Maynooth University Ireland: Maths Case Study

1. Context

X	Maths Case Study School
XMA	Maths Case Study Teacher
XMA_S1-30	Students of the Maths Case Study Teacher
XMB	Second FaSMEd maths teacher in school X
XMB_S1-30	Students from the second FaSMEd maths teacher in school X
T1-3	Interviews with teacher at time 1, 2, 3

Table 1: Key to codes used within Ireland Maths Case Study

School

The school (X) is a co-educational, multi-denominational school established in 2008. Student's ages range from 12-18. There are currently 1013 students enrolled in the school with 79 teachers. The school community is diverse, with students from 58 separate nationalities. The school strives to meet the needs of students from different cultural, ethnic, religious and social backgrounds. The school offers a broad and balanced curriculum, including programmes such as Transition Year (TY), and the Leaving Certificate Applied (LCA). It is part of a group of schools under the patronage of Dublin and Dún Laoghaire Education and Training Board (DDLETB). The school has adopted Assessment for Learning (AfL) strategies and the Principal described the school as an AfL school. The strategies implemented up to starting the FaSMEd project are traffic light cups, mini-white boards and lollipop stick questioning which are made use of in the majority of lessons. Interactive whiteboards are also available in all classrooms. FaSMEd is the first large-scale research project the school has participated in. At the start of the project the school was looking at the role of technology in teaching and learning and exploring the introduction of tablets for incoming first year students in September 2015.

In 2013 the Mathematics Department underwent a subject inspection carried out by the Department of Education and Skills. The report's main findings suggested that the Mathematics Department have very good assessment practices resulting from very good whole school and department planning. The report recommended that

teachers work on how learning outcomes are framed within the mathematics classroom. In addition it recommended that extension activities during lessons should include more open-ended questions to engage the students in problem solving (Department of Education and Skills, 2013). The FaSMEd team explored these recommendations during professional development sessions with teachers and throughout classroom observations.

Teacher

XMA is a teacher of mathematics and business studies. She had nine years of teaching experience before participating in the project; six of those years were in her current school. She is currently a Year Head and prior to that was a Head of Department. She is in the 31-40 age range and her past experience of working in a research project includes being the link teacher of a numeracy initiative in which her school is piloting. She is currently studying for a Postgraduate Diploma in Educational Leadership.

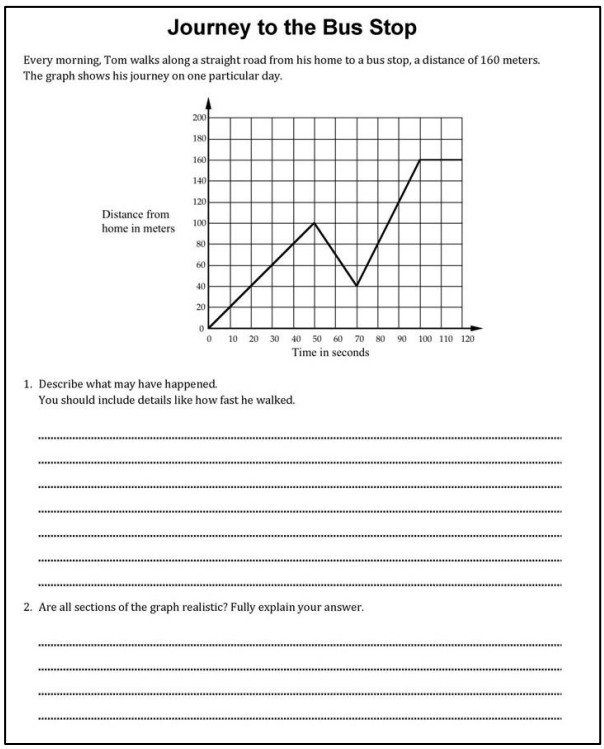
Class

The students in this class range in age from 13-15. There are 30 students in total in the class with equal numbers of boys and girls. The class is of mixed ethnicity and mixed ability. According to their teacher the class work very well together. They are all part of the same tutor group so are with the same group for most of their lessons apart from two option subjects. There are nine students in the class who have some degree of special education needs including dyslexia, English language difficulties and literacy difficulties.

2. Tasks and Resources Used

The tasks and resources used in this case study were based around the distance-time lessons. In the spirit of design-based research, twice the teacher taught this series of lessons. The first time the teacher taught the lesson she made use of the original

distance-time lesson from the Mathematics Assessment Project (MAP) materials[1]. The lessons began with the teacher recapping on the pre-assessment task (*Journey to the Bus Stop*, Figure 1) she handed out prior to the class. She analysed these tasks before the first lesson and used them to build feedback into her lesson to move students forward in their learning.



Journey to the Bus Stop

Every morning, Tom walks along a straight road from his home to a bus stop, a distance of 160 meters. The graph shows his journey on one particular day.

1. Describe what may have happened.
   You should include details like how fast he walked.

2. Are all sections of the graph realistic? Fully explain your answer.

Figure 1: Journey to the Bus Stop assessment task

Following on from the brainstorm based on pre-assessment task the students made use of their individual mini-whiteboards in the *matching a graph to a story task*. They then shared their answers with the class during a think, pair, share activity.

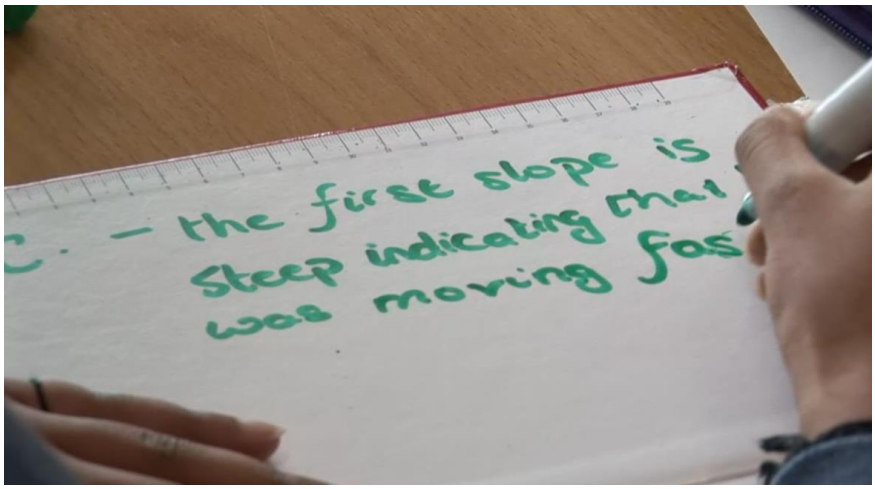


Figure 2: Student writing on a mini-whiteboard

[1] Available at http://map.mathshell.org/lessons.php?collection=8&unit=8225

After this task the students engaged in a card matching activity within co-operative groups. When the card matching exercise was complete the students were given the opportunity to reattempt the *Journey to the Bus Stop* pre-assessment task.

During the second *reteach* lesson the teacher made the following changes to the series of lessons:

- She spent more time addressing misconceptions with the students after analysing the pre-assessment task; she felt this would help their progress through the tasks in the lessons.
- She integrated more technology within the lesson by utilising her tablet device to screencast student answers to questions on the interactive whiteboard. She also felt that by using her tablet she would be able to move freely around the class and interact with students throughout the lessons.
- Students also used her tablet to share their thinking.

3. Work with Teachers

Timperley and colleagues, in their *Best Evidence Synthesis*, highlight the importance of creating dissonance or cognitive conflict in teachers' thinking in order to bring about changes in their practice. They need to confront what they are doing at present and see better alternatives, rather than layering new thinking onto old practice (Timperley, Wilson, Barrar and Fung, 2007). This is especially important in the development of formative assessment (FA), as many pedagogical practices used may appear familiar to teachers. Work with teachers in Ireland had the following key characteristics:

1. Workshops were interactive and activity-based, encouraging participants to develop their own thinking on FA to encourage individual and collective professional learning.
2. Workshops focused on pedagogical practices to enhance student learning.
3. Key readings were provided for participants to engage with research underpinning the pedagogical practices advocated in order to promote reflective professional enquiry.

4. Participants were encouraged to share practice in both a formal and non-formal way during professional development events, to encourage collaboration focused on learning and teaching.
5. Workshops were tailored to suit the needs of the participating schools but were at all times focused on formative assessment in order to optimise resources and structures.
6. Participants were encouraged to think and plan how they could develop formative assessment, to build on existing practices, and to explore new practices using a *do, review* and *redo* cycle, promoting reflective enquiry.
7. Participants were encouraged to discuss FaSMEd classes with their students and to be explicit on FA skills they were developing so that students were focused on their own role in learning.
8. Participants were encouraged to view each other's practice and to give feedback so as to promote mutual respect, trust and support.

The teachers participated in four professional development sessions with the researchers throughout the 2014/2015 academic year. The sessions were between three and five hours long. These sessions were followed up by school visits and informal conversations following classroom observations. Between sessions, teachers shared their reflections and student work on *Schoology* (discussed later in the case study). This sharing of practice between sessions encourages peer support and professional sharing.

