D 5.3 Cross comparative analysis of country studies

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Deliverable D5.3 Introduction

In each country the partners have produced an analysis framing the results from FaSMEd within the policy and practice of their country. This report constitutes the final comparison of the experiences.

The collection of data from each partner country was managed by asking all partners to fill in a questionnaire developed by the WP5 leaders. The questionnaire was set up with four categories,

1. The National education context
2. Digital resources/Technology
3. Formative assessment/Pedagogic practices
4. Lower achievers

Within each category, partners were asked, whenever applicable, to link their analysis to previous context/reports.

This D5.3 report links closely to deliverable D2.1 *Report on comparative data on the landscape for low achievers in mathematics and science in the partner countries*. Parts of the analysis carried out in the present deliverable are thus an update on the previous report.

In each of the above-mentioned four categories we will give voice to the individual partner countries before we look at similarities, commonalities and also differences.

1. The national education context

In this section the partner countries' education systems will be described. This includes the number of schools and learners, the ages at which learners start school and transfer between tiers, the assessment system, the share between public/private education and the performance of the country in international comparisons like OECD Pisa tests and TIMSS, where these are available. Figures to demonstrate the attainment levels in science and mathematics at stages in the learners' development will be provided.

Education system in partner countries

Among the eight participating countries within the FaSMEd project, compulsory general education varies from 9 to 13 years, see Table 1. In England and the Netherlands schooling is mandatory from age 5, while children in all other countries start at age 6. All countries distinguish between primary and secondary school, but the ages, at which learners transfer between tiers varies, e.g. Norway has two school stages, South Africa three phases and England four key stages. An overview of the different systems is given in the table below.

Table 1 Overview of the compulsory general education in the partner countries

Country	Compulsory general education	Structure of compulsory education
England	Age 5-16, key stages 1-4	Primary school: Key Stage 1 - Foundation year and Years 1-2 Key Stage 2 - Years 3-6 Secondary school: Key Stage 3 - Years 7- 9 Key Stage 4 - Years 10-11
France	Age 6-16, grades 1-9	(Ages 3-5: Nursery schools, école maternelle, the majority of children start at this age) Grades 1-5 = Primary (Ecole élémentaire) Grades 6-9 = Middle school (Collége)
Germany	Age 6-16, grades 1-9 (10 grades in five Länder)	Grades 1-4 = primary school Grades 5-9 = secondary level 1
Ireland	Age 6-16, grades 1–9 (10)	(Ages 4-6 = infants, the majority of children begin school at the age of four) Grades 1-6 = primary school Grades 7-9 = secondary, junior cycle Grade 10 = secondary, transition year (may be compulsory, depending on school
Italy	Age 6-16, grades 1-11/13	Grades 1-5 = Scuola primaria (primary school) Grades 6-8 = Scuola secondaria di primo grado (first grade secondary school) Grades 9-13 = Scuola secondaria di secondo grado (second grade secondary school) OR Grades 9-11/13 = Formazione professionale (vocational education)
The Netherlands	Age 5-18, kindergarten, grades 1-7, grades 8-11/12/13	Ages 4-6 = Kindergarten, compulsory from age 5 Grades 1-7 = primary school Grades 8-11/12/13 = secondary school (practical education/VMBO/HAVO/VWO – tiers are selected based on performance during primary)
Norway	Age 6-16, grades 1-10	Grades 1-7 = primary school Grades 8-10 = lower secondary school
South Africa	Ages 6→[1], grades 1-9, three phases	Grades 1-3 = Foundation phase Grades 4-6 = Intermediate phase Grades 7-9 = Senior phase

Education statistics for partner countries

Table 2 gives an overview of the number of schools, teachers and learners in the eight participating countries (only available figures are included). The share between public and private education, as well as data for special education or special schools is also included for most of the countries. In Ireland and the Netherlands private schools are very rare, e.g. only three private schools exists in Ireland. In the other countries the percentage of private schools varies from 8% to 14%. The percentage of pupils in special schools is commonly around 1%.

[1] According to the South African national census of 2011, among the South African population, 35.2% of black/African, 32.6% of coloured, 61.6% of Indians/Asians and 76% of white citizens have completed an education of high school or higher. 41.7% of the total population has completed an education of high school or higher, whereas 8.6% of the population aged 20 years and older has not completed any schooling.

Table 2 School statistics for participating countries, figures from 2013-2016 (depending on country)

Country	Number of schools	Number of teachers	Number of pupils
England	24317 (total) (10% private)	438000 (public)	8438145 (total) (75% 'white' ethnic origin, 7% privately educated, 1.2% in special schools)
France	63600 (total)	1052700 (total) (13,1% private)	12285700 (total) 6788600 (primary, incl kindergarten)
Germany	42493 (total) (13.6% private)	737943 (total)	10872127 (total)
Ireland	3277 (primary) 732 (post-primary) (3 private schools)	33613 (primary) 24455 (post-primary)	544696 (primary) 339207 (post-primary)
Italy	8384 (incl primary, secondary and kindergarten)		7862022 (total)
The Netherlands	6837 (incl primary and kindergarten, 4.2% special schools). Unknown no of sec schools. Private schools very rare (number unknown)		1457000 (primary, incl kindergarten) Special education: 36800 (primary) 39000 (secondary)
Norway	3327 (primary and secondary) (8,2 % private)	79285 (primary and secondary)	817 214 (primary and secondary, 49672 with special needs)
South Africa	30 027 (total) (85.7% public, 14.3% other edu institutions)	447 149 (total)	12883888 (total) (93% in public schools, 0.9% in special schools)

Assessment system in partner countries

Main aspects of national assessment systems are given in FaSMEd deliverable D2.1, as attached tables. In the OECD document "Synergies for Better Learning. An international perspective on evaluation and assessment" (2013)[2] policy priorities connected to evaluation and assessment are identified. "OECD of Evaluation and Assessment in Education" and Country background reports are available for Norway, the Netherlands, Ireland and France. In these documents strengths and challenges of the different assessment approaches are discussed and potential future directions are suggested. Main findings for FaSMEd participating countries are given in FaSMEd Deliverable 2.1.

Attainment levels in mathematics and science at stages in the learners' development

In **England** from 1989 until 2014, learners' progress has been measured through national tests at the ages of 7, 11, 14 and 16. These ages mark the end of the 'stages' of education called 'Key Stage', so 7 is the end of Key Stage 1 and so on. Until 2014 the results of the teacher assessment and statutory tests at ages 7, 11 and 14 were reported as 'levels' with each level corresponding to a set of criteria. At 16 the results were reported as a General Certificate of Education grade A* - G (with A* the highest and grade C established as the 'pass' level for all subjects). Governments announced targets for schools,

[2] OECD (2013). *Synergies for Better Learning. An International perspective on evaluation and assessment*. OECD Reviews of Evaluation and Assessment in Education. Paris: OECD Publishing.

setting out the percentage of pupils expected to achieve these target levels. Pupils not achieving the targets were thus regarded as being 'low achievers'.

However, from 2014 this system changed, with levels being abolished. The new arrangements set the expectations that ALL children will be taught and achieve the 'attainment targets' which are contained in the programmes of study. Schools are being invited to develop their own methods of assessment in relation to these new arrangements. In 2015, 87% of pupils at KS2 (11) attained the expected grade and at KS4 67% attained the expected progress in mathematics. At KS4 in science 57% attained the expected grade. Despite government statistics showing continual progress in children's understanding in mathematics through these assessments, independent research shows that little progress is made in children's understanding of mathematics between the ages of 11 and 14, and attainment has not changed very much across a 30-year period. Independent research into children's understanding in science is less clear in its results.

In **Germany** student attainment is measured in centralized final examinations (lower and upper secondary education) and by national assessment studies performed by the IQB (Institute for Educational Quality Improvement at Humbolt-Universität zu Berlin). In 2012 the IQB National Assessment Study tested the Competences of (appr. 44.500) students in Mathematics and Science at the End of Secondary Level I (9th grade). The results show that proficiency levels vary widely from one state to the next. On the global scale, the difference between the highest-performing state (Saxony) and the lowest (Bremen) is 65 points, placing students in Saxony on average approximately two school years ahead of their peers in Bremen. (Pant et al. (Eds.), 2013, p.5)[3]. This study also showed that 94.5% of the German students in the 9th grade reach at least the minimal standards for the *Hauptschulabschluss.*

In **Italy**, the teachers have the responsibility of assessing students, documenting this assessment through periodical tests and choosing the appropriate assessment tools, consistent with the national curricula. From 2004 the teachers also have the responsibility of certifying the competencies developed by students during kindergarten and the first cycle of instruction (primary school and lower secondary school), completing the Portfolio, a collection of all the most significant documents of the students' educational path (compulsory documents are the document of assessment, the certificate of admission, the vocational guidance, a document on pupil's progress, modalities of adherence / self-assessment of the pupil).

In 2004 a research institute with the status of legal entity governed by public law was created to evaluate the effectiveness of the Italian Education System and its efficiency in the national context: the INValSI (National Institute for the Evaluation of Education and Training System).

The evaluation process is carried out using annual National tests of learning aimed at pupils and students, compulsory for each school, and a questionnaire of System (aimed at analysing the social context). The tests, which involve only Mathematics and Italian, are self-administered by schools to students of grades 2, 5, 8 and 10. INValSI publishes an annual report on its activities. The 2014 report on the results of the national tests highlighted a profound gap between the Northern and the Southern Italian regions, with the Northern ones better performing. In particular this gap increases with the progress of students' school career.

Since 2004 all students in **Norway** in grades 5, 8 and 9 sit national tests in mathematical literacy[4]. In grade 10 Norwegian students sit one written exam in either mathematics, Norwegian or English. There are no national tests in science, except at upper secondary level. Results from 5th and 8th grade national

[3] https://www.iqb.hu-berlin.de/laendervergleich/lv2012/Bericht

[4] The test at grade 9 is identical to the test at grade 8

tests from 2012 and 2015 shows that the scores for boys are higher than for girls in mathematical literacy. This is mainly due to the larger number of boys at the highest level. Figures from 9th grade also shows that it is a positive development from 8th to 9th grade (more students at the highest level in 9th grade).

In **South Africa**, the Department of Basic Education (DBE) has introduced Annual National Assessments (ANAs) as a strategy to measure progress in learner achievement annually, in an attempt to move towards the 2014 target of ensuring that at least 60% of learners achieve acceptable levels in Literacy and Numeracy. In the 2013 ANA tests, the percentage of learners in Grade 6 who did not achieve the minimum level was 36.2 and only 3.1% achieved outstanding performance. In the most poorly performing province, Limpopo, 49% did not achieve the minimum level (30%) and in the best, Gauteng, 25.6% did not reach this level. In Grade 9, the national average score was 13.9%, with 3.4% of learners achieving 50% and more. In Limpopo, the most poorly achieving province, 95.9% of learners did not reach the minimum mark. Major challenges are large classes, teaching supply, teachers' lack of subject knowledge in mathematics, high rates of absenteeism (almost 20% of teachers are absent on Mondays and Fridays), the language of instruction (11 languages, up to grade 3 it is usual for all lessons to be in the home-language of the learners, but from grade 4 the language of instruction is English or Afrikaans – which is difficult to understand in many rural areas). The 2014 World Economic Forum report 'The Global Information Technology Report 2014: Rewards and Risks of Big Data' ranks South Africa's education system at 146 out of 148, and maths and science education at 148 out of 148.

Performance of the FaSMEd countries in international comparisons

TIMSS 2011

In 2011, nationally representative samples of students in 63 countries and 14 benchmarking entities (regional jurisdictions of countries, such as states) participated in TIMSS. Countries and benchmarking participants could elect to participate in the fourth grade assessment, the eighth grade assessment, or both: 52 countries and 7 benchmarking entities participated in the fourth grade assessment, and 45 countries and 14 benchmarking entities participated in the eighth grade assessment. In total, more than 600,000 students participated in TIMSS 2011.

Mathematics achievement

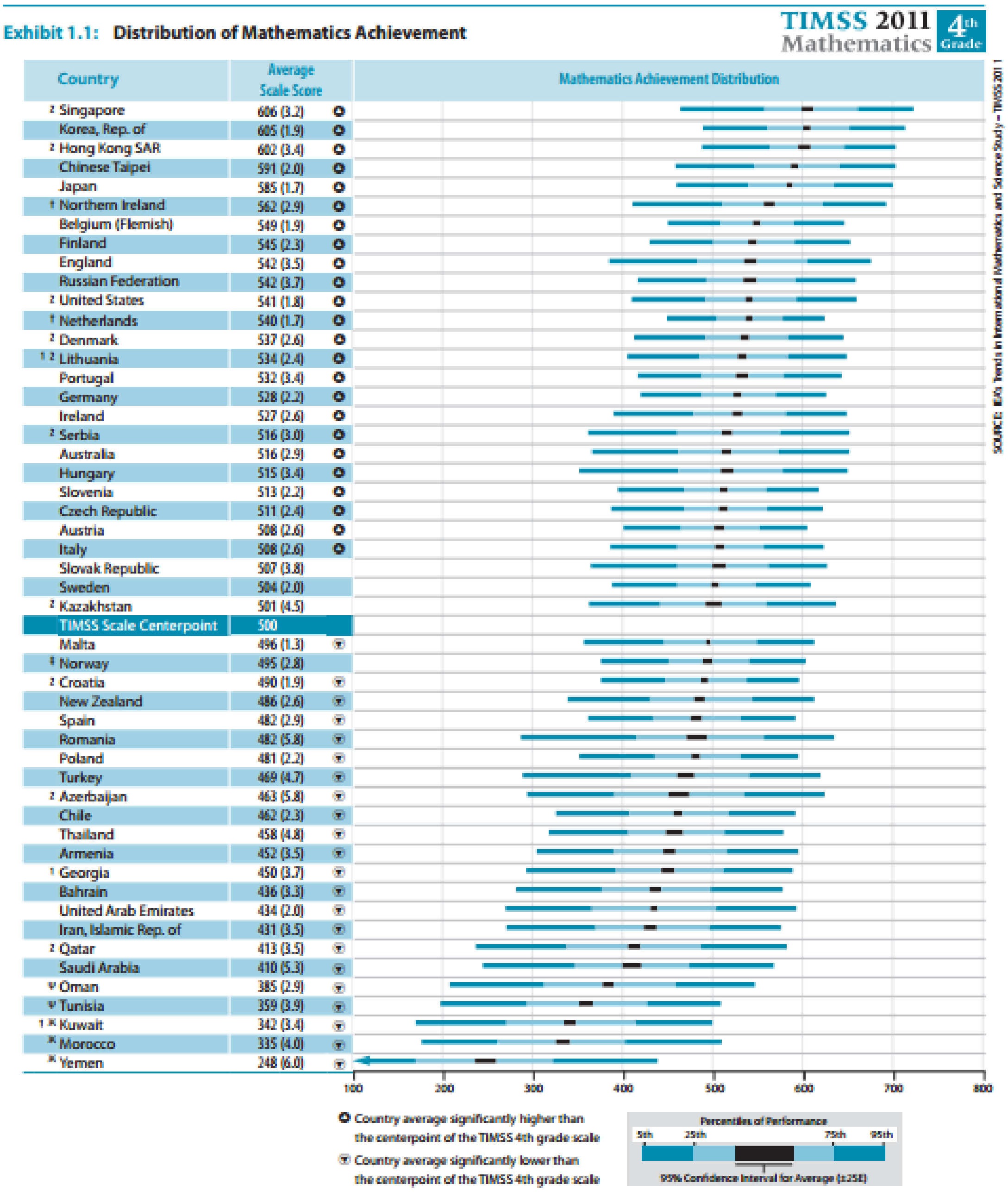
While there were small differences from country to country, there was a substantial range in performance from the top-performing to the lower performing countries. Twenty-two countries at the fourth grade and the three assessing their sixth grade students had average achievement below the TIMSS scale centerpoint of 500, as did two benchmarking participants. At the eighth grade, 27 countries and the three assessing their ninth grade students had average achievement below 500, as did three benchmarking participants.

