes is the national Teacher Competence Development Centre. This Centre also initiated projects devoted to argumentative competence development. The projects usually contain training packs, resources about argumentation.

4.2.3: Scotland

Whereas argumentation occupies an important, if only implicitly articulated, position with a *Curriculum for Excellence* in the sciences (see the policy section, above), the emphasis in the continuing professional development programme made available by *Learning and Teaching Scotland*[58] is in the direction of rhetorical skills rather than scientific argumentation. *Debating in Schools* (English Speaking Union Scotland, 2009) does pay lip service to the four capacities of the new curriculum, and indeed promotes speech-making and debating activity as being an 'invaluable and efficient teaching tool in the classroom'. However, the content of the many short courses that are available to teachers, while offering advice on 'grouping and allocating arguments', does tend towards the 'well crafted message and dynamic delivery' of the debating society. The courses are intended to be interdisciplinary rather than subject-specific, but are not directed towards scientific argumentation.

There are some courses promoting argumentation. For example, the University of Dundee's *Rich Tasks for Teaching and Learning Science* project addresses the discontinuity

---

[57] http://www.azteachscience.co.uk/resources/materials/talking-science.aspx

[58] http://www.ltscotland.org.uk/ From July 2011, this will be replaced by the Scottish Education Quality and Improvement Agency, which also incorporates Her Majesty's Inspectorate of Education.

between science learning in primary and secondary school teaching. According to HMIe (2008, p.11), good curricular links in science between primary and secondary schools were often ‘poorly developed’ in Scottish schools, which, ‘together with the lack of reliable assessment information gathered at the primary stages, affected continuity in learning when young people entered S1 [the first year of secondary school]’.

4.2.4: Spain

Teacher Professional Development programs, as well as the development of curriculum and the organization of primary and secondary education, are the responsibility of the 17 Autonomous Communities. There are, however, periodical meetings of the Educational Conference, where representatives from the Ministry of Education and the Autonomous Communities discuss issues related, among others, to TPD, and reach agreements about its contents. So, although the responsibility for TPD is with each Autonomous Community, there is a substantial degree of agreement on the type and content of activities. The Institute of Evaluation publishes annual reports about education in Spain, addressing some different indicators each year. The last report discussing TPD was issued in 2006 [59]. According to it, 64% of Secondary teachers participated in short (less than 50 hours) activities and 33% in long activities, with a mean number of 61 hours each year. About half of these hours correspond to courses and the other half to school-based TPD activities or teachers' networks.

Most TPD courses and activities are organized by the Autonomous Communities through networks of teachers and Resource Centres. TPD is also provided by universities, teacher professional associations and other institutions.

Before the term 2007-2008, when the key competences were introduced in the curricula, argumentation was not addressed in TPD. Beginning in 2008, a series of courses about competences, including evidence-based reasoning, were delivered throughout Spain. The first courses explicitly including argumentation were organized in 2009, including a one-week summer course at the University of Santiago de Compostela, part of the dissemination activities of the project *Mind the Gap*[60].

[59] Ministerio de Educación y Ciencia, Instituto de Evaluación (2006). Sistema Estatal de Indicadores de la Educación. Madrid: Author. http://www.institutodeevaluacion.educacion.es/dctm/ievaluacion/indicadores-educativos/ind2006.pdf?documentId=0901e72b80110f28

[60] http://www.uv.uio.no/english/research/projects/mindingthegap/

In 2010, as a direct outcome of the S-TEAM national workshop held with representatives from the Ministry of Education and the Autonomous Communities, the subject of the main TPD summer course for science teachers (from all over Spain) was IBST, and the course included two workshops about argumentation. A workshop about argumentation was also integrated into the other two courses organized for the whole country. From 2009-2010, argumentation is part of the regular courses in Teachers Centres.

One of the main resources used in these courses is the *Mind the Gap* project booklet (Jiménez-Aleixandre et al., 2009), as well as other resources in the USC web[61]. A book about argumentation and the use of evidence, directed to science teachers, was also been published in 2010 (Jiménez-Aleixandre, 2010).

4.2.5: Israel

The educational system can be seen as a pyramid with central supervisors at the top. They guide groups of mentors who guide principals. These in turn lead teachers who are responsible for other teachers. As of 2009, 17,500 teachers have taken part in continuing education programs (Zohar, 2009). Reasoning (argumentation) education poses complex pedagogical challenges for teachers who need to integrate its teaching into the curriculum by creating learning environments that stimulate curiosity, and provide challenges that nurture exchanges. This involves developing ways of formulating questions that prompt argumentation, and ways of analyzing forms of argumentation. Teachers have to learn how to evaluate reasoning strategies including argumentation. In order to respond to these challenges, all degrees now require the fulfilment of a professional development program.

A central supervisor 150-hour workshop took place in 2007-2009, involving 35 participants. The goal was empowerment learning, teaching and evaluating processes by emphasizing deep understanding and thinking in different disciplines. The participants created unified language and skills, but they were free to adapt the implementation, and various models were developed. This workshop led to a series of changes in each discipline, including training of teachers, the design of types of instruction, classroom implementation, and updating the curriculum and methods of evaluation (Zohar, 2009).

[61] www.rodausc.eu

Resources: The teaching of thinking skills is now required in every textbook submitted for approval to a team of 12 consultants appointed to approve textbook content. Guidelines were formulated to integrate tasks promoting thinking (Levi, 2009).

The Ministry of Education website features a demonstration of ways to teach argumentation for the fourth grade (age 10), and includes eight activities (roughly 20 lessons altogether) which explicitly teach basic concepts in argumentation such as identification, construction, evaluation and comparison of arguments. One activity is "Clean Air in a Park" in which students have to put forward an idea about the optimal location of a park based on their experimental findings[62]. An example for the high school curriculum integrating argumentation is presented in environmental science. Environmental Ethics (Shtessel, 2009), which was developed as a new type of syllabus, requires higher order thinking skills, especially argumentation. Argumentation is required in questions; role plays on global warming, discussions on environmental issues, and encourages students to take informed stances.

4.2.6: Sweden

The Swedish "Skolverket" has funded a national TPD series lead by Britt Lindahl, and one of several themes has been argumentation. Also Dr. Birgitta Norberg-Brorsson has a focus group with teachers discussing argumentation in science as a typical genre of speech.

Resources: *Concept Cartoons* are widely known in Sweden, but sessions are typically run by invited guest professors.

Argumentation addressed in the context of some particular programmes

In the case of seven countries, Norway, France, Czech Republic, Denmark, Germany, Estonia and Turkey, argumentation forms part, in most cases explicitly, in others implicitly, of particular TPD programmes or courses.

4.2.7: Norway

Municipalities and Counties are responsible for teacher professional development, respectively at primary and lower secondary level, and at upper secondary school. The Ministry of Education and Research, in cooperation with the Norwegian Association of Local and Regional Authorities and the teachers' trade unions, reached an agreement about how TPD should be carried out. This agreement states that the Municipalities or Counties are

[62] http://cms.education.gov.il/EducationCMS/Units/Mazkirut_Pedagogit/OfekPedagogi/Digmy_Horha/Yessodi/Tyon.htm

responsible for making an overview of the needs for professional development at each school in collaboration with the schools (Ministry of Education and Research[63], 2008). Necessary measures are to be taken in accordance with which needs the teachers and schools feel should be met and prioritized.

There is no national control or overview of how many or which TPD courses teachers are offered. This may therefore vary between different Municipalities or Counties. However, it may be noted that the TPD courses offered to teachers at primary and lower secondary school usually include a combination of subject and didactics (methods). The selection of TPD courses is the responsibility of each Municipality or County in collaboration with the schools, hence there are no nationally organized TPD programmes. With 430 municipalities and 19 counties in Norway, it is difficult to give a clear 'yes or no' answer to questions about the presence of argumentation.

There is, however, one particular field in science education, which forms a natural arena for argumentation in science: biotechnology. Argumentation in teaching biotechnology has been an integrated part of various TPD courses in biotechnology for science teachers. Some good materials have been developed by the Government-funded Norwegian Biotechnology Advisory Board, Bioteknologinemda (2009a; 2009b).

4.2.8: France

Each local authority is responsible for TPD programmes, thus it is impossible to provide a definitive answer, although few TPD programmes explicitly address IBST. Most of them address scientific activities (modeling and evidence, classification), the understanding of teaching content (pedagogical content knowledge) and teaching approaches from new programmes and new forms of assessment. Nevertheless, these programmes and forms of assessment promote IBST and argumentation. Thus argumentation is implicitly included within most TPD programmes.

An in-depth inquiry within three French educational regions (Grenoble, Lyon, Rennes) was conducted for the WP4a report[64]. It showed that the descriptions of TPD programme contents and goals suggest that IBST methods are a central concern, and are often explicitly mentioned, in contrast to the lack of 'argumentation' in TPD course titles. Furthermore, the

[63] Ministry of Education and Research (2008): *Kompetanse for kvalitet. Strategi for videreutdanning av lærere*. URL: http://www.regjeringen.no/en/dep/kd/pressesenter/pressemeldinger/2008/--vidareutdanning-for-lararar-skal-gi-be.html?id=533971

[64] Available at www.ntnu.no/s-team

use of terms such as 'experimental' or 'inductive' teaching approaches or the description of problem-solving situations suggests that TPD programmes rely heavily on IBST methods. Analysis of course goals highlights the desire to make teachers rethink their own roles, and those of pupils, in this type of educational approach. Finally, these courses aim to ensure that teachers use new assessment methods, particularly in relation to pupils' experimental abilities. Observation, experimentation and reasoning, acquisition and mobilization of knowledge are central for these teaching approaches. For instance, in Grenoble “argumentation” (as “evidence-based reasoning”) is the object of regular TPD programmes in mathematics, lasting 12 hours each.

4.2.9: Czech Republic

The current system of Teacher Professional Development Programmes is rather loosely regulated in the Czech Republic, which is unfortunate. There are hundreds of providers of in-service teacher education programmes and courses, mainly universities and other educational facilities accredited by the Ministry. There is no national initiative or policy, though some of these courses are provided by organizations directed by the Ministry. Other are offered by schools, universities, public or private providers.

Argumentation per se is not included in TPD programmes, although a small number of programmes, usually workshops or short courses, deal with the topic of pupils’ key competence development, where argumentation is embedded as a part of problem solving competence. As an effective system of TPD is still missing, and argumentation is still not seen as a priority in TPD, there are no general training packs, books or resources. Argumentation as it is integrated into TPD for subject didactics (e.g. in courses for specific topics in mathematics, or in courses on improvement of pupils’ problem-solving competence in physics, etc.) may, in any case, be fostered by such subject-specific materials, usually developed by a provider of TPD for particular workshops or courses.

4.2.10: Denmark

As noted in the section about ITE, Denmark has a long national tradition of dialogue in education, but does not have a national standard for argumentation in education, or in TPD. The national curriculum described in the section about policy is supported by a number of local initiatives, including the Danish Web site for teacher inspiration in teaching argumentation mentioned below.

Resources: A Danish curriculum Web site[65] (in Danish and English) serves as a reservoir for ideas and lessons for teachers to teach argumentation. The opening page of this teacher resource in argumentation is introduced by this sentence: "Here you can find inspiration on how to work with arguments." The entire resource can be accessed at the link reproduced in the footnote. It consists of different resources packs, three of them summarized below:

Stages of reasoning: "Argumentation, rhetoric and credibility" is the title of this course over eight blocks. – Daily Game trainer argument: Let students work with democratic conversation standards and train in forms of debating games developed for use in high school. Here subjects such as Danish, philosophy, rhetoric, social studies and science interact in engaging ways. Some examples of the debate games are: "Confrontation" on the topics diet, nutrition and public health; or "Played on power " where the student choses among the roles of politician, spin doctor or journalist.

Hear America speak: This page provides an opportunity to hear the voice of living people: A database of American speeches and statements, mostly from the 20th century, concerning particular political and religious matters. It also has quotes from movies and articles on rhetoric.

Other available resources include books, such as *Arguing for a Position* (Holmbroe, 2010), released by the Danish Teachers' Union in its "short & good" series. It offers a range of Danish academic approaches to language, instruments, target groups, communicative strategies in attitude campaigns and other communications. It contains some good exercises for students. The Danish Teachers' Union also published *Arguments in written communication* (Illum, 2004) about reasoning in theory and practice, with reviews and analysis of a series of argumentative texts written by both experienced writers and secondary school students.

4.2.11: Germany

The TPD courses of two federal states in Germany were examined. The search included courses in the three science subjects for Gymnasium teachers between September 2009 and August 2010. This yielded about 30 courses for each subject in each state with a significant overlap across the subjects. Most of the courses were offered twice during the year.

[65] http://translate.googleusercontent.com/translate_c?hl=da&sl=da&tl=en&u=http://www.emu.dk/gym/tvaers/studiekp/laerere/metoder/argumentation.html&rurl=translate.google.com&usg=ALkJrhgQ81W2k3_9Jjle3Tc14wb7Gu85Ag

There was no course explicitly mentioning argumentation in its heading or description. In each federal state there were courses about competence-oriented teaching (referring to the national educational standards). These courses might have included argumentation.

4.2.12: Estonia

Teachers professional development programs are not nationally organized. There are some lists of teacher competences, which do not emphasize argumentation competence or how to teach it to students.

Argumentation embedded in reasoning has been taught on some long (160 credits) in-service courses for science teachers. In particular, there have been courses about scientific reasoning in model-based learning, and about argumentation practices during dilemma-solving activities. These courses were combined with research activities and empirical implementation at schools.

Recently, interest in the introduction of argumentative and reasoning practices has decreased, and the focus is currently on Scientific & Technological Literacy (STL)[66] and inquiry learning contexts. Collaborative argumentation practices are not introduced or empirically studied in science education, and there are no researchers currently involved in this topic. There is a lack of appropriate materials about argumentation practices, in particular about argumentation and reasoning in science education for teachers, or about collaborative argumentation practices. There are resources about inquiry learning, where some scientific argumentation is introduced.

It needs to be noted that some science education researchers also conduct empirical in-service training as part of their research projects (Pata & Sarapu, 2006; Rannikmäe & Laius, 2010).

4.2.13: Turkey

The Department of In-Service Training under the Ministry of National Education is responsible for organizing training activities and services for approximately 750,000 teachers and other ministry personnel who work in the central or regional organizations of the ministry. Annual in-service training plans are prepared by the Department of In-service Training in collaboration with other departments. Each department specifies the training needs of their

[66] See, e.g. http://www.icaseonline.net/sei/14-4-2003/14-4-2003-21_28.pdf

central or regional organizations' personnel, priorities and justifications, time, place and date of the training period, programme and teaching staff.

Teacher Professional Development in Turkey is not as successful as it should have been[67] [68]. TPD programmes are too short to make an impact, and most teachers do not value these programmes enough to learn from them. The nationwide training plan is mainly put into practice during two weeks within the summer holidays. There have been some in-service training activities related to Inquiry Based Science Teaching[69] and introducing the new Science and Technology Curriculum. However, there is no specific agenda for supporting argumentation in these programmes. There are no training packages or specific teaching resources for argumentation. Nonetheless, there has recently been high levels of interest amongst researchers and doctoral students in the field of argumentation.

Finally, there are two countries, Finland and Cyprus where argumentation has no presence in TPD.

4.2.14: Finland

Argumentation is not included in Professional Development programmes, and there are no training packs, books, or resources about argumentation.

