FaSMEd S & T Findings

Raising achievement

The FaSMEd project aimed to address the needs of lower achievers in science and mathematics education. As part of Work Package 2, two surveys were completed by the partners at the beginning of the project. The first was to map the 'landscape' for lower achievers in science and mathematics across the partner countries and their typical learning trajectories (Deliverable D2.1) and the second to survey the systemic practices of partner countries for addressing the needs of lower achieving students (Deliverable D2.2).

Established approaches 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 (Wright et al, 2015). In contrast, the TIMSS seven-nation comparative study shows that high achieving countries (Hiebert et al., 2003) adopt approaches which preserve the complexity of concepts and methods, rather than simplifying them. Hence, FaSMEd partners were encouraged to develop resources, processes and technological tools which would allow all students to engage with complex concepts and methods successfully and to improve motivation.

The FaSMEd project was based on the evidence (Black & Wiliam, 1998) that FA strategies can raise levels of achievement for students. The project also builds on the evidence of research from, for example, the LAMP (Ahmed, 1987), RAMP (Ahmed & Williams, 1991) and IAMP (Watson, De Geest, & Prestage, 2003) projects in mathematics teaching and the CASE (Shayer & Adey, 2002) project in science teaching in the UK and elsewhere which adopted approaches focused on the proficiencies of the students rather than their deficiencies. These projects adopt what Shulman (2002) calls 'pedagogies of engagement', characterised by: revisiting student thinking, addressing conceptual understanding, examining a task from different perspectives, critiquing approaches, making connections and engaging the whole class.

Partners were encouraged to identify activities in science and mathematics which built on recent meta-analyses of the accumulated corpus of research on effective teaching that have examined teaching components in mathematics and science (Seidel & Shavelson, 2007), teaching strategies in science (Schroeder, Scott, Tolson, Huang, & Lee, 2007), and teaching programmes in mathematics (Slavin & Lake, 2008; Slavin, Lake, & Groff, 2009). These provide

clear indications of the relative effectiveness of some types of teaching component for lower achievers.

The FaSMEd framework

During the first year of the project, time was allocated to establish a common understanding of the key concepts of FaSMEd. These were articulated through a series of Position Papers[1] and an agreed Glossary (Deliverable 1.2)[2].

We recognised that an approach to learning through active participation in, and reflection on, social practices, would be desirable. Further, FaSMEd activities should stimulate 'conflict' or 'challenge' to promote re-interpretation, reformulation and accommodation (see FaSMEd position paper[3]). The aim is to devolve problems to learners so that learners can articulate their own interpretations and create their own connections.

Partners were encouraged to create and adopt activities from their own contexts which reflected this approach to learning. However, since this approach increases the cognitive load for students it is important that the learning environment is engineered to support students and FaSMEd included technology as part of the design of the environment to provide such support. The FaSMEd project case studies [4]provide examples of where this approach has worked successfully with lower achieving students.

Wiliam and Thompson (2007, adapted from Ramaprasard, 1983) focus on three central processes in teaching and learning: (a) Establishing where the learners are in their learning; (b) Establishing where the learners are going and (c) Establishing how to get there. Considering all agents within the learning processes in a classroom: teacher, students and peers, they indicate that FA can be conceptualized in five key strategies (see figure 1):

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 learners forward;
4) Activating students as instructional resources for one another;
5) Activating students as owners of their own learning.

[1] https://research.ncl.ac.uk/fasmed/positionpapers
[2] https://research.ncl.ac.uk/fasmed/deliverables/
3 https://research.ncl.ac.uk/fasmed/positionpapers/Cognitive+conflict_Nottingham_ude_revised.pdf
[4] https://research.ncl.ac.uk/fasmed/deliverables/

	Where the learner is going	Where the learner is right now	How to get there
Teacher	**1** Clarifying learning intentions and criteria for success	**2** Engineering effective class-room discussions and other learning tasks that elicit evidence of student understanding	**3** Providing feedback that moves learners forward
Peer	Understanding and sharing learning intentions and criteria for success	**4** Activating students as instructional resources for one another	
Learner	Understanding learning intentions and criteria for success	**5** Activating students as the owners of their own learning	

Figure 1: Key strategies of Formative Assessment (Wiliam & Thompson, 2007)

The key strategies by Wiliam and Thompson (2007) constitute the foundation of the theoretical framework that has been developed within the FaSMEd project. They represent, indeed, the starting point for the development of a three-dimensional framework (see figure 2) aimed at extending their model to include the use of technology in FA processes.

The FaSMEd framework (Figure 2) takes into account three main dimensions which enabled the project team to characterise technologically enhanced FA processes: (1) the five key strategies of FA introduced by Wiliam and Thompson (2007); (2) the three agents that intervene in the FA processes and that could activate these strategies, namely the teacher, the student and the peers; (3) the functionalities of technology.