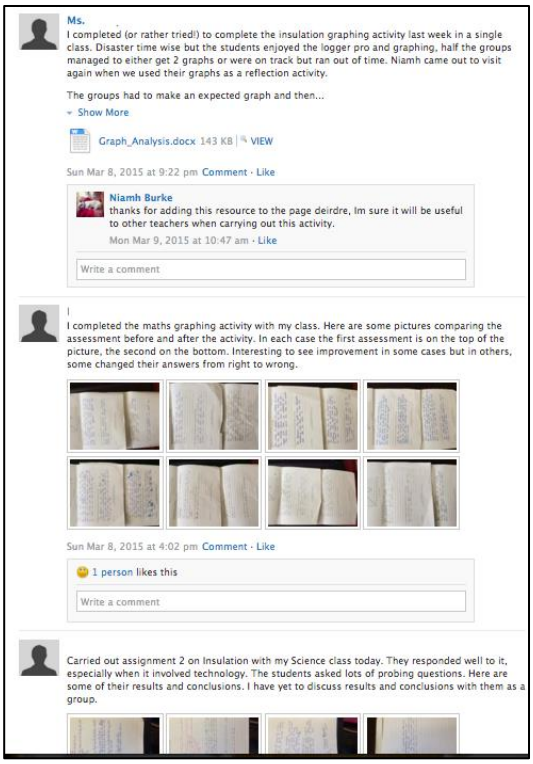


Figure 3: Screenshot of FaSMEd Schoology page

Typically sessions after the first introductory one began with people sharing their experience of teaching the classes using the FaSMEd toolkit. It was important to interrogate these inputs and to explore the complex nature of

FA development, so as to avoid the surface or layering-over treatment of the toolkit. In addition, as the work on developing FA required teachers to move to a more constructivist approach to teaching, it was important that the workshops adopted a constructivist approach to teacher learning and provided opportunities for teachers to build on what they already knew and to interpret FA and construct their own meaning with colleagues. As Reid (2006) posits, *the pedagogical challenge is to plan learning experiences with reference to the whole competency/capability, even while one aspect of it might be the focus of a specific experience* (p. 46). This was a challenge in the work on FA, with some teachers seeing the development of the FA as an addition to the learning rather than an integral part of the process. The sessions were activity based, striving to model the process of FA development and to enable teachers to develop their own skills, knowledge and attitudes towards FA. Teachers also got to try the lessons and to get familiar with the technology with their peers and teachers from the other participating schools. They then planned for how they would teach the lessons with their students and made suggestions for changes and for timing of the lessons in their local context. *Schoology* also played a role in this planning process as teachers shared student work, however, this rarely moved beyond the sending and sharing role for technology between teachers.

These sessions focused on the following aspects of formative assessment:

1. Building on prior knowledge and feedback
2. Identifying and responding to conceptual difficulties
3. Improving questioning
4. Increasing student collaboration
5. Students as assessors

Each session included a focus on technology and how it could be integrated into the different activities. Technology functioned in sending and displaying student work, processing and analysing student information and creating an interactive environment for student to collaborate together using technology.

Day 1: Building on prior knowledge and feedback

The first session was held with teachers in November of 2014, and ran from 10am to 3pm. This session focused on introducing teachers to the project, providing them with information around formative assessment and setting them a problem solving activity to carry out with students. In particular the following questions were explored with teachers:

- How can assessment be used to promote learning?
- What kinds of feedback are most helpful for students and which are unhelpful?
- How can students become engaged in the assessment process?

The teachers were tasked with carrying out a problem solving activity with their students aimed at improving their feedback practices. The resources from this activity were obtained from the FaSMEd toolkit and the teachers were to make use of one of the following problem solving activities:

- Cats and Kittens
- Security Camera
- Counting Trees

The teachers got the opportunity to try these activities for themselves during the session and provided each other with feedback on the activity. In the afternoon technology was discussed and teachers were introduced to *Schoology*, a learning management and social network system that would be utilised throughout the project. During the session teachers were encouraged to interact on the groups *Schoology* page outside of the professional development sessions, by sharing resources and reflections on the prescribed lesson once they had taught it to their students. This is evident in Figure 3.

Day 2: Identifying and responding to conceptual difficulties

The second session with teachers took place in January 2015, and ran from 10am to 3pm. The day began with teachers reviewing and giving feedback on Activity 1. Teachers were organised into two groups and made posters about Activity 1. Each group had a mixture of mathematics and science teachers. Using the posters the teachers and the facilitators had a group discussion about the activity.

Overall the teachers felt this activity was pitched too high for their students however did comment that once given some feedback to scaffold the learning, the students spent longer trying to figure out the activities. Teachers commented that students had difficulties, as they were uncomfortable because there was no correct answer.

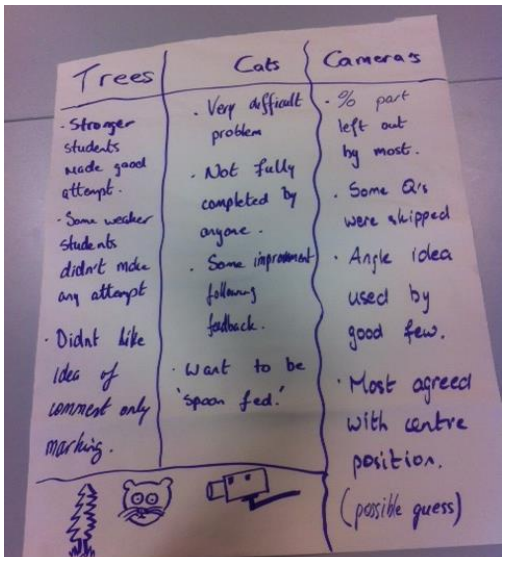


Figure 4: Poster created by FaSMEd teachers portraying their feedback on activity 1

In the afternoon the teachers explored student misconceptions and how these might impact a maths lesson. The teacher's task was to carry out a pre-assessment with students prior to teaching a topic. They then had to use this pre-assessment to plan for the following lessons. The mathematics teachers worked on the distance-time lesson from the FaSMEd toolkit. They trialled the lesson in groups and then discussed how they might implement this series of lessons in their own schools.

Day 3: Improving Questioning and Increasing Student Collaboration

The third session with teachers was in March 2015 and lasted from 10am to 3pm. This session took place in one of the participating FaSMEd schools. The researchers chose to carry out two activities with teachers on this day due to the short length of the Irish school year. In the morning the teachers reviewed the second activity carried out with students.

The researchers made use of FaSMEd professional development materials with the teachers on the topic of questioning. The teachers were asked to utilise what they learned about effective questioning in their future lessons and to video record each other's lessons in pairs, make observations around each other's questioning and then to participate in peer assessment following the recorded class.

This session also involved teachers improving student collaboration. Once again the researchers made use of professional development materials provided by FaSMEd and adapted them to suit their teachers. The mathematics teachers looked at

Number Operations, Ordering Fractions and Understanding the Laws of Arithmetic. They trialled each of these lesson plans and discussed what they might use with their classes.

Day 4: Students as Assessors

The final session with teacher took place in April 2015 and was a half-day session (09.30-12.30). In the morning the teachers provided feedback on the previous two activities. Feedback from the questioning activity was largely positive with teachers appreciating the constructive comments their peers gave them on their questioning practices, they also remarked that they became very aware of their questioning and reactions to students questions with teachers placing an emphasis on the importance of body language in the classroom.

Figure 5: FaSMEd teachers and researchers engaged in discussion about their questioning practices

The final activity that teachers had to implement in the classroom was around self and peer assessment. The students were to make use of graphic organisers as revision for their summer examinations. They were then to swap organisers and peer-assess them using a rubric that the teacher designed. Students also had to self-assess by filling out reflection sheets at the end of the lesson.

The teachers were given the option of using the application *Popplet* that allows students to create these graphic organisers on their tablet device. This would allow

for the sending and displaying functionality of the technology where the completed graphic organisers were to be uploaded to the class *Schoology* page and shared among the students. Some teachers opted to get the students to create pen and paper graphic organisers.

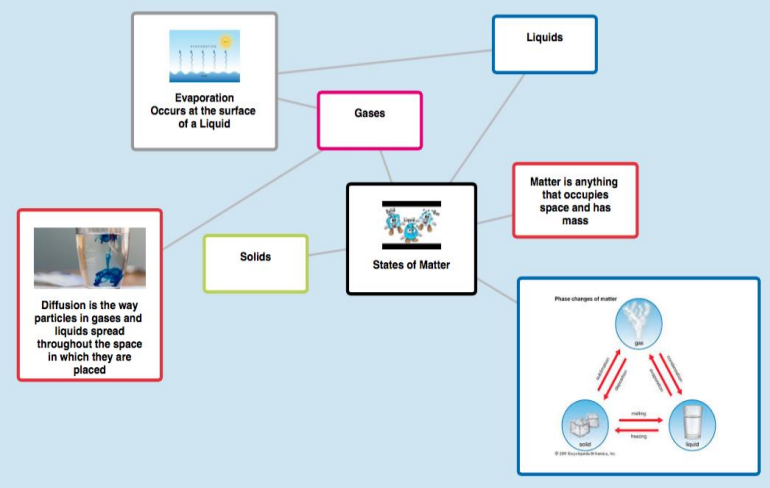


Figure 6: Sample Popplet

4. Classroom Teaching

The Maths Case Teacher (XMA) was interviewed on three occasions. She was initially interviewed at the beginning of the project (T1) and at the end of the first cycle of the project (T2). She was then interviewed once more (T3) following her distance time lesson that she had adapted and retaught.

