Final toolkit
Deliverable D3.3

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FaSMEd: Improving progress for lower achievers through Formative Assessment in Science and Mathematics Education
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Deliverable D3.3 Final toolkit

Introduction

This deliverable sits within Work Package 3 – Design and production of the toolkit for teaching and assessment. This is the core of the project and involves the design and production of activities for teachers and students, together with guidance on approaches to teaching and assessment and the use of technology. This deliverable builds upon previous work: Deliverable D3.1 Prototype Toolkit[1] and D3.2 Evaluation of Toolkit[2].

The FaSMEd project aims to investigate technology-enhanced Formative Assessment (FA) practices in order to support teachers and raise student achievements in mathematics and science. As a result, the FaSMEd project has developed and finalised a toolkit that is being published as a website (www.fasmed.eu). This is most optimally viewed using Google Chrome.

As described in Deliverable D3.1 Prototype Toolkit, the toolkit is presented in English but contains information and tools in all of the partner languages, namely Dutch, English, French, German, Italian and Norwegian. Furthermore, links to country specific versions of the FaSMEd toolkit (French and Norwegian) are provided. The website is mainly addressed to teachers (except for the integrated professional development package, see 1.5 below), but is also meant for teacher trainers/educators, stakeholders and other interested parties across Europe and beyond.

1. Structure and description of the final toolkit

The final FaSMEd toolkit is organised in seven sections: *Home, How to use the Toolkit, Formative Assessment, Tools for Formative Assessment, Professional Development, Research* and *About*. These sections are presented in the top menu of the website (Figure 1) and are described in detail below.

Figure 1: Overview of the seven toolkit sections (top menu)

1.1 Home

The first section of the toolkit, called *Home*, introduces the main ideas of the FaSMEd project. It stresses FaSMEd as a European collaborative development project that combines FA practices with the investigation of the use of technologies in science and mathematics

[1] https://research.ncl.ac.uk/fasmed/deliverables/
[2] https://research.ncl.ac.uk/fasmed/deliverables/

classrooms. Besides presenting the name FaSMEd as an acronym for Raising Achievement through Formative Assessment in Science and Mathematics Education, the flags of all partner countries as well as some photographs of the project's work with teachers and in classrooms are shown. Furthermore, a short introduction summarizes the key aspects of the project. These can be experienced and understood in more depth by watching the FaSMEd film[3], which includes various discussions between researchers and teachers, scenes from FaSMEd project meetings, lessons, classroom discussions, the use of different technologies and tools as well as interviews. Finally, to make navigation easier for users, the *Home* page presents a table. It includes a short description of the toolkit and where to find classroom materials in each partner language (Figure 2).

Figure 2: Screenshot of the *Home* page

1.2 How to use the Toolkit

This section of the toolkit provides guidance on how to use the website. It shows a 'map' of the toolkit's sections (Figure 3) and explains how to enter the different subsections. Furthermore, short descriptions, aims and advice on who should visit each section are given. This makes the use of the toolkit more effective for the different users, namely teachers, teacher trainers/educators, stakeholders and other interested parties.

[3] https://research.ncl.ac.uk/fasmed/deliverables/Deliverable%20D74%20Film.pdf

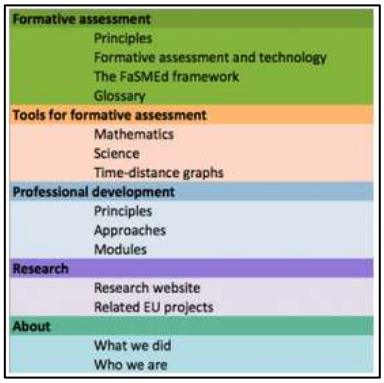

Figure 3: 'Map' of the toolkit sections and main subsections

1.3 Formative Assessment

The third section of the toolkit draws on theory and research related to FA. It is intended for a wider audience and outlines FaSMEd's understanding of what FA is, and in particular, how technology can be used within it. Furthermore, the conceptual FaSMEd Framework (Figure 4) of the project is introduced as a means to conceptualise technology enhanced FA processes in the classroom. The section's main page presents a definition of FA and sets it in contrast to summative assessment. It is stressed that not only the collection of evidence about student achievement(s) is important but that a resulting action by the teacher and/or students is needed in order to make assessment formative. It is stressed that FA can be part of any phase in teaching and learning. Further information on the theoretical and empirical foundation of FaSMEd is divided into the subsections: *Principles, Formative Assessment and Technology, FaSMEd Framework* and *Glossary*.