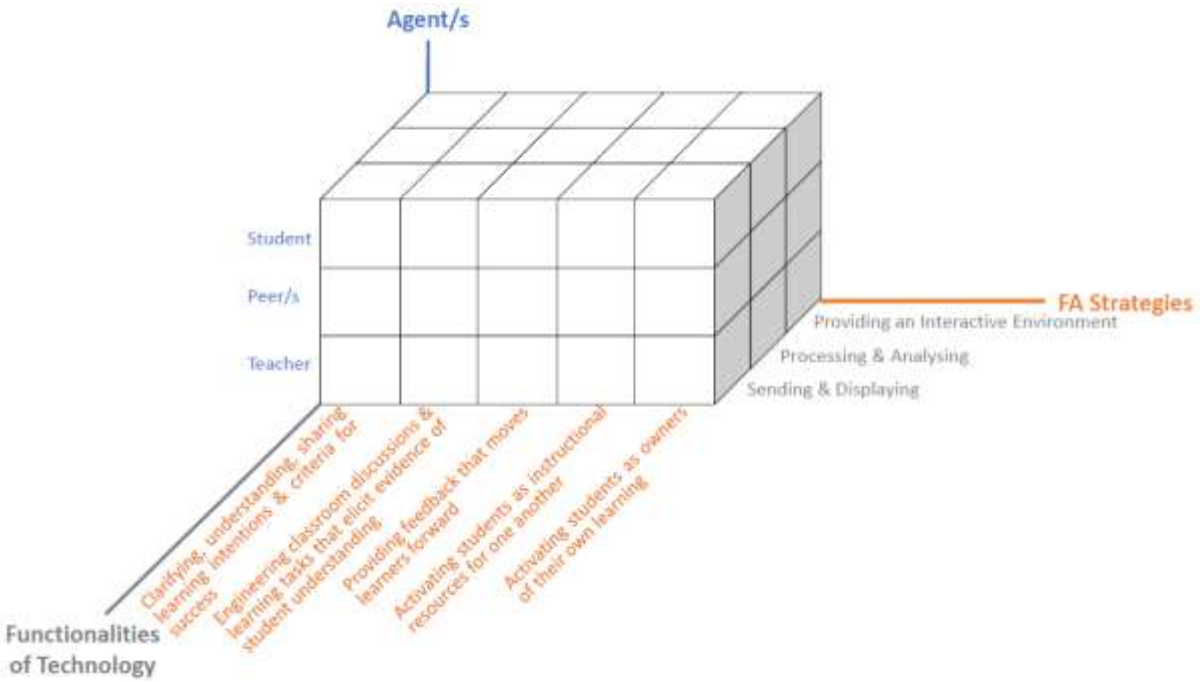


Figure 2: The FaSMEd framework

We introduced the third dimension **Functionalities of Technology** with the aim of highlighting how technology could support the three agents involved in FA processes when they activate the different FA strategies. The functionalities of technology are subdivided into three categories: sending and displaying, processing and analysing and providing an interactive environment. This subdivision was based on the FaSMEd partners' experience in the use of technology to support FA processes.

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 screens or 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 a 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 polls or questionnaires as well as the tracking of students' learning paths.

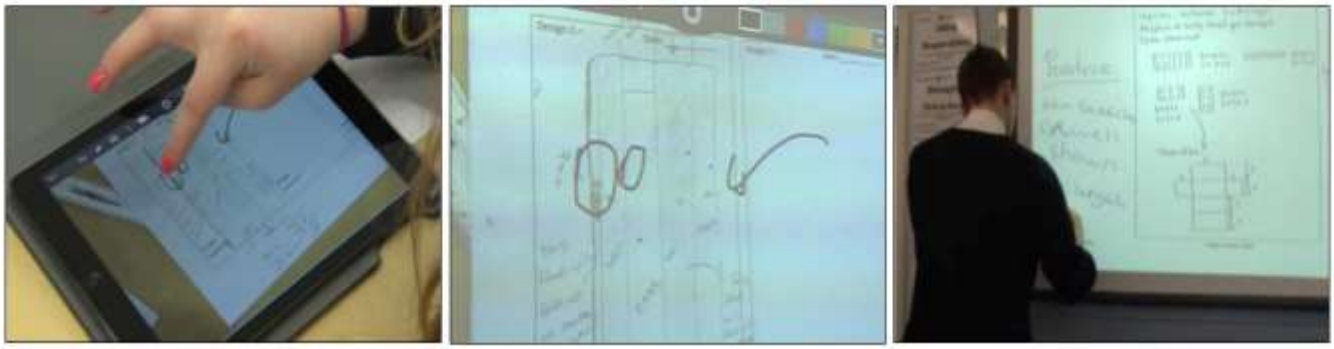
The third category, **Providing an Interactive Environment**, refers to those functionalities of technology that create a shared interactive learning environment within which students can work individually or collaboratively on a task to explore mathematical/scientific concepts and processes. This category includes, for example, shared worksheets, dynamic geometry software files, graph plotting tools, spread sheets, dynamic representations or ChemSketch models.

Figure 2 shows how the subdivision of each dimension into different sub-categories identifies small cuboids within the diagram. Each cuboid helps to locate specific FA practices, highlighting the agents involved in this practice, the main FA strategies that are activated and the functionalities of the technology that is involved. The framework is not hierarchical in that no section of the cube is viewed as being more or less desirable than others. The framework has been used to identify and locate each of the cases reported by the partners in the project and has been the focus of a number of published papers and presentations at international conferences.[5]

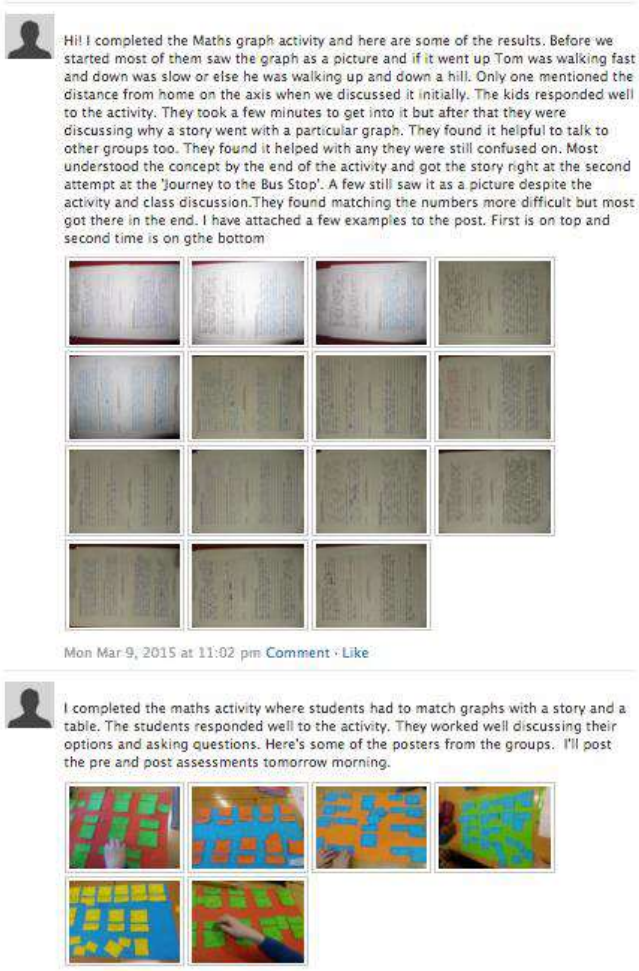
Examples of sending and displaying in practice

One school working with Newcastle University (UK) implemented interactive whiteboards with a reflector technology into classrooms. While students worked on the activity 'Designing Candy Cartons' on their iPads, the technology enabled the teacher to display a student's screen to the whole class, sharing his/her work, while making it possible to annotate and comment visibly in real time:

[5] See our dissemination activities at: https://research.ncl.ac.uk/fasmed/disseminationactivity/