Previous experience of formative assessment and technology

Prior to FaSMEd she emphasised that Assessment for Learning techniques were adopted on a whole school basis within her school. She utilised approaches in the classroom such as lollipop stick questioning, sharing the learning objectives, making use of mini-whiteboards and collaborative work among students. On joining the FaSMEd project this teacher had implemented many of these AfL practices and this provided a rich basis to build on the

Figure 7: Traffic light cups and mini-whiteboards on each table in the maths classroom

more student centred formative assessment (FA) practices such as using learning tasks that elicit evidence of student understanding and providing feedback to move students forward. At pre-intervention stage she maintained that she got information on student understanding from pupils during homework corrections and some of her feedback practices were only at surface level not providing information to the students to move forward in their learning.

> "Obviously test results as well, oral feedback and general well done, particularly telling students who didn't do great in the last exercise, tell them they made a massive improvement which really helps." (XMA_T1)

From this quote the teacher is focusing feedback on the test result rather than on the student's understanding. When asked about what assessment practices she views as being important indicators of successful student performance she commented that:

> "Written tests, them definitely, but I think just checking for understanding." (XMA_T1)

In the above quote she is putting emphasis on using tests as a means to check for student understanding.

From participating in the project, it was felt that the teacher's co-operative learning practices, questioning, and feedback skills would be enhanced and that she would gain a theoretical understanding of formative assessment to build on what she was already doing. In addition, the project provided her with an opportunity to explore the role of technology in FA and to integrate the use of interactive whiteboard and tablet into her teaching in a way to enrich it. The school in which this teacher is working is in the process of integrating Microsoft Surface Pro's with the first year students of 2015/2016 with each student owning their own device. XMA had not utilised these devices before being involved in the FaSMEd project. The school did have interactive whiteboards in all classrooms that were used in teaching but not with a specific emphasis on FA. She had not previously been part of an online collaborative learning community. The project would consist of her being actively involved in the online community *Schoology* and using this space to share ideas and collaborate with other teachers on the FaSMEd activities.

Opinions surrounding and uses of formative assessment

After her participation in the FaSMEd project, at T3 XMA expressed her views of formative assessment:

> "It means checking students understanding as often as possible not in our formal written exams. Developing a student's ability to answer questions orally, to take responsibility for their own learning, to encourage others around them to learn, to do a piece of work and reflect back on it, say was that my best piece of work, could I have done something differently, if I had to do it again would I change it, would I add something else on, what did I do really well, did I reach today's lesson objective, where was I, was it the best class I ever had, what could I do differently in the next lesson to try and improve that learning." (XMA_T3)

In the above comment it can be deduced that the teacher has moved away from her reliance on summative assessments to monitor student performance and has adapted a more student centred approach to her teaching by activating students as owners of their own learning. This is particularly important for low achieving students to build on their maths self efficacy and therefore improve their performance in class. She also expresses how she believes that clarifying, sharing and understanding learning intentions is an important aspect of student learning.

Following the project, the teacher noted how her questioning and feedback techniques had improved. Initial interview (T1) revealed that this teacher felt lollipop stick questioning was an important aspect of her assessment for learning techniques. This form of randomised questioning allows students the equal opportunity to get involved in classroom discussions.

> "We don't do hands up really in this school so using lollipop sticks… everybody has a chance to engage with a question and think about it first." (XMA_T1)

This is of benefit to all students especially low achieving students as it keeps them actively involved in the class. During this interview (T1) the teacher did not make

reference to the types of questions she was asking, in particular questions of a higher order were not alluded to. Therefore it was felt that by participating in FaSMEd this teacher would employ more higher order questions within her maths lessons. Post interview highlighted how the teacher had become conscience of her questioning style with her students.

> "Particularly the questioning one (referring to the activity), I found that one good, from a teachers point of view to reflect on what I have been doing in my own class and how body language and things like that can have an impact, things that I need to remind myself of." (XMA_T2)

She found that the task A3 (improving questioning through teacher peer observation and analysis) was quite beneficial to her teaching practice as it made her more aware of her questioning practices:

> "It made me reflect…particularly the question one…I videoed XMB and she came in and videoed my class, that definitely made me reflect on practices and what she was doing and see of there was anything I could take from her classes as well, which there was." (XMA_T2)

Advantages and disadvantages of formative assessment

According to XMA the advantages of using formative assessment in the classroom include keeping students engaged in classroom activities, getting them to build resilience to stick at a problem, and building student confidence to participate in co-operative learning activities. She noted how this led to the student's fear of the wrong answer being diminished and according to her, the students who participated in FaSMEd "don't mind if they're not right" (XMA_T3). She also alluded to how students enjoyment of maths class had increase since she adapted more formative assessment practices in the classroom, in particular co-operative learning and peer assessment as the students enjoyed being active and participating in their maths lessons. Following her revised distance time lesson at T3 she commented on how formative assessment techniques allowed her to act as a *facilitator of learning* meaning that she was not doing all the work in the lesson but it was her task to keep the lesson flowing. She commented that:

> "I'm putting the onus back on them to take responsibility for their own learning and to help each other to learn." (XMA_T3)

Here she is conveying how she believes that the formative assessment practices she carried out during class was enabling students to be more self-regulated, autonomous and open to aiding their peers with work and not reliant on her for guidance all the time.

> "I can certainly assess whether they are understanding and reaching the lesson objective by standing back and observing sometimes, or by directing questions either individually or to groups." (XMA_T3)

In relation to the technology the teacher implemented in her lessons, she illustrated how the use of her Microsoft Surface has developed her teaching and has allowed her to be removed from the top of the classroom and become involved in the lesson among her students.

> "It just means that I'm not at the front all the time." (XMA_T3)

She continued to comment that she often gives her Surface over to her students so that they can work on a problem that gets projected on the board for the whole class to engage with. One of her students commented how:

> "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 only you can see, then the whole class can see it and tell you where you went wrong." (XMA_S15)

Technology also allows her to gain insight on student's ideas and thoughts about different activities that can be shared and discussed among the class.

> "She could still be walking around class and helping people but I guess it gives us more options so that the whole class can participate so it's not just one person and she doesn't have to walk back and forth to the board." (XMA_S9)

Teaching style and strategies

Prior to participating in the project the teacher's style of teaching maths was of a stereotypical nature. When asked about how she would teach a lesson she commented on the daily routine of her maths lessons:

> "'I'd tend to start with the homework on the board already so I'll tell them what their homework is going to be for the end of the lesson and I put up the learning objective. With maths I usually correct the previous nights homework first of all, take student input with the lollipop sticks and so on, and then I tend to teach a new topic or whatever we are moving on to, or do that activity. Then I usually would let them start a question or two from the homework that I've set just to get them used to what they are going to be doing that evening." (XMA_T1)

Here it is apparent that the teacher is placing herself at the centre of the class is focusing on getting the curriculum covered with the students. She does not refer to how she gets the students engaged or involved in the lesson and although she shares the learning objective with the students she fails to comment on what benefit this is to the class or how it is used. Student understanding is not talked about in any of the T1 interview; her focus is very much on organisation of the learning. She is trying to implement FA strategies, but the focus is still on her as the implementer, not the students and their experience.

Following participation in the project and in the professional development session with other teachers, her teaching practices have been noticeably altered. During post interview she commented on the effectiveness of certain formative assessment practices explored within FaSMEd:

> "I was surprised from a maths point of view how much they enjoyed doing the graphic organisers. We do peer assessment in the school because we are an AfL school, but they were very good at picking out the good points and the bad points and giving pointers and they got very involved in that and they enjoyed it as well so I definitely would do that again." (XMA_T2)

Here she is conveying how she believed that certain activities would not be effective in her classes due to the stereotypical nature of teaching mathematics. During this interview she commented on how had made use of matching activities (from the FaSMEd toolkit) with her other maths classes maths students as it engaged her students with her lessons. At T3 she commented on how group work doesn't just happen "by accident". She explained how she had previously organised groups so that students of different abilities could work together. She maintains that this method of co-operative organisation provides low achieving students the opportunity to interact with more academically able students during class, and therefore become less reliant on the teacher for guidance. She also noted how she would be using and adapting this technique in her classes in the future.

From her engagement with the toolkit it is clear that the teacher adopts active learning methodologies in her lessons to promote student engagement and learning, she has removed herself from the epicentre of the lesson and now allows students to become actively involved in their own learning. She has built on her good practice and is using technology to provide opportunities for students to send and share in class. She is using *Schoology* to help plan her lessons.

Supporting students

In initial interviews XMA explained how she supports students who are having difficulties in her lessons. Here she is conveying how she pays particular attention to low achieving students:

> "Sometimes I will speak to the student individually maybe on my own, sometimes I would do pair work and have a stronger student working with a weaker student. We do team teaching so I would have somebody in two periods a week for maths with me, so I would usually have identified those students with the teacher and make sure that teachers focusing on them as well." (XMA_T1)

The teacher is focused on how to organise the lesson and to allow time for re-teaching with weaker students. However, she is not thinking about student

understanding or student re-engagement. She did not allude to this in post interviews (T2 and T3) however it was observed during classroom observation that when her students were unsure of how to progress she recommended that they use their peer as a resource. She also cited the value of pre-assessments in giving her the information on student's misconceptions so that she could focus her feedback to each learner to move them forward.