1.3.1 Principles

This subsection summarises research findings about the implementation of FA in six principles. These aim to give teachers an orientation on how to effectively realise FA practices in their classrooms. The principles for effective FA are listed below and are explained in more detail in the toolkit:

- Make the objectives of the lesson explicit,
- Assess groups as well as individual students,
- Watch and listen before intervening,
- Use divergent assessment methods (Show me what you know about …),
- Give constructive, useful feedback,
- Change teaching to take account of assessment.

1.3.2 Formative Assessment and Technology

This subsection lists the potential that educational technologies have to enhance FA. For example, their ability to provide immediate feedback, enable teachers to monitor students' incremental progress or to create learning environments are addressed.

1.3.3 FaSMEd Framework

This part of the toolkit introduces the conceptual FaSMEd Framework. It takes into account three main dimensions that make it possible to characterise and analyse technology enhanced formative assessment processes: *agent/s*, *formative assessment strategies* and *functionalities of technology* (Figure 4).

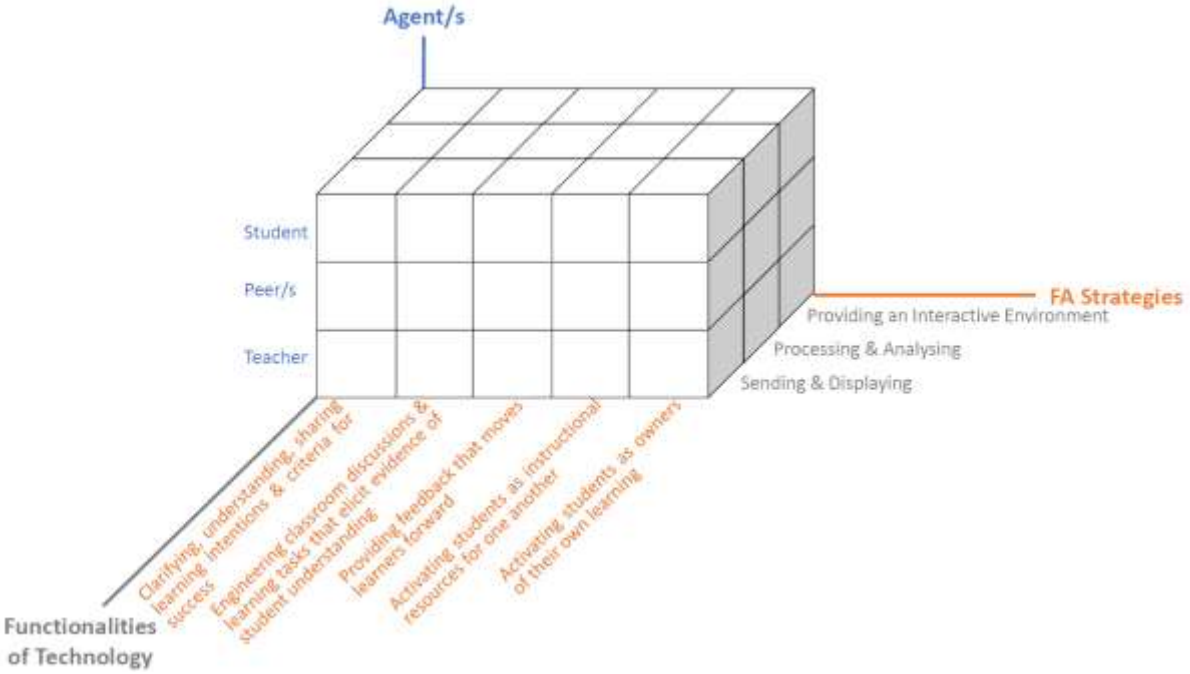

Figure 4: The FaSMEd framework

Each of the dimensions is addressed in detail in a separate sub-subsection:

- **Agents doing Formative Assessment**

The first dimension of the FaSMEd framework specifies which agent/s is/are using FA strategies in the classroom: the individual student, peers or the teacher. It is stressed that an active involvement of students by peer and self-assessment is a key characteristic of FA (Bernholt et al. 2013). The reflection of their own/their peers' work helps students to use metacognitive strategies, interact with multiple approaches to a solution and adopt responsibility for their own learning processes (Harlen 2007, Sadler 1989). Moreover, peer assessment can provide valuable information to the teacher about the students' own ideas as they comment on their partner's solutions (Lindsay & Clarke 2001). Finally, it is explained that the teacher can improve his/her FA practices by making learning intentions and criteria for success visible, by rethinking his/her questioning, by involving students in fruitful classroom discussions and by giving effective feedback.