4.2.15: Cyprus

Official in-service training for teachers in public schools is offered primarily by the Pedagogical Institute of Cyprus, and, to a lesser extent, by the Inspectorate. The courses are open to consultants and interdepartmental committees from the Ministry of Education and Culture for support and feedback. The Pedagogical Institute offers professional training courses to pre-primary, primary, secondary and vocational educators, through a series of optional seminars (Georgiou et al., 2001). The seminars focus on school subjects, social and psychological issues, educational research skills and information technology. Additionally, school-based seminars are organized on specific topics of interest to the staff of a school, in agreement with the Pedagogical Institute. The Pedagogical Institute also organizes seminars, one-day workshops and conferences in cooperation with the teachers' unions and teachers'

---

[67] https://www.ntnu.no/wiki/download/attachments/6595698/S-TEAM+report2a3a.pdf?version=1

[68] Esme, I. (2009). *Öğretmen Yetiştirmede Geri Adımlar*. Available at: http://yunus.hacettepe.edu.tr/~cakmakci/esme.pdf

[69] http://www.vitaminogretmen.com/merak-ettikleriniz/omgep/

associations of specific subjects (Pedagogical Institute, 1999). The only courses offered by the Pedagogical Institute that are compulsory for public educators, in agreement with the existing educational legislation and the service schemes, are for teachers who have been promoted to administrative posts. These focus on the theoretical principles of administration and school management, the analysis of duties, effective practice and specific innovations.

Probably due to the absence of any reference for argumentation in the national curriculum, argumentation is not a topic that is explicitly covered during professional development programmes or seminars in Cyprus.

4.3 The state of the art of argumentation in Teacher Professional Development

The state of the art of argumentation in Teacher Professional Development in Europe, in particular in the national contexts of the 15 countries involved in the S-TEAM project, can be summarized by saying that argumentation forms part of the current programmes and contents of TPD in all but two of the countries examined, although with a range of weighting and formats, as well as with differences ranging from explicit presence in goals and contents, to being embedded in broader topics, such as competences, inquiry based science teaching (IBST) or reasoning.

In six countries argumentation is integrated in TPD into the framework of national programmes, although the courses contents exhibit a great deal of variation, from explicit modules about argument construction and examples of activities to introduce it into the classroom, as, for instance, in England and Wales, Spain or Israel, to an implicit presence embedded in material about reasoning, communication or debate.

Argumentation forms part of specific TPD programmes and courses in seven countries. Therefore its presence within each country varies, depending on the institutions, teacher centres, universities or associations organizing the programme. However, the available data reveal differences between countries, ranging from contexts, as Denmark, where the wealth of available resources for teaching argumentation suggests a continued presence in local initiatives, to others where attention to argumentation is inferred from the presence of courses about competences or reasoning.

It should be noted, as with ITE, that responsibility for TPD is attributed to different agencies in the various European countries. In contexts where the Ministry of Education is responsible to some extent, either for organization or for guidelines, the presence of argumentation (or of other topics) in national programmes might be expected. On the other hand, where this responsibility is ascribed to teacher centres or local authorities, there is a higher degree of diversity.

Consequently, the results of this survey need to be contemplated not as general claims, but rather as a snapshot representing part of a reality that is complex and fluid. TPD programmes are in a constant process of change for, unlike ITE (or curriculum), they are not usually framed by steering documents or instituted as compulsory programmes.

However, the available data suggest that argumentation is gradually being introduced into TPD programmes. As in the case of ITE, some national reports connect the presence of argumentation to the introduction of key competences into national curricula, calling for an update of teachers that will prepare them for competence-oriented teaching.

We may point also to the impact of some European projects, on the one hand in the introduction of argumentation and IBST in TPD programmes, as illustrated by the effect of the Spanish S-TEAM national workshop on the Ministry of Education summer courses, and on the other in the availability of resources for teaching argumentation, as illustrated by the use of the *Mind the Gap* resources in England & Wales and Spain.

Section 5: Discussion and suggestions for future developments

In this section, first we discuss the main conclusions about the state of the art of argumentation in the three dimensions examined, then, drawing on these empirical data and on the available literature, some lines for future developments are suggested. Table 4 (overleaf) summarizes the results about argumentation in the three dimensions.

Table 4. Argumentation in Policy Documents, Initial Teacher Education (ITE) and Teacher Professional Development (TPD) in European countries

Country	Policy documents E (explicit)/ I (implicit)	ITE E (explicit)/ I (implicit)	TPD E (explicit)/ I (implicit)
Norway	E Competences / Inquiry	I	I
France	E Inquiry	E Evidence-based reasoning	I
England & Wales	E Evidence-based reasoning	E Evidence-based reasoning	E
Lithuania	E Communication	E Reasoning	I
Czech Republic	E Competences	E	I
Denmark	E Competences / Skills	E Reasoning	E
Scotland	I Reasoning	I Evidence-based reasoning	E
Germany	E Competences	I Scientific methods	I
Spain	E Competences / Inquiry	E Evidence-based reasoning	E
Finland	I Evaluation	I	Not included
Estonia	I Competences	E Inquiry	I
Israel	E Thinking skills	E Thinking strategies	E
Country	**Policy documents**	**ITE**	**TPD**

	E (explicit)/ I (implicit)	E (explicit)/ I (implicit)	E (explicit)/ I (implicit)
Sweden	E SSI	E Communication	I
Turkey	E Evidence-based reasoning	I IBST	I
Cyprus	I Reasoning	I	Not included

From our examination of steering documents from the 15 European countries involved in the project, and from the available data about Initial Teacher Education (ITE) and Teacher Professional Development (TPD), we may conclude that argumentation is addressed in all but one of the national curricula, in 11 cases explicitly; and in the ITE programs of all countries, in nine of them explicitly and implicitly in the remaining six countries. Argumentation also seems to form part of current TPD programmes in all but two countries, although its role is variable, making it difficult to draw a common picture, even within each country.

We interpret these results to show, as some of the national reports suggest, that this presence, which seems to have emerged over the last five or six years, is connected to the introduction of key competences in the curricula and guidelines, following the European recommendation of eight key competences (EU, 2006). Argumentation and evidence-based reasoning are emphasized in the PISA framework (OECD, 2006) as part of scientific competence.

The introduction of argumentation in the national curricula, whilst not guaranteeing that argumentation is promoted in the classroom, constitutes a first step, which may take some time to translate into classroom practice. For this to happen, teachers need resources, both intellectual, in other words appropriate initial or in-service teacher education (ITE or TPD), and material, such as teaching units, activities and others.

Several national reports suggest that the presence of argumentation in ITE is connected to its inclusion in the curricula. Current changes to ITE programmes in a number of countries, related to the process of alignment with the Bologna Framework, may provide a context facilitating the introduction of new topics. These changes emphasize the active role of university students in the construction of knowledge, calling for more interactive teaching methods and focusing on the development of competences, rather than on the accumulation of content knowledge. Argumentation learning environments, promoting the capacity of students to evaluate knowledge and to justify their claims, are in tune with this perspective.

Most science teachers in European countries were trained when argumentation was not integrated into ITE. For this reason, the inclusion of argumentation in TPD is as necessary as it is in ITE, in order to reach classrooms. It seems that TPD throughout Europe is responding to these needs, although the implementation of courses addressing argumentation is contemplated in national programs or frameworks only in six countries, while in others it depends on particular agencies organizing TPD.

The report also explores the existence of resources for ITE and particularly for TPD. The data collected suggest that there is a range of resources in the form of websites, training packs, books, pamphlets and teaching units. It is worth noting the exchange of resources among countries, as with *Concept Cartoons* (produced in the UK), which are used in Sweden or *Mind the Gap* resources produced in Spain, which are used in Denmark.

This may be an instance of the impact of European projects on moving new perspectives from the research literature into the pedagogical content knowledge of teachers, a necessary step for reaching classrooms. Another instance is the introduction of argumentation in TPD courses prompted by S-TEAM national workshops, as seems to be the case in Spain.

Some country reports also illustrate the role of particular researchers and stakeholders in influencing the introduction of new perspectives, as in argumentation, in curriculum and in teacher education. For instance, in Israel, Professor Anat Zohar, a scholar well known for her work on argumentation, thinking strategies and teacher education, has been part of the staff in the Ministry of Education for some years. As noted in Israel's report, she is the author of the Document "Pedagogical Horizon, 2006-2009", which set new goals and pedagogical targets, including the development of thinking strategies.

In summary, we may say that argumentation is beginning to make its way into national curricula and teacher education programs, both initial and in-service, throughout Europe. The question now is: How can progress, beyond the state of the art, be supported, and through which lines of development?

The literature suggests that the roles of students and teachers in learning environments promoting argumentation are fundamentally different from those in classrooms with a traditional approach based in knowledge transmission. These roles are aligned with constructivist and inquiry-based teaching approaches (Jiménez-Aleixandre, 2008). As Zohar (2008) points out, teaching argumentation requires a fundamental shift in the pedagogies that teachers use. For this author, in order to teach argumentation, teachers need to have both a sound knowledge of argumentation strategies, and a sound pedagogical knowledge in the context of teaching argumentation. This pedagogical knowledge is related to teachers' theories of instruction.

Therefore, Zohar suggests that ITE and TPD programmes must be "of considerable duration" (Zohar, ibid p. 264), and that these programs should provide support and feedback for teachers beginning to introduce argumentation in their classrooms. She recommends coaching, but when budget constraints do not allow it, at least the program needs to provide an environment supporting reflection and feedback regarding classroom experiences.

5.1: Recommendations

We suggest that, in order for argumentation to be introduced in science classrooms:

1. Teacher Education programs, both ITE and TPD, should include argumentation modules and guidelines. To be effective, these modules need to be of some duration, allowing teachers to practise, and to be involved in, argumentation. WP7 in S-TEAM will produce guidelines for professional development and training programs (one of those, S-TEAM deliverable 7a, has already delivered by Kaunas University of Technology (KTU)[70].

2. ITE and TPD programmes should support teachers in the introduction of argumentation to their classrooms, providing environments which support reflection and feedback.

3. These supporting environments could be provided, for instance, by teacher networks, as in the German SINUS project.

4. The production of appropriate resources is also needed in order to support teachers in the introduction of argumentation in science teaching. WP7 in S-TEAM will produce teaching sequences for use both in schools and in teacher education.

5. There are existing resources for teaching argumentation that could be disseminated, translated or adapted, for use in different countries or contexts. The *Mind the Gap* project resources are one example.

6. It is necessary to reach stakeholders in order to exchange new perspectives and to know how different countries are facing these challenges. S-TEAM National Workshops provide an example of how gathering stakeholders may be effective.

[70] Available from www.ntnu.no/s-team

References

Aasen et. al (2010a), Nasjonale retningslinjer for grunnskolelærerutdanningen 1.-7- trinn. http://www.hio.no/Enheter/Rammeplan-for-laererutdanningen/Retningslinjer-1.-7.-trinn

Aasen et. al (2010b), Nasjonale retningslinjer for grunnskolelærerutdanningen 5.-10. trinn. http://www.hio.no/Enheter/Rammeplan-for-laererutdanningen/Retninglinjer-5-10

Andersson, B. (2010), Att utveckla undervisning i naturvetenskap: kunskapsbygge med hjälp av ämnesdidaktik, Göteborgs Universitet Institutionen för pedagogik och didaktik.

Bioteknologinemda (2009a), http://www.bion.no/

Bioteknologinemda (2009b), Etisk argumentasjon om bioteknologi, http://www.bion.no/tema/etisk_argumentasjon.shtml

Caamaño, A. (Ed.) (2010), Didáctica de la Física y la Química (Physics and Chemistry Education). Barcelona: Graó.

Cañal, P. (Ed.) (2010), Didáctica de la Biología y la Geología (Biology and Geology Education). Barcelona: Graó.

Carrington, V. (2007), '"I'm Dylan and I'm not going to say my last name": some thoughts on childhood, text and new technologies', *British Educational Research Journal*, 34/2, pp. 15 – 166.

Duit, R., Gropengießer, H., & Stäudel, L. (Eds.). (2004), *Naturwissenschaftliches Arbeiten. Unterricht und Material* 5-10, Seelze-Velber, Friedrich Verlag.

English Speaking Union Scotland (2009), *Debating in Schools* http://www.ltscotland.org.uk/debatinginschools/index.asp (accessed 30/09/2010).

Erduran, S., & Yan, X. (2009). *Minding gaps in argument: continuous professional development in the teaching of inquiry*, Bristol, University of Bristol, *Mind the Gap*.

European Union (2006). Recommendation of the European Parliament and of the Council of 18 December 2006 on key competences for lifelong learning. Official Journal of the European Union, 30–12–2006, L 394/10–L 394/18. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:394:0010:0018:en:PDF

Glassner, Amnon (2008). *Cultivation Dialogic Thinking for Significant Learning. A Course for the Teaching Certificate*, Ben-Gurion University. (In Hebrew) http://cms.education.gov.il/EducationCMS/Units/Mazkirut_Pedagogit/OfekPedagogi/Achshra/Ben_Guryon.htm

Holmbroe, E. (2010), At argumentere for en holdning. (Arguing for a position). Copenhaghen: Dansklærerforeningen.

Illum, B. (2004), Argumenter i skriftlig kommunikation. (Argument in written communication). Copenhaghen, Dansklærerforeningen.

Jiménez-Aleixandre, M. P. (2008), Designing argumentation learning environments. In: S. Erduran & M.P. Jiménez-Aleixandre (eds.), *Argumentation in science education: perspectives from classroom-based research* (pp. 91–115), Dordrecht, Springer.

Jiménez-Aleixandre, M. P. (2010), *10 Ideas Clave: Competencias en argumentación y uso de pruebas* (*10 key ideas: Competences on argumentation and use of evidence*). Barcelona, Graó.

Jiménez-Aleixandre, M.P. & Erduran, S. (2008), Argumentation in science education: An overview. In: S. Erduran & M.P. Jiménez-Aleixandre (eds.), Argumentation in science education: perspectives from classroom-based research (pp. 3–27), Dordrecht, Springer.

Jiménez-Aleixandre, M. P., Gallástegui-Otero, J. R., Eirexas-Santamaría, F. & Puig-Mauriz, B. (2009), *Resources for introducing argumentation and the use of evidence in science classrooms*. Santiago de Compostela, Danú. Project *Mind the Gap* [There are also versions in Galician and Spanish]. Downloadable from www.rodausc.eu

Lavelle, L. B., & Erduran, S. (2007), Argument and developments in the science curriculum. *School Science Review*, 88/324, pp. 31-39.

Millar, R. (2007), 'Twenty First Century Science: Insights from the Design and Implementation of a Scientific Literacy Approach in School Science', *International Journal of Science Education*, 28/13, pp. 1499 – 1521.

Møller, Jorunn, Tine Prøitz and Petter Aasen (eds.)(2009), *Kunnskapsløftet – tung bør å bære? Underveisanalyse av styringsreformen i skjæringspunktet mellom politikk, administrasjon og profesjon*, Oslo, NIFU STEP.

OECD (2006), PISA 2006: *Assessing scientific, reading and mathematical literacy: A framework for PISA 2006*. Paris: OECD.

Osborne, J., Erduran, S., & Simon, S. (2004), *Ideas, evidence and argument in science education*, DVD and Teacher Training Resource, London, King's College London.

Pata, K. & Sarapuu, T. (2006), A Comparison of Reasoning Processes in a Collaborative Modelling Environment: Learning About Genetics Problems Using Virtual Chat, *International Journal of Science Education*, 28/11, pp. 1347-1368.