East Asian countries continue to lead the world in mathematics achievement. Singapore, Korea, and Hong Kong SAR, followed by Chinese Taipei and Japan, were the top-performing participants in TIMSS 2011 at the fourth grade. Similarly, at the eighth grade, Korea, Singapore, and Chinese Taipei outperformed all countries, followed by Hong Kong SAR and Japan. In addition to the five top-performers at the fourth grade, Northern Ireland, Belgium (Flemish), Finland, England, and the Russian Federation rounded out the top ten high achieving countries. At the eighth grade, the Russian Federation, Israel, Finland, the United States, and England were also included in the top ten high-achieving countries.

Table 3 (Exhibit 1.1) presents the results for the 50 countries that assessed students at the TIMSS target population of the fourth grade. Five of the FaSMEd countries were ranked above the TIMSS Scale Centerpoint (England, the Netherlands, Germany, Ireland and Italy), Norway were slightly below the Centerpoint and France did not participate until 2015. South Africa entered Grade 9 pupils (most other countries entered Grade 4 and/or 8) and scored second to last.

England ranked 10th, Germany 16th, Ireland 17th, Italy 24th, The Netherlands ranked 12th and Norway 29th with regard to mathematics in 4th grade.

Table 3 Distribution of mathematics achievement in fourth grade, TIMSS 2011



Country	Average Scale Score	
² Singapore	606 (3.2)	▲
Korea, Rep. of	605 (1.9)	▲
² Hong Kong SAR	602 (3.4)	▲
Chinese Taipei	591 (2.0)	▲
Japan	585 (1.7)	▲
† Northern Ireland	562 (2.9)	▲
Belgium (Flemish)	549 (1.9)	▲
Finland	545 (2.3)	▲
England	542 (3.5)	▲
Russian Federation	542 (3.7)	▲
² United States	541 (1.8)	▲
† Netherlands	540 (1.7)	▲
² Denmark	537 (2.6)	▲
† ² Lithuania	534 (2.4)	▲
Portugal	532 (3.4)	▲
Germany	528 (2.2)	▲
Ireland	527 (2.6)	▲
² Serbia	516 (3.0)	▲
Australia	516 (2.9)	▲
Hungary	515 (3.4)	▲
Slovenia	513 (2.2)	▲
Czech Republic	511 (2.4)	▲
Austria	508 (2.6)	▲
Italy	508 (2.6)	▲
Slovak Republic	507 (3.8)	
Sweden	504 (2.0)	
² Kazakhstan	501 (4.5)	
TIMSS Scale Centerpoint	500	
Malta	496 (1.3)	▼
‡ Norway	495 (2.8)	
² Croatia	490 (1.9)	▼
New Zealand	486 (2.6)	▼
Spain	482 (2.9)	▼
Romania	482 (5.8)	▼
Poland	481 (2.2)	▼
Turkey	469 (4.7)	▼
² Azerbaijan	463 (5.8)	▼
Chile	462 (2.3)	▼
Thailand	458 (4.8)	▼
Armenia	452 (3.5)	▼
¹ Georgia	450 (3.7)	▼
Bahrain	436 (3.3)	▼
United Arab Emirates	434 (2.0)	▼
Iran, Islamic Rep. of	431 (3.5)	▼
² Qatar	413 (3.5)	▼
Saudi Arabia	410 (5.3)	▼
ψ Oman	385 (2.9)	▼
ψ Tunisia	359 (3.9)	▼
¹ ※ Kuwait	342 (3.4)	▼
※ Morocco	335 (4.0)	▼
※ Yemen	248 (6.0)	▼

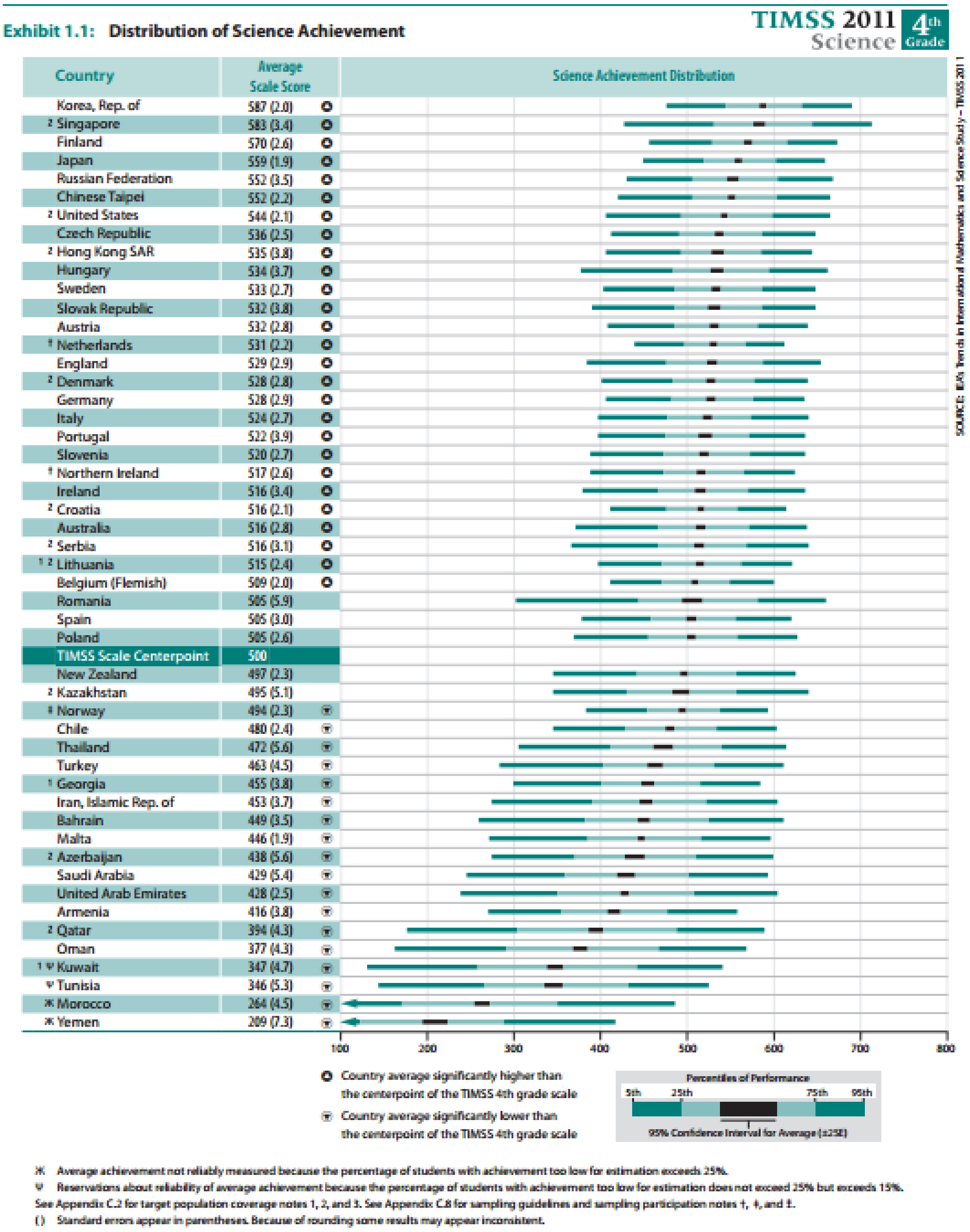
※ Average achievement not reliably measured because the percentage of students with achievement too low for estimation exceeds 25%.
ψ Reservations about reliability of average achievement because the percentage of students with achievement too low for estimation does not exceed 25% but exceeds 15%.
See Appendix C.2 for target population coverage notes 1, 2, and 3. See Appendix C.8 for sampling guidelines and sampling participation notes †, ‡, and ‡.
( ) Standard errors appear in parentheses. Because of rounding some results may appear inconsistent.

Science achievement

Korea and Singapore were the top-performing countries in science in TIMSS 2011 at the fourth grade, followed by Finland, Japan, the Russian Federation, and Chinese Taipei. At the eighth grade, Singapore had the highest average achievement, followed by Korea, Chinese Taipei, and Japan. Finland was the next highest-performing country. Since 1995, fourth grade students have shown more improvement than reduction in science achievement (eight of these countries raised their levels of science achievement and only one had a decrease), but improving eighth grade student achievement has been more difficult (11 up vs. 6 down).

Table 4 (Exhibit 1.1) presents the results for the 50 countries that assessed students at the TIMSS target population of the fourth grade. The results show that many countries performed well in TIMSS 2011 at the fourth grade, with 27 countries having higher achievement than the scale centerpoint of 500 (e.g. England, the Netherlands, Germany, Ireland and Italy) and several countries having average achievement above the High International Benchmark of 550. Norway were slightly below the Centerpoint in science as well, and France did not participate until 2015. South Africa entered Grade 9 pupils and in science it came last.

Table 4 Distribution of Science Achievement in fourth grade, TIMSS 2011



PISA 2012

PISA 2012 is the programme's 5th survey[5]. It assessed the competencies of 15-year-olds in reading, mathematics and science (with a focus on mathematics) in 65 countries and economies. In 44 of those countries and economies about 85 000 students also took part in an optional assessment of creative problem solving; and in 18 countries and economies, students were assessed in financial literacy. Around 510 000 students between the ages of 15 years 3 months and 16 years 2 months participated

[5] OECD (2014). *PISA 2012 Results: What Students Know and Can Do – Student Performance in Mathematics, Reading and Science*, Volume I. OECD Publishing.

in PISA 2012 as a whole representing about 28 million 15-year-olds globally. Results are discussed in FaSMEd deliverable 2.1, thus only main findings are repeated here.

With regards to the performance in mathematics, on average across OECD countries with comparable data, between 2003 and 2012 there was an increase of 0.7 percentage points in the share of students who do not meet the baseline proficiency level in mathematics and a reduction of 1.6 percentage points in the share of students at or above proficiency Level 5. With regards to the performance in science, the PISA 2012 report highlights that, across OECD countries, 18% of students perform at or below Level 1 (13% perform at Level 1 and 5% perform below Level 1). However, in both the mathematics and science "PISA 2012 results" reports, it is observed that these trends vary across countries.

The country reports of "PISA 2012 Results", available for most FaSMEd countries (France, Germany, Italy, Norway and UK), enable us to highlight peculiarities of these school systems, concerning regional differences, different uses of student assessments, percentages of resilient students, equity in the distribution of resources, levels of between-school variation in performance, levels of mathematics anxiety.

The French country report, for example, has highlighted a decrease in the mathematics performance between PISA 2003 and PISA 2012 making **France** become one of the countries which are below the OECD average. On the contrary, the science performance, which is stable, is at the OECD average. The percentages of high-performing and low-performing students are, respectively, 13% and 22%, at the OECD average.

The German country report shows that students perform above average in both mathematics and science. **Germany** reduced its share of low-achievers in mathematics by almost 4 percentage points, while the share of top-performers has not changed significantly over time. Also in science the percentage of students who do not achieve the baseline level of proficiency (12%) is below the OECD average (18%).

The **Italian** country report shows that, although this is one of the countries with the largest improvement in mathematics and science performance, both the mean mathematics performance and the mean science performance among 15-year-olds are still below the OECD average. The report also reveals large regional differences in mathematics performance, with some regions that score well above the OECD average and others scoring below this average.

According to the **Norwegian** country report of "PISA 2012 results", Norwegian students perform around average in mathematics, but below average in science. Although the performance in mathematics did not change significantly since 2003, the mean performance declined since the previous PISA assessment in 2009. The share of low performers in mathematics is close to the OECD average, while the share of top performers is below that average.

Table 5 Snapshot of performance in mathematics, reading and science in PISA 2012[6]

Snapshot of performance in mathematics, reading and science

- Countries/economies with a mean performance/share of top performers above the OECD average; Countries/economies with a share of low achievers below the OECD average
- Countries/economies with a mean performance/share of low achievers/share of top performers not statistically significantly different from the OECD average
- Countries/economies with a mean performance/share of top performers below the OECD average; Countries/economies with a share of low achievers above the OECD average

	Mathematics				Reading		Science	
	Mean score in PISA 2012	Share of low achievers in mathematics (Below Level 2)	Share of top performers in mathematics (Level 5 or 6)	Annualised change in score points	Mean score in PISA 2012	Annualised change in score points	Mean score in PISA 2012	Annualised change in score points
OECD average	494	23.1	12.6	-0.3	496	0.3	501	0.5
Shanghai-China	613	3.8	55.4	4.2	570	4.6	580	1.8
Singapore	573	8.3	40.0	3.8	542	5.4	551	3.3
Hong Kong-China	561	8.5	33.7	1.3	545	2.3	555	2.1
Chinese Taipei	560	12.8	37.2	1.7	523	4.5	523	-1.5
Korea	554	9.1	30.9	1.1	536	0.9	538	2.6
Macao-China	538	10.8	24.3	1.0	509	0.8	521	1.6
Japan	536	11.1	23.7	0.4	538	1.5	547	2.6
Liechtenstein	535	14.1	24.8	0.3	516	1.3	525	0.4
Switzerland	531	12.4	21.4	0.6	509	1.0	515	0.6
Netherlands	523	14.8	19.3	-1.6	511	-0.1	522	-0.5
Estonia	521	10.5	14.6	0.9	516	2.4	541	1.5
Finland	519	12.3	15.3	-2.8	524	-1.7	545	-3.0
Canada	518	13.8	16.4	-1.4	523	-0.9	525	-1.5
Poland	518	14.4	16.7	2.6	518	2.8	526	4.6
Belgium	515	18.9	19.4	-1.6	509	0.1	505	-0.8
Germany	514	17.7	17.5	1.4	508	1.8	524	1.4
Viet Nam	511	14.2	13.3	m	508	m	528	m
Austria	506	18.7	14.3	0.0	490	-0.2	506	-0.8
Australia	504	19.7	14.8	-2.2	512	-1.4	521	-0.9
Ireland	501	16.9	10.7	-0.6	523	-0.9	522	2.3
Slovenia	501	20.1	13.7	-0.6	481	-2.2	514	-0.8
Denmark	500	16.8	10.0	-1.8	496	0.1	498	0.4
New Zealand	500	22.6	15.0	-2.5	512	-1.1	516	-2.5
Czech Republic	499	21.0	12.9	-2.5	493	-0.5	508	-1.0
France	495	22.4	12.9	-1.5	505	0.0	499	0.6
United Kingdom	494	21.8	11.8	-0.3	499	0.7	514	-0.1
Iceland	493	21.5	11.2	-2.2	483	-1.3	478	-2.0
Latvia	491	19.9	8.0	0.5	489	1.9	502	2.0
Luxembourg	490	24.3	11.2	-0.3	488	0.7	491	0.9
Norway	489	22.3	9.4	-0.3	504	0.1	495	1.3
Portugal	487	24.9	10.6	2.8	488	1.6	489	2.5
Italy	485	24.7	9.9	2.7	490	0.5	494	3.0
Spain	484	23.6	8.0	0.1	488	-0.3	496	1.3
Russian Federation	482	24.0	7.8	1.1	475	1.1	486	1.0
Slovak Republic	482	27.5	11.0	-1.4	463	-0.1	471	-2.7
United States	481	25.8	8.8	0.3	498	-0.3	497	1.4
Lithuania	479	26.0	8.1	-1.4	477	1.1	496	1.3
Sweden	478	27.1	8.0	-3.3	483	-2.8	485	-3.1
Hungary	477	28.1	9.3	-1.3	488	1.0	494	-1.6
Croatia	471	29.9	7.0	0.6	485	1.2	491	-0.3
Israel	466	33.5	9.4	4.2	486	3.7	470	2.8
Greece	453	35.7	3.9	1.1	477	0.5	467	-1.1
Serbia	449	38.9	4.6	2.2	446	7.6	445	1.5
Turkey	448	42.0	5.9	3.2	475	4.1	463	6.4
Romania	445	40.8	3.2	4.9	438	1.1	439	3.4
Cyprus[1,2]	440	42.0	3.7	m	449	m	438	m
Bulgaria	439	43.8	4.1	4.2	436	0.4	446	2.0
United Arab Emirates	434	46.3	3.5	m	442	m	448	m
Kazakhstan	432	45.2	0.9	9.0	393	0.8	425	8.1
Thailand	427	49.7	2.6	1.0	441	1.1	444	3.9
Chile	423	51.5	1.6	1.9	441	3.1	445	1.1
Malaysia	421	51.8	1.3	8.1	398	-7.8	420	-1.4
Mexico	413	54.7	0.6	3.1	424	1.1	415	0.9
Montenegro	410	56.6	1.0	1.7	422	5.0	410	-0.3
Uruguay	409	55.8	1.4	-1.4	411	-1.8	416	-2.1
Costa Rica	407	59.9	0.6	-1.2	441	-1.0	429	-0.6
Albania	394	60.7	0.8	5.6	394	4.1	397	2.2
Brazil	391	67.1	0.8	4.1	410	1.2	405	2.3
Argentina	388	66.5	0.3	1.2	396	-1.6	406	2.4
Tunisia	388	67.7	0.8	3.1	404	3.8	398	2.2
Jordan	386	68.6	0.6	0.2	399	-0.3	409	-2.1
Colombia	376	73.8	0.3	1.1	403	3.0	399	1.8
Qatar	376	69.6	2.0	9.2	388	12.0	384	5.4
Indonesia	375	75.7	0.3	0.7	396	2.3	382	-1.9
Peru	368	74.6	0.6	1.0	384	5.2	373	1.3

The **UK** country report highlights that the students' performance in mathematics is at the OECD average in the United Kingdom. Also the proportions of top performers and low performers are similar to the OECD average. On the contrary, the performance in science is above the OECD average, together with the proportion of top performers, while the proportion of low performers is below the OECD average.