- **Strategies for Formative Assessment**

The second dimension of the FaSMEd framework describes the strategies for FA that can be activated by the different agents. The strategies dimension draws on Wiliam and Thompson (2007), who state that formative assessment can be conceptualized in five key strategies:

1. Clarifying/ Understanding/ Sharing learning intentions and criteria for success;
2. Engineering effective classroom discussions and other learning tasks that elicit evidence of student understanding;
3. Providing feedback that moves learning forward;
4. Activating students as instructional resources for one another;
5. Activating students as owners of their own learning.

It is explained how FaSMEd understands these strategies introduced by Wiliam and Thompson (2007) in a broader sense involving all of the agents in the classroom.

- **Functionalities of Technology**

This third framework dimension, Functionalities of Technology, was introduced by the FaSMEd project with the aim of highlighting how technology is able to support the three agents in their use of formative assessment. Based on the developed tools and the consortium's experiences in the use of technology to support FA, the dimension was subdivided into the three categories:

1. Sending and Displaying,
2. Processing and Analysing,
3. Providing an Interactive Environment.

The ***Sending and Displaying*** category includes those functionalities of technology that support communication and fruitful discussions between the agents of FA processes. For example, the teacher sending questions to the students or displaying a student's screen to show his/her work to the whole class. Several other functionalities such as sending messages, files, answers or displaying students' worksheets belong in this category.

The functionalities that support the agents in the processing and analysis of the data collected during the lessons are included in the category ***Processing and Analysing***. This could include software that generates feedback based on a learner's answer or an application which creates statistical overviews of solutions of a whole class, e.g., in a diagram or table. Other examples are the generation of statistics of students' answers to quick polls or questionnaires as well as the tracking of students' learning paths.

The third category, ***Providing an Interactive Environment,*** refers to those functionalities of technology that enable the creation of a shared interactive environment within which students can work individually or collaboratively on a task or a learning environment where mathematical/scientific contents can be explored. This category includes, for example, shared worksheets, GeoGebra files, graph plotting tools, spreadsheets, dynamic representations or ChemSketch models.

Besides explaining these categories, this subsection of the toolkit also provides examples from the FaSMEd activities. These explain how a specific technology used in the classroom in a certain way functions in a FA process. For example, in *Designing Candy Cartons* a combination

of software, namely Socrative and Reflector, together with an interactive Whiteboard is used in order to display one student's screen to the whole class (Figure 5). The examples help the readers to understand the categories of the framework better and link them directly to the suggested activities for further information.