Rannikmäe, M. & Laius, A. (2010), Enhancing students' creativity and reasoning skills. In Çakmakci, G. & Tasar, M. F. (Eds.), *Contemporary Science Education Research: Scientific Literacy and Social Aspects of Science. A collection of papers presented at ESERA 2009 Conference*. (pp.155 - 159), Turkey, Istanbul; ESERA: A Pegem Akademi

SEP (Science Enhancement Programme) (2004), *Teaching ideas and evidence in science at key stage 3*, CD-ROM of support materials available from: www.sep.org.uk

Shtessel, Z. (2009), *Environmental Ethics*. Jerusalem, Science Education Center, Hebrew University. (In Hebrew)

Simon, S., & Maloney, J. (2006), Learning to teach 'ideas and evidence' in science: a study of school mentors and trainee teachers, *School Science Review*, 87/321, pp.75-82.

Wolfe, S. and Alexander, R.J. (2008), Argumentation and dialogic teaching: alternative pedagogies for a changing world, 18 pp, London, Futurelab. http://www.beyondcurrenthorizons.org.uk/wpcontent/uploads/ch3_final_wolfealexander_argumentationalternativepedagogies_20081218.pdf

Zimrot, R. (2009), *Teaching models for integrating higher order thinking skills in Chemistry teaching*. Al Chimia 15. (In Hebrew)

Zohar, A. (2008), Science teacher education and professional development in argumentation. In: S. Erduran & M.P. Jiménez-Aleixandre (eds.), *Argumentation in science education: perspectives from classroom-based research* (pp. 245–268), Dordrecht, Springer.

Learning Argumentation Skills in Mathematics

Argumentation Skills Supporting Instruction

inspired by Philosophy for Children Adapted to Mathematics

SECTION ONE

Teacher Training Programme Description

Introduction – Why Argumentation and why *Philosophy for Children adapted to Mathematics*?

To put it briefly, argumentation is a discussion in which reasons are advanced for and against some proposition or proposal. Although no one doubts the need for background knowledge to support successful argumentation, recent research has highlighted the issue of training for argumentation skills. Kuhn (1991) demonstrated that many children (and also less well educated adults) are very poor at co-ordinating and constructing the relationship between evidence (data) and theory (claim) that is essential to a valid argument. Kuhn's research shows the need for practice in acquiring the skill to use valid arguments:

> Argument is a form of discourse that needs to be appropriated by children and *explicitly taught* through suitable instruction, task structuring and modelling. Just giving students scientific or controversial socio-scientific issues to discuss will not prove sufficient to ensure the practice of valid argument[1]

- Argumentation belongs to the most difficult but also the most attractive parts of instruction – both for the students and for the teacher.
- Especially important in mathematics and science is the need to educate students about how we know what we know, and why and when we can believe in scientific views of the world.
- Mathematics and science are to be taught as a way of knowing not as a set of knowledge.
- Construction of an argument, and its critical evaluation is a core discursive activity for accomplishing this.

Learning to argue is to coordinate evidence and theory to support or refute an explanatory conclusion, model or prediction space, in order to address conceptual and epistemic goals in learning and make student's scientific thinking and reasoning visible for the teacher (so that he/she can evaluate and facilitate it further).
Therefore, learning to argue is an essential element of any contemporary (science) education.

Current Czech educational reform explicitly states the importance of learning to argue. **Argumentation** is an integral part of the general definition of key competencies as well as of the description of the goals in the mathematics and science subjects. For instance the problem-solving competency states that an elementary-school graduate:

> (...) thinks critically; makes prudent decisions and is able to defend them; realises the responsibility for his/her decisions; is able to evaluate the results of his/her decisions (...)

Objectives of the Educational Area *Mathematics and its Application* states (amongst other things) that instruction is aimed at forming and developing key competencies by guiding the pupil towards:

[1] Osborne, J., Erduran, S. and Simon, S. (2004) 'Enhancing the quality of argument in school science', *Journal of Research in Science Teaching,* 41/10, pp. 994-1020.

developing combinatorial and logical thinking, towards judging critically and argumenting comprehensively and factually by solving mathematical problems (...)

developing the confidence in his/her own abilities and potential when solving problems, towards systematic self-control at each step of the solution procedure, towards developing methodical habits, persistence and precision, towards forming the ability to express hypotheses on the basis of experience or experiment and towards verifying them or repudiating them using counterexamples[2]

Nonetheless, this is not an easy task, for teachers the world over.
To quote Elizabeth Beazley from Chicago, who very well expresses the feelings of mathematics teachers around the world:

> I have found that students struggle greatly with the transition from experiencing mathematics as answer-driven to placing emphasis on, and valuing the construction of the argument itself. My experience teaching Chicago Public Schools teachers has revealed resistance to breaking away from thinking about math as purely algorithmic. In my courses, I endeavor to take students beyond these modes of thinking; to encourage them that mathematics is not merely about obtaining answers, but rather about a process of exploration and discovery that allows one to take an informal or intuitive idea and turn it into a rigorous logical argument.
>
> In mathematics courses at all levels, it is important to model good problem-solving and proof-writing technique, but I also focus on explaining the process of generating the ideas for and constructing the argument.
>
> ...
>
> I employ a Socratic technique in helping students to break down problems and develop their own capacity to recognize which arguments are commonly used to formalize which flavors of intuition. Although mathematics at times greatly resembles a highly creative art form, it is important to convey to students that they are capable of cultivating their own abilities to generate and formalize these ideas, independent of whether the material is introductory or advanced.[3]

When we think about argumentation in mathematics, it is important to mention that scientific argumentation is more difficult than social or socio-scientific argumentation[1] , both for students and for teachers, which is connected with the fact that it demands background theoretical knowledge, and students cannot therefore make much use of their previous informal learning and personal experiences in natural life settings.

Frequently, approaches to teaching argument are formal. That is, they see arguments as formal procedures that must have certain features if they are to be complete or effective[4]. The formal approach often refers to British philosopher Stephen Toulmin, author of the book *The Uses of Argument* (Toulmin, 1958). Toulmin talks about practical argument, and focuses on the justificatory function of argumentation, as opposed to the inferential function of theoretical arguments. Whereas theoretical arguments make inferences based on a set of principles to arrive at a claim, practical (or substantial) arguments first find a claim of interest, and then provide justification for it. Good argument means good

---

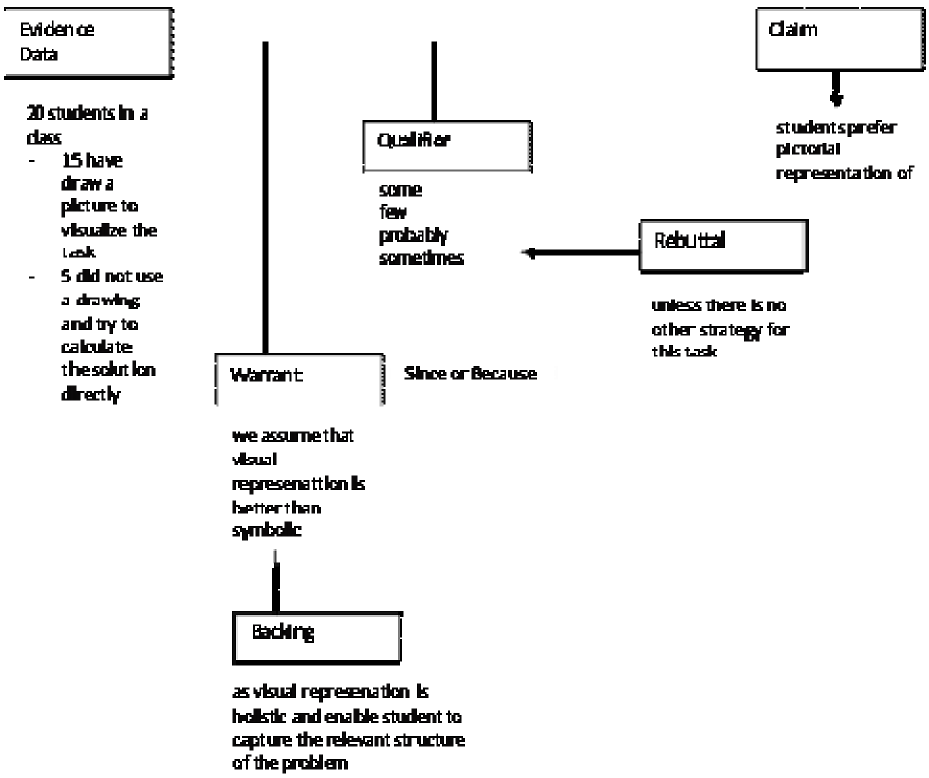
[2] Framework education Program for Elementary Education. (Rámcový vzdělávací program pro základní vzdělávání (se změnami provedenými k 1. 7. 2007), VÚP Praha 2005.

[3] http://www-personal.umich.edu/~ebeazley/ETB_TeachingStatement.pdf

[4] See also S-TEAM deliverable 7a available at : www.ntnu.no/s-team

justification for a claim. Toulmin's view on the process of argumentation can be illustrated by the following schema (fig.1 below):

Figure 1: Toulmin's structure of argument



The difficulty with formal approaches to argument is primarily the uses people make of them. It is far too easy to turn a thoughtful, philosophical analysis into a prescription. In domains where people do have a lot of experience they see formal procedures of reasoning as too demanding of effort and time, and thus rely on heuristics, thought sometimes making mistakes[5]. This adherence to experience in reasoning shows that we have a tendency to rely on overlearned, generalized representation of the problem, assuming we have such experience. Hejný (2004) talks about the causes of formalism in mathematical knowledge and shows that if we learn a new piece of knowledge as information (transmissive model of instruction), not as a generic model of a situation/problem (constructivist method, inquiry based instruction), we are not able to apply it outside of the frame in which it was learned. There is, therefore, little likeliehood of transferring formal schemes of argumentation to the regulation of one's own thinking in everyday contexts.

Students need to develop deeply rooted experiential skills of critical thinking, which means successfully and critically interrogating their own ideas. However, parallel individual activities, as well as class discussions themselves, do not ensure that our students will improve their critical thinking skills. Many students work passively, unmotivated, simply absorbing information. They do not challenge their own ideas. However, when students search for answers to their own authentic questions (rather than just following instructions) they cannot remain passive players.

[5] Tversky, A., Kahneman, D. (1974). Judgement under uncertainty: heuristics and biases. *Science*, 185, 1124-1131.

Osborne et al.[1] describe pedagogical strategies fostering argumentation. At the core of such strategies is the requirement to consider not singular explanations of phenomena but *plural* accounts. Students must spend time considering not only the scientific theory but also an alternative such as the common lay misconception, (e.g. that all objects fall with the same acceleration versus the notion that heavier things fall faster). Argumentation is fostered by a context in which student-student interaction is permitted and encouraged, where students work collaboratively in problem solving groups and where procedural guidelines for the students are established to facilitate the process of argumentation (e.g. guidelines for discussion).

Section 1: Philosophy for Children adapted to Mathematics

A very promising approach to fostering not only argumentation skills but critical, creative and ethical thinking in general, is the programme *Philosophy for Children adapted to mathematics* (P4CM).
It combines emphasis on correct arguments with great respect for children's epistemological needs

Below we cite part of the text of Marie-France Daniel, Louise Lafortune, Richard Pallascio, Pierre Sykes *Philosophizing on Mathematics*, which describes the core ideas of this programme[6].

How to bring pupils to philosophize on Mathematics

*The Philosophy for Children program, as conceived by Matthew Lipman and Ann Margaret Sharp, suggests a three-*step approach *to encourage youngsters to philosophize (see Daniel, Pallascio and Sykes, 1996). During the first step, pupils begin by reading, in turn and out loud, a few sentences or a paragraph of the novel. During the second step, pupils who wish to do so can formulate questions that came into their mind when reading these sentences or paragraphs. Doing so, they establish their reflection schedule for the following weeks. The third step refers to the philosophical discussion within a community of inquiry.*

When practicing Philosophy for Children adapted to mathematics*, we use these three steps. We also add some moments of personal reflection, so pupils can clarify their thoughts, as well as some mathematical activities (individual or group). These steps are detailed in the following pages.*

Reading

In Philosophy for Children adapted to mathematics*, as in the initial* Philosophy for Children *programme, pupils start the inquiry process by reading a chapter of the novel. This reading is shared. In other words, pupils read out loud and in turns, a few sentences or a paragraph of the novel. Shared reading is fundamental because it allows youngsters to appropriate the contents of the novel, as a group. It also allows them to actively integrate the community of inquiry.*

Pupils' Questions

Individually, in small teams or in a large group, pupils formulate questions that emerged from reading of the text. Each question is written on the blackboard with the name of the pupil who thought of it, as well as the page and the line of text it concerns. This gives the pupil recognition as the author of a question. Questions must truly emerge from the text. If not, pupils must explain the link they see. As they

[6] We cite an unpublished English translation of the Chapter "Philosophizing on Mathematics".

learn to formulate their questions, pupils are brought to ask philosophico-mathematical questions. These questions are not problems to be solved with one single answer, but rather "open" questions that allow the emergence of a variety of points of view.

Among other criteria, it can be said that a question is philosophical when it is focused on a search for meaning and a comprehension of concepts; when it is general instead of specific; when it is built around the origin or the cause, the consequences, the relationships (linguistic and logical) between words, sentences, ideas, or concepts; when it searches for similarities and differences; when it brings subtleties to light; when it questions criteria, biases and traditions; when it searches for "good reasons" and justifications.

Individual Reflection prior to Discussion

As suggested by Clark (1994), at the beginning of the philosophical process, it is better to let pupils reflect about the chosen question or think about it individually, so that afterwards each pupil can better participate in the group discussion. This step is particularly important when pupils are not accustomed to these types of discussions. They usually need time to think and organise their ideas. We believe that a greater number of pupils will be motivated to participate in the discussion if they have had time to reflect upon the question individually before addressing the question in the community of inquiry. Each person can thus build an opinion, take a stand and conceive of relevant arguments to justify their point of view.

Philosophical Discussion in a Community of Inquiry

To initiate the philosophical discussion on mathematical questions posed by pupils within a community of inquiry, the present work suggests two instruments for teachers: first the discussion plans, then the exercises and activities.

The first consists in using discussion plans that refer to philosophical concepts related to mathematics. In the discussion plans, there is often a back and forth movement between mathematics and elements of everyday life. It is our belief that bringing pupils to think about these aspects in parallel helps them make the transfer between mathematics and other subject matters, between mathematics and "real" life, between school and social issues. Indeed, we know that it is only when pupils realise that what they learn in school can help improve their everyday life that they start to enjoy learning and profit from it (Daniel, Lafortune, Pallascio and Sykes, 1994).

The second is a group of exercises or activities intended for pupils; some pertain to mathematical notions that are part of the regular curriculum; others pertain to myths and biases conveyed in the field of mathematics; finally, others pertain to emotional aspects that influence learning mathematics. To address mathematics, some of these activities make more use of philosophical reflection, whereas others are primarily focused on the discipline itself to foster philosophical discussions.

To facilitate such discussions, we recommend using the present Manual because it provides several avenues that favour group work, philosophical discussion, as well as the search for meaning regarding a number of mathematical notions. With the help of a few simple questions, a discussion plan concerning a notion chosen by pupils can lead to multiple avenues of reflection and discussion. The same goes for exercises and activities related to a concept or a notion where play, the manipulation of objects and team-research foster reflection and discussion among peers.