According to OECD, **South Africa**'s students rank second-to-last in the world in maths and science. OECD findings, based on the test scores of 15-year-olds from 76 countries, show South Africa ranked 75th globally – with only Ghana scoring below South Africa. The maths and science rankings were

[6] http://www.oecd.org/pisa/keyfindings/PISA-2012-results-snapshot-Volume-I-ENG.pdf

based on a combination of international assessments, the OECD's PISA test, the TIMMS tests, and TERCE tests conducted in Latin America.

National policies for science and mathematics education

National policy on education consists of several levels, ranging from government laws, white papers, national or local projects, and documents that constitute the intended curriculum, to locally developed teaching plans. Despite differences between partner countries, several similarities exist in these countries' ways of thinking and practicing education and educational policies.

In **England**, both mathematics and science curricula to age 16 are determined by a national policy, the 'National Curriculum' which sets out an entitlement for every child. However, in practice both mathematics and science is dominated by a discourse of 'ability' which largely determines the trajectory of children's attainment through a system of educational 'triage', explained as "a process of goods distribution whereby a number of linked practices are enacted to achieve a specified aim, usually related to maximising attainment outcomes". The impact of this is that some learners – mainly the low achieving – receive reduced mathematical learning experiences.

In mathematics the most recent government report comes from the Office for Standards in Education, Children's Services and Skills: Mathematics: made to measure. (The Ofsted report, usually issued every three years). A key message is that pupils of different ages, needs and abilities receive significantly unequal curricular opportunities, as well as teaching of widely varying quality, even within the same year group and school.

Years later, when pupils leave compulsory education aged 16 years, the gap between the mathematical outcomes of the highest and lowest attainers is wide. "Too often, pupils' relative start and end points align, but not always: some outstanding schools break the cycle of low attainment. The challenge, nationally, is to raise the achievement of the lower and middle attainers without constraining that of the most able, too many of whom are also underachieving in relation to their actual potential. The aim is to improve progression for all pupils, so that all are mathematically equipped for their futures. This is not simply about improving the quality of teaching, although that is a key element."[7]

In 2011 the European Commission noted: "In the United Kingdom there is a high academic value placed on mathematics in terms of accessibility to further study and future careers. Further emphasis is placed by schools on the mathematics examinations taken by students in England, Wales and Northern Ireland at age 16. Although this is not the end of upper secondary education, the results of these examinations are part of the criteria used to benchmark the performance of schools. Despite the high value placed on mathematics attainment, it is interesting to note that the four regions of the United Kingdom were found to have some of the lowest levels of participation in mathematics beyond age 16."[8] In schools the Ofsted report states that: "The most common strategies to raise attainment focused the use of assessment data to track pupils' progress in order to intervene to support pupils at risk of underachievement, and in secondary schools to exploit early entry and resit opportunities on modular courses. Leaders monitored the quality of teaching more frequently than previously and through a wider range of activities such as learning walks and scrutiny of pupils' books. While weak performance was generally challenged robustly, attention to the mathematical detail, so crucial in improving

[7] Marks, R. (2014). Educational triage and ability-grouping in primary mathematics: a case-study of the impacts on low-attaining pupils. *Research in Mathematics Education 16*(1), 38-53.
[8] Eurydice (2011). Mathematics Education in Europe: Common Challenges and National Policies. Brussels, European Commission: Education, Audiovisual and Culture Executive Agency.

teachers' expertise, was lacking. Moreover, information gleaned from monitoring and data analysis was rarely used to secure better quality provision, usually because analysis was linked to intervention and revision and monitoring focused on generic characteristics rather than pinpointing the subject-specific weaknesses or inconsistencies that impeded better teaching and greater coherence of learning."[9]

For science at primary level, Ofsted inspectors noted that: "Where achievement was rising over time, the improvements could be traced to these six features– in no particular order:

- increasingly accurate assessment
- a high profile accorded to science in the school
- coverage of the full science National Curriculum programmes of study, rigorously monitored
- staff who were confident in teaching pupils how to work scientifically
- strong links between literacy and science
- very good, regular monitoring of achievement in science for individuals and groups of pupils. "

At both primary and secondary level, Ofsted notes: "If significant improvement in science provision is to happen, that vision must deliver the purpose of science education as set out in the National Curriculum old and new, and not just offer a comprehensive management plan that maintains existing provision. Very few of the science improvement plans seen measured the department's performance against that lofty goal of 'maintaining curiosity'; they played safe, and merely aimed to maintain their grades. There were exceptions, however, where the subject leader set out to raise standards and post-16 participation as well as students' engagement in science. Although they might not have arrived at that destination, and therefore might not yet be outstanding, they knew what was needed."

In **France** education is part of the citizenship development of students, also in mathematics and science. The main objectives of mathematics and science are: a) To train students to mathematical and scientific activity through inquiries; b) To give a coherent view of scientific knowledge and their practical applications; c) To give students mathematical and scientific tools both for general and professional subjects; d) To train data reading, and criticism and data processing using digital technology; e) To develop written and oral communication skills.

The three core themes in the **German** educational policies are: Language, Digitalization and Inclusion. In Germany there are National Educational Standards that are determined by the Standing Conference of the Ministers of Education and Cultural Affairs of the Länder in the Federal Republic of Germany. At the moment there are different National Standards for primary education (end of grade 4) for the subjects Mathematics and German, Hauptschulabschluss (end of grade 9, lower secondary school-leaving certificate) for the subjects Mathematics, German and first foreign language (English or French), Mittlerer Schulabschluss (end of grade 10, intermediate school-leaving certificate) for the subjects Mathematics, German, first foreign language (English or French), Biology, Chemistry and Physics and Allgemeine Hochschulreife (general higher education entrance qualification) for the subjects Mathematics, German, and first foreign language (English or French). Content related mathematical competencies in the subject Mathematics are assigned to one of five mathematical "key ideas", namely number, measuring, space and shape, data and chance, functional relations. In addition there are content related scientific competencies for biology, physics and chemistry (for example "Development" in biology, "chemical reaction" in chemistry and so on).

In the last decade, the importance of fostering the teaching-learning of STEM subjects in **Italy** has been stressed by the Ministry of Education, which promoted several National initiatives with this concern,

[9] Ofsted (2012). Mathematics: made to measure, HMI. 110159.

like projects for involving students in laboratory activities, improving competence of in-service teachers, improving teaching of mathematics in schools and raising students' achievements.

In the **Netherlands** students have to perform according to various sets of National standards of reference levels at certain points during their educational career. Schools are required to track performances of each student with a monitoring system. There is a distinction between applied or abstract mathematics (wiskunde) and calculations (rekenen), for which students are tested separately.

In science there have been made national attempts to stimulate the choice of secondary school students to pursue a career in STEM[10]-related fields. However, there is no formal policy to engage students more in these subject areas. Examination at the end of secondary school has been standardised, but this state of affairs is no different from that in any other school subject.

In **Norway**, compulsory schooling constitutes the years 1-10. All pupils have the right to three years of upper secondary education (years 11-13). Pupils study science years 1-11 and mathematics years 1-12 out of the 13 years of schooling. After this they can choose whether to continue with physics, biology, chemistry, mathematics for social studies or mathematics for natural sciences. The curriculum contains basic skills (orality, writing, reading, numeracy, digital skills) and competence aims for grades 2, 4,7,10 in primary and lower secondary school.

Mathematics and science education in the Norwegian school system is supposed to develop the mathematical and scientific competencies that society and the individual needs. Pupils should get rich opportunities to work practically and theoretically and to use explorative, creative, playful and problem solving activities and exercises. A new government strategy, *Tett på realfag - Nasjonal strategi for realfag i barnehagen og grunnopplæringen (2015-2019)*, has four overarching goals: 1) To enhance all students' competences in mathematics and science, 2) Reducing the number of low performing students in mathematics and science, 3) Increasing the number of high achieving students in mathematics and science, 4) Increasing teachers' competences in mathematics and science.

Norwegian educational policy emphasizes developing critical thinking for democratic reasons, for understanding environmental issues and for the evaluation of available information and analyses. Mathematics is also seen as a tool for other areas like medicine, technology and science. There are a number of projects in action to help low achievers, and to improve mathematics and science teaching and teacher training in Norway (Virtual mathematics school, The Budding science and literacy project etc.). Further, it is important in mathematics and science education in Norway to work for gender equity, sustainability and lifelong learning.

The national strategy "Realfag, naturligvis - Strategi for styrking av realfagene 2002 – 2007"[11] laid the foundation for the formation of national centres in both mathematics and the natural sciences. In 2010 The Norwegian Centre for ICT in Education was founded. These centres "shall make contributions towards the implementation and execution of national educational policy so that children, youths and adults are provided with equal and adapted education of a high quality and as part of an inclusive community"[12].

In **South Africa** mathematics education is supposed to contain the following skills:

- a critical awareness of how mathematical relationships are used in social, environmental, cultural and economic relations

[10] Science, technology, engineering and mathematics
[11] https://www.regjeringen.no/no/dokumenter/realfag-naturligvis/id105788/
[12] http://www.naturfagsenteret.no/c1405593/artikkel/vis.html?tid=1442390

- confidence and competence to deal with any mathematical situation without being hindered by a fear of mathematics
- an appreciation for the beauty and elegance of mathematics
- a spirit of curiosity and a love for mathematics
- recognition that mathematics is a creative part of human activity
- deep conceptual understandings in order to make sense of mathematics
- acquisition of specific knowledge and skills necessary for:
    - the application of mathematics to physical, social and mathematical problems
    - the study of related subject matter (e.g. other subjects)
    - further study in Mathematics.

To develop essential mathematical skills the learner should:

- develop the correct use of the language of mathematics
- develop number vocabulary, number concept and calculation and application skills
- learn to listen, communicate, think, reason logically and apply the mathematical knowledge gained
- learn to investigate, analyse, represent and interpret information
- learn to pose and solve problems
- build an awareness of the important role that mathematics plays in real life situations including the personal development of the learner.

The science curriculum aims to provide learners with opportunities to make sense of ideas they have about nature. It also encourages learners to ask questions that could lead to further research and investigation. There are three specific aims in Natural Sciences, “Doing science” (i.e. analysing problems, using practical science skills and processes), “Knowing the subject content and making connections” (i.e. technological and environmental knowledge) and “Understanding the uses of science” (i.e. scientific history, improving water quality). In terms of process skills, the teaching and learning of Natural Sciences involves the development of a range of process skills that may be used in everyday life, in the community and in the workplace. Learners also develop the ability to think objectively and use a variety of forms of reasoning while they use these skills. Learners can gain these skills in an environment that taps into their curiosity about the world, and that supports creativity, responsibility and growing confidence. Several cognitive and practical process skills that learners should develop are listed, like observing, comparing, measuring, predicting etc.

Cross country summary

It is clear that in all countries the international comparison surveys like TIMSS and PISA have had a substantial impact on educational policy and priorities in both mathematics and science. Scores at the international tests have been applied as arguments to increase time spent on these subjects in school, give priority to further education of mathematics or science teachers, and change the curriculum to align more with these tests. The impact of international tests do not always reflect the real achievement or ranking of the countries. In countries that perform around average, and this goes for most FaSMEd countries, an average level of performance is not considered sufficient in view of the political priorities and resources applied.

National tests and monitoring systems are common, and are used to rank individual schools and districts in ways that may not be meaningful at the individual level or in the particular classroom. These types of tests are of a summative nature and are usually not readily applicable for the day-to-day teaching practices. It is necessary to consider formative types of assessment that are more suited to bringing students forward in their learning processes. Projects like FaSMEd, which focuses on formative assessment to raise lower achievers, is thus an important contribution.

There are different ways of structuring mathematics and science in the different countries, but also many similarities. One way is structuring education into basic skills. The idea of *basic skills* is dominant in all subject areas in the Norwegian curriculum (grunnleggende ferdigheter), and is also stressed in France (Developing written and oral communication skills), Germany (Communicating as a skill and also core themes like language and digitalization), and South Africa (confidence and competence, thinking objectively, reasoning). Most countries structure their curricula along general competences (e.g. testing hypotheses in science or modelling in mathematics) and content specific competencies (solving linear equations or balancing chemical reactions). The countries who reported on curriculum design seem to organize mathematics and science in a similar manner to this.

To improve teaching and learning in mathematics and science, a number of national centres have been set up in several countries. The centres typically have a mandate to help teachers and schools developing and implementing mathematics and science education, running professional development projects, and may also engage in educational research.

2. Digital resources/Technology

National initiatives

In this section national initiatives concerning digital resources/technology will be described. This includes national policy documents, national guidelines, school/classroom research initiatives, curriculum and textbooks for compulsory school and teacher pre- and in-service education.

In **England** the development of tools and technology to support teaching and assessment in mathematics and science has a long history of development from both industry and public funds. Government support in England included the establishment of the National Council for Educational Technology (NCET) in 1993, which subsequently became the British Educational Communication and Technology Agency (Becta) in 1997 – this closed in 2011. Becta provided rigorous research and evaluation to evaluate the impact of technology on the education and skills system. It provided expert, independent advice to:

- help schools make informed choices about technology and plan, buy and use it effectively
- help learners and their families access technology, become involved in learning and stay safe online
- ensure government policy took full account of the opportunities and challenges technology brings.