At the University of Maynooth (Ireland), teachers used Schoology. This is a learning management and social network system, used in classrooms as a way for teachers and students to communicate by sharing materials, learners uploading their work, teachers sending out tasks and providing a way to give feedback and ask questions:



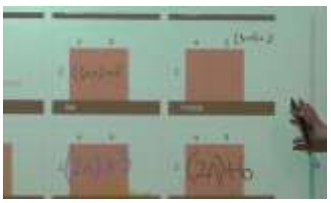
Hi! I completed the Maths graph activity and here are some of the results. Before we started most of them saw the graph as a picture and if it went up Tom was walking fast and down was slow or else he was walking up and down a hill. Only one mentioned the distance from home on the axis when we discussed it initially. The kids responded well to the activity. They took a few minutes to get into it but after that they were discussing why a story went with a particular graph. They found it helpful to talk to other groups too. They found it helped with any they were still confused on. Most understood the concept by the end of the activity and got the story right at the second attempt at the 'Journey to the Bus Stop'. A few still saw it as a picture despite the activity and class discussion.They found matching the numbers more difficult but most got there in the end. I have attached a few examples to the post. First is on top and second time is on gthe bottom

Mon Mar 9, 2015 at 11:02 pm Comment · Like

I completed the maths activity where students had to match graphs with a story and a table. The students responded well to the activity. They worked well discussing their options and asking questions. Here's some of the posters from the groups. I'll post the pre and post assessments tomorrow morning.

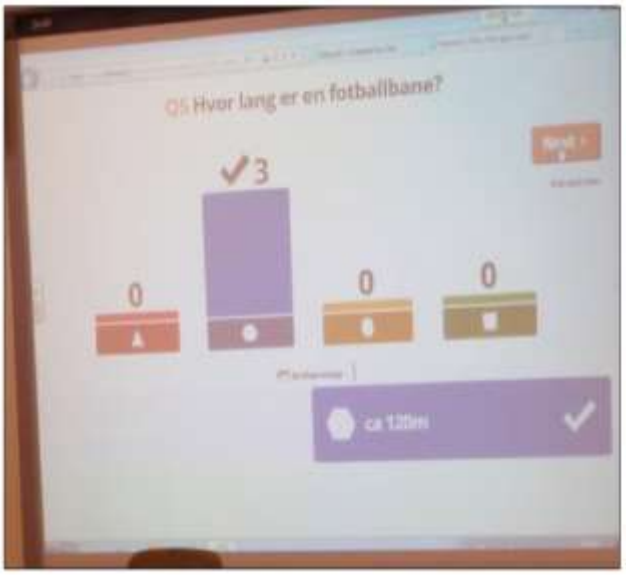
An example from the University of Nottingham (UK) arose during lessons in which areas of rectangles were used to explore algebraic expressions. The software *Nearpod* was used by the teacher to send questions to students to complete on their iPads. Students returned their answers using *Nearpod* and an array of student responses was then displayed for the class to compare and discuss.



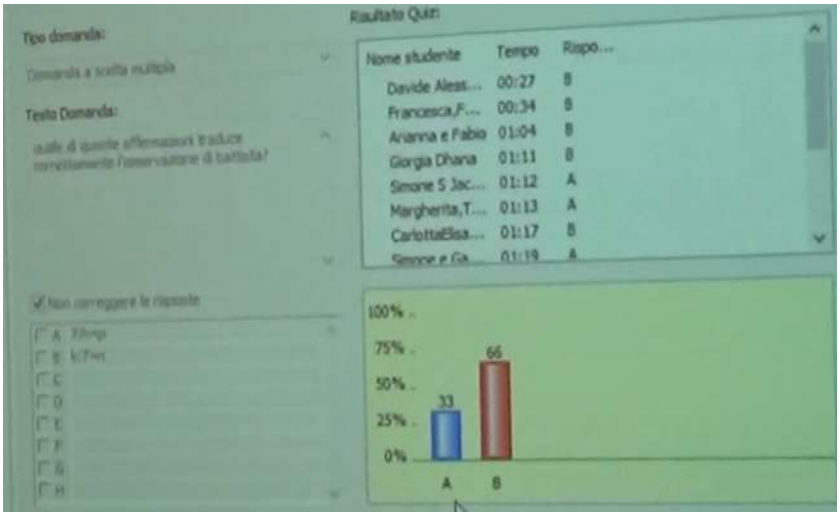


Examples of processing and analysing in practice

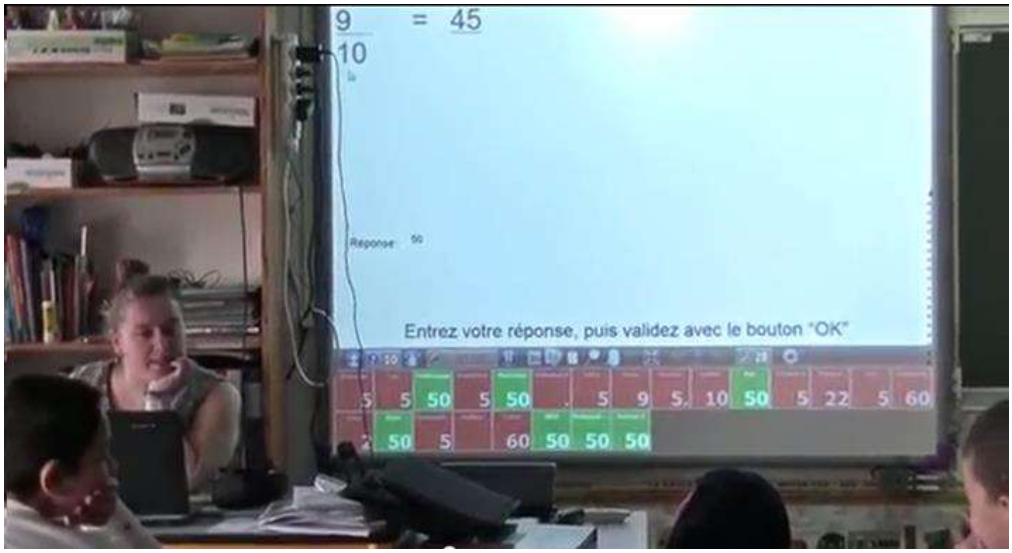
In the activity 'Unit of length' developed by the University College of Trondheim (Norway) the applet Kahoot is used for sending questions to students, sending their answers to the teacher and the teacher displaying the students' solutions to discuss and give feedback. What is more, the technology produces a statistical overview represented in a bar diagram of the whole class' answers and therefore helping students and the teacher to grasp all students' solutions at once:



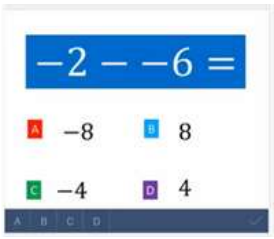
Also in the teaching interventions carried out by the University of Turin (Italy) with the software IDM-TClass, results of test and polls are gathered and processed on the teacher's laptop, and shown on a wider screen by means of a data projector or an interactive whiteboard. In this case the technology collects all the students' choices and processes them, displaying an analytical record (collection of each answer) as well as a synthetic overview (bar chart). The teacher can choose to provide or not an immediate automatic feedback to students' answers (right/wrong). The Italian team's choice was to use the results provided by the software as a starting point for engineering class discussions.



Another example of this functionality is the tool 'Equivalence of fractions' developed at Ecole Normale Superieure De Lyon (France). It uses a student response system (Je leve la main) to display a question to the whole class, which each learner then answers individually via a remote control. Then, the technology analyses the answers indicating in green or red colour whether a student's solution was correct and shows what the answer of each individual student was. The teacher can finally display all the sent in solutions to discuss the problem with the whole class and give feedback:

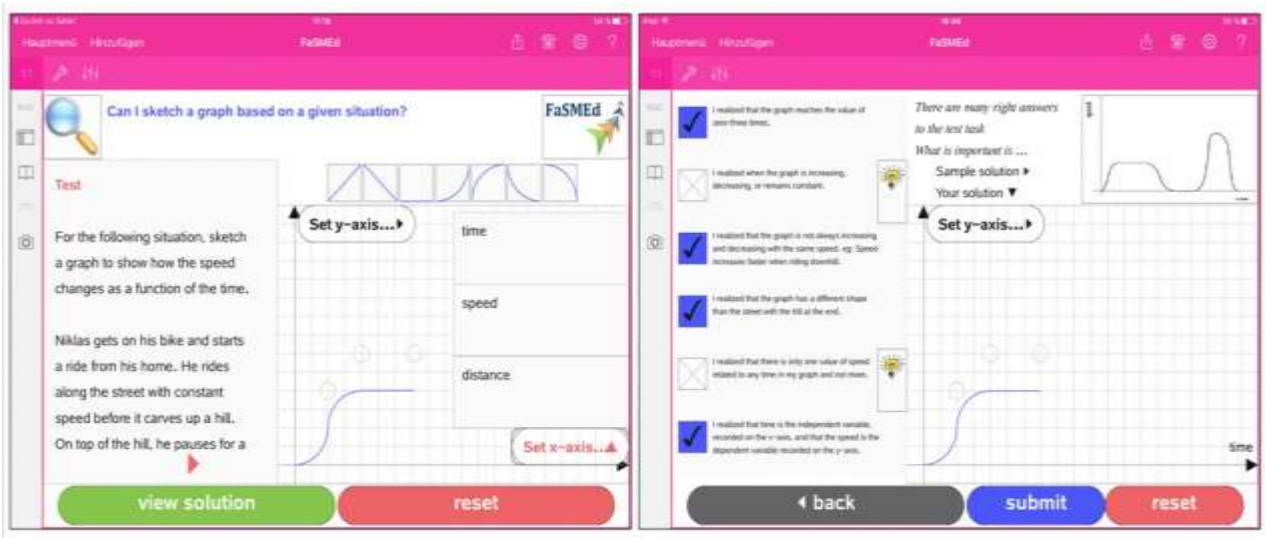


Pre-lesson assessment was carried out by one school working with the University of Nottingham (UK) using diagnosticquestions.com. Students completed multiple choice questions before the lesson and an overview was provided for the teacher so that they could adjust their lesson plan to suit the level of prior understanding of the students and address any particular misconceptions.

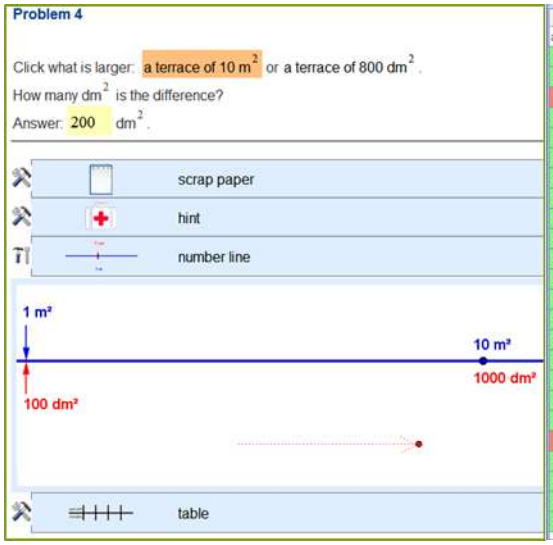


Examples of providing an interactive environment in practice

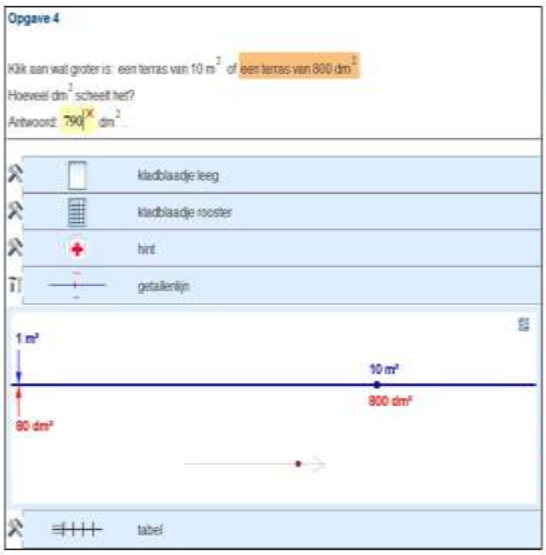
The digital self-assessment tool 'Can I sketch a graph based on a given situation?' developed at the University of Duisburg-Essen (Germany) functions as an interactive environment, in which students can explore the mathematical content of sketching a graph dynamically and assess their own work based on a presented check-list:

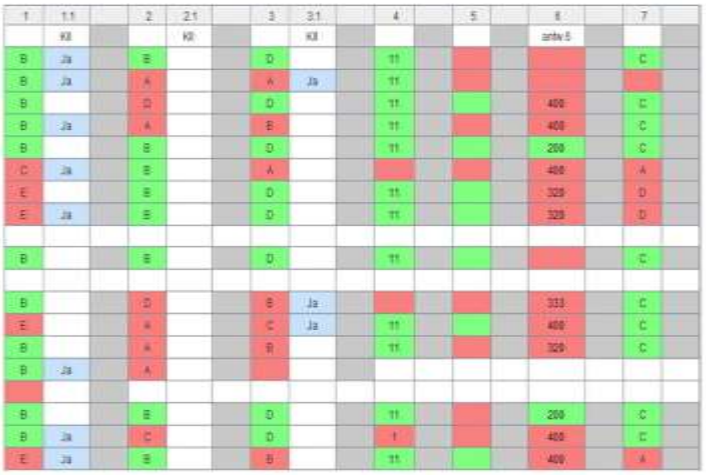


Another example of technology used for formative assessment in the functionality of 'Providing an Interactive Environment' was designed by Utrecht University. They created four different modules in an online Digital Assessment Environment (DAE), for instance one on the metric system. Within this environment, learners work on a series of questions while being able to choose between a number of different tools to help them solve a problem, like tables, scrap papers, hints, percentage bars, etc. The technology then presents an overview of the students' work, their chosen tools and answers to the teacher, who can use this data formatively:

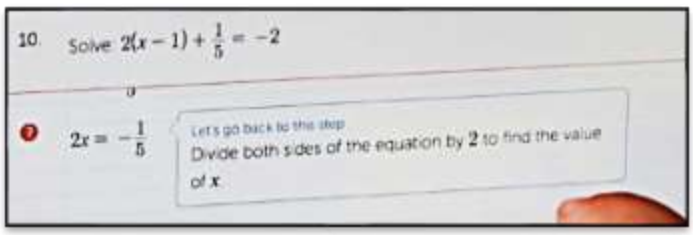


1	1.1	1.2	1.3	1.4	1.5	2	2.1	2.2	2.3	2.4	2.5	3	3.1	3.2	3.3	3.4	3.5	4	4.1	4.2	4.3	4.4	4.5
antw.1	Kll	Klr	Hin	Get	Tab	antw.2	Kll	Klr	Hin	Get	Tab	antw.3	Kll	Klr	Hin	Get	Tab	antw.4	Kll	Klr	Hin	Get	Tab
2000						3						4						200					
2000	Ja					3	Ja					4	Ja					200	Ja				
2		Ja				3		Ja				0.2		Ja				200		Ja			
2000						3	Ja					4						70					
2000	Ja					3	Ja					4	Ja					700	Ja				
2000	Ja	Ja	Ja	Ja		3	Ja					40	Ja	Ja	Ja			700					
2000						300	Ja					7500	Ja	Ja	Ja	Ja		700					
2000		Ja				3	Ja		Ja			750	Ja		Ja			70	Ja				
2000						3	Ja					4	Ja					700					
2000						3						4			Ja	Ja		200					
2000	Ja					3	Ja					7.5	Ja					200					
2000						3	Ja			Ja		4	Ja					200					
2000						3						4						200					
2000						3	Ja					4	Ja					200	Ja				
2000						3	Ja					90	Ja					200	Ja				
2000						3						4	Ja					200					
2000	Ja		Ja			3	Ja					75	Ja					700	Ja				
2000	Ja				Ja	30						5	Ja		Ja			20	Ja				
2000						300						4			Ja			500			Ja		
4,3						3						75		Ja	Ja			700					
2000				Ja		300	Ja					4	Ja					79.90	Ja			Ja	
2000				Ja		300	Ja					40	Ja					200	Ja				
2000						3						2				Ja		700					
2000						0.3	Ja					2	Ja					200	Ja				





Other students in England (University of Nottingham) used existing systems such as *Mathspace* which provides questions and hints for students to help them reflect on their own learning and progress relatively independently from the teacher.



The design of socio-technical approaches to raising achievement in mathematics and science education

Teachers' experiences of the design process

Through FaSMEd, consortium partners (and teachers) have engaged in the design process of socio-technical approaches aimed at raising achievement in mathematics and science education. Here we provide illustrative examples of the experiences of teachers and students using FaSMEd socio-technical approaches.

Looking across the cases, it is clear that the technology tools provided immediate feedback for teachers about pupils' difficulties and/or achievement with a particular task. For example, in the case of the DAE tool being used in a mathematics lesson, it provided opportunities for collecting and processing students' summative results, and subsequently for further analysing individual student work, based on students' use of various optional auxiliary tools. As another example, a mathematics teacher mentioned that "*other effective moments are the polls, since they are immediate and interesting*".

We found that teachers see the technological tools as *opportunities* for changing practices, in the sense that teachers expanded their repertoire of strategies with the technological tools:

> *"[Before FaSMEd] the use of Formative Assessment was implicit. I had very low awareness of it. No specific tool was constructed or used for this purpose. [Now FA is] gathering information at all steps of the teaching act."*

Teachers adapted their preferred strategies in new or different ways: for example, one teacher reported that the tablet made her work more cooperatively with her class and removed her from the 'constraints' of the whiteboard:

> *"It just means that I'm not at the front all the time."*

Another teacher commented that although questioning was his predominant approach, he was aware that:

> *"not all students are comfortable to answer questions vocally or to be putting their hands up [....] sometimes you have to use other methods that are not as intrusive, things like using mini whiteboards where everyone can respond and no-one feels under pressure".*

The tool (or resource), such as a clicker or iPad, used in an applied way, becomes an instrument for a particular FA strategy as outlined in the FaSMEd framework. Within our cases, FA practices were then associated with particular functionalities of the technology tool/s: for example, with sending and displaying questions; and with displaying students' answers.