The use of problem solving and card matching activities, coupled with class discussions on understanding has meant that student's fears surrounding mistake making during maths class is not an issue with XMA by T3. During her second post interview (T3) she commented on how her students were okay with not getting the correct answer all the time in class and how this led to an increase in student confidence when attempting maths problems. This is discussed further in Section five of this case study.

5. Lessons

For the distance time lesson, there were two observers in the classroom. Observer 1 took detailed field notes about what was happening during the lesson while observer 2 recorded the lesson. The video camera was not stationary and observer 2 moved around the room during the lesson to capture student work and conversations as well as the teacher's interactions with students. Both close up shots of student work and discussions, and wide shots of the entire class were captured.

The aim of the distance time lesson (A2) was to alleviate misconceptions students might have about graphing, in particular reading a graph as a picture rather than a diagram showing the relationship between two variables. XMA accomplished this by identifying and responding to their conceptual difficulties through questioning, feedback and the use of a pre-assessment task. She also made use of co-operative learning pairs and groups so that students could help each other with tasks and peer assess each others work by moving to the other groups within class to review and challenge other's answers to the different matching activities.

Figure 8: Classroom set up for the lesson, students working in pairs and groups.

Within the distance time lesson the students had to work in groups on three tasks. Task 1 involved students working in groups on a multiple-choice problem presented by the teacher. During this activity the students could make use of their mini-whiteboards to demonstrate their understanding. This task was carried out using a think, pair, share activity.

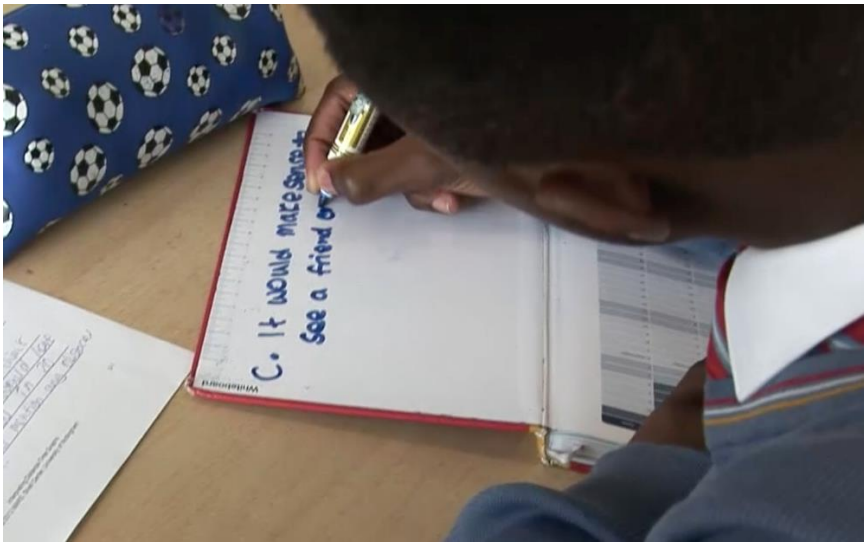


Figure 9: Student utilising a mini-whiteboard to share his thoughts with the class

Task 2 was the first card matching activity of the lesson, whereby students had to match stories to graphs and make up their own stories for graphs, students worked co-operatively on this task. The final task (Task 3) was another card matching activity, it required students to decide on appropriate units of measure for the distance time graphs; they completed this task in groups. Throughout the lesson the students took part in discussions with the teacher on the tasks, they utilised each other as resources for learning and they also had the opportunity to work alone at points to build their own self-regulatory skills.

Co-operative Learning and Peer Assessment

Throughout the lesson it was observed and documented in field notes that the students were very engaged in their class tasks, and appeared to be both motivated to complete the activities while simultaneously enjoying the lesson. This became apparent due to the teachers use of co-operative learning tasks and peer assessment. The first co-operative activity the teacher tasked the students with was a think, pair, share exercise. It was clear from observations that students were very familiar with this type of activity and got immediately involved. To motivate the students and keep them focused on the lessons activities, the teacher constantly encouraged students to have a *mathematical argument* with their peers. What the teacher meant by this was that she was encouraging them to challenge their classmates and make sure that they were able to defend and explain their reasoning. This demonstrated how the teacher was promoting peer assessment among the students in a simple and effective manner. Due to this, as well as developing their peer assessment skills, the teacher was building self-regulated learners whereby the

Figure 10: Students engaging in the lesson and having mathematical arguments.

students became confident in their own work and did not rely on the teacher to give them guidance. This method of peer assessment was particularly of benefit to low achieving students.

Further in the lesson while the students were involved in pair and group work, pupil engagement could clearly be witnessed. On numerous occasions students of all abilities were seen to probe each other for understanding and participate in *mathematical arguments* as suggested by their teacher. Students can be heard asking each other questions such as "why do you think C matches" and explaining their reasoning to their peers. This once again emphasises the teacher's strategy of peer assessment among students. A misconception that many students were having in the class was that the graph was a picture and therefore if the graph increased then the person was walking up the hill. In this lesson it was observed how co-operative learning resolved this misconception among peers. One student (S1) believed that "if he ran down (the hill) then the line would be down", this is clearly not the case for a graph and her peer (S2) explains to her that if the line is going down it means that the person is returning home not going downhill. The students (S1) *eureka* moment was clearly witnessed on her face when she suddenly understands more clearly the concept of distance on the graph.

Figure 11: Students helping each other with matching activity.

S2 then went on to relieve the same misconception with another of his peers by clarifying that " he's going down the other side of the hill so he's going away from

home". The fact that the students are using colloquial language to help resolve each other's misconceptions is of great benefit to students, especially low achievers, as they are becoming more independent of the teacher and therefore can take charge of their own learning without constantly relying on the teacher for guidance.

Figure 12: S1 explaining to another student on her table the difference between graphs and pictures.

Interestingly when S1 had resolved her misconceptions, later in the class she was seen to help another student figure out the graph versus picture dilemma by explaining to him that "if he was at his house the it would be down here (pointing at the bottom of the graph), he didn't come from his house". This once again demonstrates how co-operative activities are helping students to learn without the need for the teacher present.

Field notes gathered from this lesson further support the students' excellent co-operative learning skills. Notes gathered illustrate how students co-operative learning skills and communication skills were very well developed, they show how it was clear that the students are familiar with this type of learning and they demonstrate how throughout the lesson the students engaged in co-operative learning to problem solve, peer assess and make their reasoning visible to others.

Questioning and Feedback

It became apparent during observations of the distance time lesson (A2) that the teacher had made enhancements to her questioning techniques, and she was making use of the lollipop stick questioning method to randomise the questions, her questions now also challenged the students to think for themselves. For example, during a conversation between the teacher and a group of students she probed a student for understanding by asking her higher order questions:

XMA: *Do you want to explain to me why you went with that one?*

Student: *Because the steeper the slope the less time you take and the distance doesn't go further up, that means that's where the bus stop is. So he ran from home so it shows the shorter amount of time and he walked back so it's longer.*

XMA: *And why do you think this one is run and this one is walking (pointing at the graph)?*

Student: *Because it's not as steep, it shows that maybe he took more time to go back.*

XMA: *And what about here (pointing at the graph)? Why do you think that he's standing still here? How did you come to that conclusion?*

Student: *At the bus stop he stopped and waited.*

XMA: *How do you know he is waiting here?*

Student: *Because the distance isn't changing.*

XMA: *And what is happening with time?*

Student: *The time is passing.*

XMA: *The time is passing, well done, very good; you're really starting to get the hang of it. Keep going there guys.*

Field notes of A2 illustrated how the teacher made use of higher order questioning throughout the lesson to elicit evidence of student understanding and to move students forward with their learning. The teacher made use of questions such as "what do you think (about a certain card match)" and "how do you know it's

changing (in relation to speed on the graph)" so that the students could think for themselves about the activity rather than her giving them all the solutions.

Video analysis established how the teacher was probing for understanding during group work. The teacher, throughout the entire lesson was posing such questions as "if he's running back to his house, what is happening here with the distance from home?" (XMA). With this question, the teacher was in the process of giving a student feedback on an incorrect card match up. Following on from asking this question the teacher is then seen to encourage the student to have a conversation with her peer about the mismatch. This highlights how the teacher is not focused on giving the student the correct answer but how she wants the student to come to the right answer herself perhaps by using the help of her peer.