It is not necessary to use all of the questions suggested in the discussion plan, or to complete all the exercises and activities related to a concept or a notion to prepare the discussions. Instead, only a few of the avenues suggested could be explored with the pupils. It is only after the pupils read a chapter, and after they choose the questions they wish to discuss that the teacher will turn to the discussion plans and to the exercises and activities.

All of the exercises and activities are not necessarily suitable for all pupils. Indeed, this work is intended for teachers of second or third cycle of elementary schools and first cycle secondary schools. Teachers must therefore choose, among the proposed exercises and activities, those that best match the *interests of their pupils, in other words, choose the exercises and activities that are most apt to contribute to their intellectual stimulation.*

Most notions and concepts are accompanied by an introduction of a philosophical or mathematical nature, reminding the teacher of some basic principles supporting this notion or concept. These introductions serve to prepare the work that will be done with the pupils concerning the discussion plans, exercises and activities related to a notion or a concept.

As to the definition of a "philosophical discussion", in the following paragraphs, we will attempt to put forward some criteria[7]. First, one might think that, in the classroom reality, an activity with the pupils is philosophical when the underlying theme is philosophical (liberty, beauty, goodness…). This may be a fundamental condition, but not a sufficient one.

Also, one might think that a discussion is philosophical when one observes the presence of logical elements in pupils' discourse (inferences, comparisons, syllogisms, cause-effect relationships, etc.). However, it is difficult to uphold that logical reasoning determines, on its own, the philosophical nature of a discussion. Indeed, the exchange of relevant information, according to a logical thought process, could be intelligent, reflective and articulated without being philosophical.

First and foremost, a philosophical discussion needs questioning, and questioning that one intends to deepen. This appears to be one of the important criteria to qualify a discussion as philosophical. And, from there, it can be construed that even if there are more questions than answers at the outcome of a discussion, it may have been truly philosophical because questioning is a means that leads to the refinement of criticism, analysis or doubt in relation to so-called facts.

A second criterion should be added: that of autonomous thinking. Indeed, if philosophical discussion is, as Justus Buchler claims, an intellectual adventure that develops by building on comments, like a pyramid, we can therefore suppose it implies a part of autonomous thought. By using the image of the pyramid, we mean to convey that philosophical discussion does not develop in a simple linear process, but is organised in the form of multiple interlinks. Philosophical discussion is constructed; in other words it is gradually structured, based on the various statements of autonomous participants.

On top of these two criteria, there is the critical sense. Discussion can become linear if one does not question established views, if hypotheses of solutions are not verified. In this sense, it is important to be sensitive to context and to be able to reconsider one's position, so as to rectify the errors in this position or recognize its limitations. Objectivity, open-mindedness and self-correction, such are the characteristics of critical thinking; such are the elements that allow a dialogical exchange to evolve and personal reflection to develop.

Critical sense cannot develop without the contribution of divergent and creative thinking. Indeed, to reach a philosophical discussion, one must go beyond the simple delivery of a beautiful speech with well-worded phrases. Often these phrases have already been thought, said or written by others. They are phrases that we have heard, taken from a book or from somewhere else. It is of utmost importance that thoughts be authentically original and creative. Naturally, creativity implies a series of "philosophical virtues", namely the courage to assert oneself, the will for change and concern for others.

As we have just said, an idea is a personal construction that only materialises in relation to peers. This helps to understand that active participation in a community of inquiry constitutes another fundamental criterion for any philosophical discussion. In other words, discussion becomes philosophical when individuals, instead of competing, become partners in a common research project. Indeed, a community of inquiry favours the development of certain moral and social behaviours such as active listening, respect of peers' ideas, open-mindedness, as well as the desire to be transformed by others. These different attitudes favour dialogical exchanges and contribute to raise the discussion to a philosophical level. A discussion cannot be truly philosophical if, as previously mentioned, it is simply linear. Each person is responsible for elaborating her/his comments based on peers' comments and for participating at the cooperative climate in the classroom. In short, a discussion is philosophical to the extent that it brings into play the autonomous, critical, creative and responsible thinking in participants.

---

[7] The following elements are adapted from Beausoleil and Daniel (1991).

Individual Reflection following the Discussion

Clark (1994) suggests another step of individual reflection in which pupils have a few minutes to think in written form about what they have discovered, learnt or constructed during their discussion in a community of inquiry. This allows pupils to make their own assessments. Instead of providing a single and expected answer to a question, they can synthesise and highlight elements that emerged from the discussion in the community of inquiry. This step is a logical consequence of any well-led community of inquiry. Indeed, the purpose of the community of inquiry is to foster questions to be looked into, to awaken pupils' curiosity and to encourage them to pursue the process of inquiry initiated in the classroom. One must decide how to achieve this step, according to the content and the development of the pupils' philosophical discussions.

The Mathematical Adventures of Matilda and Damian, tells the story of twins Matilda and Damian who attend the same elementary school, but are not in the same class. Matilda succeeds very well in mathematics and worries about not being attractive to Matthew because of her high achievements in maths. Damian hates mathematics and succeeds better at art. The novel introduces questions and reflections these youngsters and their classmates have with regard to mathematics and to learning this subject matter, and with the attitudes needed to be successful.

Within the framework of the project conducted with youngsters from two elementary schools, pupils demonstrated an ability to philosophize on mathematics. Reading the novel gave rise to several philosophical questions such as: Can a perfect cube exist? Must the teacher know everything about mathematics? Is the number of grains of sand on earth infinite or indefinite? Are we freer to undergo a maths exam than an exam in another subject? Can all lines be considered a representation of a geometric figure? Why don't all geometric figures have names?

Community of Inquiry Contributions to Learning Mathematics

In order to properly understand the Philosophy for Children adapted to Mathematics *program it is important to understand what a community of inquiry is and to know some of its theoretical foundations. As soon as an educational approach seems interesting and relevant, we all too often tend to want to know how to use it in the classroom without dwelling on its underlying theoretical aspects. However, we believe that knowing the theoretical foundations of an educational approach allows us to use it with more freedom, adapting it in accordance to its basic principles and to the personality of the group it is intended for. This theoretical knowledge is all the more necessary because the community of inquiry is not usually used by teachers, no matter what is taught. In the following pages, we will explain in more detail what the philosophical community of inquiry is and we will present two epistemological principles that come within the scope of the socio-constructivist and pragmatic perspectives it is based on, namely personal construction of meaning and intrinsic motivation.*

Community of Inquiry

The community of inquiry is probably the most innovative element in Lipman and Sharp's program. Its roots are found in Socratic pedagogy and it is characterised by philosophical dialogue. For Lipman and Sharp, as well as for pragmatists, dialogue is not synonymous with talk or conversation. Dialogue is understood in the sense of the Greek dia-logos. Dialogue within a community of inquiry then becomes an "authentic communication" attempt; it invites youngsters to participate as a group in the reconstruction of the personal and social discourse. In other words, dialogue implies a search for meaningful exchanges among peers, which values inter-subjectivity and pluralism.

Pluralism, at the very essence of the philosophical community of inquiry's dialogue, should not be mistaken for any form of relativism. Indeed, the goal of a philosophical dialogue is to develop autonomous, critical and responsible thought, and construction of meaning by youngsters. In other words, the purpose of a philosophical dialogue is to verify the validity and relevance of what is known, of traditions, of norms and of social values; its purpose is also to verify the validity of personal beliefs and opinions. The goal is personal and social improvement.

A gathering of people is not a community of inquiry. A community of inquiry is formed when the people gathered communicate with each other in an authentic manner, when each person considers that inter-subjectivity is preferable to subjectivity and recognises the importance of the parties to the overall success (Daniel, 1994, 1996). The true community of inquiry is not formed after a single group discussion in the classroom. Pupils learn to experience it through practice. It is formed when pupils elaborate their ideas based on solid reasoning, feel they are responsible for contributing to the group, follow the quest for meaning wherever it leads, respect the points of view of others, self-correct if necessary, are delighted with their and the group's achievements, and practice the art of judging well in the dialogical context of an inquiry in common.

According to many teachers that regularly facilitate communities of inquiry, self-esteem, tolerance, logical reasoning, critical sense and open-mindedness with regard to differences are some of the qualities that gradually develop through regular practice within a community of inquiry.

Basic Principles

The basic principles of the Lipmanian approach stem from pragmatist and socio-constructivist paradigms (Daniel, 1992). Contrary to the traditional model that too often prevails when teaching mathematics, these paradigms emphasize personal construction of ideas rather than their memorisation. This epistemological distinction opens a parenthesis on the ever-popular debate between teaching and learning.

In fact, although teaching and learning refer to two different aspects of education, they are not in opposition to each other and, within the context of the classroom, both activities must be present. However, we believe, as do the socio-constructivists and the pragmatists, that to achieve authentic education, more importance must be given to construction of meaning by the pupil than to transmission of information by the teacher.

With this perspective in mind, we will examine two fundamental principles of the Philosophy for Children program. The first specifies that learning is a process based on the construction of knowledge by the person learning. The second refers to the need for intrinsic motivation within the act of learning.

First Principle

According to John Dewey and the pragmatists, a person learns insofar as he or she is placed in a state of doubt or uncertainty, which is a starting point to questioning and intellectual inquiry (Dewey, 1916/1983; 1913/1967). Ernst Bayles (1960) takes up the words of the pragmatists when he says that learning is a double process. On one hand, there is the formulation of insights by the learner and, on the other hand, the logical organisation of this information by the person. As to Piaget and the constructivists, they uphold that learning begins with personal appropriation of knowledge and with a personal construction of the problem and its possible solutions (Bednarz and Garnier, 1989; St-Onge, 1992).

Following the steps of the pragmatist and constructivist perspectives and influenced by Lipman and Sharp's educational methods (in particular see Lipman, Sharp and Oscanyan, 1980), we come to postulate *that learning mathematics becomes significant insofar as the person learning also feels responsible for this learning. In other words, we believe that the role of the teacher should consist in stimulating pupils to embark in a process of construction and appropriation of knowledge, rather than giving them problems to solve and asking them to find the right answer. It is our opinion that schools reach their educational ends when they invite children to participate in a process of inquiry, since this is the condition that fosters a person's transformation, readjustment, reconstruction and improvement.*

According to our conception of mathematics, it is not an infallible science whose solutions are already recorded "somewhere". Instead, we argue that mathematics is a science elaborated by the human mind and, consequently, it includes both elements of research and of personal construction. From this viewpoint, each step of the problem-solving process calls for a personal contribution from the learner. To begin with, there is a construction of the problem by this person, but it also involves personal construction work with regard to the meanings of the concepts contained in the problem posed, with regard to the possibility of transferring solutions to other problems or other situations (in particular those of daily experiences), and with regard to personal attitudes to be acquired in difficult situations (perseverance, courage, etc.).

We will go so far as to say that regular practice of an educational method centered on the construction of meaning should have an impact on the development of the person. Some studies, carried out during Language Arts and Moral Education classes in elementary schools, established a correlation between weekly practice of the Philosophy for Children *program and pupils' development of creativity and self-esteem. As Vincent (quoted by Brossard and Marsolais, 1992) points out, learning mathematics does not only mean acquiring mathematical skills and knowledge, it also means learning how to improve one's way of thinking, feeling, acting, and being. This conception is confirmed by an increasing number of researchers who demonstrate that learning mathematics is strongly linked to attitudes, emotions, and to the person as a whole (Lafortune, 1992).*

Second Principle

The second principle of learning, over which we would like to linger, concerns intrinsic motivation. According to pragmatist John Dewey (1913/1967; 1916/1983), there are two types of interest in the accomplishment of an activity. The first is the interest the person experiences towards the activity. This interest is likely to induce success in achieving the activity. It is referred to as intrinsic motivation. The second type of interest for an activity comes from an exterior pressure (obligation, etc.), generally through the intervention of another person and it is less likely to lead to a successful outcome. We refer to this as extrinsic motivation.

More specifically, Dewey sustains that as soon as learning mathematics is dissociated from personal interest and social usefulness, in other words when mathematics are presented as a body of formulas and technical relations, they become abstract, futile, and uninteresting for most pupils. John Dewey also recognizes the educational and epistemological need to take into account, in learning mathematics, the experience of the pupils and their personality.

Piaget also recognizes the importance of personal interest in learning. In one of his works (1962, quoted by Lafortune, 1992), he writes that for more than half the pupils, failure in mathematics is due to emotional blocks. For Piaget, affectivity plays a part in the very structures of intelligence and represents a source of knowledge and of original cognitive actions (see also Daniel, 1992).

We consider that dialogue on mathematics favours the pupils' comprehension of this subject matter and gives them a form of "power" as a learner. From this viewpoint, and considering the importance of reflexive dialogue in the classroom, we believe that each pupil should have the possibility, *during maths class, to share with their peers the elements he or she constructed to solve the problems. As Dewey would say, pupils have no reason to make any efforts to solve a problem if: a) there is a single correct answer to the problem; b) the teacher knows the answer; c) all the pupils in the classroom already know the procedure because they studied various similar problems (1909/1969).*

In short, we maintain, with the pragmatists and the constructivists, that pupils will become motivated to make efforts to solve the mathematical problems they are given insofar as they can see that their solution or they understanding of the problem could make a difference and be useful to others (see, among others, Bayles, 1960; Daniel, 1992; Blaye, 1989; Gilly, 1989; Lefebvre-Pinard, 1989).

Teacher training programm inspired by P4CM

Rationale and purpose

The purpose is to draw teachers‘attention to the need to teach argumentation explicitly and to facilitate their thinking about how to do this. The core idea of the programme is based on work with the same material as the children will use, because it allows for different levels of philosophical reasoning.
At the same time, working with the texts and task for children enable us to think about possible instructional consequences and share them in groups.

Materials

The Textbook for children and Manual for teachers was created on the basis of the P4CM (kindly agreed with the first author of the novel *The Mathematical Adventures of Matilda and Damian*, and teachers' manual *Philosophizing on Mathematics*) and supplemented with some other materials (they are cited in the Manual).

Duration

10 meetings each of 1.5 hours.

Outline of meetings

1. Introduction – argumentation in science and mathematics, *Philosophy for Children adapted to Mathematics*.
2. Part 1: Focused on....cube!
3. Part 2: My relation to mathematics
4. Part 3: Only some like mathematics and they are....
5. Part 4: Problems and mystery
6. Part 5: Math is like...
7. Part 6: Mathematics as inquiry
8. Part 7: Observation and reasoning
9. Part 8: To learn to think means to think about thinking
10. Part 9: We can learn from each other

Checklists and evaluation schemas

The following tools we used to reflect upon the argumentation during the meetings. We also used mind maps at the beginning and at the end of the program to look for prospective shifts in participants' view on argumentation and its teaching.