Several of our case study teachers reported that particular technical difficulties, such as setting up the technology, or handling it with students, prevented them from using the technology tools more often. However, once they managed the tools successfully, and

moreover saw the advantages of using them for FA, they regarded them as beneficial both for their instruction and for student learning. One teacher suitably commented:

> *"[before FaSMEd] the collection of information was done through conventional controls, activities at the beginning of the lesson, oral exchanges, observations of students in their activities. The quality and consistency of the treatment of such information varied widely. There were some technical difficulties related to the handling of the material, during the first two months of the FaSMEd project. Today I see only advantages of using digital technologies for formative assessment."*

Students' experiences of the design process

For students, there was an appreciation of the value of FA and that through sharing and explaining work the teacher would "*know you haven't just copied, because if you had copied then you wouldn't have been able to explain the answer*". One student did explain that it was important not to be judged or humiliated. The classroom culture created by the teacher would therefore appear to be crucial if 'in the moment' FA strategies are adopted, i.e., students need to feel it is safe to explain their ideas even if they might be wrong:

> *"If you're in class and you're doing a question on the tablet, if you get something wrong it's easier to tell than just writing it in your copy where you only can see, then the whole class can see and tell you where you went wrong."*

Students thought that the technology also helped teachers to get a better (i.e. objective and observable) overview of how students were progressing:

> *"well, [teachers] can see what we've done better, it's hard to explain, if we do stuff on technology they can save it … they can see it … it's hard for them to know how we're getting on…"*

Representing their knowledge in a meaningful way was perceived to be especially beneficial to lower achieving students, as it allowed them to represent their learning pictorially. Students could make sense of images and videos within a particular application (e.g. iPad application Popplet).

Some students reported that working with these technology tools helped them to improve their learning, and facilitated their understanding of mistakes. It was reported that after FaSMEd, students changed their minds on the utility of using clickers in maths and science lessons, in particular for using the projected answers for discussions with respect to their own results/answers. Selected students reconsidered the status of mistakes for their learning, they realised that mistakes could be useful in the learning process:

> *"You made a mistake, that's all, but [now] you know that you have understood."*

Nearly all the case studies reported on the positive effect of technology in terms of facilitating and encouraging classroom discussions, either between teacher and students, or amongst students. Many students appeared to have had ample opportunities for peer interactions, partly due to the technology, in terms of: paired discussions; students compared samples

displayed, interpretations and strategies from peers, suggestions from peers, solutions, working and explanations from peers.

All the case studies reported an impact on student motivation and engagement. One teacher reported:

> *"I feel that my students are more confident in approaching unfamiliar tasks. They are more likely to 'have a go' at a task. The need to share work with their partner and to improve their own work, has helped them to appreciate the need to get something down on paper and to try things out. It has also helped their accountability in needing to complete a task, rather than just saying say 'I don't know what to do'."*

In some cases, teachers reported increased engagement and an improvement in the quality of student work due to the key role that technology played in displaying their work to their peers:

> *"If they know that they are going to have to present their work to the rest of the class they make much more effort with it".*

In other words, it was not the technology itself, but the knowledge that the technology *could* be used which had an impact on the quality of some students' work.

Cross-comparison of the FaSMEd cases

Our schools and teachers have used very different technological tools in their mathematics and science classrooms, and worked under different conditions and environments. Hence, a true comparative analysis was not possible, as many variables change with the use of different tools, change of environment, etc. As outlined in Deliverable D5.1, our intention was not to compare teachers internationally, but rather to develop deeper insights into how FA strategies (in particular technology-based) can help teachers and students to develop better learning trajectories. The following statements summarise the main findings from the cross case study analysis (Deliverable D5.2)[6]:

> *Statement 1*
> *The technology can provide immediate feedback, potentially useful for teachers and students. However, the usefulness depends to a large extent on teachers' skills to benefit from it, as they often do not know how to helpfully interpret and use the feedback into their teaching, in particular for using it formatively to benefit pupil learning.*

> *Statement 2*
> *The technology potentially provides, and even seems to encourage, ample opportunities for classroom discussions. Moreover, it appears that the technology helps to develop more cooperation within the class: teacher-student cooperation; and opportunities for cooperation between individual students/within groups.*

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

Statement 3
Technology appears to provide an 'objective' and meaningful way for representing problems and misunderstandings.

Statement 4
Technology can provide opportunities for using preferred strategies in 'new' or different ways.

Statement 5
The technology helps to raise issues with respect to FA practices (for teachers and students), which are sometimes implicit and not transparent to teachers. In nearly all the cases the connection of FA and technology tools helped teachers to re-conceptualize their teaching with respect to FA.

Statement 6
Different technological tools provide different outcomes: in principle, each tool can be used in different ways, for example, feedback to an individual; feedback to groups of students; feedback to the whole class and discussion. Often a mix of technology was used, and the orchestration of the technology tools needs particular skills.

Disseminating the outcomes of FaSMEd

The FaSMEd Toolkit

The main objectives for the FaSMEd project were to produce (through design research) a Toolkit for teachers and teacher educators (Deliverable D3.3) [7] and a Professional Development (PD) resource (Deliverable D3.6)[8]. The expression 'toolkit' refers to a set of curriculum materials and methods for pedagogical intervention. These were designed to support the development of practice and are disseminated through a website produced by the partners, and can be accessed at: http://fasmed.eu.

Professional Development package

The Professional Development (PD) package produced by FaSMEd reflects the range of ways in which partners have worked with teachers in their countries and offers examples for teachers and teacher educators to use. These include a set of six PD modules designed to help teachers use FA and technology more effectively in their classrooms. The resources also include a theoretical section on principles for effective professional development and a practical section on ways in which professional development can be organised. This section is meant to be used by people who are organising professional development for teachers of

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

mathematics and science but can also be used by teachers either individually or working with peers.

The FaSMEd position paper on Professional Learning of teachers[9] warned that Professional Development (PD) is perceived and experienced differently across countries. Partners were aware, therefore, that it was important not to assume too much about expectations and norms in other countries. However, the position paper then goes on to conclude that there is a high degree of convergence in descriptions of successful professional learning and the partners generally agreed. Typically, these include securing interest and engagement from the teachers, providing a theoretical framework for understanding of the innovation/strategy/programme and offering some practical tools to apply to classroom practice (Timperley et al., 2008).

The position paper also notes that *Professional Learning Communities* (PLC) (Wenger, 1998) emerge as one of the most promising structures for professional learning, particularly when these involve collaborative inquiry (e.g. OECD, 2013; Ermeling, 2010; Nelson et al., 2008). This is because the conditions for effective professional learning, fundamentally require teachers to feel safe to experiment, examine the impact of their innovations, to talk openly and to establish principles about effective student learning (Joubert & Sutherland, 2008). Partners were thus encouraged to engage with groups of teachers who were willing to collaborate as active participants in the design process of the resources for the toolkit and to support PLC's where possible.