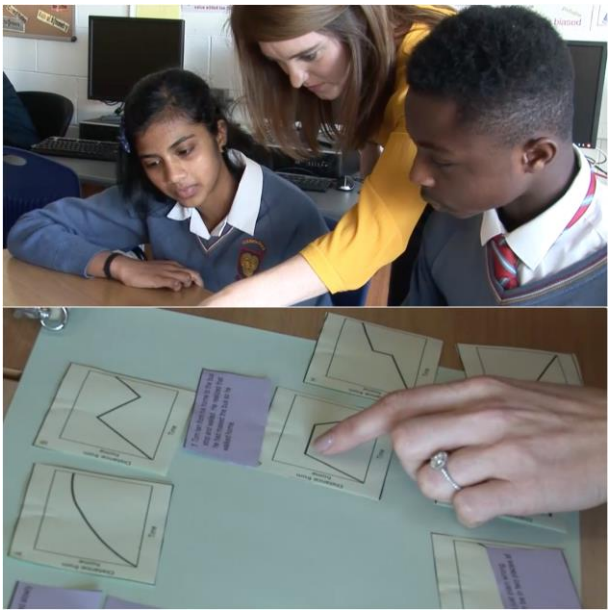


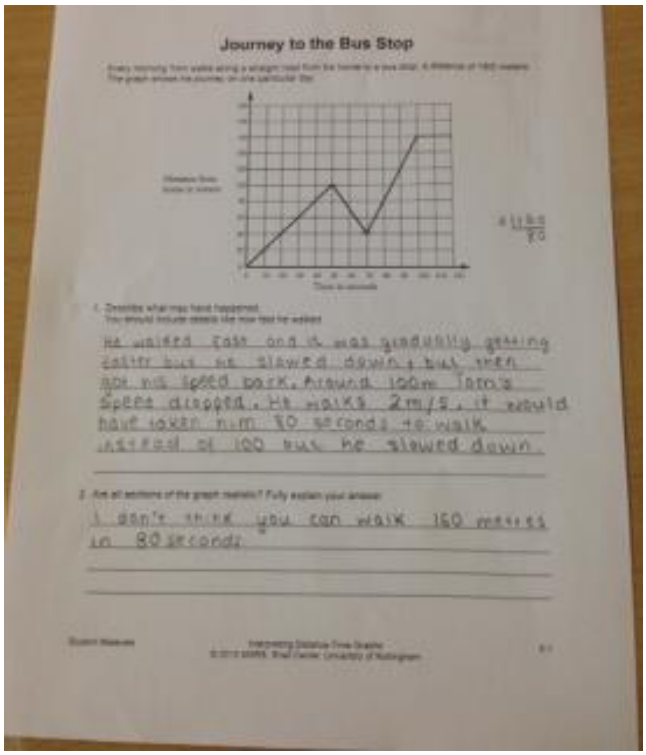
Figure 13: XMA engaging with the students

This idea of the obtaining the correct answer was something that appeared repeatedly in classes especially with A2. The teacher made use of effective feedback within the lesson to guide students to the correct solution without her revealing it to them. During the distance time lesson it was observed how the students were at ease with the idea of not knowing the right answer. Video analysis revealed how when the teacher told the students she would not be telling them the right answers to the matching activity during the lesson, students were comfortable with this, demonstrating how they are now familiar with this way of learning. Following the lesson when the teacher was interviewed at T3, she commented on how their reliance on having the correct answer had been reduced by her providing students with effective feedback to move the learning forward. In her own words she commented on how the FaSMEd students "don't mind if they're not right" (XMA_T3)

and how they understand that she was aiming to lead them to a point of "self-discovery, self-learning and self-assessment" (XMA_T3). She was also very positive about how during the lesson she witnessed a *eureka* moment when the students were realising the right answers not from her telling them but from her asking them certain higher order questions.

Field notes communicated how the teacher was using her feedback to guide students away from their misconceptions and toward graphical understanding. Notes gathered illustrate how the teacher's feedback to students was clear and descriptive and how it related to student interpretation by focusing on the graphic activity. Her feedback also helped the students move forward in their learning by suggesting to students that they should have a conversation their peers about the activity and that they should explain their reasoning explicitly. Time was allocated during the lesson to give students a chance to make use of teacher feedback on the card matching activity and she also mentioned to students that they would have the chance re-attempt their *Journey to the Bus Stop* task in the following lesson. The teachers questioning and feedback practices were clearly of benefit to the students as at the end of the lesson the students conveyed that they wanted to alter their original *Journey to the Bus Stop* pre-assessment, demonstrating that they had learned from the teachers questioning and feedback during the distance time lesson.

The pre-assessment task was an important aspect of the distance time lesson (A2). It would allow the teacher to assess any misconceptions students were having about graphing prior to the lesson and help her to plan her lesson accordingly. Prior to the observed distance time lesson XMA handed out the pre-assessment task (*Journey to the Bus Stop*) and gave students 10-15 minutes


Journey to the Bus Stop

I don't think you can walk 160 metres in 80 seconds

Figure 14: Sample pre-assessment task completed by a maths student.

to complete it in class. She explained to the students that it was okay if they didn't get the correct answer. She then used the pre-assessment to direct her questions and focus them on the difficulties the students were having with the activity. During the interview following the lesson (T3), XMA praised the use of a pre-assessment, commenting on how it helped her give feedback to her students. She noted how it was important for her to take time outside of the classroom to reflect on student misconceptions and think about how she could plan the lesson so that the students could spot the misconceptions themselves rather than her telling them what they were.

> "Just for me to jot down a couple of misconceptions that I'm spotting by quite a few students and to take a bit of time outside the classroom to reflect on that and see how I could address them and how I could direct the learning so they could spot those misconceptions, those errors, as opposed to just saying you did this wrong, this is what you should have done."
>
> (XMA_T3)

From the pre assessment task the teacher deduced that the students were having difficulties with calculating speed and with relating distance travelled with time taken. At the beginning of the lesson, the teacher used feedback in the form of questioning during a group discussion to clear up their misconceptions. At the start of the lesson she posed such questions as: "do you think Tom's speed is steady or is it changing?" and "how do you know it's changing?" She encouraged students to get involved in the discussion by asking them if they disagreed with their peers and why. She also asked other students about their opinions on Tom's speed "who else feels it's changing?" She asked students to challenge their classmates on their responses leading to the class becoming engaged in the activity whilst addressing their misconceptions. The bouncing of questions around the room worked very well and many students shared their opinions. While the teacher's use of higher order questions was good, during the activity she gave the students little wait time to answer the questions. Perhaps this was due to her eagerness to move on to the main activity as later on in the class it was observed that she allowed students appropriate time to answer questions on occasion. However it was felt that because she was

trying to cover a significant part of the lesson plan during the class, her wait time for questions was reduced.

Conclusion

In terms of teaching strategies that were supportive of formative assessment in the classroom, XMA made use of questioning, feedback, co-operative learning and peer assessment. She utilised these formative assessment strategies to *engineer effective classroom discussions and used other learning tasks that elicit evidence of student understanding* and to *provide feedback that moves students forward* while *activating students as instructional resources for one another.* She adopted the techniques of *clarifying, sharing and understanding learning intentions and criteria for success* and *activating students as the owners of their own learning* however these strategies were noticed to a lesser extent and the teachers practices around these strategies still needs to be refined.

ICT did not play a crucial role in this lesson. Although the teacher made use of her tablet device and the interactive whiteboard throughout the lesson, the card matching activity stimulated the rich discussion and feedback. The technology was merely a more efficient tool to display student answers and to allow the teacher move between groups and use the tablet to add material to the interactive board. The students also could share their answers using the tablet; this enhanced their engagement with the learning as is evident in data presented in section six. Hence the technology functioned to send and share information between, students and teacher in to a lesser extent, engineering effective classroom discussions and providing evidence.

Within teaching and learning improvements can always be made and with regards to practices that were hindering formative assessment, such as the teacher's allocated wait time for answers from her students was very short. Making use of self-assessment with students was mentioned by the teacher when interviewed after the

class, however due to time constraints the teacher did not get to practice this with her students during this observed lesson.

In relation to what the teacher thought about the lesson, she felt it was successful in alleviating student's misconceptions around graphing. She credited the pre-assessment task for aiding this. She had praise for the task commenting how it gave her time to reflect on her lesson planning outside of the classroom and allowed her to plan structured feedback for the students prior to the upcoming lesson. She commented on how questioning formed a big part of the lesson and how she was constantly getting students to explain their reasoning even when an answer or a particular card match was correct.

6. Pupil Perceptions

Data Collection:

Data were gathered from the mathematics students participating in the FaSMEd project during a Q-Sort activity. 139 students also completed questionnaires (see Appendix A) During the Q-Sort activity students individually sorted 48 statements onto a placemat, see Figure 15. During the activity the students were engaged in discussions with the interviewer about their perceptions of maths and learning. Photographs were taken of the completed Q-Sort placemats for later analysis. At the beginning of the interviews, students were asked to arrange the 48 statements into two groups: statements they agreed with, and statements they disagreed with. Here the students had the opportunity to ask the interviewer about any statements they were unclear about and afforded the researcher to give examples if needed. The students then had to rank the statements in a quasi-normal distribution by arranging them in a Likert manner, ranging from strongly agree to strongly disagree.

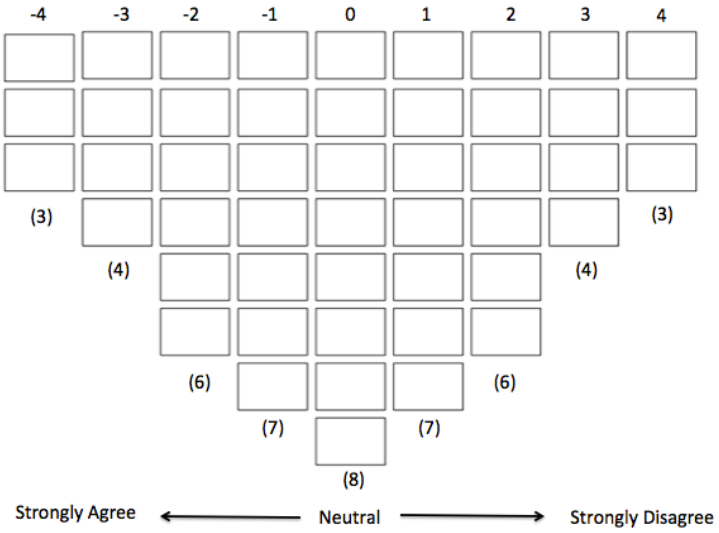


Figure 15: Placemat in Fixed Quasi-Normal Distribution. Ranking values range from -4 to +4. Numbers in brackets indicate the number of items that can be assigned to any particular rank. A total of 48 items can be sorted in the distribution illustrated.