Becta provided practical tools for schools to save time and money, improve teaching and learning and share best practice. The resources developed by Becta are still available in the UK government online archive. Currently most schools have access to projective technology in most classrooms. Fewer schools provide access *for pupils* to ICT in the general classroom, although a growing number are experimenting with tablets and some also provide 'voting' devices. A small number use other hand held devices such as graphing calculators. In 2014 the government introduced the compulsory program of study of 'Computing' into the curriculum for children of all ages, where they will learn how computers and computer systems work, they will design and build programs, develop their ideas using technology and create a range of content. A large number of schools subscribe to a range of online resources for mathematics and science which give teachers access to more or less 'scripted' lessons and these also frequently provide assessment materials online which pupils can access from home. The BBC also has an extensive library of educational online materials, although its expansion of these was stopped when industry protested about unfair subsidized competition.

In **France** the Department of Information and Communication Technology in Education (DGESCO-A3) is responsible for coordinating ICT development in education. The department's mission covers the following main areas:

- Encouraging teaching practices using ICT;
- Developing school equipment;
- Creating networks;
- Teacher training (both initial teacher education and continuing professional development);
- Supporting the production and distribution of multimedia resources;
- The product and services industry.

The académies (the regional structures of the Ministry of Education) are responsible for implementing national directives and policies. This includes the development of ICT. The overall ICT policy in France covers the following key areas:

- Proposing and implementing measures for increasing the use of the internet and ICT;
- Providing training for families, children and others in the use of ICT;
- Preparing and implementing guidelines for the development of ICT for educational purposes in schools and higher education;
- Monitoring the use of ICT in these contexts;
- Supporting the production of digital resources;
- Establishing partnerships and agreements with regional authorities and companies.

The DGESCO-A3 is part of the Ministry of Education. Some examples of current programs, of tools and materials to support teachers in their mathematics and science classrooms are listed in D2.3 at pages 12-14.

In **Germany** use of technology is highly recommended in the National Educational Standards and either recommended or mandatory in some state curricula, but use in school differs considerably. In some states it is possible to find this recommendation in the curricula – in other states it is even a duty to use digital tools, for example graphic calculators or even computer algebra is compulsory for the final examination. Nevertheless, independent of recommendation or duty, the concrete use and integration of technology in the classroom differs a lot from school to school and even from teacher to teacher. Concerning digital tools, it is most common for students to use scientific calculators from grade 6. In relation to graphic calculators, Germany does not have a long tradition and is still not used in a lot of schools (Barzel, 2006). If graphic calculators are used, they are introduced in grade 9, mainly in the gymnasium. More often teachers use the computer lab of their school, but only occasionally in single mathematics and science lessons (usually spread sheets, like Excel, or geometry software like GeoGebra).

There are some new Initiatives on the national level. The DZLM (German Centre for Mathematics Teacher Education) has recently held teacher training workshops with the contents "Blended Learning" and "Use of graphical calculators in secondary grade 2" in several Länder. There are also interesting projects going on, like The Kolleg Didaktik:digital (project of Joachim-Herz-Stiftung) which is working on potential possibilities for the usage of digital tools in scientific lessons.

In **Ireland**, although almost all primary schools and the majority of post-primary schools are locally owned and managed, schools have relatively limited autonomy, especially in relation to curriculum and the pedagogical methods employed. Ireland have a "Digital Strategy for Schools 2015-2020: Enhancing Teaching, Learning and Assessment". This strategy provides a rationale and a Government action plan for integrating ICT into teaching, learning and assessment practices in schools over the next five years. The strategy builds on previous strategies in the area of ICT integration and it takes cognisance of current education reforms that are already underway within the education system at primary and post primary level. This strategy focuses on the school sector, and the proposed actions are designed to embed ICT more deeply across the system to enhance the overall quality of Irish education (Department of Education and Skills, 2015[13]).

In **Italy**, The Ministry of Education, University and Research (MIUR), which is the principal administrative body in Italy, and other local governmental bodies, such as the regional and provincial education officers, are the main referees for the school use of ICT in teaching and learning. However, recently the degree of autonomy in how schools organize tuition and conduct the teaching and learning processes have increased considerably. The country profile of the document "*Survey of school: ICT in education*" (European Schoolnet, 2012), highlights that in Italy the infrastructure conditions needed to underpin teaching and learning with ICT are not in place in all schools, with relatively high ratios of students to computers, and over three times the EU percentage of students in schools without broadband. In spite of this, teachers' use of ICT at grades 4 and 8 is close to the EU average.

The Eurydice's *Key Data on Learning and Innovation through ICT at school in Europe* shows that, according to Italian official steering documents, students and teachers at all levels are expected to use ICT in all subjects for complementary activities and also in class at secondary education level, although there are no central recommendations on the use of ICT in student assessment. In both primary and secondary schools ICT is taught as a general tool for other subjects/or as a tool for specific tasks in other subjects. Different national strategies covering training and research measures for ICT in schools have been developed in Italy. Several projects have been developed as a result of these strategies: The National Project "*Scuola digitale*" (Digital School), *ARDESIA TECH* is an example of a research project developed within "*Scuola digitale*". Another national program that activated eLearning initiatives for teachers and other members of school staff was the *ForTic* Program ("Piano nazionale di Formazione degli insegnanti sulle Tecnologie dell'Informazione e della Comunicazione" – National plan for the training of teachers on ICT). With a similar aim of offering support and guidance for teachers to integrate software and multimedia into the teaching/learning process, an online service was established in 1999 by the Italian Research Council's Institute for Education Technology (ITD-CNR): *ESSEDIQUADRO* [14].

In the **Netherlands** there have been projects to support teaching and assessment through technology, including:

- Programs/Initiatives aimed at fostering the use of ICT in school
- Programs that involve teacher professional development to promote an effective use of ICT
- Programs and initiatives aimed at developing activities to raise students' achievement in Mathematics and Science through the use of digital technologies
- Web-based test and materials to support teachers in students' assessment
- Web-based practice programs for students

[13] https://www.education.ie/en/Publications/Policy-Reports/Digital-Strategy-for-Schools-2015-2020.pdf
[14] http://sd2.itd.ge.cnr.it/guidaeng/index.htm

- Projects involving the use of question-response systems/tablets or other digital tools in the teaching/learning process and for assessment purposes.

In **Norway** the use of ICT in compulsory school and in teacher education is directed through national policy and strategy documents, the national compulsory curriculum; and through legislations and national frameworks for teacher education. Digital competence is one of five basic skills that should be integrated in all Norwegian compulsory school subjects. The Norwegian strategy for digital competence is based on *Stortingsmelding no 30 (2003-0*4) [Government policy document] - *Kultur for læring* ["Culture for learning"]. The policy document defines "digital competence", and is based on the international literature concerning digital literacy. Four dimensions are mentioned: 1) ICT skills; 2) ICT used in several subjects, 3) Learning strategies and metacognitive abilities, 4) Cultural competence and digital education (in a broad sense). In a recent report about future school reforms in Norway (NOU 2015:8) the proposal is to remove digital skills from the basics skills (which are redefined to "basic competences" which will include only reading, writing and orality). Digital skills is proposed to be connected stronger to the school subjects as well as integrated in several cross-subject competences. The questions about digital competences is broadly discussed, and changes are likely to occur.

In the Norwegian national framework for teacher education for future primary and lower secondary school teachers (1-7th grade and 5-10th grade) [Grunnskolelæreutdanningen 1-7 og 5.10] digital skills is considered one of the basic skills as part of the different subject curricula. The implementation differs among universities.

Advisory books or booklets for teachers concerning ICT in the classroom exist, but textbooks for the students in primary and secondary school are less frequent, or missing. One exception is books for pure ICT subjects in upper secondary or booklets about more instrumental ICT-subjects as "touch method" for word processing or "how to use spreadsheets". For teacher education, quite a lot of textbooks have been published the last few years about ICT and digital skills more broadly or connected to the different school subjects. The situation for mathematics and science are similar, there exist both instructional books about specific tools (spreadsheet, calculation etc.) and more broadly about digital literacy, ethics, and didactics.

In **South Africa**, overall, the provision of digital technology is variable, and up-to-date statistics related to the numbers of computers in schools, for example, are difficult to come by. According to the Department of Education's Draft White Paper on e-Education, in 2003, 39.2% or schools had one or more computers, and 26.5% had computers that could be used for teaching and learning. This same paper suggested that ICTs could and would be introduced to all schools in the country. It has not been possible to follow up what happened in terms of policy, but the reality is that this initiative has not been rolled out. Equipping schools is a matter for the provincial departments and there is some variability in the way this has been done. According to a report (in ITWeb) dated 16th July 2015, "Despite continuous mention of government's intent to connect South African schools to a broadband network and to inject technology into the classroom, it appears efforts to modernise the country's education system remain fragmented….". In 2010, the government launched the Teacher Laptop Initiative. Teachers were given the opportunity to receive a laptop, software, Internet connectivity and insurance for their laptops. Teachers were expected to fund the package, although they would receive a taxable monthly allowance of R130. Training on how to use the laptops and the software was included in the package. There are no numbers on how many teachers took advantage of this scheme, but, as the same report (above) states: it 'appears that certain ICT in education initiatives – such as … the Teacher Laptop Initiative – have either fallen by the wayside, or have stalled.' The one-laptop-per-child initiative was introduced in 2008, but it seems that only 650 devices had been put into the hands of children by July 2015. There are also some local initiatives.

Cross country summary

France, Germany, Ireland, Italy and Norway describe clear strategies for the use of ICT on a national level. England has a strong tradition through the Becta (British Educational Communication and Technology Agency organization), but this was ended in 2011. A new governmental programme was introduced in 2014 where the government introduced the compulsory program of study of 'Computing' into the curriculum for children of all ages. In all these countries the local implementation varies, some countries have strategies on regional level (Germany and France), the same seems to be the situation in Italy. Ireland and Norway have quite clear strategies at national level. In Ireland there is also an action plan for the next 5 years. The implementation in Norway is however not consistent, there are local interpretations of the curriculum for both compulsory school and teacher education, and the school or teacher practice varies. South Africa reports about a diverse landscape with difficulties about accurate statistics of the use of ICT. National reports describe difficulties with the capacity of broadband connection and enough computers available. There have been some initiatives for example to stimulate teachers to invest in their own laptops.

The use of ICT and technology in general is thus recommended in national policy papers in most or all countries. The implementation varies, as there is great autonomy as to how to operationalise the national initiatives, projects and policy. It may vary across different parts of a country, across school districts, from one individual school to another, and also from one teacher to another. The lack of appropriate resources is a substantial hindrance for the more widespread use of ICT in the mathematics and science classrooms. In a pressed economic situation, it is hard for schools to give priority to ICT hardware that usually is considered quite expensive and with a short lifespan. Computers and tablets are rapidly becoming obsolete. ICT hardware needs constant updating to be meaningful for teachers and students. This is a considerable obstacle also for more meaningful use of technology in mathematics and science at the school level. Appropriate software for meaningful use in the learning of mathematics and science does often not come for free, and is thus an economic investment that may not be considered the most important in a school's budget. On an international level, it also has to be said that software in mathematics and science aimed at school use is too often aimed at endless repetition and rote learning instead of contributing to developing conceptual understanding in an inquiry based pedagogical setting. It is well known that deductive teaching and rote learning does not contribute to developing competences needed in the present day society, and more inquiry based pedagogies are recommended[15]. For example, the EU report *Science Education for Responsible Citizenship* recommends that education policies and systems should "Support schools, teachers, teacher educators and students of all ages to adopt an inquiry approach to science education as part of the core framework of science education for all".[16] Use of technology is an integrated part of modern society and there is great potential for pedagogical use that aligns with inquiry-based pedagogies that foster deep learning. To meet this, it is important that national and international strategies are given sufficient support at the classroom level.

[15] E.g. Rocard et al. (2007). *Science education now: a new pedagogy for the future of Europe*. Available at http://www.eesc.europa.eu/?i=portal.en.lso-observatory-documents-background-documents.9003

[16] Hazelkorn et al. (2015). *Science Education for Responsible Citizenship*. doi:10.2777/12626

FaSMEd and the national initiatives on digital resources and technology

In this section we describe how the FaSMEd project in the partner countries and results from the case studies are related to the national initiatives and the practices in the countries concerning digital resources and technology.

In **England** the FaSMEd team has focused solely on mathematics. Development of resources and professional practice in science and mathematics are now occurring in a piecemeal fashion, through commercial initiatives from publishers such as Pearson or OUP or through subject associations of mathematics and science teachers or through groups of schools organized into 'academy chains'. There is also a chain of 'National Science Learning Centres'[17], a virtual 'National Centre for Excellence in Teaching Mathematics'[18] which supports a website and a National Science, Technology, Engineering and Mathematics (STEM) Learning Centre at York University[19], all of whom are providing professional development courses and resources for teachers and students. In addition, the NCETM is coordinating the development of 35 local 'Maths Hubs'[20].

These networks will allow us to disseminate the findings from the FaSMEd project to a wide range of audiences. One further development is the growth of interest in 'evidence based practice', stimulated in part by the Education Endowment Foundation (EEF) who are an independent grant-making charity. EEF will be funding £200 million of research projects over the next 15 years which will focus on tackling the attainment gap. Findings from the FaSMEd project will be shared with funders such as EEF in order to provide them with evidence to shape future research directions.

In **France** the FaSMEd project has solely focused on mathematics, and the project is in line with French national policies. In addition, it aims at accompanying the introduction of technologies in the classroom with a reflection about how these technologies can support formative assessment practices. Linking the use of technology with the purpose of formative assessment is something new for French policies.

In **Germany** the FaSMEd team has focused on mathematics and science. The German Case Study "Can I sketch a graph based on a given situation?" is in line with initiatives and policies concerning technology in the matter that:

- Digital media and tools take on a more and more important role in German educational policies in mathematics, e.g. the use of graphing calculators have been made mandatory for higher secondary education in the year 2014
- The group student interview and q-sorting showed that in some schools it is still very uncommon to use technology and digital media in mathematics classrooms.

The German Case Study "Who has the juiciest apple?" is in line with initiatives and policies concerning technology in the matter that:

- The tool guides through the natural scientific way to acquire knowledge (key scientific competency)
- The q-sorting and interview showed that the students like to use technology and digital media when it's supportive and rejected a general use (supporting instead of replacing existing tools and media).

17 https://en.wikipedia.org/wiki/Science_Learning_Centres
18 https://www.ncetm.org.uk/
19 https://www.stem.org.uk/
20 http://www.mathshubs.org.uk/

In **Ireland** the FaSMEd team has focused on mathematics and science. Initiatives in Ireland so far have focused more on integrating ICT into the education system rather than how ICT can function in relation to assessment. As outlined in deliverable D2.3, initiatives so far highlight how the use of technology has led to positive changes in learning environments as well as increased motivation on the students' part. These findings are similar to that of the case studies where students held positive opinions about the use of technology during lessons, however science students were more positive about technology then the mathematics students. The Digital Strategy for Schools 2015-2020 has as one of its assessment objectives to "Explore and facilitate the use of ICT for formative and summative assessment purposes." (p.26). However, the strategy does not outline how exactly this will be implemented in schools. Within the science case study, the teacher utilised technology (specifically iPad technology) to build on her feedback practices by using work completed on iPads in groups to assess students understanding and provide them with feedback to help their learning move forward. She furthermore utilised the iPads to promote peer assessment and self-assessment. The teacher making use of technology to implement formative assessment practice outlines how the science case study fits with the objectives of the Digital Strategy for Schools.

In **Italy** the FaSMEd team have focused solely on mathematics. The FaSMEd approach is in line with the main ideas about the use of digital resources and technologies at school promoted by the Italian Ministry of Education and supported by educational research:

- the focus on laboratorial activities, where technology represent a fundamental support for teaching-learning processes;
- the active involvement of teachers and the stress on the need of fostering effective professional development path to enable teachers to become aware of the potentials of digital tools to support their work;
- the focus on the study of the effects, on the school practice, of the different ways of using digital technologies in the classroom.