In FaSMEd all partners used an *active* involvement of the teachers in the design-based research process as professional development. Teachers were involved through cluster meetings and school visits throughout the intervention phase of the project (2014/2015). These meetings included dialogues with the FaSMEd researchers, sharing of practice with other teachers as well as participating in the 'design-do-review cycles' of classroom materials. However, the organisation of this approach was very different for each FaSMEd partner but essentially fell into three main types: courses; learning groups and individual teachers[10].

Conclusions

The main objective for the project was to produce a toolkit for teachers and teacher educators and a professional development resource, implemented through a website, which would support their application of FA strategies using technology. This output [11] has been

[9] https://research.ncl.ac.uk/fasmed/positionpapers/TeacherProfessionalLearningPositionPaperRevised_Final_.pdf

[10] http://fasmed.eu/professional-development/approaches/

[11] http://fasmed.eu

successfully produced and is now ready for teachers and others to use. This resource now sits alongside the resources developed by SAILS[12], MASCIL[13], PRIMAS[14] and ASSIST-ME[15].

We conclude that most mathematics and science teachers in our study were not familiar with processing FA data (from students) using a range of technologies. In short, despite the widely recognised powerful impact of FA on student achievement, this practice utilising technology is not yet fully realised and there is much room for improvement. This is both in terms of ergonomics, with respect to the technology tools, as well as regarding teacher professional development to helpfully build in such tools into FA instructional practices.

Through the FaSMEd project, selected teachers managed to build the FA tools into their teaching, and reported a desire to embed these practices in future teaching. However, whilst the majority of teachers used the technology to collect and store data, it was not always used formatively in subsequent steps. It became clear that unless teachers were experienced and confident teachers of mathematics/science, the combination of FA practices and technology for the purpose of becoming more informed about student learning and understanding was challenging. Overall, we conclude that the full potential of FaSMEd activities and tools has not been realised in most partner countries at this stage.

Teachers involved in the project were faced with a number of challenges. In addition to introducing one of a variety of technologies into their classrooms, they were also asked (in most cases) to adapt to both a pedagogy of engagement and a pedagogy of contingency (Wiliam, 2006). The challenge to adopt a pedagogy of engagement caused a number of tensions. For example, (as recognised in the cross-country report, Deliverable D5.3), anxieties about performance in both mathematics and science are raised by the way in which governments and school management interpret international test results. Hence 'productivity' and 'performance' come into conflict with a pedagogy of engagement where reflective periods for examining alternative meanings and methods are required. Indeed, it must be recognised that FA requires teachers to prioritise learning over teaching – and that learning takes time, whereas teachers have a limited amount of time in which to deliver the required curriculum content.

The adoption of a pedagogy of contingency challenged teachers to translate formative 'intention' into formative 'action'. While all teachers appreciated the information about students' learning being made visible through the activities, assessment opportunities and technological support, some teachers found it difficult to use the information to make adjustments to their teaching to better meet their students' learning needs. This was particularly where the information was generated in the middle of an active lesson.

However, in schools where the leadership created time for teachers to come together regularly and frequently to plan, discuss and review, the teachers were generally much better equipped to engage with these challenges and tensions. We would argue that time for

[12] http://www.sails-project.eu/
[13] http://www.mascil-project.eu/
[14] http://www.primas-project.eu/
[15] http://assistme.ku.dk/

professional development is a necessary (but not sufficient) prerequisite for successful innovation in the classroom.

Where the conditions for professional learning are good, there is some evidence that practices trialled through FaSMEd were being embedded into teachers' pedagogy and general classroom practice. For example, one UK teacher said:

> *"The information gleaned from the pre-assessment tasks has always proven to be invaluable in finding out where the stumbling blocks for the students are and where teacher intervention is required. While the barriers for completing the task is sometimes similar for all students – and where I would have probably expected – occasionally it has thrown up surprises. This is a highly transferrable strategy which I plan to use before all units of work to inform my planning for the group."*

Another teacher commented:

> *"The FaSMEd project has reinvigorated my every day teaching and made me think about how I approach lessons and their structure. I am already starting to use photographs of students' work (displayed anonymously) to aid discussion and model working out/explanation. I already do a lot of pair work, but I am thinking more carefully about which students are paired together and I'm trying to mix students up more."*

In regard to the students, our investigations (and interventions) have shown a relatively positive picture: students seemed to welcome the FA data provided by the technology (and the teacher/s) and they were ready to usefully build it into their learning strategies. Overall, we could identify selected promising patterns of engagement and motivation, in particular for lower achieving students.

In conclusion, whilst we acknowledge the complex and challenging environments in schools, we believe the FaSMEd activities - combined with the appropriate technological tools - have the potential to mediate the learning process. This can be achieved through active engagement with the FaSMEd Toolkit and rigorous professional learning, as exemplified through the FaSMEd Professional Development Package.

References

Abrahamson, L., Davidian, A., and Lippai, A. (2002). *Wireless calculator networks –Why they work, where they came from, and where they're going.* Paper presented at the 13th Annual International Conference on Technology in Collegiate Mathematics. Atlanta, Georgia.

Ahmed, A. (1987). (Low Attainers in Mathematics Project), Better Mathematics. London: HMSO.

Ahmed, A., & Williams, H. (1991). Raising achievement in mathematics project. London: HMSO.

Ares, N. (2008). Cultural practices in networked classroom learning environments. *Computer-Supported Collaborative Learning*, 3, 301–326.

Black, P., Harrison, C., Lee, C., Marshall, B., & Wiliam, D. (2003). *Assessment for Learning: Putting it into practice*. Maidenhead: Open University Press.

Black, P., & Wiliam, D. (1998). *Inside the Black Box*. London: King's College School of Education.

Burkhardt, H., & Schoenfeld, A. H. (2003). Improving educational research: Toward a more useful, more influential, and better-funded enterprise. *Educational Researcher*, *32*(9), 3-14.

Cohen, L., Manion, L., & Morrison, K. (2000). *Research Methods in Education*. (Fifth edition) London and New York: Routledge.

Collins, A., Joseph, D., & Bielaczyc, K. (2004). Design research: Theoretical and methodological issues. *The Journal of the learning sciences*, *13*(1), 15-42.