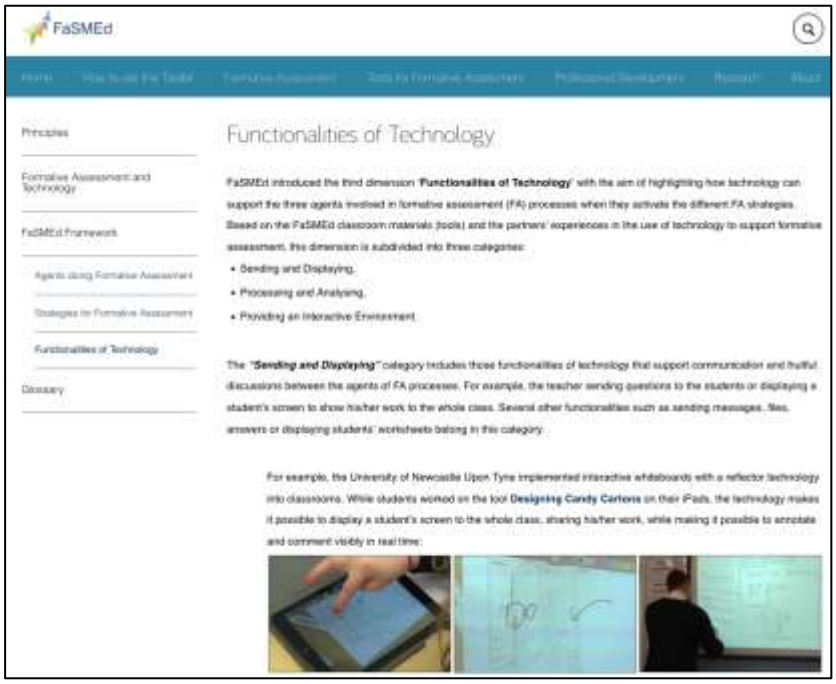

Figure 5: Detail screenshot of the Functionalities of Technology page

1.3.4 Glossary

This subsection provides descriptions of some of the key terms in the FaSMEd project, which are: Formative Assessment, convergent and divergent assessment, design study/research, toolkit, case study, professional development, tool/technology, and feedback. The glossary is presented in English but pdf versions can be downloaded in all of the partner languages[4].

1.4 Tools for Formative Assessment

The tools section of the website is aimed at teachers and entails the actual toolkit. It is a collection of all the classroom materials produced by the FaSMEd partners that teachers can implement in their own classrooms. These are organised in three overarching categories: mathematics, science and time-distance graphs. A tool is understood to be a page of the website with a certain format to ensure easy handling. Each tool page consists of a title; a descriptive sentence; a table presenting key information (subject, age of students, hardware, software, functionalities of technology, time needed and FaSMEd partner); a summary and a downloadable teacher guide (Figure 6). In addition, some tools provide classroom materials such as student handouts, worksheets, questions, digital worksheets, or learning environments to download. This structure makes it easy for teachers to get a first impression

[4] https://research.ncl.ac.uk/fasmed/deliverables/

of the presented tool and to know which teacher guides they would like to download for further information.

The **teacher guides** describe the classroom activities within a lesson or a series of lessons; give insight in the mathematical or scientific content and highlight aspects of FA as well as technology used. There are two different types of teacher guides in the FaSMEd toolkit: lesson plans and lesson accounts. Lesson plans have been developed, based on the experience of teachers who trialled original materials in the sense of the design-based research approach. They describe classroom activities in detail and can be used in other teachers' classrooms. Lesson accounts focus more on the design experiments. They address what happened in FaSMEd classrooms and help teachers to develop their own lessons based on the described experiences. This encourages teachers to adapt FaSMEd tools based on their own context, their students' abilities and the technologies that they have available.

To simplify the search for tools aimed at certain content, technologies, student ages, languages and so on, the tools are organised in different categories and with the help of tags. The toolkit user can select a category and/or tag (see list on the left of Figure 6) to see all the related tools. The categories and tags work simultaneously but the categories provide a more structured search option as they allow the use of sub-categories. The following categories and tags are used in the toolkit:

- Subject: mathematics, science;
- Content: algebra, early algebra, geometry, number, probability, space and shape, time-distance graphs;
- Functionalities (of technology): sending and displaying, processing and analysing, providing an interactive environment;
- Hardware: cards, clickers, heart monitor, iPad, PC, probe, tablets;
- Software: connected classroom technology, data logger, diagnostic questions, digital assessment environment, Educreations, ExplainEverything, Google forms, Kahoot, Maple TA, mathspace, nearpod, NetSupport school, showbie, socrative, student response system, tessellation creator;
- Language: Dutch, French, German, Italian, Norwegian;
- Level: primary, secondary;
- Partners: African Institute for Mathematical Sciences Schools Enrichment Centre, Ecole Normale Superieure De Lyon, Maynooth University, Norwegian University of Science and Technology, University of Duisburg-Essen, University of Newcastle, University of Nottingham, University of Turin, Utrecht University;
- Problem solving.