It is possible to highlight also some specificities of the FaSMEd project, compared to the other initiatives developed in Italy:

- the FaSMEd teaching experiments are focused not only on the use of digital technologies, but especially on the implementation of specific methodologies, which constitute the fundamental basis for all the planned activities;
- the FaSMEd project involves a small number of teachers, so it enables to work closely with them and, in this way, to involve them as active participants.

In the **Netherlands** the FaSMEd team has solely focused on mathematics and have based themselves primarily on the previously discussed national reference levels to determine the scope of the problems in the DAE. They have developed the digital resources within the FaSMEd project, but within the Digital Mathematics Environment (DWO/DME[21]). Teachers, in their daily teaching, make use of digital resources resulting from different projects to varying degrees, but this has no direct influence on the case studies.

In **Norway** the FaSMEd team has worked with both mathematics and science. The Norwegian case studies are related to the overall strategy of ICT as one of five basic skills. The national policy and strategies in Norway do not explicitly connect formative assessment and ICT, or lower achievers and ICT. However, there exist projects with the explicit aim to use technology directed at both high and

[21] https://app.dwo.nl/site/index_en.html

low achievers at secondary education[22]. In the ICT strategies and policy documents, as well as in curriculum documents, the strategies for digital skills are described as general cross subject skills, as well as more specific in-subject goals and competences.

In **South Africa** the FaSMEd have focused solely on mathematics. Their implementation of FaSMEd did not use digital technology. As described in D2.1, few schools are equipped, in terms of both hardware and teacher knowledge, to use technology in their classrooms.

Cross country summary

All the countries except South Africa, that did not use ICT in their case studies, seem to have connected the FaSMEd project and the case studies to national ICT policy and strategies. Some countries (Norway and France) mention that the national ICT strategies do not include explicit connections to assessment or lower achievers and accordingly, the FaSMEd project brings in new dimensions. On the other hand, Ireland mention that their Digital Strategy for Schools 2015-2020 has as one of its assessment objectives to “Explore and facilitate the use of ICT for formative and summative assessment purposes.”

Linking technology and formative assessment is a key feature of FaSMEd. The use of ICT in mathematics and science classrooms is still not very common despite the huge potential of technological tools in these subjects. The FaSMEd partner experiences are that students and teachers alike find that the use of technology may contribute to the learning and understanding of mathematical and science topics in meaningful ways. Implementation of technological tools does, however, not come automatically and requires that the teachers stay up to date on available technology and its possible use in the classroom. Working closely with the FaSMEd team, whose members has experience and knowledge in both mathematics and/or science, of ICT and how to use ICT in the subjects, has been instrumental for the successful implementation of ICT in the partner countries mathematics and science classrooms.

3. Formative assessment and pedagogic practices

National initiatives

In this section national initiatives concerning formative assessment and pedagogic practices will be briefly described. This includes national policy documents, national guidelines, school/classroom research initiatives, curriculum and textbooks for compulsory school and/or teacher pre- and in-service education.

In **England** formative assessment (FA) is generally referred to as ‘Assessment for Learning’. The publication of the literature review on formative assessment by Black and Wiliam (1996) ‘Inside the Black Box’[23] had a very significant impact on education in England with the publication of a wide range of guidance and advice to schools and teachers about how to implement formative assessment strategies. For example, in 2008 the government invested £150 million in an ‘Assessment for Learning Strategy’. However, the impact of these initiatives in schools seems to be variable. Research undertaken in the Teaching and Learning Research Programme (TLRP) investigated how such FA practices were developed by teachers in 40 English primary and secondary schools (Marshall and

[22] https://dvm.iktsenteret.no/
[23] Black, P. and D. Wiliam (1996). *Inside the Black Box*. London: King's College School of Education.

Drummond 2006)[24]. The results of this longitudinal study found that what was defined as the "spirit" of assessment for learning was hard to achieve. Although many teachers used pedagogic techniques associated with assessment for learning, such as sharing success criteria or increasing "thinking time", few did so in ways that enabled pupils to become more autonomous learners (ibid, p.20).

In **France**, there are no national initiatives concerning formative assessment in classroom except that FA is presented as a "good practice", a general incitement for having a student-centered pedagogy and participative learning.

In **Germany**, the KMK Standards for Teacher Education (2004) name "assessment, evaluation and counselling" as one of 11 curricular foci in the education of teachers and state that "assessment and fostering of individual learning processes as well as the assessment and evaluation of student achievements" need to be the content in every teacher's education[25]. Further, the project UDiKom[26] aims at fostering teachers' diagnostical competencies in order to qualify them to deal with the heterogeneity in their classrooms and enable them to foster students individually. Another is a programme for teacher professional development *SINUS* (Increasing Efficiency in Mathematics and Science Education) concerning low achievers described in D2.1.3 (p.28-30).

In **Ireland** assessment policies are divided into their relevant age group: early childhood, primary level and second level. Aistear[27]; *the Early Childhood Curriculum Framework* (2009) was developed and launched by the National Council for Curriculum and Assessment (NCAA) in 1999. It is for children from birth to six years. It provides information for adults to help them plan for and provide enjoyable and challenging learning experiences, so that all children can grow and develop as competent and confident learners within loving relationships with others. Aistear describes the types of learning (dispositions, values and attitudes, skills, knowledge, and understanding) that are important for children in their early years, and offers ideas and suggestions as to how this learning might be nurtured. The Framework also provides guidelines on supporting children's learning through partnerships with parents, interactions, play, and assessment (ibid). The Primary School Curriculum[28] was also developed and launched by NCAA in 1999 where a strong focus on appropriate assessment practice was evident. It discusses how "assessment is an integral part of teaching and learning" while identifying the various needs of children in the long and short term, and putting the steps in place to ensure those needs are met. This document puts a strong focus on assessing students in many different ways both informally and formally through diagnostic and standardised testing. The major emphasis in this document however was to use appropriate assessment tools to provide students with effective learning experiences throughout primary school (ibid.).

The assessment policy at the second level distinguishes between the Junior and Senior Cycle Framework 2015. In the Junior Cycle Framework Science will be one of the first subjects assessed as part of the new Junior Cycle. The Junior Cycle Science Specification will be introduced in Irish post

[24] Marshall, B. and M.-J. Drummond (2006). How teachers engage with assessment for learning: lessons from the classroom. *Research Papers in Education 21*(2), 133-149.

[25] https://www.kmk.org/fileadmin/Dateien/veroeffentlichungen_beschluesse/2004/2004_12_16-Standards-Lehrerbildung.pdf

[26] UDiKom: Aus- und Fortbildung der Lehrkräfte in Hinblick auf Verbesserung der Diagnosefähigkeit als Voraussetzung für den Umgang mit Heterogenität und individuellen Förderung

[27] NCCA, 2009, Aistear, p. 6, retrieved from http://www.ncca.biz/Aistear/pdfs/PrinciplesThemes_ENG/Principles_ENG.pdf

[28] Department of Education and Science (DES), 1999, Primary School Curriculum: Introduction, p. 11, retrieved from http://www.curriculumonline.ie/getmedia/c4a88a62-7818-4bb2-bb18-4c4ad37bc255/PSEC_Introduction-to-Primary-Curriculum_Eng.pdf

primary schools in September 2016 with first year students. The Specification is based on 46 learning outcomes with the Nature of Science being central to teaching and learning. The assessment related to this Specification comprises two components: school-based, counting for 40% of the final grade, and a final assessment, marked by the State Examinations Commission, counting for the next 60%. In the Senior Cycle **(**See question 1(a)) there is a high stakes examination at the end of this cycle, i.e. 6th year of second level. Very little formative assessment practice takes place due to the nature of the leaving certificate points race whereby students are awarded points based on their grades and these points are then used to secure a place in third level education.

In **Italy**, although formative assessment is not specifically addressed in the national guidelines ("Indicazioni nazionali per il curricolo della scuola dell'infanzia e del primo ciclo d'istruzione"), the teacher guide on how to create a good teaching-learning environment highlights aspects that are typical of FA practices, such as fostering ability to reflect, ask questions and discussing knowledge (for instance through laboratorial activities), encouraging collaboration with peers, fostering argumentative processes enabling students to communicate and understand each other's' view and promoting students' metacognitive abilities that enhance self-regulate learning.

In the last years, a few national projects and initiatives concerning formative assessment in Mathematics and Science have been developed: AVIMES (*Autovalutazione d'Istituto per il Miglioramento dell'Efficacia della Scuola-Institute* or Autoevaluation for Improving School Efficiency)[29] – a regional research and innovation project on school self-evaluation, based on the use of achievement tests and questionnaires to evaluate school performance in order to improve quality - The information gathered is stored in a database, which is periodically updated and can be used for: internal and external reporting, improving school organisation, refining the curriculum planning, improving the quality of classroom practice, fostering the professional development of teachers and school-heads. One of its products is a catalogue of tests for diagnostic and formative assessment of students' mathematics competencies (grades 1-6). Another project is the European project FAMT&L (Formative Assessment of Mathematics Teaching and Learning)[30] led by the University of Bologna. Its main goal is to develop a training model (using e-learning) for middle school in- and pre-service mathematics teachers focused on educational planning and assessment (both formative and summative assessment) and on the didactics of mathematics. The aim of the training model is to develop teachers' competencies in planning specific methodologies and tools for learning processes. In particular, the stress is on the competences that enable teachers to:

- make hypotheses and plan educational strategies and techniques in order to detect difficulties and offer remedial for an effective learning of math;
- using on-going assessment with a formative purpose in order to verify, rearrange and improve teaching methods and to allow students to assess themselves and become conscious of their own learning processes.

In the **Netherlands,** assessment in general is a hotly debated issue. In recent years, the Ministry of Education has heightened the emphasis put on test results and added the tests to compare the students' performance to national reference levels (1F-3S). These all concern summative tests, and new policies have met a lot of resistance from educational practice. Two years ago, a new diagnostic test to index learning progress in general was proposed, but it was not made mandatory, following the advice of Sander Dekker, State Secretary of the Ministry of Education. He proposed that the test should

[29] http://www.avimes.it
[30] www.famt-l.eu

be developed into a tool for formative assessment, adaptive to the level of the student, and resulting in clear advices for individualised instruction.

Recent studies have also focused on formative assessment in both primary and secondary education. For example: *Prerequisites for effective formative assessment* (a literature study focusing on published assessment methods)[31] and *Improving classroom assessment* (a research and development study about FA for classrooms)[32].

In **Norway**, formative assessment (*Vurdering for læring*, Assessment for learning) has been and is still a prioritized area from the government. Due to a well-established tradition of school autonomy, in which individual schools are «owned» by local authorities and accountable to them rather than the national authorities, there is a need for national framework for evaluation and assessment. In 2004 the Norwegian authorities established such a framework, called National quality assessment system (NKVS)[33] aiming at helping schools and school owners to evaluate the quality of teaching practices and student outcomes. NKVS provides a range of tools and data that teachers, school leaders, school owners and education authorities can use to evaluate their performance and inform strategies for improvement. These tools include both formative and summative elements (see Table 6, ibid, p.25).

Table 6 Key tools for evaluation and assessment developed since the establishment of NKVS

Key tools	Description	Use of results by	Purpose
National tests	Mandatory for Years 5, 8 and 9. Assessments of students' basic skills in reading, mathematics and English.	National authorities School owners Schools	At the national level, results are used to inform education policy and allocation of resources towards municipalities with special challenges. At the local level, results inform school evaluation and improvement.
User surveys	Pupil Surveys are mandatory in Years 7, 10 and Vg1. Schools can also administer them in other years. Parent Surveys and Teacher Surveys are voluntary.	National authorities School owners Schools	Results are used at all levels to analyse and develop the learning environment. Results may also be used for research purposes.
Mapping tests	Available for Years 1, 2, 3 and Vg1. Assessments of basic skills in reading and mathematics. Some are mandatory and some are voluntary.	School owners Schools	Identify pupils who need extra help and adapted teaching at an early stage in their schooling.
Point-of-view analysis tool	Available for schools to structure a systematic review of their teaching practice and results.	Schools	Inform school self-evaluation and improvement.
Organisational analysis tool	Available for schools to review the school as a workplace for its staff and identify aspects that may impact teaching and learning quality.	Schools	Inform school self-evaluation and improvement.
Template to prepare local status reports	Available for school owners to assist them in the preparation of their annual status reports. The Template tool includes data for both mandatory and suggested indicators	School owners	Assist school owners in the requirement to complete annual status reports and strengthen education system monitoring at the local level.
School Portal	A web-based information tool presenting information from the national tests and the user surveys, and basic school data about enrolment, resources and completion rates. Comprises an open part and a password-protected part where schools and school owners can access their own data.	General public National authorities School owners Schools	Provide all stakeholders with access to key information on basic education at the national and local (school owner) level. Provide school owners and schools with specific information concerning their own results to inform school evaluation and improvement.

Source: Adapted from Norwegian Directorate for Education and Training (2011).

The establishment of NKVS witnessed for the strong political will in Norway to prioritize assessment and evaluation, and especially formative assessment has «gained increasing prominence in both policy and practice» through a statutory requirement to implement FA (ibid, p.130). In order to support teachers with the implementation, the Norwegian Directorate for Education and Training gives support by providing tools and materials, and by launching of a teacher professional learning initiative: the 4-

[31] https://www.nro.nl/kb/411-11-697-effectieve-kenmerken-van-formatief-toetsen/

[32] http://www.nwo.nl/onderzoek-en-resultaten/onderzoeksprojecten/i/11/7711.html

[33] OECD(2011), Norway, OECD Reviews of Evaluation and Assessment in Education, retrieved from https://www.oecd.org/**norway**/48632032.pdf

year *Assessment for Learning* programme (ibid p.130). This programme/initiative started in 2010 and has been extended until now[34]. It is targeted at lower secondary schools in Norway. Research reports, surveys and feedback from participants show that (ibid):

- The systematic work with assessment of pupils and apprentices leads to better understanding of curricula and competency goals.
- Several schools and school owners have developed a common assessment culture, so that assessment is no longer an individual responsibility of the individual teacher.
- The participant schools of this initiative show greater motivation/ driving force in developing good assessment practices and working locally with curricula than schools who have not participated.
- The pupils have better knowledge of the (learning) objectives and evaluation criteria than before.

There are still challenges. Several reports, including research on individual assessment in school (Sandvik & Buland, 2014)[35], show that there are some major variations in practice between schools and school types, and also internally within each school. The gap seems to increase between the teachers and schools that have good formative assessment practices, including peer-assessment, and those who do not give students the same opportunities. It is also evident that "general pedagogy has been emphasized to a greater extent than subject-related and didactical approaches to assessment" (ibid, p. 16).

In **South Africa** the policy on formative assessment can be found in Annual National Assessment (ANA)[36], The Curriculum and Assessment Policy Statements (CAPS)[37] and in the National Protocol for Assessment Grades R-12[38]. The ANAs report from 2013 states that "the evidence in this report must be built into normal teaching programmes and also be used to inform specific interventions to improve the levels and quality of learner performance in schools" (p.7). The report also addresses teachers' professional learning in terms of providing tools to map teachers' specific need for support. The CAPS documents emphasise that formative assessment is assessment for learning, that it is mainly informal and that learners should be given constant feedback regarding their learning processes. Self-assessment and peer-assessment are two of the means of implementing formative assessment referred to in CAPS. The National Protocol for Assessment Grades R-12 sets guidelines for formal and informal assessments in the classroom. It aims at providing guidance for "an indication of learner achievement in the most effective and efficient manner" (p. 3). Assessment for learning, also referred to as informal, daily assessment, is encouraged as a tool for increasing learners' progress though emphasis is largely placed on the use of formal assessments to provide teachers with a "systematic way of evaluating how well learners are progressing" (p. 4).