Department of Basic Education (2012). Report on Annual National Assessments 2012 Grades 1 to 6&9. Johannesburg: Department of Basic Education.

Dufresne, R. J., Gerace, W. J., Mestre, J. P., & Leonard, W. J. (2000). ASK-IT/A2L: Assessing student knowledge with instructional technology (technical report No. UMPERG-2000-09). Amherst: University of Massachusetts Physics Education Research Group.

Ermeling, B. A. (2010). Tracing the effects of teacher inquiry on classroom practice. *Teaching and teacher education*, *26*(3), 377-388.

Gravemeijer, K., & Cobb, P. (2006). Design research from a learning design perspective. *Educational design research*, 17-51.

Hiebert, J., Gallimore, R., Garnier, H., Givvin, K. B., Hollingsworth, H., Jacobs, J., Stigler, J. (2003). Teaching Mathematics in Seven Countries: Results From the TIMSS 1999 Video Study. Washington, DC.: U.S. Department of Education National Center for Education Statistics.

Irving, K.I. (2006). The Impact of Educational Technology on Student Achievement: Assessment of and for Learning. *Science Educator*, 15(1), pp. 13-20.

Joubert, M., & Sutherland, R. (2008). Researching CPD for teachers of mathematics: A review of the literature. *National Centre for Excellence in the Teaching of Mathematics*.

Kaput, J. J. (1992). Technology and mathematics education. In D. Grouws (Ed.), Handbook on research in mathematics teaching and learning (pp. 515-556).

Looney, J. (2010). Making it Happen: Formative Assessment and Educational Technologies. *Thinking Deeper Research Paper n.1, part 3*. Promethean Education Strategy Group.

Luckin, R., Bligh, B., Manches, A., Ainsworth, S., Crook, C. & Noss, R. (2012*) Decoding Learning: The proof and promise of digital education*. London: Nesta.

Nelson, T. H., Slavit, D., Perkins, M., & Hathorn, T. (2008). A culture of collaborative inquiry: Learning to develop and support professional learning communities. Teachers College Record, 110(6), 1269–1303.

OECD (2013) TALIS report: Fostering learning communities amongst teachers. Retrieved from *www.oecd.org/talis*

Rocard, M., Csermely, P., Jorde, D., Lenzen, D., Walberg-Henriksson, H., & Hemmo, V. (2007). Science Education NOW: A renewed Pedagogy for the Future of Europe. Luxembourg: Office for Official Publications of the European Communities.

Roschelle, J., and Pea, R. (2002). A walk on the WILD side. How wireless handhelds may change computer-supported collaborative learning. *International Journal of Cognition and Technology*, 1(1), 145-168.

Roschelle, J., Penuel, W.R. and Abrahamson, L. (2004). The networked classroom. *Educational Leadership*, 61(5), 50-54.

Roschelle, J., Tatar, D., Chaudhury, S.R., Dimitriadis, Y. and Patton, C. (2007). Ink, Improvisation, and Interactive Engagement: Learning with Tablets. *Computer*, 40 (9), 42-48. Published by the IEEE Computer Society.

Roschelle, J., Rafanan, K., Estrella, G., Nussbaum, M., Claro, S. (2010) From handheld collaborative tool to effective classroom module: embedding CSCL in a broader design framework. *Computers & Education, 55* (3), 1018–1026.

Schroeder, C. M., Scott, T. P., Tolson, H., Huang, T.-Y., & Lee, Y.-H. (2007). A meta-analysis of national research: Effects of teaching strategies on student achievement in science in the United States. *Journal of Research in Science Teaching, 44*(2), 1436-1460.

Seidel, T., & Shavelson, R. J. (2007). Teaching effectiveness research in the past decade: The role of theory and research design in disentangling meta-analysis research. *Review of Educational Research, 77*(4), 454-499.

Shayer, M., & Adey, P. (2002). *Learning intelligence: cognitive acceleration across the curriculum from 5 to 15 years*. Buckingham: Open University Press.

Shayer, M., & Adhami, M. (2007). Fostering cognitive development through the context of mathematics: Results of the CAME project. *Educational Studies in Mathematics, 64*(3), 265-291.

Shirley, M., Irving, K.E., Sanalan, V.A., Pape, S.J. and Owens, D. (2011). The practicality of implementing connected classroom technology in secondary mathematics and science classrooms. *International Journal of Science and Mathematics Education*, 9, 459-481.

Shulman, L.S., (2002) Making Differences: A Table of Learning, *Change: The Magazine of Higher Learning,* 34:6, 36-44

Slavin, R., & Lake, C. (2008). Effective programs in elementary mathematics. *Review of Educational Research, 78*(3), 427-515.

Slavin, R., Lake, C., & Groff, C. (2009). Effective programs in middle and high school mathematics. *Review of Educational Research, 79*(2), 839-911.

Swan, M. (2000). Improving Learning in Mathematics: Challenges and Strategies. From http://www.nationalstemcentre.org.uk/elibrary/collection/282/improving-learning-in-mathematics

Swan, M. (2006). *Collaborative learning in mathematics: a challenge to our beliefs and practices*. Leicester: National Institute of Adult Continuing Education.

Swan, M, (2014). Design Research in Mathematics Education. In Lerman, S, (Ed.), *Encyclopedia of Mathematics Education* Dordrecht, Springer.

Thompson, A. G. (1992). Teachers' beliefs and conceptions: A synthesis of the research. In D. Grouws (Ed.), *Handbook of research on Mathematics teaching and learning* (pp. 127-146). New York: Macmillan.

Timperley, Helen, Aaron Wilson, Heather Barrar, and Irene Fung (2008) Teacher professional learning and development. (2008): 61-74.

Wenger, E. (1998). *Communities of practice: Learning, meaning, and identity*. Cambridge: Cambridge University Press.

Wiliam, D., (2006). Assessment for Learning: why, what and how. In *Excellence in Assessment: Assessment for Learning* Cambridge: Cambridge Assessment Network

Wiliam, D., & Thompson, M. (2007). Integrating assessment with instruction: what will it take to make it work? In C. A. Dwyer (Ed.), *The future of assessment: shaping teaching and learning* (pp. 53-82). Mahwah, NJ: Lawrence Erlbaum Associates.

Wright D, Clark J, Tiplady L. (2015) Making learning visible in mathematics with technology. *Mathematics Teaching*, 249, 30-36.