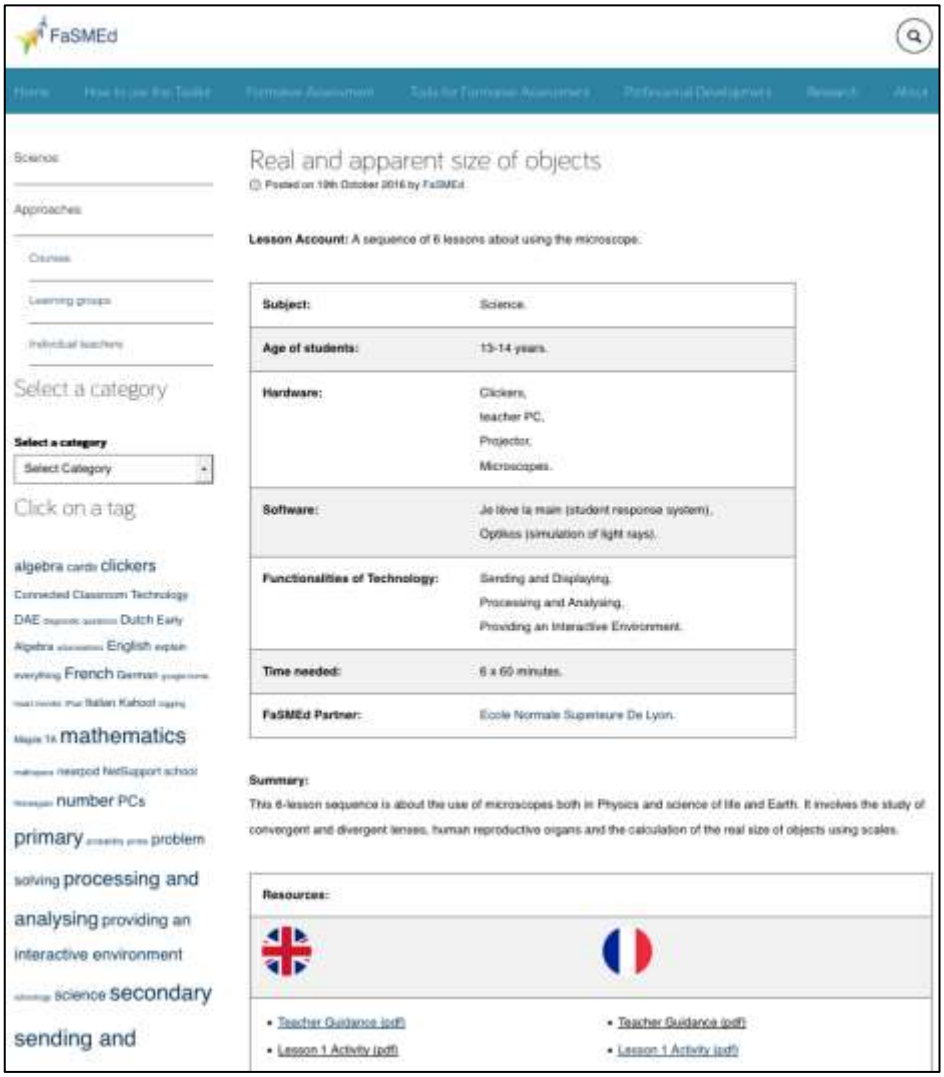

Figure 6: Example of a FaSMEd tool (Real and apparent size of objects)

All tools (title, label of lesson plan/account and descriptive sentence) of the toolkit are listed as follows according to the main categories and in alphabetical order. Note that some tools appear in several categories.

1.4.1 Mathematics

- Algebraic Equations – Lesson Account: A concept development lesson focusing on developing understanding of multi-step linear equations.
- Algebraic Expressions – Lesson Account: A concept development lesson focusing on connections between algebraic expressions and the area of rectangles.
- Areas and Perimeters – Lesson Account: A lesson about clarifying the concepts of area and perimeter.
- Can I sketch a graph based on a given situation? / Kann ich zu einer gegebenen Situation einen Graphen erstellen? – Lesson Plan: A digital tool for formative self-assessment.
- Designing Candy Cartons – Lesson Plan: A problem-solving activity involving 3D shapes and nets.