Checklist for the argumentation reflection

	Levels of Performance			
Criteria	1	2	3	4
1. **Organization and Clarity**: viewpoints and responses are outlined both clearly and orderly.	Unclear in most parts	Clear in some parts but not over all	Most clear and orderly in all parts	Completely clear and orderly presentation
2. Use of Examples and Facts: examples and facts are given to support reasons.	Few or no relevant supporting examples/facts	Some relevant examples/facts given	Many examples/facts given: most relevant	Many relevant supporting examples and facts given
3. Formulated claims clarity, preciseness	Unclear, vague, ambiguous formulation	The core is clear, the formulation is vague (e.g. qualifiers missing etc.)	Clear , concepts accurately formulated	Clear, sounded, precisely formulated
4. Use of Arguments: reasons are given to support viewpoint.	Few or no relevant reasons given	Some relevant reasons given	Most reasons given: most relevant	Most relevant reasons given in support
5. Use of Rebuttal: arguments made by the others are responded to and dealt with effectively.	No effective counter-arguments made	Few effective counter-arguments made	Some effective counter-arguments made	Many effective counter-arguments made
6. Justification reasoning based on theoretical knowledge	With no backup theory	Some references to theoretical background	The reasons driven from the theory used	Theoretical justification, well organized, alternative claims disproved

adapted from http://mh034.k12.sd.us/classroom_debate_rubric.htm

Checklist for the teacher/discussion facilitator reflection

Criteria	Comunity of inquiry facilitation What I did	What else I could do
1. Discussion management		
2. Facilitation of argumentation (forming the claims, rebuttal, justification)		
3. Facilitation of inquiry (asking for examples, alternatives, suggestions for exploration etc.)		

Student experiences

We have tried the program with three groups of future teachers, both future math teachers and those who will teach other subjects.

Below we list the difficulties the students, who were gradually forming the community of inquiry, had to overcome during their communal effort to improve their own argumentation.
They were related both to starting misconceptions as well as to the process of argumentation itself, and the lack of background knowledge:

- Impatience – wanted to get the answer prematurely
- Sometimes argument confused with debate, with insufficient justification but with strong emotional loading
- Sometimes argument conceived as a fight – it is necessary to clear it up, but it takes time
- Sometimes argument mistaken for opinion, weakly supported or poorly reasoned
- Sometimes too complex task, lack of self-discipline in discussion is disruptive
- Unfamiliarity with this mode of instruction, sometimes passivity

References:

Daniel, M-F., Lafortune, L., Pallascio, R., Sykes, P. (2004). *Philosophizing on Mathematics*, Quebec: Le Loup de Gouttière

Kuhn, D. (1991), *The Skills of Argument*. Cambridge: Cambridge University Press.

Hejný (2004). Mechanismus poznávacího procesu. In M. Hejný, J. Novotná, N. Stehlíková, N. (Eds.). *25 kapitol z didaktiky matematiky*, 1.díl. Praha PedF UK.

Osborne, J., Erduran, S. and Simon, S. (2004) 'Enhancing the quality of argument in school science', *Journal of Research in Science Teaching* 41/10, pp. 994-1020.

Toulmin, S. (1958). *The Uses of Argument* . Cambridge: Cambridge University Press. 2nd edition 2003.

Tversky, A., Kahneman, D. (1974). Judgement under uncertainty: heuristics and biases. *Science*, 185, 1124-1131.

.

Appendix: Mind maps – student J.S. participating in the training programme.

Fig. 1: Mind map drawn at the first meeting

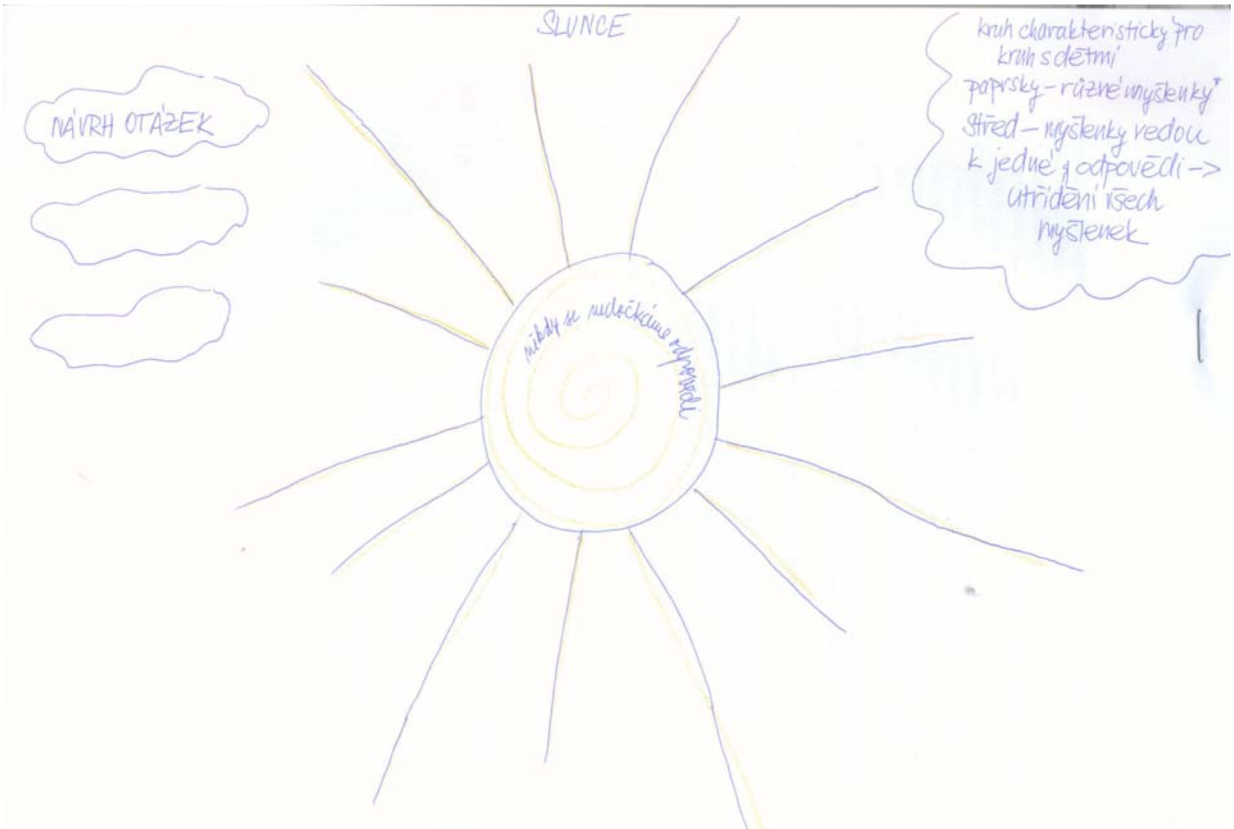
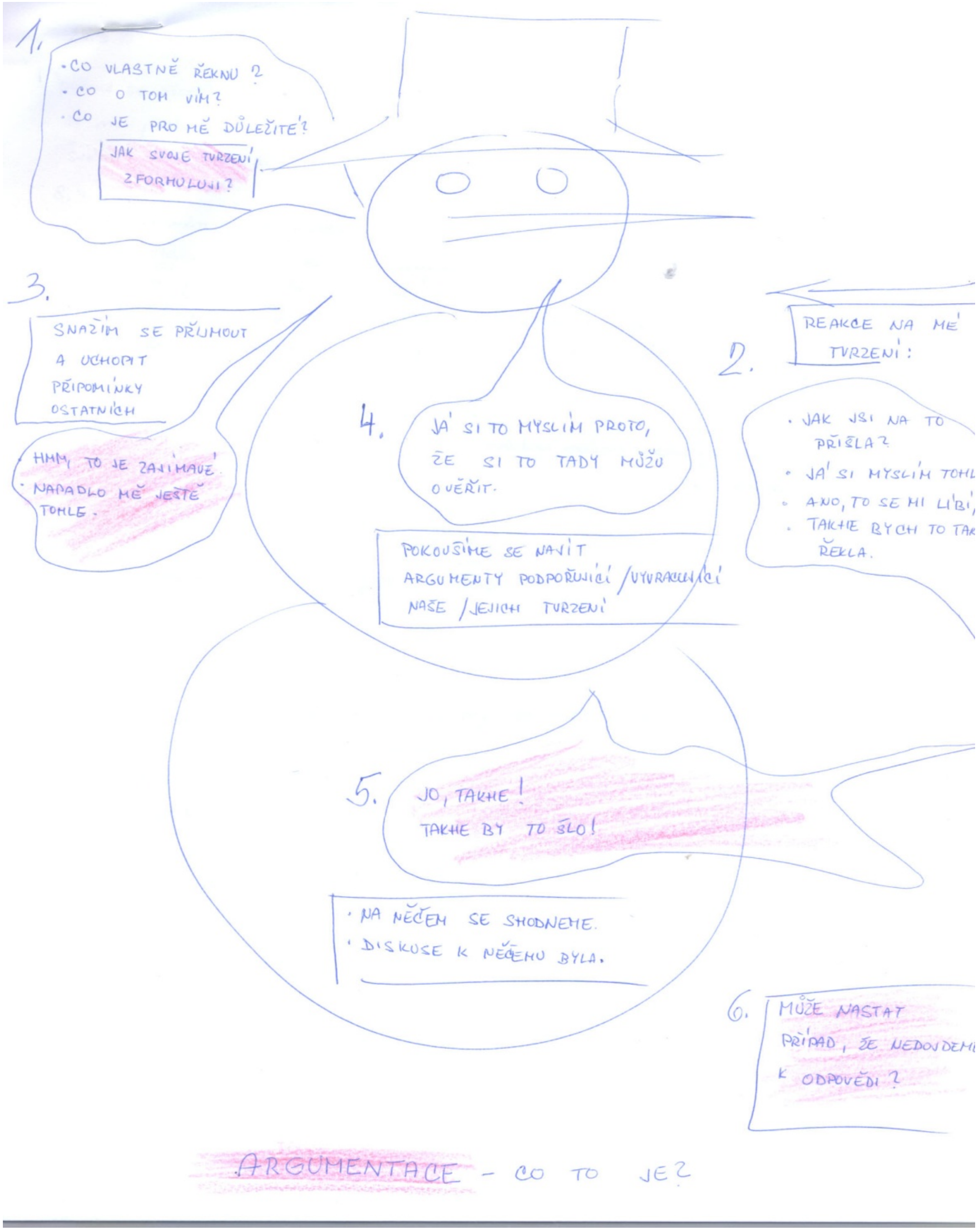


Fig.2: Mind map drawn two weeks after finishing the training programme



SECTION TWO

Manual for teachers: Philosophy for Children adapted for mathematics

(Contains texts for children)

About the manual

The authors are teachers of Department of Pedagogy and Psychology of University of Bohemia:

Iva Stuchlíková

Alena Hošpesová

Yvona Mazehóová

Students of USB participated in piloting of the programme, several pupils and students from schools in Ceske Budejovice work with the textbook in their free time activities with Iva Stuchlikova.

Introduction

Teaching programmes facilitating argumentation skills must be based on supplying children with their own space, and on enabling them successfully and critically to review their own thought processes. The present material originates from the Philosophy for Children[1] program (FPD) that endeavors to develop critical, creative, empathic, and ethical judgment of children from preschool all the way up to high school (upper secondary level). Its key idea is a shared search for answers (community inquiry) to authentic children's questions and the deepening of their abilities to discover and formulate essential understanding to which they arrive by the path of mutual "philosophizing". Texts describing lives of children's peers were developed in order to facilitate and deepen this kind of inquiry and discovery, and to stimulate them to ask curiosity motivated questions. Text utilizing the main ideas of FPD was prepared for elementary mathematics as well, and was used by the authors in their work with children aged 9 to 13 years of age.

The basis for the way children themselves think in mathematics and how they proceed in their mathematical judgments is the story of twins - Michelle and Damian – and their friends, *The Mathematical Adventures of Michelle and Damian***.**

Authors:
Marie-France Daniel, University of Montreal
Louise Lafortune, University of Quebec in Trois Rivires
Richard Pallascio, University of Quebec in Montreal
Pierre Sykes, personne-ressource en philosophie

Original title:
Les aventures mathèmatiques de Mathilde et David
Quebec: les èditions Le Loup de Gouttière, 1996

English version:
Mary Tiles and Tom Jackson, University of Hawaii at Manoa, 2002

Czech version from English translation:
Ram Thein, Romana Pistorová, Iva Stuchlíková, University of South Bohemia in České Budějovice, 2010

This manual contains texts for children as well as further suggestions for the teacher to develop individual topics. The core of the workbook is the description of the story from *Mathematical Adventures of Michelle and Damian* and some passages from it.

The main ideas in the work with any text in the program *Philosophy for Children* are[8]:

[8] see also the Introduction in the Teacher Training Programme Description

1) Shared reading of the text: students can take turns reading each sentence, one after the other.

2) Reflection on the text and formulation of questions triggered by the text: all students should formulate their questions and afterwards they can discuss their questions in small groups and together choose those questions that interest them the most. Questions should then be recorded with the names of their authors on a blackboard or a flipchart, so that they will be visible (side board may be better in order to enable an easy return to the topic if it cannot be covered during the given time. It is important that the questions remain on the top and that they will be philosophical (with respect to the character of the concepts as they appear, with respect to the meaning and sense of the relationships and events, etc. – see also Introduction). As this approach can be at first somewhat difficult for the children to follow the teacher's aid will be will be of great value in assisting them in the deepening of their questions. Answering one question together may elicit additional, more insightful questions.

3) Communal search for answers to formulated questions (creation of a searching community of all children with their teacher): During this search the teacher facilitates a discussion, maintains appropriate way of reasoning, encourages corrections of errors, and supports creativity. If there is an assistant, s/he may take over the function of observing how the discussion and search are proceeding, so that he or she may help the students reflect on the evolution of the search. Gradually, as the children get accustomed to this style of work, the teacher may encourage the students to reflect individually on their way of working. He may also request that the assistant or one of the pupils observes the development of the discussion and of the search, and that they try to evaluate the process (the teacher will supply them with tools for observation and evaluation). We should not underestimate children in this sense- children frequently reflect, although often in private or accidentally- nevertheless, this skill can be fostered and has an important value for the development of argumentation skills and for critical thinking.

The aim of the programme *Argumentation Skills Supporting Instruction* built on *Philosophy for Children adapted to Mathematics* (P4CM) is to focus on the development of critical thinking and of valid argumentation skills. It is, therefore, appropriate to offer, besides the work with the P4CM text, additional questions, exercises and activities that can repeatedly encourage the children to make an effort and to argue correctly, and simultaneously to become aware of the process. On occasions, it will be more suitable to begin with preparatory exercises and on others to start with the text, all depending on the difficulty of the selected demonstration and on the children's readiness to relate themselves to the questions contained in the exercise.

For these reasons, suggestions for discussions, various activities and even mathematical tasks that may aid the children in their realization of how they arrive at their conclusions and how they justify their claims are placed adjacent to some parts of Michelle's and Damian's story.

For better clarity the manual is in other parts organized in such a way that the basic text matches the workbook for children, and that the complementing, expanding text for teachers is marked in blue.

Suggestions and exercises are based to a great extent on the text and the manual of the programme: *Philosophy for Children Adapted for Mathematics*:

- Samples out of chapters 1 and 2 from the story text in *Mathematical Adventures of Michelle and Damian.*
- *S*amples of activities, exercises, and suggested topics for discussions that stimulate the development of correct argumentation selected from the chapters 1, 3, 5, 6 of the manual *Philosophizing on mathematics* [9]

We further utilized topics from other sources:

Hejný, M., Novotná, J., Stehlíková, N. (2004). *25 kapitol z didaktiky matematiky*, *1.díl*. Praha PedF UK

Novoveský, Š., Križalkovič, K., Lečko, I. (1971). *777matematických zábav a her*. Praha: SPN

Stehlíková, N. (2007*). Náměty na podnětné vyučování v matematice*. Praha: PedF UK

We added some exercises or suggested topics based on our past practical experiences along with proposals that were formulated by our students during the verification of the training programme.