While the students were engaged in the Q-Sort activity, the interviewer asked the students questions about their choices. Students were given the opportunity to swap statements if necessary, however it was emphasised that they had to place the statements in the quasi-normal shape only, producing a forced distribution of the statements. After the activity the students were asked questions about the FaSMEd activities they had engaged in during class.

In the questionnaires, students were asked to indicate their levels of agreement on a five point Likert scale with 48 statements taken from the Q-Sort activity. 139 mathematics students participating in the project completed this questionnaire.

Data Analysis:

The images gathered from the Q-Sort activity were analysed quantitatively using PQ method software (Schmolck and Atkinson, 2002). Both centroid analysis and principal components analysis was carried out followed by varimax rotations. The results of both methods of analysis did not differ significantly. This case study will report on the results of the principal component analysis with varimax rotation. Furthermore, during the Q-Sort activity students were interviewed about their perceptions of maths and their views of the FaSMEd activities they had participated

in. These data were audio recorded, transcribed, coded and analysed using MAXQDA.

Theme	Example	Number of Statements
Views of maths (VOM)	*I am good at maths*	9
Use of technology in learning (UOT)	*Using technology helps me understand maths better*	12
Perceptions of examinations (POE)	*Doing exams motivates me to work harder in maths*	3
The usefulness of maths (UOM)	*Maths helps us to understand the world around us better*	7
Ideas about maths teaching and learning (MTL)	*It best way to learn maths is by working with others*	12
The nature of maths (NOM)	*Maths means exploring and experimenting*	5

Table 2: Emergent themes from the Q-Sort and questionnaire data including examples of questions and the number of statements in each theme

The questionnaire given to students had 48 questions (these were identical to the questions used in the Q-sort process); the order of the questions was randomised so as to avoid asking lots of similar questions together. The same questionnaire was given to both the mathematics and the science students with appropriate adjustments; for example the statement *I am good at maths* was converted into *I am good at science* for the science group. Prior to the analysis, all three researchers considered the 48 questions and initially divided them into six scales (Table 2 and Appendix A): View of Maths/Science (VOM/S), Use of Technology in Learning (UOT), Usefulness of Maths/Science (UOM/S), Nature of Maths/Science (NOM/S), Ideas about Maths/Science Teaching and Learning (M/STL), Perceptions of Examinations (POE). The responses from the questionnaires of all students (both science and maths groups) were inputted into an SPSS file. The data were anonymised; students and teachers were given codenames. The answers to the Likert questions were coded as follows: 1- definitely agree; 2- agree a bit; 3- not sure; 4- disagree a bit; 5- definitely disagree.

The analysis of the questionnaire used SPSS and Winsteps (Rasch analysis software). A factor analysis was carried out to identify themes. The scree plot suggested five factors. When these were studied it was found that the questions which loaded on the first factor (accounting for 17% of the total variance) were mostly from the VOM/S scale, the second factor mostly had questions on the UOT scale (explaining 10% of total variance), the third factor mostly had questions from the UOM/S scale (7% of total variance), the fourth factor had questions from the M/SLT (on teaching) and POE scales (5% of total variance), and the last factor had questions from the M/SLT scale (on learning) (4% of total variance).

Rasch analysis was completed to investigate the scales further. Codes for the negatively worded questions were reversed, for example Q1 - *I find science/maths difficult*, and denoted this version of the question as Q1R. It was found that the VOM/S scale worked well using questions 1R, 3R, 14, 16R, 19, 35 (See Appendix A). The Cronbach alpha for this scale was 0.878, the item reliability was 0.94, and the person reliability was 0.81. Note that the item reliability index estimates the chances of getting the same item measure ordering if the questionnaire was given to a similar group of students. This index is given on a scale running from 0 to 1. The person reliability index estimates how robust the person ordering would be if a similar test was used with the same group of students, and it is similar to the Cronbach alpha statistic. The fit statistics for each item were within acceptable limits and the point-biserial correlations were all high. Winsteps was used to create a measure for each student on this scale. Due to the way the answers to the Likert questions were coded, a low measure corresponds to a positive self-view in relation to maths/science. The same analysis for the other scales was carried out and found that the UOT scale (Q6, 11R, 26, 29R, 30R, 31, 32, 34, 43R, 44, 46R), the UOM/S scale (Q5, 8R, 21, 22R, 25R, 36, 38), and the POE scale (Q4R, 12, 28) behaved well and measures for each student on these scales were created. The M/SLT and NOM/S scales did not fulfil the Rasch analysis reliability criteria; therefore, measures for the students using these scales were not calculated.

Results:

Correlations between the measures created and the students' Christmas and summer mathematics examination marks were considered. The Christmas and summer marks are significantly correlated with each other – the correlation is 0.577. Both are also significantly correlated with the VOM measure (correlations are -0.415 for Christmas and -0.412 for Summer – note the negative correlation means students with positive views did better on the exams). The Christmas mark is significantly correlated with the UOM measure and the summer marks are significantly correlated with the POE measure. A person's view of the subject (VOM) is significantly correlated with everything except the UOT measure. In fact UOT is only significantly correlated with the UOM measure.

A linear regression was carried out to see if the summer mark could be predicted given the Christmas mark and the four measures. It was found that only two variables that were kept in the model were the Christmas mark and the VOM. The R-square was 0.362, which means only 36% of the variation of the summer exams scores in Maths is accounted for by these two variables.

Analysis of data from some of the questions relating to technology and formative assessment provide interesting results.

Question	**Definitely Agree**	**Agree a bit**	**Not sure**	**Disagree a bit**	**Definitely Disagree**
Using technology helps me understand maths better.	15.1%	23.0%	33.8%	16.5%	11.5%
Our maths teacher has a better idea of how we are doing when s/he uses the technology to record our answers.	13.6%	22.9%	50.0%	8.6%	5.0%
Technology helps me find out for myself how I am doing in a maths activity.	15.3%	21.9%	39.4%	17.5%	5.8%
The technology we use in maths class helps me see where I am going wrong.	18.2%	28.5%	38.0%	10.2%	5.1%
Our maths teacher always uses some	30.4%	29.7%	17.4%	13.8%	8.7%

kind of technology in class.					
We use a lot of technology in our maths classes.	6.4%	24.8%	21.3%	26.2%	21.3%

Table 3: Responses to Technology and Formative Assessment questions

Notice that the students gave quite different answers to the last two questions in Table 2; they seem to draw a distinction between the teacher using technology in class and they themselves using it. Maybe for this reason, the students seem unsure about how to answer the other technology questions with more than a third of responses to these questions being *Not Sure*. However, the students are generally positive about the effect of technology on their learning and the proportion of students who agreed with these statements is considerably larger than the proportion that disagreed.

Within Case Analysis

Two factors were observed when analysing the Q-sort data; three out of the five students were contained in factor one, and the other two students made up factor 2. There was minimum correlation between the two factors. Z-scores were used to analyse the level of agreement or disagreement the students had toward a statement. Z-scores indicate how many standard deviations a statement is away from the mean. More positive Z-scores indicated disagreement and negative Z-scores indicated agreement.

Factor 1:

Demographic information

Three out of the five students who took part in the Q-Sort were loaded on factor 1, two were female (S9 and S15) and one was male (S11). S9 is a high achiever. Her grades generally range from 80% - 100%. This student's maths grade increased by 5% after her participation in the FaSMEd project. She does not have special educational needs. She is from a family of three and she is the eldest child. Her parents were not born or educated in Ireland.

S15 is an above average student whose grades generally range from 55% - 85%. She is the only student out of the group of five whose grade decreased after the project. Her summer examination grade was 10% lover than her Christmas examination grade. She also does not have special educational needs. She is from a family of three children where she is the eldest child. Her parents were not born or educated in Ireland.

S11 is a student of average ability. His grades generally fall between 45-60%. He had an increase in grade of 8% following the FaSMEd project. He has some special education needs around literacy and EAL (English as an Additional Language). He finds reading difficult. His maths teacher commented that he needs a lot of encouragement in her class. There are three children in his family and he is the middle child. His parents were not born or educated in Ireland.

Factor Interpretation

The students loaded on this factor have strongly positive opinions on the usefulness of maths, they believe that the most effective maths classes are the ones when they are active and participating in maths activities, and they also find exams boring however feel they are important indictors of performance. The agreed strongly with the following statements:

Statement	**Theme**	**Z-Score**
Maths helps us to understand the world around us better	UOM	-1.639
It is important to study maths	UOM	-1.513
The best way to learn maths is by working with others	MTL	-1.368
I like exams because the results show me how I am doing	POE	-1.317
Maths means exploring and experimenting	NOM	-1.299

Table 4: Statements that the students in factor 1 strongly agreed with

It can be observed here that students have strong views about the applications of mathematics outside of the classroom. During interviews students commented how relevant and important mathematics is in everyday life:

"Say you're in the shops and you want to know the best value for a price, you could use division in that case, so you're able to do that in real life."