- Developing a sense of scale – Lesson Plan: A problem-solving activity involving students recognising the relationships of direct proportions.
- Directed Numbers – Lesson Account: A concept development lesson focusing on developing understanding of directed numbers.
- Equivalence of fractions – Lesson Account: Two lessons for consolidating the concept of equivalent fractions.
- Festa di Primavera – Lesson Plan: Festa di Primavera is a sequence of lessons set within the context of early algebra. The tasks within this sequence involve: (a) identifying and verbalising relations between variables; (b) representing relations by means of symbolic expressions; (c) interpreting graphs that represent relations.
- Fractions (DAE module) / Breuken (DTO module) – Digital Assessment Environment: Guidance for using the fractions assessment module.
- Graphic organisers – Lesson Plan: Two peer-assessment lessons about creating graphic organisers on a chosen topic.
- Graphs (DAE module) / Grafieken (DTO module) – Digital Assessment Environment: Guidance for using the graphs assessment module.
- Improper fractions – Lesson Account: A lesson for consolidating the concept of improper fractions.
- Interpreting equations – Lesson Plan: A concept development lesson about matching equations and statements.
- Introducing probability – Lesson Account: A sequence of 3 lessons defining the notion of probability through a game.
- Introduction to fractions- Lesson Account: A sequence of five lessons following the introduction of the concept of a fraction.
- Linear functions – Lesson Account: A sequence of 4 lessons introducing the topic of linear functions.
- Måling og lengdeenheter / Units of measurements – Lesson Plan: This Norwegian lesson concerns choosing the right units of measurement, and being able to convert between different units of measurement.
- Metric system (DAE module) / Metriek (DTO module) – Digital Assessment Environment: Guidance for using the metric system assessment module.
- Percents (DAE module) / Procenten (DTO module) – Digital Assessment Environment: Guidance for using the percents assessment module.
- Properties of exponents – Lesson Plan: A concept development lesson about matching expressions and statements involving exponents.
- Properties of quadrilaterals – Lesson Plan: A concept development lesson about using properties to determine the quadrilateral.
- Scales – Lesson Account: A sequence of 3 lessons which use proportionality for understanding scale.
- Security Cameras – Lesson Plan: A problem-solving activity about optimisation involving the construction and calculation of areas and the comparison of percentages.
- Selling Soup – Lesson Plan: A problem-solving activity about proportional relationships and the ratio concept in the context of maximising profit.
- Sharing costs travelling to school – Lesson Plan: A problem-solving activity about understanding the ratio concept and mathematical reasoning.
- Tessellation – Lesson Account: A lesson focusing on 2D shapes and tessellations.
- The ‘Magic V’ investigation – Lesson Account: An inquiry based lesson involving number.

- The Archaeologist Giancarlo – Lesson Plan: The archaeologist Giancarlo is a sequence of lessons set within the context of early algebra. The lessons involve interpreting, comparing and discussing different representations (verbal, symbolic, graphical) of a relationship between two variables.
- The Meatball problem – Lesson Account: A problem-solving lesson using the concepts of volume, capacity and surface area.
- Walking a graph – Lesson Plan: A lesson using motion sensors for understanding time-distance graphs.

1.4.2 Science

- Acid-protective effect of toothpaste / Säureschutzwirkung von Zahnpasta – Lesson Plan: Planning and performing an experiment about the acid protective effect of toothpaste.
- Graphic organisers – Lesson Plan: Two peer-assessment lessons about creating graphic organisers on a chosen topic.
- Heart Rate Investigation – Lesson Plan: Two lessons investigating the effect of exercise on heart rate.
- Insulation – Lesson Plan: Two lessons about insulation using temperature probes and data logger software.
- Microorganisms – Lesson Plan: An inquiry based lesson including an experiment about preventing bacteria spreading.
- Real and apparent size of objects – Lesson Account: A sequence of 6 lessons about using the microscope.
- Scales: – Lesson Account: A sequence of 3 lessons which use proportionality for understanding scale.
- Time-temperature graphs – Lesson Account: A sequence of 10 lessons using a student response system.
- Who has the juiciest apple? / Wer hat den saftigsten Apfel? – Lesson Plan: Planning, performing and recording an experiment about the surface-to-volume ratio.

1.4.3 Time-distance graphs

This category features a special collection of tools that share the common topic of time-distance graphs. It aims to give teachers an example of how adaptions of one classroom activity could look like based on different contexts. Therefore, each FaSMEd partner adapted the FA lesson Interpreting Distance-Time Graphs designed by the Mathematics Assessment Project[5]. All of the tools in this section are also tagged with the category 'mathematics' but only appear in that category, if the tool differs fundamentally from the MAP lesson plan.