[9] Daniel, M-F., Lafortune, L., Pallascio, R., and Sykes, P. (2004), *Philosophizing on mathematics*. Quebec, Canada: Le Loup de Gouttière.

Part 1

Mathematical adventures of Michelle and Damian tell the story of twins, Michelle and Damian, who attend the same elementary school, although not the same class, and of theirs and their friends' and class peers' experiences. Michelle is very successful in mathematics and is concerned about how attractive she is to Mark who considers her a nerd. Damian, on the other, struggles with maths, does not like it, and prefer art class where he excels. Among their friends is also Wai Lun, a Chinese boy, who arrived in the country only three years ago. Children tend to tease him. Even if Wai Lun laughs at the jokes they play on him, in his heart of hearts their kidding hurts him. Recently, he even cried in secret. He has an impression that some students are biased against him. He would like to understand why that is, and to establish his position in class is not always easy for him. In the story, teachers also appear, for instance Mr. Ginosa who teaches maths, and who is genuinely adored by the children. Mr. Ginosa is a super-teacher. He does not denigrate the pupils even if they don't comprehend maths. Occasionally he himself makes mistakes and says that it is normal! He always searches for new ways to teach topics. He always consults with his pupils before deciding anything. It seems he truly loves his pupils and the mathematics that he teaches.

Mathematical adventures of Michelle and Damian I.

Michelle arrives home from school. Kicks off her shoes and goes into the house letting the screen door slam behind her. She goes straight to her room and as usual dumps her backpack in a corner and throws herself onto her bed. Ahhh! How good it feels!

Michelle likes her room. It's small, but comfortable, with a square floor.
"Oh! one could say it's almost a cube! Mrs Toyama told us about cubes this morning, in geometry class. What exactly did she say?" Michelle frowns, trying to recall.

Slowly the words of her teacher, Mrs Toyama, come back to her. Things always happen like that in Michelle's head. At first her thoughts form a kind of large dense cloud. Then, one by one, her ideas emerge from the depths of the cloud. It is only then that she can grasp and inspect them.

While continuing to think reflectively, Michelle lets her eyes wander round the room. She wonders:

“Can a room really be a cube or does it only look like a cube? Mrs Toyama told us, I remember now, that on earth it was not possible to have an absolutely perfect cube. That's astonishing!”

Michelle tries to reflect further on this question, but she is tired. She gets bogged down in her ideas, gets impatient, and finally gives up.

“Tomorrow I am going to ask Mrs Toyama to explain this. After all, she is the teacher! She must surely know all about geometry.”

Michelle´s thoughts take wing, freed from their mathematical problem. She starts to dream about Marco. She would so like him to be her boyfriend.

“Ahhh! Marco, what a special boy! He is so different from the others. And I think he´s really handsome, even if some of the other girls in the class don't! And he's intelligent as well. If only he could show a little more interest in me.”

What comes to your mind after reading the text? Articulate a question that boggles your mind after reading the text. It should be a “clever” question that would make even King Solomon sweat. Michelle herself has to think hard about some questions – for example, “Is it possible that my room is really a cube or it only looks like one?”

Focused on……a cube!

ACTIVITY 1

Draw various pictures that could represent a cube. Afterwards exchange your pictures with peers and observe them together. Are they similar?

And now try to answer the following questions:

- Are the pictures that you just drew really cubes or they just look like that? Explain your answer.
- When you think about a cube, what numbers come to your mind? Are they 1, 2, 3, 4, 5, 6? Or some other numbers? Explain why?

Teacher guidelines

Further questions for discussion

- What are the differences and similarities between a cube and a geometric shape that represents a cube?
- Establish a parallel between a cube and other elements. For example, take the word tree. Is the word itself a tree or just a concept that encompasses every type of tree that exists on the planet?
- What is the difference between the word tree and a real tree?
- Now take the name Matthew. Is the name Matthew a particular boy or simply a name given to some boys?
- Now suppose you write a 4 on a sheet of paper and that you lose this sheet of paper. Do you think you have lost the number 4 forever or just the copy you made of it?
- Can you draw a parallel between the geometric shape called a cube, the word tree, the name Mathew and the number 4?
- Can you answer the question Michelle asks herself: “What is the difference between being a cube and looking like a cube?”
- Is a cube a square? Explain the similarities and the differences.
- Does the amount of faces, summits and edges vary according to the size of the cube? Depending on whether we refer to a small cube or a large cube? Why?

ACTIVITY 2

Teacher guidelines

Let the children play with various everyday cubes. Then give them enough time to think about how to prepare a model of a cube. Hejný and Jirotková suggest asking pupils to imagine being a tailor trying to “dress” the cube as a good metaphor, which stimulates the generation of effective solutions.

After some time in individual activity, pupils could share and compare their development plans and look for some more shapes (or all possible ones), which will look like a cube when folded. During this task pupils should distinguish between those which are, and are not, plans for a cube.

Distribute six square pieces of cardboard to each team in order to help them imagine their own development plan.

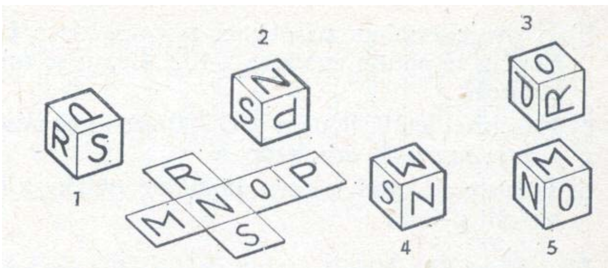
ACTIVITY 2

Let’s think about preparing a model of cube from paper. Give two examples of a development plan from which a cube can be built. Give two more examples of a development plan from which a cube cannot be built.

- Which of these development plans looks most like a cube? Why?
- Can each development plan form a cube? Why?

ACTIVITY 3

One of the five cubes numbered 1-5 matches the cube that is laid out in the form of a cross. Which cube is it?



- How did you proceed?
- Have you taken a wrong step during the solving process?
- How did you notice that it was wrong?

ACTIVITY 4

To build a square while using 4 matches is easy. But could you build 6 squares while using 12 matches? If you succeeded, congratulations. Can you explain to someone who can only hear you (let’s say on the phone and has no matches available at the moment) why exactly your solution is the correct one?

- What skills are required to find good reasons?

Teacher guidelines

Pupils must solve a problem and then think about the solution. Ask them do describe the process of solution and explain steps they took to solve it. Try to stimulate the discussion about solving the problem by trial-and-error and by generating and excluding hypotheses (using the “fresh” previous experience and knowledge about cube to will facilitate the difficult step of moving from plane to space solution.

Part 2

Mathematical adventures of Michelle and Damian II.

"I have a problem, Michelle." Damian entered Michelle's room.

"Oh yes? Really, me too. You 're my problem!" Michelle pulled a face.

In fact, Michelle adores her twin brother. They often play together. And they rarely squabble. Michelle very much admires Damian and believes he will eventually become a famous artist. Only she has never got around to telling him all that. On the contrary, she always replies to him grumpily. But Damian knows his sister and he acts as if he hasn't heard anything,

"No, please, listen to me. I have a serious problem. I think I've failed my math test again this afternoon."

"Why do you say that, Damian?"

"What a question! Because that's what I think, see!" replies Damian a bit surprised.

Michelle continues: "You said: 'I think I've failed my math test again.' What made you say that? Your fear of failing? Or the predictions you spend your time making, on the basis of bad experiences last year? Or what else?"

Damian responds honestly: "I don't really know. It's just an impression I have."

"But have you, at least, good reasons for believing this?" Michelle demands. "Just because you failed some tests last year it doesn't mean that you will fail them all this year."

"I know, but I so hate math!" Damian replies stubbornly.

"Damian, you keep saying: 'I hate math, students who don't like math are generally losers, so I am going to fail my tests'. With an attitude like that, it is not surprising that you suffer setbacks, you defeatist!"

"I'm not a defeatist but I find that math is good for nothing except provoking stress. And then, it's boring, difficult and so requires lots more work outside class time. Me, I prefer to play basketball with the boys in the class. Or to draw, alone in my room. I am very good at drawing."

"There I agree with you Damian. When it comes to drawing you are really brilliant!"

After a moment's silence, Damian adds, eyes full of tears:

"So there, that's what I'm going to do anyway. I am going to draw my frustrations in my room. That will do me good."

My relation to mathematics

Mathematics might be difficult and our continuing attempts to solve mathematical problems may not be successful. Sometimes we feel discouraged.

But no one knows everything in mathematics and even the greatest mathematicians are not knowledgeable in every field of mathematics! So there is always a chance to learn more and to understand better and be more capable. – there is a chance for everybody.

DISCUSSION THEMES – Think about these questions and try to formulate your answer:

- Do you know many things in mathematics?
- Do you understand everything you know in mathematics?
- What is most important to you: knowing 100 things or understanding 5 things? Why?
- Do you know your best friend in the same way you know the algorithm for multiplications? Why?

ACTIVITY 1

Damian says he is not good at mathematics and, therefore, he will fail. What does the word *failure* mean?

According to you, is failing math more or less serious than failing Civic Education? Languages? Arts? Science? Explain.

Teacher guidelines

Further questions for discussion

- Can failure have a positive sense? Explain.
- What is the relationship between failing math and a pupil’s knowledge?
- What is the relationship between failing math and a pupil’s intelligence?
- What is the relationship between failing math and a pupil’s interest for this topic?
- Would it be possible to consider failing math as a necessary means to progress or as a necessary step towards comprehension? Why?
- Do you see a difference between a pupil who uses his mistakes in a positive manner to improve and a pupil who uses his mistakes and failures to justify her/his laziness? Explain the consequences of both courses of action.

ACTIVITY 2

Sometimes we can feel at the edge, feel that whatever we do, we are not able to solve a particular problem. And we may be prone to start thinking that we lack a special gift for mathematics. But, instead, it could be lack of experience and practice which makes the problem so difficult. Do you believe this? Let's try.

EXERCISE

- Try to solve this task :

If we know that the following is true:

All math teachers are adults.
All adults are human.

Then **All math teachers are human.**

is the right conclusion, isn't it?

Now we can write it in formal mathematic language
A= math teachers, B=adults, C= human:

If we know that the following is true:

	All A (math teachers) are B (adult) or simply	All A are B
	All B (adults) are C (human)	All B are C
Then	**All A (math teachers) are C (human)**	**All A are C**

is again the right conclusion,isn't it?

Not too difficult? Yes, we somewhat lost the teachers in the pile of letters, otherwise everything is OK.

So, let's try to work with the letters even more. Try to determine whether the other conclusion is right as well.
If we know that following is true:

All A are B
All C are B.

Then is the conclusion **All A are C** right?.

This is more difficult, isn't it? - and, maybe, you don't like it and don't want to solve it at all?
Try to decide this one instead:

All boys are pupils.
All girls are pupils.
All boys are girls.

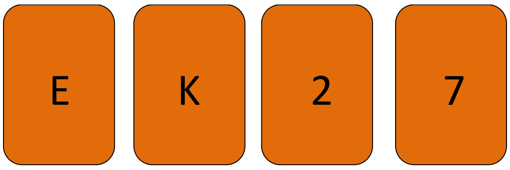
This was quite easy, wasn't? Try to explain why?

Teacher guidelines

Further questions for discussion

- How do you deal with the role of a) and b)?
- What is the difference?
- Do you have a similar experience?

This is our (in)experience which matters. We are not used to reason in a formal way in the daily life, as our everyday experiences are not represented formally either. Wason and Evan (1975) showed that many people fail in conditional reasoning tasks.
Consider the Wason task:
The person see these four cards and knows that every card has a number on one side and the letter on the other.

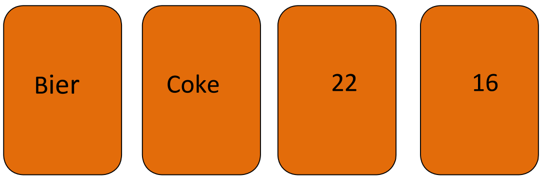


Suppose the experimenter told you: “If a card has a vovel on one side, then it has an even number on the other side.”

Which card must you turn over in order to determine whether or not the experimenter is telling the truth?

Such formal task is puzzling to many adults (out of 128 people given this task, 59 choose the alternative to turn over E and 2, and another 42 subjects just choose the alternative to turn over E). Nonetheless, if the same task is presented in the context they are familiar with (and have a precise mental representation of) like:

“If a person is drinking beer, then he/she must be older than 21 years”...

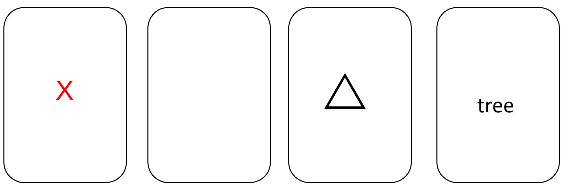


...it does not induce problems. Similarly, the pupils will be able to solve the task if dealing with something they have good comprehension of. For example, you can show them their capacity to solve the tough problems (and increase their feeling of self-efficacy) by comparisons of two similar tasks - one difficult with less elaborated mental representation, the other one of the same kind but simpler as the mental elaboration of it is more elaborated.

ACTIVITY 3

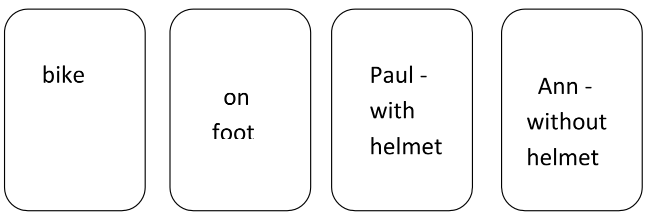
The first, more difficult (because it is weakly represented) variant:

Let’s imagine that the teacher prepared the cards (shown below) for pupils. **If the card has a red cross on one side, then the other side depicts some geometric shape.** But as the cards were unfortunately mixed with some others which are not yet finished, some cards lack either the cross or the shape. The teacher has created a mathematical task from this situation. How to pick up all the cards that are finished already but use the minimum number of turns?



And now the simpler one.:

Peter is in duty to check all the pupils preparing for a cycling contest in the playground. **If they arrived on their bikes, they must have a helmet,** if they came on foot they can wear helmets, but don’t need to, as they will wear costumes with a mask and will not ride a bike. As Peter had to quit for a while, Stan took over and made notes on cards for Peter. He wrote “with helmet” or “without helmet” on one side together with the pupil’s name on one side and wrote “”bike”or “foot” on the other side of the card. Which card must Peter turn over in order to determine whether all arriving pupils followed the rules of safe riding?



ACTIVITY 4

Ask pupils to mentally visualise failing in another field than math. Ask them to explain their reactions, what they did to counter these negative reactions and the solutions they used. The discussion will be about solutions only.

- Can failing math be compared to failing in another field?
- Could the solutions you used to overcome your fear of failing in other fields also be used in math?

  What do you suggest others do to overcome their fear of failing math?

Part 3

Mathematical adventures of Michelle and Damian III.

A few days later...

"Speaking of math, Damian, have you had the result of the math test that you were so afraid of failing?"

"No. Not yet", Damian replies, sighing.

"I hope you aren't still afraid!"

Damian responds all in one breath:

"Yes, I am still sick with fear. And if you want to know, I am sick with fear before and after each math test!"

Michelle tries to encourage him: "You are really stupid to be so afraid!"

But Damian does not like to be ridiculed. He replies quite sharply: "Aw! Michelle, quit it! You never understand anything about other people's problems. Or at least, you never want to understand anything, because you, you are good at math! Besides, no one who is good at math can understand how other people could have difficulties."