(XMA_S9)

"Maths is everywhere, everything around you has to do with maths."

(XMA_S11)

"You need maths in everything, so it's an important subject."

(XMA_S9)

From the Q-Sort they also convey their enjoyment of the practical aspect of mathematics by strongly agreeing that the best way to learn maths is by working with others and that maths means exploring and experimenting.

"If you get an answer wrong and you think it's right, you could ask someone and they could think its right and you could be wrong so you have a maths argument and you find out who's right." (XMA_S11)

This concept of a maths argument, whereby the teacher encourages the students to make their reasoning evident and question their peers came up repeatedly within the data collection. It is discussed in more detail in section five of the case study.

This cohort of students strongly disagreed with the below statements:

Statement	**Theme**	**Z-Score**
I can do without maths	UOM	2.093
I don't see the point in doing maths	UOM	1.714
The best way to learn maths is by doing loads of exercises from the book	MTL	1.570
I hate maths	VOM	1.513
Maths is only for the maths classroom and has nothing to do with real life	UOM	1.481

Table 5: Statements that the students in factor 1 strongly disagreed with

It can be observed here that students can see the importance of learning mathematics and also the applications of mathematics outside of the classroom. Here their views are also expressing the importance of the practical nature of maths learning by disagreeing with the statement *the best way to learn maths is by doing loads of exercises from the book.*

With relation to the usefulness of maths theme from the questionnaires, the results from factor 1 are consistent with the data gathered from the questionnaires distributed to all students. 78% of students disagreed with *I can do without maths*, 78.4% of students disagreed with *I don't see the point in doing maths* and 78.7% of students disagreed with *maths is only for the maths classroom and has nothing to do with real life.* Students from the questionnaire also agreed with *maths helps us to understand the world around us better* (70.5%) and *it is important to study maths* (89.9%).

The students in this factor differed from the overall cohort of students in relation to their views of maths teaching and learning. While the factor 1 students strongly disagreed with *the best way to learn maths is by doing loads of exercises from the book*, only 29.2% of all FaSMEd maths students disagreed with this. Similarly while the factor 1 students felt strongly that *the best way to learn maths is by working with others*, only 51.1% of the entire group of students shared this opinion.

Factor 2

Demographic Information

Two out of the five maths students were contained in factor 2, one was male (S5) and the other was female (S24).

S5 is a high achieving student. His grades generally range from 80% - 100%. He had the highest increase in his maths grade out of all five students. His grade increased by 14% from before the FaSMEd project. He does not have special educational needs. He is from a family of two children where he is the eldest child. His parents were not born or educated in Ireland.

S24 is a student of average ability. Her maths teacher knows her to be a very hard working student. Her grades generally range from 50% - 75%. Her grade increased by 2% following participation in FaSMEd. She does not have special educational needs. She is from a family of two children where she is the eldest child. Her parents are Irish born and were both educated in Ireland.

Factor Interpretation

The tables below illustrate the statements that these students strongly agreed and disagreed with:

Statement	Theme	Z-Score
It is important to study maths	UOM	-1.872
Maths helps us to think systematically and logically	NOM	-1.617
In maths the answer is either right or wrong	NOM	-1.554
Maths makes sense in the real world	UOM	-1.515
Our maths teacher always uses some kind of technology in class	UOT	-1.388

Table 6: Statements that the students in factor 2 strongly agreed with

Statement	Theme	Z-Score
I hate maths	VOM	1.935
I never know what to do with the technology	UOT	1.808
The best way to learn maths is by doing loads of exercises from the book	MTL	1.745
I don't see the point in doing maths	UOM	1.515
Maths is only for the maths classroom and has nothing to do with real life	UOM	1.452

Table 7: Statements that the students in factor 2 strongly disagreed with

These students are similar to those in factor one whereby they disagree with the same 4 statements *(I hate maths, I don't see the point in doing maths, maths is only for the maths classroom and has nothing to do with real life* and *the best way to learn maths is by doing loads of exercises from the book*). This conveys their beliefs about the usefulness of maths in the wider world and the importance of being actively engaged in maths class. By strongly agreeing with *it is important to study maths* they further emphasis their opinions. The factor 2 students also had strong opinions about the nature of maths and expressed their familiarity with technology in maths class.

What makes the factor 2 students differ from factor 1 is their strong reliance on the teacher coupled with their lack of motivation to push themselves in maths class. This is demonstrated by the factor 2 students placing *doing well in maths depends on having a good maths teacher* in the strongly agree section (-3 column) of the

placemat while the factor 1 students placed it in the disagree area (2 column). Factor 1 students also placed *if I don't understand something in maths I work on it until I get it right* in the agree section (-2 column) while the factor 2 students strongly disagreed with this statement (3 column). When questioned about the statement *doing well in maths depends on having a good maths teacher* the students in factor 2 replied that:

> "If you have a bad maths teacher how are you going to learn anything off that person?" (XMA_S24)
>
> "I need written examples and I need it explained by the teacher so I can really understand the methods rather than just reading it off a book and not understanding why they're after using that specific formula." (XMA_S24)

The above comments convey the student's need for the teacher's guidance in class whereas the students in factor 1 do not feel as strongly about that statement:

> "It's not all about having a good teacher, it's about trying to get what you want to achieve." (XMA_S11)
>
> "I like talking to the teacher just because it's easier, but I like knowing with technology was well because you might learn new tricks that the teacher might not have used." (XMA_S15)

This reliance on the teacher demonstrated by the factor 2 students strongly links to a lack of student autonomy in this factor. When asked about what they do if they don't understand something in maths, one student commented that:

> "If you don't understand something, like if you have no idea what it means, if there's no one there to help you with it you're never going to get it." (XMA_S5)

Once again this is not the opinion shared by the factor one students as their opinions about maths conveyed their internal motivation to learn and keep working on a problem until they find the solution for themselves.

> "If you're working something out you shouldn't really give up on it until you get the right answer because you might never get it right." (XMA_S9)

Formative Assessment and Technology

Although the students loaded in factor 2 conveyed their familiarity with technology during the Q-Sort activity, quantitative analysis of the Q-Sort did not convey a significant impact of technologically enhanced formative assessment practices on student's learning. The technology utilised in this case study functioned in providing the teacher with an interactive learning environment where she could communicate with other teachers and improve her formative assessment practices by engaging with *Schoology* and its resources (see Figure 16). Therefore although technology was used to improve student learning by improving the teacher's practices in class, a hands on application of technology was not evident for students.

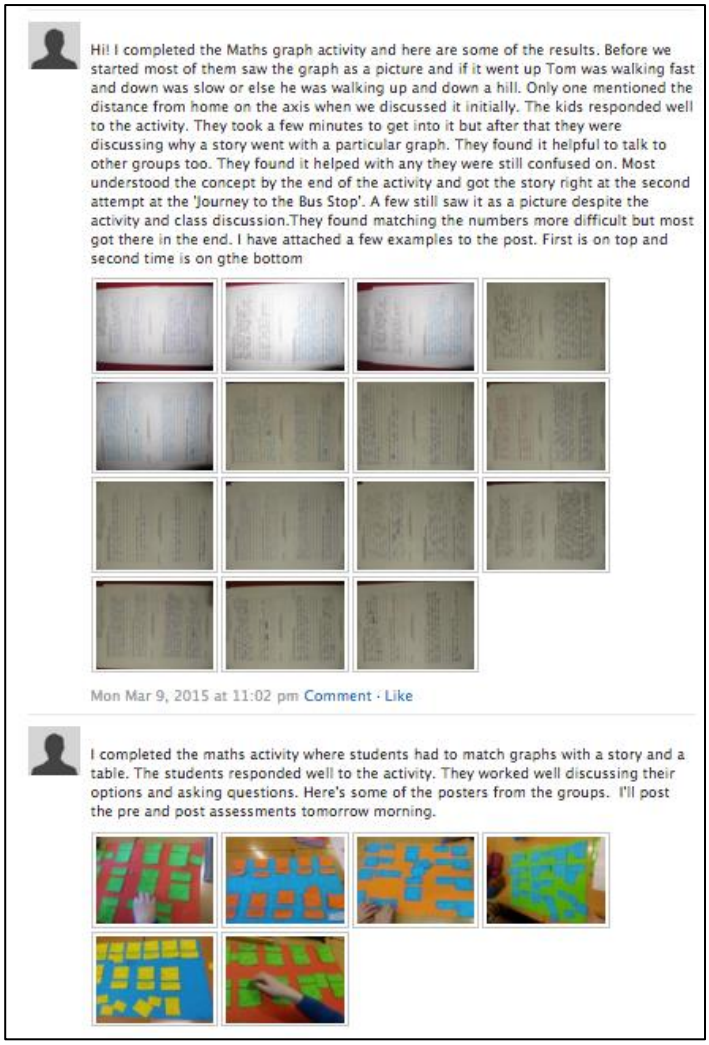


Figure 16: Screenshot of teacher interaction via Schoology

Between phase one and phase two of the toolkit implementation, the teacher integrated more technology with her students. Her Microsoft Surface was often shared among students in class to demonstrate work and for students to work as a class to aid other students who were having difficulties. She also made use of it to detach herself from the whiteboard and become more involved with the class. This impact of technology was evident with students in their comments during the Q-Sort. They remarked that:

> "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 only you can see, then the whole class can see it and tell you where you went wrong." (XMA_S15)

> "She could still be walking around class and helping people but I guess it gives us more options so that the whole class can participate so it's not just one person and she doesn't have to walk back and forth to the board."
>
> (XMA_S9)

Although the above students are conveying the benefit of having technology in the classroom, not all students felt that technology was necessary to have an effective maths class or to learn maths:

> "Technology is not always going to be there for you, but you're brain is always going to be there for you." (XMA_S11)
>
> "I don't know if it would be helpful to use a tablet… but I really think that with pen and paper you can't go wrong with working it out for yourself rather than having to use technology all the time, I mean nowadays everyone is so reliant on technology, why cant you just use a book or write it down?"
>
> (XMA_S24)

Cross Case Analysis

Ten mathematics students, five from the case study class and five from a different FaSMEd class in school X engaged with the Q-Sort activity for cross case analysis. Of these ten students, five were male and five were female. Q-Sort data were again analysed quantitatively using principal component analysis with a varimax rotation, and qualitatively by coding the data into themes in MAXQDA. In the cross case analysis two factors, similar to the factors in the case study, emerged.