- Can I sketch a graph based on a given situation? / Kann ich zu einer gebebenen Situation einen Graphen erstellen? – Lesson Plan: A digital tool for formative self-assessment.

[5] http://map.mathshell.org/

- Card matching time-distance graphs – Lesson Plan: A concept development lesson about matching graphs, descriptions and tables (card matching).
- Graphing in mathematics – Lesson Account: Two lessons using tablets and an interactive whiteboard to share student work and promote discussion.
- Graphs (DAE module) / Grafieken (DTO module) – Digital Assessment Environment: Guidance for using the graphs assessment module.
- Time-distance graphs in tablet-using classrooms – Lesson Account: A sequence of 3 lessons using NetSupport School.
- Time-distance graphs with Showbie – Lesson Account: A lesson using the application Showbie to collect and display student responses.
- Time-distance graphs with applications – Lesson Plan: A lesson using applications to collect and display student responses (Socrative, Classflow, Plickers or Showme).
- Time-distance graphs with IDM-Tclass – Lesson Plan: A sequence of lessons using the connected classroom technology, IDM-TClass
- Time-temperature graphs – Lesson Account: A sequence of 10 lessons using a student response system.
- Walking a graph – Lesson Plan: A lesson using motion sensors for understanding time-distance graphs. Subject: Mathematics.

1.5 Professional Development

The fifth section of the toolkit website hosts FaSMEd's final Professional Development (PD) package. It is aimed at people organising professional development for teachers of mathematics and science but can also be used by teachers, either individually or working in groups. It includes a theoretical section on principles for effective PD, describes different approaches to PD, shows practical examples of PD courses carried out by FaSMEd partners and includes six PD modules designed to help teachers use FA more effectively in their classrooms (see deliverable D3.6 Final Professional Development Package for a detailed description).

1.6 Research

This section of the toolkit is dedicated to the research approach and results of the FaSMEd project. It describes design research as a:

> *formative approach […], in which a product or process is envisaged, designed, developed, and refined through cycles of enactment, observation, analysis, and redesign, with systematic feedback from end users* (Swan 2014, p.148).

Moreover, the FaSMEd project's focus on the use of technology for FA is stressed and its use of case studies is described. The readers can also learn about FaSMEd's research questions in this section. Furthermore, the main research reports about the project's methodology, comparison of case studies and of country reports can be downloaded. Finally, the research section of the toolkit contains two sub-sections: research website and links to related projects.

The first links to the FaSMEd research website[6] hosted by the University of Newcastle upon Tyne, UK. This separate website holds more general information about the project, informs about the different dissemination activities of the consortium and lets the reader download all of the project's newsletters and deliverables (Figure 7).