Teachers may use aspects of formative assessment in their day-to-day teaching but there is little evidence on the ground that the teaching and learning strategies are used explicitly in the classroom as tools for identifying where learners are at, where they need to be and the steps they need to take for progress to be made. The FaSMEd team's experience with teachers at AIMSSEC is that little is known or understood about progression in learning with much emphasis placed on curriculum coverage and pace setting in the classroom. This emphasis may be necessary for different reasons as

[34] http://www.udir.no/laring-og-trivsel/vurdering/nasjonal-satsing/om-satsingen/

[35] Sandvik, L. V., & Buland, T. (Ed.) (2014). *Vurdering i skolen. Utvikling av kompetanse i fellesskap*. Trondheim: NTNU PLU og SINTEF Teknologi og samfunn.

[36] http://www.education.gov.za/Curriculum/AnnualNationalAssessment.aspx

[37] http://www.education.gov.za/Curriculum/CurriculumAssessmentPolicyStatements(CAPS).aspx

[38] http://www.education.gov.za/Portals/0/CD/Curriculum%20doc%20question%20Papers2007/NSC%202012%20Tshivenda%20SAL%20P1%20Nov%202012%20Memo%20Limpopo.pdf?ver=2013-02-25-104256-000

indicated by the 2011 National School Effectiveness Study[39] i.e. the average number of curriculum topic areas covered in the best learners' workbooks ranges from 11.8% to 34.5% in the provinces. This corresponds to research (e.g. Mkhwanazi, 2011[40]; Khosi, 2009[41]; Mantsose 2012[42]) that has shown that teacher knowledge of what formative assessment is, and how they can use it in their practice, is variable. Many teachers do not understand how to use assessment to inform their planning and do not provide constructive feedback for their learners. Khosi (2009) further points out that even when teachers know how to use assessment in formative ways, large class sizes mitigate against its effective use. This emphasizes the point made in the answer to question 2.

Cross country summary

In France and Italy there are no *national* initiatives that explicitly concern or mention formative assessment (FA), but rather descriptions of good teaching practices that share the same characteristics with FA. Italy has two projects though, in which FA is promoted, one is regional (for school self-evaluation) and the other is an EU-project on FA in mathematics education; these projects are not at national level.

In some other countries, i.e. England, Germany, Norway, Ireland and South Africa we find indications of strong policy support for formative assessment practices. There are variations though in the way this support is visible: In Germany for instance, FA is mainly addressed in teacher training (initial and in-service) by citing explicitly competency goals in assessment and evaluation. In both England and Norway there have been initiatives in terms of providing teachers and schools with a wide range of tools and guidance. In Norway formative assessment is highly prioritized and the initiative also includes a long-term school-based professional development project, not only for teachers but also school leaders and school owners, in order to build a long lasting assessment culture. A national framework for assessment and evaluation with both formative and summative elements has been established. In South Africa formative assessment or aspects of it are made explicit in official documents, such as ANA's report, the CAPS and in the National Protocol for Assessment Grades R-12. In these documents FA is referred to as informal, day-to-day assessment.

In the Netherlands, there is a strong culture for summative assessment. Formative assessment in the form of diagnostic tests was proposed, but is not mandatory. And there is no report on eventual use of this test in informing further teaching plans. There are however, recent studies pointing at the importance of formative assessment. Compared to France and Italy, the Netherlands appears to have a stronger policy support for summative assessment.

When it comes to classroom practices, Norway, South Africa and England report large variations in how, to what extent or how effective formative assessment has been integrated into day-to-day

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[39] Taylor, N. (2011). The National School Effectiveness Study (NSES). Retrieved from http://www.poa.gov.za/education/Supporting%20Documentation/The%20National%20School%20Effectiveness%20Study.pdf

[40] Mkhwanazi, H.N. (2011). Teachers' use of formative assessment in the teaching of reading comprehension to grade 3 learners. Retrieved from https://fasmedaimssec.files.wordpress.com/2014/06/research-paper-hn-mkhwanazi-a.pdf

[41] Khosi, N.T. (2009). Formative Assessment in Grade 8 in Mathematics: Teachers' Perception and Implementation. Retrieved from https://fasmedaimssec.files.wordpress.com/2014/06/ngwenya_thembayena_khosi_2009.pdf

[42] Mantsose, J.S. (2012). An Investigation of the Challenges Affecting Teachers' Classroom Assessment Practices. Retrieved from http://uir.unisa.ac.za/bitstream/handle/10500/8128/thesis_sethusha_mj.pdf?sequence=1

teaching practice. There is concern that teachers still «do not know how to use assessment to inform their planning» (South Africa), do not apply the principles of formative assessment «in ways that enabled pupils to become autonomous learner» (England) or in how much assessment culture is established in school, inclusive peer-assessment practices (Norway). It is also evident that formative assessment initiatives are often considered as a general pedagogical tool. The necessary adaptation of formative assessment practices in the different school subjects is thus left to the individual teachers, making practices vary considerably. Also in schools or districts where formative assessment is a prioritised project, there does not seem to be enough knowledge about how to implement it in mathematics and science.

Initiatives linking formative assessment and technology

This section looks at initiatives in the different FaSMEd partner countries that links formative assessment and the use of technology.

In **England**, there are commercial and academic initiatives that are attempting to link formative assessment with technology. The commercial ones are for example, Promethean's Classflow, Socrative; Plickers; Reflector; and SMART Kapp iQ. These mainly involve the functionalities of sending, sharing and processing data with and from learners. The academic initiative is for instance *Formative Assessment with Computational Technologies* (FACT)[43] project. This project is based at Arizona State University, in partnership with UC Berkeley and The University of Nottingham, with funding from the Bill and Melinda Gates Foundation. The project aims to address the challenge of producing fully computer-based versions of the Classroom Challenges (developed for the earlier Mathematics Assessment Project) without diluting their pedagogical values. Ultimately, it is intended that the computer will analyse students' work and respond with formative feedback and probing questions – or at least guide and support the teacher in doing so. FACT will develop two main software components: The Media System and The Analysis System.

The Media System aims to provide a 'natural medium' for students to work on rich tasks and collaborative activities, without constraining their ability to freely choose which mathematical tools and techniques to apply. It will also implement proven collaborative activities from the paper material, such as group card matching and poster making activities. The current plan is to use tablet computers to create a 'canvas' on which the student can freely write and draw, assisted by various mathematical tools.

The Analysis System will support teachers in analysing their students' work and deciding how and when to respond with formative feedback. Rather than traditional right/wrong scoring, this involves identifying work that embodies common misconceptions or weaknesses, and formulating probing questions to help students improve their understanding or seek more elegant solutions.

In **France** there are no initiatives (apart from FaSMEd) that attempts to link formative assessment with technology.

In **Germany** an attempt to link FA with technology is done within an E-learning strategy of the University of Duisburg-Essen in teacher education that serves as a model for school education: The E-learning tools used at UDE are moodle, LPLUS, JACK, Mathara, DuEPublico, PINGO, Adobe Connect, Blogs and Wikis. These tools are used in several courses at DUE with university students.

[43] http://fact.engineering.asu.edu/

In **Ireland**, there are no initiatives (apart from FaSMEd) that attempts to link formative assessment with technology.

As far as the **Italian** FaSMEd team knows, there are no other initiatives or projects in Italy, which attempt to link FA and technology.

In the **Netherlands**, FA is investigated within a number of projects targeting ICT and learning, for example *ICT for Algebra*[44] (ICT for the acquisition and assessment of transfer-relevant mathematics skills).

In **Norway,** NKVS provides a range of assessment tools, including diagnostic mapping tests and national tests, most conducted digitally. The results can be downloaded through the "School Portal", a web-based information tool presenting information from the national tests and basic school data about enrolment, resources and completion rate. The School Portal comprises an open part (for general public) and a password-protected part where schools and school owner can access their own data[45]. In Norway teachers hold the key responsibility for student assessment at all levels of the school system. Although the data from diagnostic mapping is mainly intended to identify pupils who need extra help or adapted teaching (ibid), teachers are encouraged to use the data to inform their teaching of other pupils as well (not only those who need special/ adapted teaching). Similarly, results from national tests shall give the teacher a better starting point for adapting the teaching to individual pupils and planning tempo, methods and contents. In addition to assessment tools provided by NKVS, digital diagnostic tests in mathematics are available from the Norwegian Centre for Mathematics Education, e.g. Alle teller and LiM[46]. Besides, most schools use online learning management systems, such as It's learning or Fronter, which contain a built-in option for running digital tests with immediate feedback for students, though they are not primarily designed for FA.

In **South Africa**, in 2015, the Zenex Foundation produced a landscape review of mathematics interventions in South Africa, mainly of current projects. The introduction to this report stated that:

'There are a plethora of mathematics related interventions in South Africa which share a common 'hoped for' output of improving school-level mathematics teaching and learning.' (p. 1)

The list below provides some examples of interventions that have some focus on FA or diagnostic assessment and which use technology, in the context of mathematics education. They do not necessarily attempt to link FA with technology: *Bottom Up: Numeracy Project* (2014 to 2015), *CASME: Inkanyezi Project* (2009 to 2016), *E-classroom* (2013 to 2015), *Green shoots* (various projects, starting and ending at different times), *LEAP Schools* (six schools, on-going) and *OLICO*.

The *Bottom Up: Numeracy Project*'s model is based on the following beliefs, as stated by them: a) Mathematics is a skill, b) Practice is essential in skill development c) Technology creates a platform for practice with immediate feedback d) Technology also creates data and knowledge for further intervention through skilled facilitators and e) Providing the opportunity for computer based training that is guided by trained staff will ultimately create more meaningful maths practice which inevitably results in better student performance.

The CASME project states that '… To facilitate the change for learners to excel in schools through higher education, we design teacher professional development programs that seek to drive teacher change.'

44 http://www.fisme.science.uu.nl/wiki/index.php/ICT_voor_het_verwerven_en_toetsen_van_doorstroomrelevante_wiskundige_vaardigheden

45 https://www.oecd.org/**norway**/48632032.pdf p. 25

46 http://www.matematikksenteret.no/content/541/Vurdering-og-kartlegging

The focus of the programme is on the use of diagnostic assessment, and a range of digital technologies is used (e.g. Khan Academy, GeoGebra).

The E-classroom initiative is an interactive platform offering maths and science test papers with mock exams and real time results. It was created to assist the learner and is available against a nominal fee. “The tests are interactive and responsive, allowing learners to input their answers, measure their response time to questions and receive their results on completion. It is an invaluable revision and study tool” and more subjects will be added into the platform.

Green shoots provides ’A structured online curriculum … that covers the full CAPS curriculum at the correct level, pace and full range of activities.’ They explain: ‘Through per-child-login there is immediate feedback on results and the per child/class summaries provide curriculum accountability for both teachers, SMT & District officials. Immediate feedback back leads to speedy and on-going diagnosis of learning barriers. Assessment for learning becomes a reality for teachers. The real-time feedback also leads to increase learner enthusiasm, engagement and ownership.’

The LEAP schools ‘provide student-centred, maths and science-focused education to promising students from grades 8 to 12.’ They use diagnostic and summative tests and online assessments pilot with Eduflex. They say ‘Intervention resources include work with Papervideo (online, paper, dvd), Rethink Education’.

OLICO provides academic support to township school youth through computer-based and tutor-led after school initiatives. It conducts diagnostic tests with learners each year and on-going summative assessment (which are also used for diagnosis and remediation) throughout the year. As part of this offering, OLICO has developed an extensive (and growing) range of open-source mathematics resources primarily focused at building number sense at the Senior Phase level to create a pathway into high school mathematics. Currently, OLICO’s custom-built eLearning tool contains over 11,000 interactive online maths questions; more than 210 explanation videos; and a range of support materials tailored to the South African context.

Cross country summary

In France, Ireland and Italy there are no initiatives or projects apart from FaSMEd that attempt to link formative assessment with technology.

In Germany, the Netherlands and partly Norway, the attempts to link formative assessment with technology is implicitly incorporated within the use of technology to support learning, such as e-learning strategies, a model for school education involving the use of a variety of tools (DUE, Germany), ICT for learning a specific topic like algebra (the Netherlands) or exploitation of learning management systems (Norway).

England in particular mentions a large range of commercial and academic initiatives for formative assessment by using digital technology. These involve systems having the functionalities of sending, sharing and processing data with and from learners, computer assisted analysis of student work and giving immediate feedback. Projects focused on formative assessment using digital tools with similar functionalities exist in South Africa and Norway, mostly in mathematics, providing teacher professional development or guide, as well as a variety of materials for teachers’ or learners’ use. In addition, the Norwegian national tests are run digitally, and the results should inform teachers for adapting their future teaching practices to learners’ need.

It is apparent that there are few, if any, initiatives in the partner countries that seek to implement formative assessment practices with the use of or linking to technology. The FaSMEd project thus has an important part to play along several dimensions. It is necessary to provide research based evidence on how to best use ICT and available technological tools in formative assessment. It is also necessary to provide research evidence on how to use formative assessment in mathematics and science. It is evident that the FaSMEd project is unique on the European scene in combining these important aspects.

FaSMEd and national initiatives on formative assessment

In this section we describe how the FaSMEd project in the partner countries and results from the case studies are related to the national initiatives and the practices in the countries concerning formative assessment.

In **England**, for mathematics, the tasks and lessons used in the FaSMEd project are based on the approaches to formative assessment developed in the Mathematics Assessment Project (MAP). This project focused on the production of lessons referred to as the Classroom Challenges. These are formative assessment lessons embodying formative assessment and collaborative learning. In FaSMEd, apart from using the same approaches, several of the MAP lessons were adapted for use with technology in different ways. We have used the MAP activities with technology.

Further, the Newcastle Jessica case study gives evidence of FA strategy B. She used Reflector and an ipad to enable the students to project their work on the interactive whiteboard using technology for 'sending and sharing' and for FA strategy D. (P.10). Within the Newcastle Thomas case study, Thomas also included the opportunity for students to respond to a multichoice quiz using the Plickers system which provided a useful way for him and the students to review the data they had used to devise their answers to the task. Thomas used this opportunity to confirm which was the correct data and to ask the students for the methods they had used to collect it (always tally charts). At the end of the lesson Thomas distributed iPads and used them for a Socrative quiz that sent out the questions provided by the resource materials. However, there was insufficient time left for the students to respond effectively and Thomas repeated the quiz at the start of the following lesson. (p.6)

In **France**, the FaSMEd project gives clues for strategies linking FA and digital technologies.

In Germany, the mathematics German Case Study "Can I sketch a graph based on a given situation?" is in line with initiatives and policies concerning FA in the matter that:

- The design of the tool is in line with the request for more assessments & individual fostering as well as the integration of all students: the tool's features ensuring an individual learning path are: the check-list, the hyperlink structure and the fostering units containing information as well as practice tasks, the extend task.
- The teacher interview showed that the teacher's focus in his assessment practice shifted from a summative approach to a formative one through the work in the FaSMEd project. He focused more on his students' understanding when creating exams and gave each student individual feedback to move their learning process forward.
- The analysis of the student interviews showed that it is possible to identify FA processes in the students' work with the digital tool.

The German Case Study in science "Who has the juiciest apple?" is in line with initiatives and policies concerning FA in the matter that:

- The design of the tool is in line with the request for more assessments & individual fostering as well as the integration of all students: the tool's features ensuring an individual learning path are: the overview guide, the hyperlink structure, the definition cards as well as the good to know cards (examples, hints, explanations).
- The student interviews and q-sorting showed that the students felt personally attached to the individual task and therefore focused more on their personal conceptions.

In **Ireland**, the framework for Junior Cycle promotes the practice of formative assessment in the classroom to monitor student understanding and to increase student learning during lessons. Both maths and science case studies emphasised the practice of formative assessment during classroom practice and professional development was adapted to suit the needs of Irish teachers teaching mathematics and science at Junior Level. At present the National Council for Curriculum and Assessment and the Department of Education and Skills are emphasising the importance of formative assessment strategies at Junior Cycle level such as co-operative group work, higher order questioning, and self and peer assessment, with the publication of a number of documents for teachers outlining how to implement these practices into classes. These aspects of formative assessment were explored within both the mathematics science case studies and the case studies demonstrate evidence that these strategies helped to improve student learning.