Factor 1

Factor Interpretation

This factor was very similar to factor 1 that was observed in the within case analysis. Of the ten students, six students were loaded on this factor including four students from the within case analysis (S9, S11, S15 and S24). S24 moved from factor 2 in the within case analysis to factor 1 in the data. This cohort of students had very strong opinions about the usefulness of maths outside of the classroom, they prefer their maths lessons to be active, participatory, they very much enjoy working in groups

and they are more intrinsically motivated than the students in factor 2. The statements demonstrate these traits:

Statement	Theme	Z-Score
If I don't understand something in maths I work on it until I get it right	MTL	-1.650
It is easier to learn maths by doing practical activities	MTL	-1.519
The best way to learn maths is by working with others	MTL	-1.410
Maths is something everybody can learn	NOM	-1.372
Maths is used in everyday life	UOM	-1.297

Table 8: Statements that the students in cross case factor 1 strongly agreed with

Statement	Theme	Z-Score
I can do without maths	UOM	1.861
You can learn maths best with just a textbook	MTL	1.682
The best way to learn maths is by doing loads of exercises from the book	MTL	1.629
Maths is only for the maths classroom and has nothing to do with real life	UOM	1.561
In maths classes there is no room for expressing your own ideas	MTL	1.415

Table 9: Statements that the students in cross case factor 1 strongly disagreed with

During interviews, these students commented that working with others is very important when it comes to learning:

> "If there's someone with a problem and you can explain it to them, you understand it better as well." (XMB_S4)
>
> "I think that its better to interact with people when doing maths because it's easier to understand and other people can explain it rather than the teacher, because they actually know how you're feeling because they probably went through it." (XMB_S24)

These results are consistent with those of the questionnaires whereby all the students surveyed strongly agreed with the statements *If I don't understand something in maths I work on it until I get it right* (74.1%), *It is easier to learn maths by doing practical activities* (74.1%), *maths is something everybody can learn* (80.4%), and *maths is used in everyday life* (84.1%). The entire cohort of FaSMEd maths students also strongly disagreed with the statements *I can do without maths* (78%), and *maths is only for the maths classroom and has nothing to do with real life*

(78.7%). The FaSMEd students who completed the maths questionnaire differed from the cross case factor 1 students as only 51.1% believed that *the best way to learn maths is by working with others*. Furthermore with regards to statements that students disagreed with only 47.2% of the entire cohort disagreed with *you can learn maths best with just a textbook*, and 45.4% of disagreeing with *in maths classes there is no room for expressing your own ideas*.

Factor 2

Factor Interpretation

This factor shares some similarities with factor 2 from the within case analysis. Four out of the ten students were loaded on this factor including one student from the within case analysis (S5). Here the student's opinions about the usefulness of maths in the wider world are still quite strong and they also convey their familiarity with the use of technology in maths class. The tables below represent the student's strongest opinions about statements:

Statement	Theme	Z-Score
Maths is used in everyday life	UOM	-2.017
It is important to study maths	UOM	-2.010
Maths is something everybody can learn	NOM	-1.946
Maths helps us to think systematically and logically	NOM	-1.342
Using technology in maths is fun	UOT	-1.315

Table 10: Statements that the students in cross case factor 2 strongly agreed with

Statement	Theme	Z-Score
I don't see the point in doing maths	UOM	1.638
Maths is only for the maths classroom and has nothing to do with real life	UOM	1.519
I can do without maths	UOM	1.400
If I don't understand something in maths I work on it until I get it right	MTL	1.361
I never know what to do with the technology	UOT	1.360

Table 11: Statements that the students in cross case factor 2 strongly disagreed with

This group of students also demonstrate their lack of autonomy when it comes to solving maths problems by once again strongly disagreeing with the statement *if I*

don't understand something in maths I work on it until I get it right. This differs drastically from the entire cohort of FaSMEd maths students with only 16.6% disagreeing with the aforementioned statement. However the entire group of FaSMEd maths students share some of the same opinions about the usefulness of maths as 84.1% agreed with the statement *maths is used in everyday life*, and 89.9% agreed that *it is important to study maths*.

7. Key Findings

In the context of the distance time lesson, XMA had noticeably enhanced her formative assessment practices due to her participation in the FaSMEd project. It was observed that the teacher had made substantial improvements to her questioning and feedback practices as well as her co-operative learning and peer assessment skills discussed in sections four and five of the case study. Within the FaSMEd framework, the strategies that this teacher improved on were her ability to *engineer effective classroom discussions and use other learning tasks that elicit evidence of student understanding, providing feedback that moves learning forward and activating students as instructional resources for one another*. In relation to technology within these formative assessment strategies, it functioned in *sending and displaying* (through the online platform *Schoology*) samples of student work, as well as communicating recommendations for and comments on the FaSMEd lesson plans among the participating teachers. XMA then used this information to structure her FaSMEd lessons and in doing so she used feedback from her peers to inform her lessons.

In relation to data gathered on pupil perceptions of maths lessons, five key findings were identified. Firstly this cohort of students perceives studying maths to be very important and is very aware of the usefulness of maths in and out of the classroom. This is evident from Q-Sort and questionnaire data. Secondly data revealed that students prefer active maths lessons for example being involved in different activates during class rather than the stereotypical way of teaching maths by making use of the book and the class following a very structured routine. Thirdly it became

evident that these students really enjoy working in groups during maths lessons and feel that it helps to ask a peer a question rather than addressing the teacher. This was revealed through classroom observation and student interview. Fourthly some of the maths students in this study are still strongly reliant on the teacher to learn. This information was gathered within the questionnaires and factor analysis and could be somewhat hindering to the students development as autonomous learners. Finally the questionnaires revealed that these maths students are generally positive about using technology in class however the majority are still somewhat unfamiliar with using it extensively in class.

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Appendix A: Themes and Statements

Scale	Statement	Number
View of Maths (VOM)	I find maths difficult.	1
	I hate maths.	3
	Maths comes naturally to some people.	7
	Maths is fun.	14
	Maths is frustrating.	16
	I love maths.	19
	I am good at Maths.	35

	I pick things up quickly in maths.	45
	Using technology in maths is useful.	26
Use of technology in learning (UOT)	Using technology helps me understand maths better.	6
	I do not like using technology in maths.	11
	Our maths teacher has a better idea of how we are doing when s/he uses the technology to record our answers.	24
	For me, the technology does not work, or help.	29
	I never know what to do with technology.	30
	Using technology in maths is fun.	31
	When we work together, it makes sense to use the technology.	32
	Technology helps me find out for myself how I am doing in a maths activity.	34
	Our maths teacher always uses some kind of technology in class.	39
	Using technology in maths is difficult.	43
	The technology we use in maths class helps me see where I am going wrong.	44
	Using technology in maths is frustrating.	46
Perceptions of examinations (POE)	Exams are boring.	4
	I like exams because the results show me how I am doing.	12
	Doing exams motivates me to work harder in maths.	28
The usefulness of maths (UOM)	Maths is used in everyday life.	5
	Maths makes sense in the real world.	21
	Maths is only for the maths classroom, has nothing to do with real life.	22
	I can do without maths.	25
	Maths helps us to understand the world around us better.	36
	I don't see the point in doing maths.	8
	It is important to study maths.	38
Ideas about maths teaching and learning (MTL)	The best way to learn maths is by doing loads of exercises from the book.	9
	If I don't understand something in maths, I work on it until I get it right.	10
	You can learn maths best with just a textbook.	13
	In maths classes there is no room for expressing you own ideas.	15
	I learn/understand maths best when I work on my own.	18
	Doing well in maths depends on having a good maths teacher.	20
	It is easier to learn maths by doing practical activities.	33
	In maths classes there is no time for reflecting on my work	37
	In maths we're always doing the same exercises over and over again.	40
	The best way to learn maths is by working with others.	42
	I prefer to talk to the teacher, rather than find out myself with the technology	2
	We use a lot of technology in our maths classes.	27
The nature of maths (NOM)	Maths means exploring and experimenting.	17
	In maths the answer is either right or wrong.	23
	Maths helps us to think systematically and logically.	41
	Maths means seeing connections.	48
	Maths is something everybody can learn.	47