Here, it is Damian's turn to touch on point where Michelle is sensitive. She goes all red and responds to him raising her voice a notch: "First, Damian, I am not good at math. If I get good marks, it is because I work hard."

And Michelle adds, more quietly, with a note of sadness in her voice: "In any case, if I am good, I'm not a nerd as some people have said."

Damian does not say anything. He continues to flip through the drawings in his portfolio.

Michelle insists.

"I think I am more hardworking than clever. What do you think?"

Damian, who is proud to have such a clever sister, adds:

"I don't think that your success is due to the fact that you are more hard working than I am. There are children in my class who are more successful than I am in math and science but who work much less than I do."

"Yes! But then what, according to you Damian, is it that makes one student succeed in math and another not succeed?"

Damian gets up and goes to look for his ball in the corner of his room. He doesn't really have any stomach for continuing this conversation about math, but he is well aware that it is important to his sister. So, looking at her he adds:

"I don't know, Michelle. Perhaps qualities such as perseverance or a sense of organization, or even both at once."

"Ah?" Michelle exclaims, surprised. "Where did you drag that up from?"

Damian continues:

"Xing Li, the older brother of my friend Wai Lun told us already that a quality such as self confidence could play a role in a student's success in math."

With wide, brimming eye, Michelle interjects:

"How complicated it is to understand all these things! Sometimes it gets me down. Pass me your ball so that I can bounce back outside."

Math can be loved only by somebody who is....

THOSE WHO ARE GOOD AT MATH CANNOT UNDERSTAND THOSE WHO HAVE TROUBLE

Sometimes we think about things, people and situations in a somewhat simplified manner. Mostly, it is helpful, as we quickly get some orientation – imagine that your new friend offers you a durian. 

It looks like an immature chestnut and smells awful. But he told you that it is a Malaysian fruit. So you – as you know that fruit is sour-sweet and juicy - expect that the taste will be refreshingly sweet and juicy. So you try ..... and .... you are right! Having a simple conception of what fruit is like was helpful.

But sometimes, the simplified (or stereotyped) view of the world is harmful. Stereotypes and prejudices may cause misunderstanding and troubles among people.

Damian hints at a kind of stereotyping when he says, "every person who is good at mathematics is a person who cannot understand that others can have trouble with math". Uncorrected stereotypes may be dangerous, because they are often very widespread and persistent – though may have nothing real. Let's think about them.

Indicate if the following lines of reasoning are correct or not, and explain your answer:

Pupils who are successful at mathematics find it difficult to understand that other pupils can find math difficult. Michaela does well in math. She would not understand Damian’s difficulties.
Boys are good at math. I am a girl. Therefore I will have trouble with math.
I am a girl and I like mathematics. Many boys prefer mathematics to English. I must be a tomboy.
All the pages of this math book are scribbled. Here is a scribbled page. It must belong to this math book.
All the pupils in the second cycle of elementary school know how to add and subtract. This pupil made mistakes in his additions and subtractions. He mustn’t be a pupil in the second cycle.
Teachers know everything about mathematics. Elizabeth is a teacher. She must surely have the answers to all the questions.
All pupils must learn mathematics. I am a pupil. Therefore, I will have to learn math as long as I go to school.

Part 4

Mathematical problems and mysteries

ACTIVITY 1

PROBLEM OR MYSTERY?

I am a wizard. Try to follow me:

Think of a number, but don't tell anyone what it is. Multiply it by two. Add 4 and divide this result by two. Take away the first number you had thought of from the last result.

I predict that your result is 2 and that the result of all your classmates is also 2.

If you don't believe me, try conferring. Ask your classmates, on your right hand-side, your left hand-side, in front of you and in back of you. Did they all get the same answer as you did?

How do you explain this? Think about it and try to find some elements of solutions.

Form into groups and discuss your answers, or actually the *mysterious* formula we used to always come up with the number 2.

To make sure *your* formula is as good as ours (we hope it is!), explain it to the members of another team.

If you succeeded, congratulations! You just transformed a mystery into a simple math problem. If not, keep up the work until you find the key to the mystery. Persevere!

And now when you revealed the solution, try to think it over:

- What is the difference between a problem and a mystery? Give an example of each.
- Is it possible that what seems a mystery to you today might become easy to understand a few weeks from now? Give an example of smething like this which you have recently experienced.
- Is it possible that what now seems a mystery to humanity will someday become a simple problem for scientists?

Teacher guidelines

Variation task – PROBLEM OR MYSTERY?

Think of a number, add 9. Multiply the result by two. Now subtract 8 and the result divide by two. And, as the last operation subtract 5. If you did all the calculations correctly, you have the original number you have being thinking of.

What happens? Why?

Further questions for discussion

- Is every difficulty a problem? Explain.
- To what extent can you say that:
- A problem represents an obstacle?
- A problem implies a question?
- A problem is a mystery?
- A mystery represents an obstacle?
- A mystery implies a question?
- A mystery is a problem?

GENERAL DISCUSSION THEMES

- Is it possible to understand a math problem without knowing the answer?
- Is it possible to know the answer to a math problem without understanding it?
- Is it possible that everyone (each person) understands all the math problems that exist? Why?
- Is it possible that a person doesn't understand any math problems?
- At what age can a child begin to understand math problems? At one day of age? At one month of age? At four years of age? At ten years of age? At nineteen years of age?
- What human qualities (intellectual and affective) are necessary for a person to understand math problems?
- Does everyone possess these qualities at birth or must they be developed?

Part 5

Mathematics is like….

ACTIVITY 1

1) Think it out - how to finish the sentence: "Mathematics is like...". try to desribe your metaphor in more details.

Teacher guidelines

Ask pupils to mentally visualise their metaphors and develop some illustrations how it fits. Afterwards, create small teams, and ask them to discuss each metaphor and choose one they could share and elaborate.

Ask them to produce illustrative examples which can be deduced from their mental model of metaphor, describe the strengths and weakness of the model.

Mathematical adventures of Michelle and Damian IV.

Mr Ginosa begins his math class.

"I want to make you like math as much as I do. But I don't know what methods to use to make contact with you. I will need your cooperation. Will you help me?"

"YES!" the other students shout in chorus.

Mr Ginosa seems pleased at so much good will. "Very good", he says. "Now we are going to begin by situating ourselves in relation to mathematics. Tell me how you perceive mathematics."

The students don't quite know how to respond to such a bizarre question. No one says anything. It is Wai Lun who breaks the ice. "Mathematics is a jungle."

"Hmm!" says Mr Ginosa opening his eyes wide. "That's original Wai Lun, but surprising. Is there someone else who would like to offer an opinion?"

Emi quickly raises her arm waving her hand frantically. Once Mr Ginosa gives her the right to speak, she says:

“Mr Ginosa, before going on to the comments of the other students, I'd like us to discuss Wai Lun´s proposal a bit. The jungle, or the animals of the jungle, is always a popular topic. Besides, I think that several of us see mathematics as a jungle.”

And without waiting for the approval of her teacher, Emi turns toward the rest of the class and asks: “What do the rest of you think?”

Various voices make themselves heard.

-Yes! Good idea! Yo! Good for you Emi! Yes!

The teacher himself is not sure that this would be a good idea! In fact, he is afraid that such a discussion will turn negative. And this is exactly the opposite of what he had planned. He hesitates. But finally, he decides to have confidence in his students. And respecting the consensus, which has been established in the class around Wai Lun´s idea, Mr Ginosa eventually replies:

“OK then! We will discuss the relation between mathematics and the jungle.”

“Wai Lun you said that, for you, mathematics is a jungle. Could you explain your metaphor a bit more, to start us off?”

Wai Lun who cannot remember having studied this notion at the beginning of the year asks, all surprised: “Excuse me, Mr Ginosa? You want me to explain my…what?”

“The metaphor that you used Wai Lun. You did say: 'Mathematics is a jungle'?”

“Yes”, replies Wai Lun, swallowing hard.

“Then you created a metaphor. Don't you remember the exercises we did about comparisons, analogies and metaphors several months ago?”

Wai Lun, not anxious about his lapse of memory; is fully content to have succeeded in creating a metaphor spontaneously. Encouraged by his linguistic “performance”, he takes the time to explain better to the class what he had in mind.

“I said that math is a jungle, because yesterday I was doing some research in the library for my social sciences class. I was looking for books on World War II. And stumbled upon the biography of a German-Jewish mathematician. Her first name was Emmy or something like that.”

“Was it Emmy Noether?” asks Mr Ginosa.

“WOW! Exactly that! How did you guess, Mr Ginosa?”

Mr Ginosa laughingly replies:

“You know, it doesn't take a magician. There are so few biographies of female mathematicians that it is easy to know them all, or almost all. One day we will talk about this again as a group, OK? Meanwhile, continue with your explanation Wai Lun.”

“OK. Well, Emmy wrote that her first mathematics book was a jungle of formulae. At first this expression surprised me but then I said to myself that it was true of all mathematics books.”

“How so?” asks Marco.

Before Wai Lun has had time to reply, June breaks in:

“If Wai Lun can say that mathematics books are jungles of formulae, then I am allowed to compare mathematical numbers to the animals that live in the jungle because…”

June stops talking and hides her face with her tee shirt.

Ben, who never misses an opportunity to needle June when she seems to be having trouble, butts in, jeeringly:

“Because what, June? Explain to us!”

June uncovers her face. In fact she was not having trouble. If she had stopped talking it was simply because she was trying to stifle the giggles that she had felt welling up in her when she has thought of the following relation:

“You can compare the animals of the jungle to math because when the animals die, they decompose just like numbers!”

“OUCH!” exclaim the rest of the class breaking into laughter.

Amused at the turn of the discussion, Marco decides to follow up on June's move. He adds: “What's more, when the animals go to war, they divide. And when they fall in love, they multiply.”

Kevin wants to add his two cents worth.

“Dont forget that, in the jungle, the animals of a single species often stay together in a group.”

“Some animals eat roots. Perhaps even square roots”, Marco chips in.

“And they know, better than humans, how to measure danger”, adds Claire.

ACTIVITY 1

COMPOSE – DECOMPOSE

Pupils, in teams of two, must *compose* an answer that could come from the statement of a mathematical problem. All the answers are placed in a box. Each team picks an answer from the box and must use this answer to build a problem. A discussion follows.

- What is easiest: *composing* an answer or the statement of a problem? Why?
- How did you proceed to *compose* your answer?
- How did you proceed to compose the statement of the problem?
- How do you think your teacher composes exam questions?
- In what way is composing the statement of a problem similar to *decomposing* or breaking down a number? Can we break down a problem? Can we compose a number? How?

ACTIVITY 2

ADDITION – MULTIPLICATION

For each of the following elements, indicate how to pass from the unit to the quantity of this unit: a) only through multiplication; b) only through addition; c) neither; d) independently, by multiplication or addition; e) in another way, and specifying it.

A person – a crowd of people
A hockey player – twelve hockey players
A hockey player – a hockey team
A hair – a complete head of hair
A hair on the table – a few hairs on the table
A finger – a hand
A youngster who weighs 25 kilos – a youngster who weighs 30 kilos
A letter of the alphabet – a word
A letter of the alphabet – a sentence
A tree – three trees
A maple tree – a forest of maple trees
A drop of rain – a shower
A drop of water – a lake
A litter of three kittens – three litters of one kitten
A math book – every math book
A math exercise – some math exercises
A page from a math book – a complete math book
The number 1 – the number 13

A number that begins with zero – numbers that begin with zero
A number that ends with zero – numbers that end with zero
A stick – two sticks
A 2 – two 2
A length – an area
A length – a volume.

ACTIVITY 3

MEASURING INSTRUMENTS

If you want to take the following measures, in the most exact way possible, what instruments and measures could you use
Size.
Area.
Space.
Mass.
Temperature.
A person's strength.
Time.
The radius of a circle.
Surface.
Volume.
Weight.
Length of a straight line.
Level of alcohol in the blood.
The solidity of a house.
The veracity of an answer in math.
Quantity of work accomplished in math.
Knowledge acquired in math.
Comprehension of mathematical knowledge

Teacher guidelines

Further questions for discussion

- Can everyone (infants, children, adults, and elderly people) correctly use every measuring instrument?
- What are the abilities or skills (physical and intellectual) needed to correctly use a minimal amount of measuring instruments?

Pupils are shown different objects and are asked to estimate the length, area, volume or weight of these objects. They then divide a sheet of paper in two, and note their estimations on the left-hand side. On the right-hand side, they note how they reached these estimations (what were their references?).

ACTIVITY 4

ESTIMATE

Please imagine that you are an investigator. Your task is to describe different things in the most precise way possible (even if you do not have any measuring tools). You may always, of course, use your observation talent. Let's try:

	Your estimate	How did you reach it? What was the reference?
The length of a pencil.		
The height of a door.		
The area of the board.		
The area of the cover page of a book.		
The weight of a pencil case.		
The quantity of water in a glass.		
The volume of a small box.		
The volume of a large box.		
The weight of a table.		

Teacher guidelines

After estimating these measures, each one is taken individually and each pupil explains how they carried out their estimations.

- How did you carry out your estimation of these measures?
- What were your reference points?

We verify the exact measure and encourage pupils to react with regards to the way they proceeded.

- Would there have been a better way of making your estimates?
- How would you do it next time?

Part 6

Mathematics as discovery and research

Stages in the process of discovery are described by Novotná[10] as follows:

On the basis of our experience with the classification of discovery in teaching mathematics we will consider the following as basic stages of the discovery process:

- *Non-systematic situation exploration:* This may take place either individually, in small groups, or with the complete class. At this stage the experiences connected to a given problem are acquired in a non-systematic way. This stage cannot be replaced, since the investigators gain during this stage at least a partial insight into the situation and they may discover an effective method for further work.
- *Systematic research*: During this stage the results are recorded in an organized manner, thus facilitating easier recognition of rules, mutual relations and structures.
- *Hypothesis formation*: To this stage belongs generalizing of results based on more cases than in the previous stages, or prediction of the results of further cases.
- *Hypothesis testing*: Hypotheses that were stated in the previous phase demand that their validity be verified. That can be accomplished either by searching/finding (for) an appropriate counter-example (that disproves the hypothesis) or by its justification, which may be variously detailed and frequently incomplete, depending on the age and abilities of the pupils.
- *Explanation* or *proving*: These are always being performed regardless of whether the hypothesis was supported or disproven. During this stage it may occur that the pupils will propose (in connection with the original hypothesis) other hypotheses that have not been studied yet. Then, they return to the previous stage and work with the newly formed hypothesis.
- *Situation evolution*, during which it is possible to observe connected tasks and new directions for exploration further. This stage does not stand by itself and it overlaps with other stages.
- *Summary*: During this phase it is stated clearly in a written or an oral form what was gained in the previous stages, how this activity might proceed further, what remained unaccomplished and why, etc. This stage should support pupils in developing the skills to summarize acquired findings and thereby to reach better insights into mathematics.

[10] Novotná, J. (2004). Matematické objevování založené na řešení úloh, 25 kapitol z didaktiky matematiky, 1.díl. Praha : PedFUK, s. 359

The experiments involving the integration of discovery into mathematics proceeded in stages according to our division of the process of discovery. It was observed that the stages do not always advance according to the order described above. Some stages were short, while in others the investigators spent a long time, in some cases the passage from one stage to another was not sharply delineated and the stages overlapped. However, the proposed model is satisfactory for the working out of teaching units and for their analysis.