In **Italy**, the approach adopted during the FaSMEd teaching experiments is in line with the national guidelines because of:

- the stress on argumentative processes to enable students to share and compare their reasoning;
- the focus on both cognitive and metacognitive aspects to enable them to become aware of their ways of learning and on the effective strategies to overcome their difficulties;
- the enhancement of the social dimension of learning, making students work in pairs or small groups and develop fruitful class discussions led by the teacher.

Referring to the AVIMES project, FaSMEd shares with it the criteria to analyse the argumentations produced by students. During the collective discussions for the comparisons of students answer, in fact, the Italian FaSMEd team make students discuss about the correctness, the clearness and the completeness of their answers.

Further, the FaSMEd project to the FAMT&L project share a similar objective as regards the preparation of teachers: both the projects, in fact, focus on constructing material and tools to provide teachers with a proper support for developing FA practices in their classes. The main peculiarity of the FaSMEd approach, compared to Italian projects and initiatives, is FaSMEd's focus on the use of digital technologies as a support for developing all the FA strategies at different levels.

In the **Netherlands**, the FaSMEd team have made use of the knowledge and experience gathered in these and other projects, but the Dutch FaSMEd project does not use tools from previous projects – they have developed those within the FaSMEd project.

In **Norway,** the FaSMEd team has worked with both mathematics and science case studies. Both Norwegian case studies are aligned with the overall national policy of promoting formative assessment. Although some of the national tests and diagnostic mapping tests provided by NKVS and the Norwegian Center for Mathematics Education are digitally driven, they, unlike FaSMEd, do not explicitly connect formative assessment with technology, nor do they focus on the use of technology to raise attainment of lower achievers. In the mathematics FaSMEd case study, the use of digital tools for the "walk-a-graph" lesson made mathematical concepts more accessible and concrete to lower achievers and helped them in better interpreting distance-time-graphs, thanks to the interactive features involving built-in diagnostic tasks and immediate feedback. In the science case study, the use of Student-Response-System technology combined with interactive board allowed sending-and-sharing formative assessment strategies that the teachers used to inform further steps. In terms of teacher professional development, the FaSMEd project conducted by the Norwegian team is in line with the national policy of increasing teachers' competency in implementing formative assessment in classroom practices, cf. the Assessment for Learning project. The difference between FaSMEd and the Assessment for Learning project is that the latter focuses more generally on formative assessment, not explicitly on the connection between FA and technology, and also not on FA in mathematics or science in particular.

In **South Africa** whereas most of the projects mentioned above use formative assessment, they do not take formative assessment as their primary focus. Generally they aim to improve teaching and learning in mathematics, and formative assessment is a one of the mechanisms through which they do so. FaSMEd, however, focuses on developing resources to support the use of formative assessment in mathematics.

Cross country summary

Ireland, Italy and Norway report the alignment of the FaSMEd project with the overall policy concerning formative assessment, both in teacher professional learning policy (Norway) and classroom practice (Ireland, Italy, Norway). England, Italy, Norway, the Netherlands and South Africa report on comparison between FaSMEd and other projects, and all of them point out the uniqueness of the FaSMEd project in terms of explicitly connecting formative assessment with digital technology (ICT) or connect lower achievers with ICT (Norway). The FaSMEd project has given France insights on linking formative assessment and ICT strategically.

It is evident that FaSMEd provides unique opportunities to link formative assessment with technology in the mathematics and science classrooms. FaSMEd provides research based evidence on how to best use ICT and available technological tools in formative assessment. Additionally, FaSMEd also researches into the use formative assessment in the mathematics and science classrooms in particular, and provides evidence on practices that combine these aspects in the search for raising achievement and motivation for all learners, and lower achievers in particular.

4. Lower achievers

National initiatives concerning lower achievers

In this section national initiatives in the FaSMEd partner countries concerning lower achievers will be described. This includes national policy documents, national guidelines, school/classroom research initiatives, curriculum and textbooks for compulsory school and/or teacher pre- and in-service education.

In **England** there have been a wide range of initiatives in mathematics and science education prompted by concern about attainment, numbers of STEM graduates and low levels of numeracy in the population. The *Numeracy and Literacy Strategy* (1997, in primary schools, later expanded to secondary schools), and *Assessment for Learning* (2008) are two such initiatives. The influential *Roberts Report* and The Smith Report *Making Mathematics Count* led to further STEM initiatives, like funding of science centres across England and founding of *NCETM* (National Centre for Excellence in Teaching Mathematics) in 2004. *STEMNET* helps encourage young people to be well informed about STEM, able to engage fully in debate, and make decisions about STEM-related issues. In mathematics, there have been a series of funded projects focused on raising attainment. The first was *LAMP* (Low attainers in mathematics project 1983-1986) then *RAMP* (raising attainment in mathematics project), and *IAMP* (Improving attainment in mathematics project) was also focused on low attaining students. A later influential project: *Improving Learning in Mathematics* (ILM) was focused on post 16 learners. *The Standards Unit: Improving Learning in Mathematics* resources were produced as a response to the Smith report. The materials use active learning approaches originally designed for post-16 mathematics but for use across the secondary phase. The *Millennium Mathematics Project* (MMP) is a mathematics education and outreach initiative for ages 3 to 19 and the general public. The focus is on increasing mathematical understanding, confidence and enjoyment, enriching everyone's experience of mathematics, and promoting creative and imaginative approaches to maths. A particularly successful intervention in both mathematics and science, which had a strong theoretical basis was *CASE* and *CAME* (Cognitive Acceleration in Science/Mathematics). These interventions were among the relatively few projects that could demonstrate a significant impact on the attainment of the learners who participated. *Every Child Counts* (ECC) helps schools to raise achievement in mathematics through support for children who find mathematics difficult. *National Numeracy* is an independent charity that focuses on adults and children with low levels of numeracy.

In **France** there is no official national definition of low achievement. Detecting low achievement in any subject includes using the results of the national tests in French and mathematics (primary years 2 and 5) and the portfolio designed for assessing the competences of the *Socle commun*. Introduced by law in 2005 and implemented starting from 2010, the *Socle commun* is the body of knowledge, skills, values and attitudes that every student must acquire at the end of compulsory education. There are two national tests to measure student achievement, where one of the main objectives is to detect problems and identifying possible remedial strategies. Remedial paths can then be proposed to students. There are not any national policy strategies mainly focusing on raising achievement for low achieving students, but there are some local initiatives in both mathematics and science.

In **Germany** PISA, TIMSS and IGLU results were considered to be alarmingly low and resulted in national educational standards that changed the system from being input oriented to focusing on output. There are different ways of defining low achievement by researchers. There are a number of initiatives concerning lower achievers: *Mathe sicher können* is aimed at developing lesson structures, concepts and materials for low achieving students in mathematics in grades 3-7. The *SINUS* program has two modules that are particularly relevant: "gaining basic knowledge" and "progress of competencies". *Co²CA* focuses on how to support learners in reducing the gap beween their current proficiency level and the learning goals by studying performance tests and feedback (see D2.1 p.29 for more details). There are also other initiatives or projects, like *KOSIMA* (mathematics), *Biologie, Chemie, Physik im Kontext* (science), *DZLM* (mathematics), *T³* (maths and science), *MintEC* (maths and science), *Ganz In* (maths and science).

Ireland identifies lower achievers through teacher designed class tests and standardised tests. At primary level, the standardised test students take part in is the *Drumcondra Primary Mathematics Test-Revised* (DPMT-R). Students at primary level may also complete the *SIGMA-T* series of mathematics attainments tests. At post-primary level the formative and summative *Junior cycle assessment* is currently replacing the earlier Junior certificate examination. The PISA 2009 report resulted in a national strategy called *Literacy and Numeracy for Learning and Life: The National Strategy to Improve Literacy and Numeracy among Children and Young People 2011-2020*, which is the Irish national strategy to improve literacy and numeracy standards among children and young people in the education system. Other projects include *Project Maths*, *Discover sensors*, *Teaching and learning for the 21st century*.

In the last 15 years specific laws has governed the identification of proper trajectories for lower achievers in **Italy**. For primary and lower secondary schools, POF (*Piano dell'offerta formative*, Plan of formative offer) provides activities aimed to fully guarantee the right to inclusion, education, training and achievement. The schools are required to organize these activities autonomously. Each school has the opportunity to devote up to 20% of curriculum time to specific projects, among them "increasing tuition time in specific knowledge domains in favour of underachievers" and "designing remedial courses". The remedial courses are part of the POF activities and must be planned according to the results of the periodical students' assessment. The Italian PISA scores resulted in a ministerial directive in 2007 specifying recovery interventions in lower secondary school. The directive suggests that schools should plan diversified models of intervention, according to students' specific formative needs, privileging the organisation of group activities for the students, subdivided according to their level. Also in 2007, a ministerial ordinance was designed to help and support upper secondary school underachievers, amongst other specifying that remedial courses must be carried out. The National Plan for Quality and Merit (PQM PON) is a program designed to raise students' achievement both by providing lower secondary schools teachers of Italian and Mathematics with training 'on the job' and by organizing remedial and extra classes outside the normal scheduled activities for students. The program worked both by increasing the number of hours of schooling and by involving teachers in training processes aimed at providing them with innovative teaching materials. Another Italian project is PON SOS-studenti, which is aimed at fostering the constitution of an e-learning environment designed to help especially low-achieving upper secondary students in mathematics, Italian, physics, and English. The research project FENIX is aimed at promoting scholastic readiness in infant schools and linguistics, logics and mathematics skills in primary school and junior high school (so the range of ages is between 5 and 12/13 years) through the development and the experimentation of innovative didactical settings that significantly employ digital technologies.

The Netherlands has no detailed national curriculum for primary school, but core goals are established for the main subjects. There are monitoring systems, which is CITO. Some diagnostic tests are available. Teachers are expected to adopt and differentiate their teaching to student needs. In some schools there may be local initiatives, like reducing the class size or remedial teachers who give extra help outside the classroom. There are several national initiatives for lower achievers, e.g. *Passende Perspectieven*, and others include *Speciaal Rekenen*, *Mathchild, Language-based support in Mathematics Education, Impulse*, *Every child deserves differentiated (special) math education, Differentiation in mathematics classrooms in vocational education, Mathematical thinking in practice*.

In **Norway** there is no official definition for the term "lower achiever". All students have the right to "*tilpasset opplæring*" (differentiated learning, education adapted to their abilities and needs). Pupils who do not have, or are unable to benefit satisfactorily from ordinary tuition have the right to special education. Teachers or parents can ask for an assessment to see if the pupil would have the right to special education. Before a decision concerning special education or a decision concerning special educational assistance is made, an expert assessment has to be made of the pupil's specific needs. This assessment shall determine whether the pupil needs special education, and what kind of instruction should be provided. In mathematics there are national tests with the purpose to identify pupils who may need further assessment at Years 1, 2 and 3. The test at Year 2 is mandatory. In addition there are several different materials and tests that teachers may use to survey their pupils to see if anyone are in need of further investigations. So far, there are no national tests in science.

Since 2012 there have been trials with "utvalgsprøver/karakterstøttende prøver" in science at year 10. Following the PISA and TIMSS results numerous national initiatives to enhance the mathematics and science competence of pupils at all school levels have been launched. Several government documents and white papers that address pupils' achievement in school have been issued[47], e.g. *Meld. St. 22 (2010 – 2011) Motivasjon – Mestring – Muligheter*; *Meld. St. 18 (2010-2011) Learning together*; *NOU 2010:7 Mangfold og mestring*; *NOU 2009: 18 Rett til læring*; *Science for the future: Strategy for Strengthening Mathematics, Science and Technology (MST) 2010–2014*. An important government paper stresses the Norwegian model for education, *Meld. St. 20 (2012–2013) På rett vei*. Here it is said that "securing good education for all is a key factor in counteracting social inequality and creating a more just society." Further, it is emphasized that the Norwegian one-school-for all (*enhetsskolen*) is an important principle that still has to be given priority. Students are normally not to be divided into classes or groups based on their level, gender or ethnicity. Everybody shall receive a satisfactory result by taking part in the common school, where teaching shall be inclusive. In the new government paper *Meld. St. 28 (2015–2016) Fag – Fordypning – Forståelse — En fornyelse av Kunnskapsløftet* the importance of deep learning with understanding is emphasized. The school system has to contribute to young peoples' development in such ways that everybody has the chance to exploit their talents and interests, regardless of their background, it is said. A new government strategy *Tett på realfag - Nasjonal strategi for realfag i barnehagen og grunnopplæringen (2015-2019)*, has four overarching goals: 1) To enhance all students' competences in mathematics and science, 2) Reducing the number of low performing students in mathematics and science, 3) Increasing the number of high achieving students in mathematics and science, 4) Increasing teachers' competences in mathematics and science. There are national initiatives that have been created, with the aim of engaging young people in science and mathematics, in the hope that pupils' achievement and understanding will improve: *FYR, Lektor 2, Rollemodell, IRIS, ROSE, Vilje-con-valg, Forskerføtter og leserøtter*.

In **South Africa** there are many non-governmental organisations and institutes working at local level to address low achievement in mathematics. These initiatives include extra classes for students and PD for teachers. The Curriculum and Assessment Policy Statements (CAPS) addresses what is seen as one of the major concerns in South African schools, viz. that many teachers omit large parts of the curriculum. CAPS specify what topics need to be covered each term and how much time is to be spent on each topic. One consequence of this is that teachers are required to move on from topic to topic week by week whether the learners understand the concepts or not. Textbooks are assessed before publication and only those deemed "CAPS aligned" are published. These textbooks all specify what need to be taught each week. In school, main challenges are large classes (>50) and language of instruction that differs from the students' mother tongue, and teachers' subject knowledge in mathematics is also often found to be lacking.

Further details on the situation in each partner country may be found in the FaSMEd deliverable D2.1.

Cross country summary

It is apparent that in many countries, results at international tests like TIMSS and PISA raised concern about student achievement. Countries like Germany, Ireland, Italy, Norway and England all report that their scores on international tests resulted in government initiatives to prioritize the development of curricula and materials to try to remedy the situation. In England it is the case that there has been concerns regarding both achievement in and motivation to pursue studies in mathematics or science. In Germany, national educational standards were set up. In Ireland the national strategy *Literacy and*

[47] All available at https://www.regjeringen.no/no/dep/kd/

Numeracy for Learning and Life was launched as a result of PISA. In Italy PISA resulted in a ministerial directive, and in Norway the national curriculum was revised as a direct result of what was considered poor results. In South Africa the problems addressed are of a somewhat different nature, with emphasis given to identifying low achieving schools rather than individual students and priority given to developing curriculum plans and textbooks.

Government funding for mathematics and science educational initiatives has been relatively generous, as e.g. reported by England and Norway. Initiatives to raise achievement and motivation for mathematics and science for all students are common across the partner countries. It differs between countries how much focus is put on raising low achievers. In France there are national tests to measure achievement, but as yet no government initiative or strategy focusing on lower achievers in particular, even if there are local initiatives. Other countries have launched projects or strategies aimed at raising the lower achieving students, like Germany (e.g. Mathe sicher können, SINUS), Italy (e.g. PQM PON, FENIX), England (e.g. ECC), Norway (e.g. NOU 2009: 18 Rett til læring).

The school system differs highly across the partner countries. In countries like Germany and the Netherlands, students are divided into three strands according to abilities and results on standardised tests at the end of primary school. In Norway, on the other hand, the focus is on the 'one school for all' concept, keeping students together in the same classes across achievement level the first 10 years at school, until they are 16 years old. In South Africa classes may comprise more than 50 students, and the instructional language is often not the students' native language. The term "low achiever" is therefore somewhat problematic to use across countries. We refer to D2.1 for further details on this.