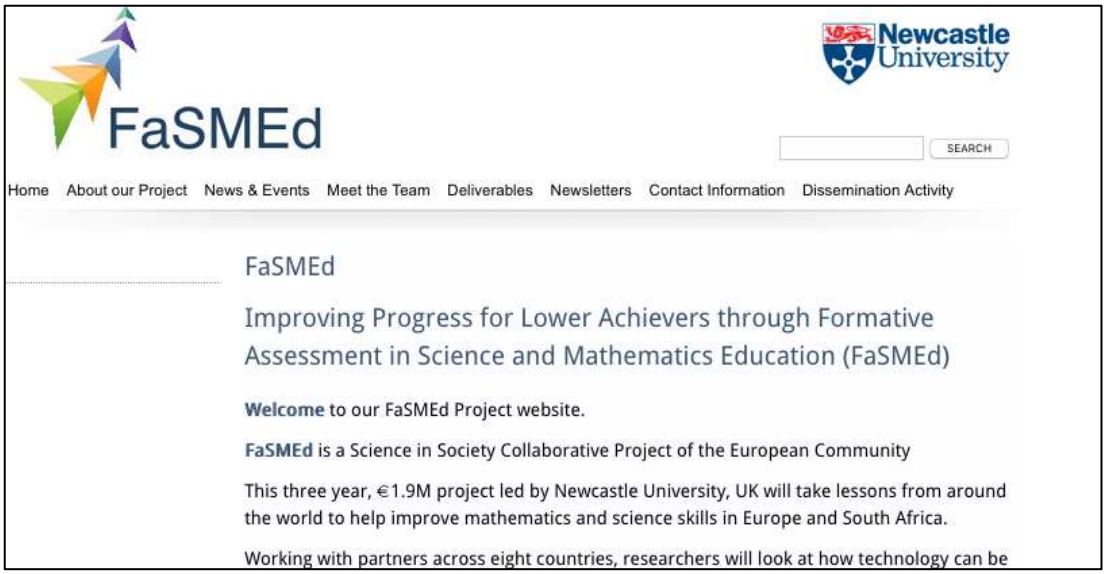

Figure 7: Detail screenshot of the Home page of the FaSMEd research website

The second sub-section provides links to other projects and networks with related topics and gives a short introduction to each of them: ASSIST-ME, Mathematics Assessment Project, PRIMAS, MASCIL, SAILS, EdUmatics, MC Squared and SCIENTIX.

1.7 About

In the final toolkit section, the FaSMEd project's work is explained in more detail. In the first sub-section called *What we did*, the FaSMEd aims and objectives are specified. The second sub-section *Who we are* is dedicated to information about the way researchers worked with clusters of schools to look at how technology can be used in FA in mathematics and science classrooms to help raise student attainment levels. Finally, the nine sub-subpages (one per partner), introduce the FaSMEd partners in more details about the institutions as well as the researchers and staff, who worked in the project.

2. Implementation of evaluations

In deliverable D3.2 Evaluation of the toolkit, the prototype toolkit (see deliverable D3.1 for more information) was assessed. The evaluation focused on the implementation of the prototype toolkit by the FaSMEd partners as well as on the additional tools that had been designed by the partners. It took into consideration the guidance given to the consortium in the form of deliverable D9.1: FaSMEd Project Evaluation Report Month 12 and the Technical

[6] http://research.ncl.ac.uk/fasmed/)

Review Report (based on our Mid Term Review in 2015). This evaluation served as a guideline for the development of the final toolkit and the following discussion highlights how the issues stated in the evaluation have been implemented in the final toolkit.

One of the main concerns of the previous toolkit evaluations was that the consortium did not take into account various technologies, especially digital resources. As stated in D3.2 Evaluation of toolkit, FaSMEd's work showed a wide range of technologies, but this was not yet visible in the prototype toolkit. The final toolkit, however, includes a number of additional tools that were not part of the prototype. The different technologies are not only emphasised by the descriptive table at the beginning of each tool page but also by the different categories and tags used to make the tools searchable.

Furthermore, the evaluation report advised that FaSMEd should *highlight the value added by this project, particularly in relation to the role of technology* wherever FaSMEd adapted resources from other projects (D9.1, p.4). What is more, the Technical Review Report states that the focus should be on *digital technologies in relation to formative assessment* (Technical Review Report, p.4). This focus of FaSMEd is highlighted in various ways in the final toolkit: the integrated FaSMEd framework provides the readers with a conceptual model that can be used to categorise and describe technology enhanced FA processes with a focus on the agents, used strategies and functionalities of technology and the connections between the three dimensions.

In addition, the PD modules, especially module six, give advice on how to support teachers in their use of technology for formative assessment. Moreover, each tool's teacher guide includes sections describing the used aspects of FA as well as the technology. Therefore the guidance of D9.1 stating that *a paragraph highlighting [the role of technology] in relation to each activity* (D9.1, p.4) should be integrated in the website and of the Technical Review Report requiring that the final tools should report on *which technology and formative assessment strategies are used and how* (p.6) has been followed.

Another issue addressed in the evaluation was the structure of the toolkit. The Technical Review Report states that the consortium should clarify *what, and how, materials and outputs should be presented on the website* and that the *toolkit website should be linked to, or integrated into, the main website* (Technical Review Report, p.6). With the final toolkit's clear structure, as described in detail above, and with the link to the research website, this goal has been achieved.

Overall, the FaSMEd project has addressed all of the issues stated in previous reviews of the toolkit and has created a final toolkit that accomplishes the aim of emphasising connections between the use of (digital) technologies and formative assessment practices as well as to include *activities for teachers and students, together with guidance on approaches to teaching and assessment and the use of technology* (FaSMEd DOW 2013, p.8).

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