ACTIVITY 1

Teacher guidelines

For this activity, pupils will need: a ruler, a measuring tape, a string, a compass, round lids of different sizes, and scissors.

The pupils are divided in several teams and each team receives a certain number of round lids of different sizes. The goal is to compare the length of the contour (circumference) with the width (diameter) of the circle. First, pupils in each team work things out their own way to compare these two elements, either directly with string or with the help of instruments. Then, they are told to measure the contour (circumference) and the width (diameter) of each lid and to write down the results in a table (see below). Each team does the divisions and writes the results in the third column. Using a calculator can make things easier for the pupils.

During this activity, all content and vocabulary specific to geometry can be avoided. If pupils don't know the meaning of *diameter*, of *circumference* or of *radius*, it doesn't matter. The goal is simply to discover that the contour/width ratio is always approximately the same, no matter what the size of the lid.

INVESTIGATION/RESEARCH

We will explore the round lids now. We would like to research on what they may have in common.

Please prepare various lids and tools that you may use for measurement of width (diameter) and contour (circumference) of the lids.

Choose the proper measurement tool and be as precise as possible. Write down your measurement first. After collecting all the data, proceed further and fill in the computation in the last column.

Table of results:

Lid No. and description	Contour	Width	Contour/Width

Now give a report on your investigation for the other teams. Pay attention to these questions:

- What do you note from the *contour/width* answers?
- How does it come that the answers are similar?
- What could be the purpose of having a *contour/width* ratio that is always the same?

Teacher guidelines

Further questions for discussion

- Do you think that other mathematical discoveries happened with the type of experience you just did? Why?
- Do we find this kind of ratio in other mathematical situations? Which ones?
- Do you think we can still discover new mathematical formulas? Why?

Note: The ratio in this exercise is the number π (worth approximately 3,14159…). The teacher can choose whether or not to mention it to the pupils.

ACTIVITY 2

Teacher guidelines

Prepare students to work with the table below. You will be able to reshape the individual lines. These strips are then sorted. When you are preparing the table it is also possible to give explanation and examples.

INQUIRY PROCESS

Study the statements in the table with care. They are all part of the inquiry process or the research process.

Then cut the table into the lines. Then organize the strips in the right order showing actions you need to do (first, second, third, etc.), when trying to solve a math problem. Stick your final solution on the sheet of paper with stickers. All pupils do the same.

When you all are finished stick your sheet on the board. Read and compare the sequences that you and the others have created. Take the time to think it out. Imagine yourself facing a real problem that you have to solve. If need be, make corrections on your sheet.

When you are sure that the sequence of your steps is logical, demonstrate it to the classroom.

Keep your corrections in mind and make sure you follow all the steps when you next solve a mathematical problem.

Reflect.
Imagine various possible solutions.
Experiment.
Feel frustrated.
Feel victorious.
Verify the solution with friends or my parents.
Doubt.
Link together different things I know.
Understand the meaning of the problem.
Try to determine if my answer is an applicable solution in real life.
Review my solution by demonstrating it.
Try to imagine that this problem really exists in my life.
Play with different elements of the problem and combine them in different ways.
Observe.
Choose the best solution.
Reflect.

Part 7

All afternoon Damian has remained intrigued by the question that Mr Ginosa had put to him.

“Could you prove to us that your painting is beautiful? Take time to reflect on my question, Damian, it was serious.”

On the way home, Damian takes the opportunity to reopen the discussion which has been preoccupying him.

“How can you prove to all the world that an abstract painting is beautiful?” he asks them, discouraged.

Linda who was also intrigued by Mr. Ginosa's question, at the beginning of the afternoon, attempts a reply:

“I think that in art it must be very difficult to prove anything, Damian. Probably much more difficult than in math, in any case.“

June protests . “I don't agree with you, Linda.”

For several seconds June searches for an example to illustrate her point. Finally she adds, looking at Linda who regularly has vehement discussions with her class mates in the math class:

“Take yourself, for example, Linda. Do you find it easy to prove to the class that your way of solving a math problem is better than or as good as that of another student, even if it is different?”

The example hits home! Linda has immediately grasped the point that June wanted to make.

“In this sense in fact I must admit that you have a point, June. In math, it is not always easy to prove that our way of solving a problem is good. On the other hand”, she adds, hesitating, “I am not not wholly convinced that what I said before was false.”

“That could depend on what you mean by 'prove'”, replies Damian.

“For me, to prove, means to confirm something”, says Christine.

“It is to confirm with certainty”, Marco adds.

“Then I agree with Damian”, comments Wai Lun. “His painting proves with certainty that he has talent.”

Kevin buts in, "Not so fast! To prove is to confirm something with certainty, I agree. But, only if all the world is convinced. Don't you remember? And me, I am still not convinced that Damian's scribbles are beautiful, so...”

June then brings in an interesting counter-argument.

“But you shouldn't think that in order to prove something, it is sufficient to convince others. That would be too easy. You would just have to surround yourself with stupid people!”

Emi adds, following up on this:

“In any case, to construct a proof of something didn't seem easy for Sherlock Homes!”

“No kidding! What do you know about it?” asks Kevin in a sarcastic tone.

Emi who is an expert on Sherlock Holmes doesn't let herself be discouraged by Kelvin's sarcastic tone. She takes a deep breath and explains in a clear voice.

“In one of the stories that I read, Sherlock Holmes said to Watson that criminal inquiry is a serious process. V-e-r-y serious. He said… wait, I still have the book in my backpack.”

Emi stops walking and rummages in her backpack. She takes out a paperback book, which from its cover looks well-used. She quickly finds the passage for which she is looking.

“I've found it! Listen! Sherlock Holmes said that a criminal inquiry was *a process which must be treated as seriously as mathematics itself!*”

“Elementary, my dear Watson!” Kevin throws in, imitating the tone of Sherlock Holmes.

“Kevin, stop making fun of Emi! I too have read almost all the Sherlock Holmes stories, adds Marco. Emi has a point, his process of inquiry is fascinating! And always the same. First, he observes everything that happens and he doubts everyone. Second, he analyses the evidence. Third, he sits down with Watson and tries to see all imaginable possibilities. Eventually, he always ends up finding the criminal. It’s mathematics!”

Observation and reasoning

Teacher guidelines

There exist two forms of observation: empirical observation and scientific observation. Empirical observation is an observation made without any preconceived ideas, its only goal is to note facts as they are; whereas in scientific observation, one must give meaning to facts; observe and infer laws with hypotheses. The latter observation serves to verify a preconceived idea.

Observation is opposed to experimentation insofar as, in experimentation, we actively play a part in modifying facts. Observation refers to the moment of findings, as opposed to the experience, which is the information that results from confronting these findings.

ACTIVITY 1

OBSERVATION

Here is a problem:

Karel and Gustav went fishing, Karel caught 9 small fish and Gustav 15. After they finished cooking the fish a tourist passed by and the boys invited him to supper. Each ate 8 fish. At the end of the supper the tourist gave the boys 8 ten-euro banknotes and left. As they received 8 ten-euro banknotes in exchange for 24 small fish, they counted ten euros for 3 fish. Karel, therefore, took 3 ten-euro banknotes and Gustav took 5 ten-euro banknotes. Was this division correct?

- What are the differences and the similarities between observing a flower, observing the hands of a watch and observing a mathematical problem?

OK. Now, after careful observing, let’s try to solve it.

- Could it be, that if you are not thorough enough when observing, you fail in solving?

Teacher guidelines

Further questions for discussion:

- When you observe a mathematical problem, should you pay more attention to your thoughts or to your feelings?
- What is the purpose of observation in mathematics: a better view of the words? A better understanding of the meaning of the problem? Etc.
- What happens when you observe a mathematical problem? What are the elements or the faculties of your person that play a part: the eyes? The brain? Etc.
- When your eyes look at the words that explain the mathematical problem, does your brain work at the same time? How? Explain.
- Think about Sherlock Holmes's investigations. Is it difficult or easy to observe?
- Is it done very fast, in a spontaneous manner, or does it take time, patience and method?

ACTIVITY 2

REASONING

Read the following sentences carefully and then choose the correct answer between: a), b) or c).

Michelle is taller than Damian, therefore:

a) Damian is taller than Michelle;

b) We cannot know if Damian is the same height or not as Michelle;

c) Damian is smaller than Michelle.

2) Mathew says: "Only right angles are 90 degree angles." Another way of saying this would be:

a) All 90 degree angles are right angles;

b) All right angles are 90 degree angles;

c) Some 90 degree angles are right angles.

3) Anthony weighs less than any of the pupils in the 6th grade class. Vincent weighs more than any pupil in the 3rd grade class. Therefore:

a) Anthony weighs more than Vincent;

b) Vincent weighs more than Anthony;

c) We cannot determine which of the two weighs the most.

4) The 4th grade pupils are better at math than the 5th grade pupils, and the 5th grade pupils are better at math than the 6th grade pupils. Therefore:

a) The 6^{th} grade pupils are better at math than the 4^{th} grade pupils;

b) the 5^{th} grade pupils are better at math than the 4^{th} grade pupils;

c) The 4^{th} grade pupils are better at math than the 6^{th} grade pupils.

5) All the math books in this classroom are objects that belong to Michelle. All the objects in this classroom that belong to Michelle are marked with a red star. Therefore:

   a) All the objects marked with a red star are math books in this classroom;

   b) All the math books are marked with a red star;

   c) All the objects marked with a red star belong to Michelle.

6) Mathew says: “The Moon is very far from the Sun.” Jane answers: “That means that the Sun is very far from the Moon.”

   a) Jane is right;

   b) Jane is wrong because the Sun is close to the Moon;

   c) Jane is wrong because what she said does not ensue from what Mathew said.

Part 8

To learn to think = to think about own thinking (to reflect)

REFLECTION

ACTIVITY 1

Which of the following terms express the act of thinking things over, of reflecting? Underline them.

1. Remembering
2. Doubting
3. Dreaming
4. Rejecting criticism
5. Supposing
6. Imagining
7. Establishing relationships
8. Being confused
9. Searching
10. Asking questions
11. Playing
12. Inventing rules
13. Liking
14. Criticising
15. Complaining
16. Crying
17. Observing
18. Writing
19. Looking at yourself in the mirror.
20. Doing your hair.
21. Giving an answer off the top of your head.
22. Adding up
23. Laughing
24. Not wanting to check your answers.
25. Experimenting
26. Understanding a problem.
27. Drawing a geometric figure.

ACTIVITY 2

When do you do mathematics? Think about it, when do you do mathematics? Is it when.....

1. When you remember?
2. When you doubt?
3. When you dream?

4. When you reject criticism?
5. When you make suppositions?
6. When you use your imagination?
7. When you establish relationships?
8. When you are confused?
9. When you search?
10. When you ask questions?
11. When you play?
12. When you invent rules?
13. When you observe?
14. When you answer off the top of your head?
15. When you laugh?
16. When you do not want to check your answers?
17. When you experiment?

Teacher guidelines

Further questions for discussion

- Does mathematics allow you to develop your own ideas? Justify your point of view.
- Does mathematics allow you to develop your imagination? Explain.
- When you give an answer in math, did you imagine all the possible answers beforehand?

ACTIVITY 1

STRATEGY

Pupils, in pairs, are invited to play the following game:

One pupil in each team chooses a number between 0 and 100 and writes it down on a sheet of paper without showing it to the second pupil on the team. The second pupil has 8 tries (5 if pupils are very good) to guess the number. On each attempt, the second pupil tries to guess the hidden number, while the first pupil (who hid the number) says *before* (if the number is smaller) or *after* (if the number is bigger). Guided by these clues, the second pupil keeps on trying. After 8 tries, the game ends and pupils exchange roles.

- Did the before and after clues help you find the number? Why?
- What strategies did you use?
- If you had to do it all over again, would you use the same strategies? Why?
- How many clues would you need if you were asked to guess a number between 0 and 200? Why did you choose this many clues? (Pupils can play with this new rule.)

Note: - There is a strategy to succeed with 8 tries. You start with the number 50 and then choose the middle number between 50 and 100 or between 0 and 50 depending on whether the clue is *before* or *after*. You keep choosing the middle number in the part between the number that was guessed and the superior or inferior limit (according to the clue). Pupils don't need to know the strategy to play. They ought to figure it out on their own. Without giving away the strategy, we can offer to play with them. This way, they might have a clue to the strategy.

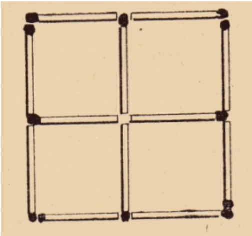
ADVANCED ACTIVITY

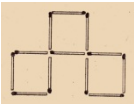
Pupils form in teams of two. In each team, pupils must share roles: one pupil works and the other observes. We give a problem to the pupil who works. The pupil who works solves the problem and expresses what he is doing out loud. The pupil who observes must make sure the other speaks by asking questions such as: *What are you thinking about?* The pupil who observes must make notes of what he observes. A discussion follows.

- What did you observe?
- Is it easier to observe than to work at solving a problem?
- Is it more useful to observe than to work and to search for a solution?
- Is it possible to observe the other person's reasoning?
- Did you observe the gestures of the other person or his reasoning?
- If you had to do it again, how would you do your observation?

Example of the problem

There are 4 squares made of 12 matches, as you can see at the picture. Move only 3 matches so that 3 similar squares are created and no matches are left over.



Solution. 

Part 9

We can learn from each other

ACTIVITY 1

THINK:
How can you divide a dial into three parts in such a way so that the sum of the numbers in all parts will be the same?

It is not an easy task. If you succeed in solving it, think about how you could explain your solution to others and how you would justify it.

Teacher guidelines

Pupils try to solve a mathematical problem individually for some limited time. They then create teams and go on problem-solving together, using the justifications developed by the members of the team up to that point. Afterwards they discuss their team solution and justify it. They write the solution and justifications on a large sheet of paper and post it on the wall. They explain it to the rest of the class. The discussion focuses on the quality of the reasons provided (not on the solution itself).

- Why are some of the reasons provided better than others?
- What skills are required to find good reasons?

What are the similarities and differences in the steps taken by individual pupils?

S-TEAM Partners

ISBN 00-0000-000-0

Cyprus	• European University – Cyprus *
Czech R.	• University of South Bohemia *
Denmark	• University of Copenhagen *
	• Aarhus Universitet
Estonia	• University of Tallinn *
Finland	• Abo Akademi University
	• Helsinki University *
	• University of Jyväskylä
France	• Centre National de la Recherche Scientifique
	• Université Pierre Mendes-France *
	• Université Rennes 2 – Haute Bretagne
Germany	• Friedrich Schiller University of Jena (1)
	• Leibniz Institute for Science Education at the University of Kiel *
	• Technical University Munich (2)
Israel	• Technion – Israel Institute of Technology *
Lithuania	• Kaunas University of Technology *
	• Vilnius Pedagogical University
Norway	• **Norwegian University of Science and Technology (coordinator)**
	• University of Oslo *
Spain	• Universidade de Santiago de Compostela *
Sweden	• Karlstad University * (3)
	• Mälardalen University
Turkey	• Hacettepe University *
	• Gazi University
UK	• University of Bristol *
	• University of Leeds
	• University of Strathclyde *

* National Liaison Partner

(1) To March 2010 (2) From April 2010 (3) From June 2010

S-TEAM
FIRING UP SCIENCE EDUCATION

SEVENTH FRAMEWORK PROGRAMME