FaSMEd and the national initiatives on low achievement

In this section we describe how the FaSMEd project in the partner countries and results from the case studies are related to the national initiatives and the practices in the countries concerning low achievement.

The **England** cases concerns only mathematics. The FaSMEd approach in Newcastle aligns well with the critique of approach produced by Ofsted (Made to Measure, 2012) and with the aims of the national curriculum. However, schools are also subject to pressure to demonstrate progress for all pupils measured by national tests and teachers' practice is inevitably shaped by this pressure to ensure that pupils achieve exam success, sometimes to the detriment of mathematical understanding. Thus teachers were taking a risk in adopting an approach which preserved the complexity of mathematical concepts, relying on the increased opportunities for feedback and assessment provided by the FaSMEd materials and technology. The case studies demonstrate the extent to which exceptional teachers, who were prepared to risk some change, worked with the FaSMEd materials and tools.

Newcastle Case study 1: Jessica was working with a class of Year 7 students (11-12 years old) during the FaSMEd project. There were 23 in the class made up of 10 males and 13 females. The year group at this time was split into 5 sets for mathematics (1= high ability, 5=students with behavioural issues) and this class was set 3. Also in the class were one student with ADHD (attention deficit hyperactivity disorder) and one with literacy problems. Jessica said she was extremely pleased with the potential that the interactive whiteboard and ipads offered. The facility to project and annotate both her own and the students' work means that she and they are able to 'talk through certain aspects' of the maths that are important.

Newcastle Case study 2 Thomas: The students who took part in the FaSMEd lessons were a low ability (Set 5) Year 7 class (aged 11-12 years). Having recently moved up from Primary School, the class were still 'very dependent on the teacher' and working independently and even quietly was 'quite a challenge' (teacher interview 2 appendix C). The teachers expressed the view that it is important to have a balance of technology use within a lesson and not create the expectation that tools like ipads will be used all of the time. It also needs to be beneficial to the students and not just a way to allow teachers to be more efficient with their time management. This was a sentiment agreed with by the students, who still valued the relationship with their teachers. This is very much in keeping with the views expressed by the teachers and students at case study school 1.

In **France**, the FaSMEd results regarding lower achievers are completely in phase with the national initiatives even if the question of assessment is often considered at a summative level more than a formative one. Processing and analysing results are left to local initiatives and in that sense the results given by the FaSMEd research can nurture them.

In **Germany**, the mathematics case study "Can I sketch a graph based on a given situation?" is in line with initiatives and policies concerning low achievement in the matter that: 1) The tool's design allows individual learning paths through the check-list and its hyperlink structure. 2) The teacher interview showed that the tool allows students to work in their own pace and engage in subareas of the content of functions that they have not mastered yet. The mathematics Case Study "Can I sketch a graph based on a given situation?" is not in line with initiatives and policies concerning low achievement in the matter that: a) The teacher interview showed that less-organised students have difficulties in understanding the tool's structure. b) The group student interview and q-sorting showed that students, who are not familiar with assessing themselves, have difficulties with giving themselves feedback rather than having the teacher or peers assess them. Therefore, it is harder for low achieving students to accept the responsibility for their own learning process, as they might be more insecure and sceptical towards their mathematical competencies. The German science Case Study "Who has the juiciest apple?" is in line with initiatives and policies concerning low achievement in the matter that: 1) The tool's design allows individual learning paths through hyperlink structure and allows students to work in their own pace. 2) The tool gives additional examples and definitions if needed.

In **Ireland**, national initiatives concerning lower achievers concentrate on providing additional support to a student with a special education need or learning difficult. Provisions are often put in place in the form of one-to-one support for the student, removal from class to be taught in a smaller group setting and the allocation of an extra class teacher for a period during the day to support the class teacher and to help students who may be having difficulties. There are however a number of strategies illustrated in the Irish FaSMEd case studies that help low achieving learners in a different yet also effective manner. In the science case study, the class teacher employed such formative assessment techniques as higher order questioning (p.15, p.22), feedback (p.15) and co-operative group structures (p.21) to keep low attaining learners engaged and motivated during science lessons. Similarly, in the mathematics case study the teacher employed mixed ability group work (p.16) to engage learners as well as utilising self-assessment to build self-efficacy in mathematics (p.12), making use of randomised questioning techniques (p.12) and getting students to use colloquial language to explain concepts to one another (p.21) was of great benefit to students, especially low achievers.

The projects and initiatives in **Italy** share with the FaSMEd project a focus on low achievers and on methods of increasing not only their cognitive abilities, but also metacognitive competences and their motivation. However, some specific peculiarities of the FaSMEd teaching experiments can also be highlighted: - while the initiatives described involve only some groups of students during extra classes (PON) or within individual remedial paths (SOS studenti and FENIX), the FaSMEd team chose to foster whole class activities, making low achievers interact with all their classmates; - while all the initiatives described devote extra classes, outside the normal scheduled activities for students, to remedial activities, we inserted all the FaSMEd activities within the regular school timetable, stressing the connection between these activities and the school curriculum.

In the **Netherlands** the FaSMEd team a) made use of the Cito Mathematics scores to monitor general mathematics achievement of the students, b) based the problems presented in the DAE on the national reference level 1S (the intended level at the end of primary school), and c) studied the availability of materials for formative assessment and added an approach not currently available using the DAE.

The FaSMEd project in **Norway** is well situated within the Norwegian one-school-for-all context even if one of our partner schools is an international school. The FaSMEd project emphasizes deep learning with understanding as compared to superficial drill and rote learning. This is now also emphasized as an important educational strategy, e.g. in the *Meld. St. 28 (2015–2016)* mentioned above. The new government strategy *Tett på realfag* is also in line with FaSMEd goals of increasing the motivation for mathematics and science in school at all levels. All in all it may be said that FaSMEd is in line with the new government papers and strategies, and also previous initiatives on formative assessment, priority on mathematics and science, and use of technology. It thus appears to be no systemic hindrances for working in ways that FaSMEd promotes. It is clear that FaSMEd provides ways to implement national strategies that otherwise may be lacking, e.g. the implementation of formative assessment at a subject specific level in mathematics and science, in contrast to a general pedagogic level that is less effective in raising achievement in these particular subjects.

In **South Africa**, the case study teachers were asked to choose a class for the research; it was not a requirement to use any particular ability or achievement level class. Two case study teachers chose to work with Grade 10 classes. These classes were made up of students who had chosen to take mathematics (rather than mathematical literacy) and science as matric subjects. Almost by definition, they would therefore tend to be relatively high achieving in these subjects. The third teacher chose to work with a 'top set' grade 8 class.

Cross country summary

In all countries the FaSMEd teams have found ways to work with mathematics and science teachers in ways that enrich the national initiatives and projects that were already in existence. At the same time, the FaSMEd teams have been contributing to new and innovative combinations of technology and formative assessment, and also on the use of technology in mathematics and science classrooms.

In both Ireland and Italy a distinguishing feature of FaSMEd is that the FaSMEd cases have been carried out in whole class settings where lower achievers have also taken part. This is different from the usual situation in these countries, where one-to-one support or teaching in smaller groups outside ordinary class hours is common for students who are having difficulties. The French FaSMEd project is deemed to be in line with existing initiatives, but FaSMEd contributes positively by shifting the focus of assessment from being summative towards being more formative. The Netherlands team have used the already existing Cito scores and national reference levels and at the same time added formative assessment approaches that were new. The Norwegian cases are well aligned with government policy and initiatives regarding formative assessment, use of technology and priority on maths and science. The combination of these aspects is however a distinguishing feature of the Norwegian FaSMEd case.

The German team points to features that put their cases in line with initiatives and policies concerning low achievement, and also features that are more problematic. Allowing for individual learning paths and letting students work at their own pace, making it possible to engage in subareas that interests them more or where they need more time to master, is considered positive features. More problematic features mentioned are that less-organised students have difficulties in understanding the structure of the used tools, and that students who are not familiar with assessing themselves, have difficulties with giving themselves feedback.

In the English case it has been difficult to recruit schools and teachers to work on the FaSMEd project because of the perceived risk involved in trying something ‘different’. Even some schools that joined in did not fully understand what the intentions of the project were and did not change their pedagogy. One school in England radically undermined the aims of the project with the result that very little was achieved and pupil response was highly negative.

In South Africa the case study teachers chose to work with relatively high achieving students, and so the results cannot point to any information about the lower achieving students. The South African cases may, however, still be relevant as interesting cases from an environment very different to the European cases.

Whereas the term “lower achiever” does not have a clear cut definition across countries, evidence from the partner case studies points at several important aspects on how motivation and achievement can be raised for all learners and those considered lowest achieving in particular. Using different types of technology is often seen as a motivating factor in itself by students. Technology like PCs, tablets or smartphones may contribute to quicker and better feedback from students to teachers, and thus puts the teacher in a better position as regards how to proceed in the classroom at large and also with individual students. It also provides students enhanced possibilities to collaborate and exchange ideas, giving peer-to-peer feedback and move forward in their learning in ways that would otherwise not take place. Use of technology in mathematics and science is still not very common in most classrooms. The ways that FaSMEd provides teachers and learners with pedagogical tools directed specifically towards these subjects, seems to be very beneficial in raising motivation and interest, in particular in raising motivation and interest among lower achievers.

Overall summary

It is clear that in all countries the international comparison surveys like TIMSS and PISA have had a substantial impact on educational policy and priorities in both mathematics and science. Scores at the international tests have been applied as arguments to increase time spent on these subjects in school, give priority to further education of mathematics and science teachers, and change the curriculum to align more with these tests. In countries like Germany, Ireland, Italy, Norway and England scores on international tests called for attention at the political level and concerns were raised over achievements that were not considered to be good enough. This resulted in several government initiatives to prioritize the development of curricula and materials to try to remedy the situation. In England there have been concerns regarding both achievement in and motivation to pursue studies in mathematics or science. In Germany, national educational standards were set up. In Ireland a national strategy was launched as a result of PISA. In Italy PISA resulted in a ministerial directive, and in Norway the national curriculum was revised as a direct result of what was considered poor results in PISA. In South Africa the problems addressed are of a somewhat different nature, with emphasis given to identifying low achieving schools rather than individual students and priority given to developing curriculum plans and textbooks. We acknowledge that a consequence of international tests like TIMSS and PISA is that there is high pressure on schools and teachers across all participating countries to demonstrate achievement, usually through success in national examination or test systems.

National tests and monitoring systems exist in all countries, and are often used to rank individual schools and districts in ways that may not be meaningful at the individual level or in the particular classroom. These types of tests are more often of a summative nature and are usually not readily applicable for the day-to-day teaching practices. It is necessary to consider formative types of assessment that are more suited to bringing students forward in their learning processes. A project like FaSMEd, which focuses on formative assessment to raise lower achievers, is thus an important contribution to developing assessment that focuses on learning rather than instant performance. It is believed that in the long run, formative assessment practices lead to more sustainable knowledge, which also will result in better performance and achievement.

Lower achievers raise particular challenges for schools and teachers in this context. The approach resorted to by many schools and teachers in response for working with such students are frequently characterised by a 'deficit' model of their potential which entails repeating material from earlier years, broken down into less and less challenging tasks, focused on areas of knowledge which they have previously failed and which involve step-by-step, simplified, procedural activities in trivial contexts. FaSMEd challenges this approach and works with teachers to adopt approaches which preserve the complexity of concepts and methods, rather than simplifying them.

Whereas the term "lower achiever" does not have a clear cut definition across countries, evidence from the partner case studies points at several important aspects on how motivation and achievement can be raised for all learners and those considered lowest achieving in particular. Using different types of technology is often seen as a motivating factor in itself by students. Technology like PCs, tablets or smartphones may contribute to quicker and better feedback from students to teachers, and thus puts the teacher in a better position as regards how to proceed in the classroom at large and with individual students. It also provides students enhanced possibilities to collaborate and exchange ideas, giving peer-to-peer feedback and move forward in their learning in ways that would otherwise not take place. Use of technology in mathematics and science is still not very common in most classrooms. The ways that FaSMEd provides teachers and learners with pedagogical tools directed specifically towards these subjects, seems to be very beneficial in raising motivation and interest, in particular in raising motivation and interest among lower achievers.

Use of technology is an integrated part of modern society and there is great potential for pedagogical use that aligns with inquiry based pedagogies that foster deep learning and motivates students. To meet this, it is important that national and international strategies are given sufficient support at the classroom level. Recommendation of the use of ICT and technology in general can be found in the national policy papers in partner countries, but when it comes to the classroom level, where implementation has to take place, the situation varies. Lack of appropriate resources is a substantial hindrance for the more widespread use of ICT in the mathematics and science classrooms. It is hard for schools to give priority to ICT hardware in a strained economic situation, and the lack of ICT infrastructure, such as access and quality of wi-fi, is an obstacle that prevents teachers from using such tools more widely. Appropriate software for meaningful use in the learning of mathematics and science is still scarce. Existing software is too often made without proper pedagogical insight and is too often aimed at endless repetition and root learning instead of contributing to developing conceptual understanding in an inquiry based pedagogical setting. It is well known that deductive teaching and root learning does not contribute to developing competences needed in the present day society, and more inquiry based pedagogies are recommended by several projects and reports, also at the EU level.

Linking technology and formative assessment is an important new feature of FaSMEd. It is apparent that there are few, if any, initiatives in the partner countries that seek to implement formative assessment practices with the use of or linking to technology. The use of ICT in mathematics and science classrooms is still not very common despite the huge potential of technological tools in these subjects. The FaSMEd partner experiences are that students and teachers alike find that the use of technology may contribute to the learning and understanding of mathematical and science topics in meaningful ways. Implementation of technological tools does, however, not come automatically and requires that the teachers stay up to date on available technology and its possible use in the classroom. Working closely with the FaSMEd team, whose members has experience and knowledge in both mathematics and/or science, of ICT and how to use ICT in the subjects, has been instrumental for the successful implementation of ICT in the partner countries' mathematics and science classrooms. It is also evident that formative assessment initiatives are often considered as a general pedagogical tool. The necessary adaptation of formative assessment practices in the different school subjects is thus left to the individual teachers, making practices vary considerably. Also in schools or districts where formative assessment is a prioritised project, there does not seem to be enough knowledge about how to implement it in mathematics and science.

FaSMEd has provided unique opportunities to link formative assessment with technology in the mathematics and science classrooms. FaSMEd provides research based evidence on how to best use ICT and available technological tools in formative assessment. Additionally, FaSMEd also researches into the use formative assessment in the mathematics and science classrooms in particular, and provides evidence on practices that combines these aspects in the search for raising achievement and motivation for all learners, and lower achievers in particular.

The FaSMEd project thus has had an important part to play along several dimensions, providing research based evidence on how to best use ICT and available technological tools in formative assessment, on how to best use ICT and available technological tools in mathematics and science classrooms, and also providing research evidence on how to use formative assessment in mathematics and science.

In all countries the FaSMEd teams have found ways to work with mathematics and science teachers in ways that enrich the national initiatives and projects that were already in existence. At the same time, the FaSMEd teams have been contributing to new and innovative combinations of technology and formative assessment, and also on the use of technology in mathematics and science classrooms. It can also be argued that where schools have joined the project and teachers have taken ownership of the project, they have inevitably shaped the activities to align with their own beliefs and attitudes as demonstrated by the case studies in the different partner countries. However, it is also the case that teachers' beliefs and attitudes have been challenged and changed by engagement with the project.

So as FaSMEd can be said to be well aligned with EU policies, it is at the same time at the forefront in the way that technology is used for formative assessment and in the mathematics and science classrooms.