Maynooth University Ireland: Science Case Study

1. Context

Y	Science Case Study School
YSA	Science Case Study Teacher
YSA_S1-24	Students of the Science Case Study Teacher
XSA	Science Teacher A from School X
XSA_S1-24	Students of Science Teacher A from School X
T1, T2	Interviews with teacher pre and post intervention

Table 1: Codes used within the case study

The school

The school (Y) in which the science case study teacher is teaching is a co-educational, multi-denominational school opened in 2014. Teachers in this school, work between two second level schools located on the one campus. Classes in this school are of a mixed ability and all first year students are required to take science. There are approximately 1350 students on campus with 105 teachers. It is a suburban school and its socio economic intake varies from lower to upper middle class with a small number of students from the travelling community. Nationally the school is performing above average with a high number of students continuing on to third level. Past experience of formative assessment (FA) in the school was on an individual teacher level, there is no whole school practice or policy. The technology utilised in the school includes data projectors, interactive white boards (in some classrooms) and two designated computer rooms. The previous experience of working with other research partners includes 16 teachers, the Deputy Principal and the Principal, working with the TL21 professional development programme[1].

[1] The TL21 Programme is a workshop-based Continuing Professional Development programme for teachers and school leaders to promote innovative practice and professional learning communities in post-primary schools. The programme is currently running as a partnership between the Maynooth University, Department of Education and five Education Centres and Dublin & Dún Laoghaire Education and Training Board. There are 33 post-primary schools participating at present.

The Teacher

YSA is a teacher of science, physics, mathematics and applied mathematics. She has been teaching for six years. She is in the 21-30 age bracket and has been working in her current school for three years. Her past experience of using formative assessment strategies within lessons included the use of mini-whiteboards, graphic organisers, exit slips, think pair share, randomised questioning and making use of walking debates to stimulate discussions. She has made use of data projectors, computers and interactive whiteboards in her lessons. She did not have any previous experience of working on a research project.

The Class

The class range in age from 12-13. They are a first year mixed ability science class. There are 20 students in the class, 11 male and nine female. The class is a mixture of Irish students and newcomer students from different ethnic backgrounds. There are some special education needs students in the class including some with borderline learning difficulties, moderate expressive language disorders and dyslexia.

2. Tasks and Resources

Within the case study, two activities were analysed, the first was based around increasing student collaboration (Activity 4, A4) and the second involved promoting students as assessors (Activity 5, A5). A brief description of the lessons is provided in this section, the lesson plans can be found in Appendix C

Increasing Student Collaboration: Heart Rate Activity (A4)

This lesson unit was structured in the following way:

Class 1:

- Students were divided into groups and the teacher discussed the rules of group work.
- Students worked in groups deciding how to measure their heart rate, recording their ideas on *Educreations*.
- The teacher analysed student responses to this task and used them to plan for class 2.

Class 2:

- A whole class discussion allowed for students to re-examine and modify (if needed) their original heart rate activity.
- Students carried out their designed experiment working as a group.
- Students answered the second worksheet as a group, recording their ideas on *Educreations*.
- The teacher analysed student responses to the task.

Two forty-minute class periods were required for this lesson. It was important that the teacher complete this lesson in two separate classes allowing time in between for the teacher to analyse the student responses to the first task and plan accordingly for the next lesson.

Figure 1: Screenshot of Educreations Application

Throughout the lesson the students made use of the iPad application *Educreations* during their collaborative group work. This application allowed for students to share ideas in group work and screencast their work for the teacher to review after the lesson. Students were audio recorded within the application so their thinking was made audible to the teacher. The functionality of technology within this application was to process and analyse student thinking.

Students as Assessors: Graphic Organiser Activity (A5)

(Graphic organisers are also referred to as concept or mind maps and allow for students to connect disjointed information pictorially to summarise their learning)

This lesson unit was structured in the following way:

Class 1:

- Students were divided into groups and the teacher discussed the rules of group work.

- Students worked in groups creating a graphic organiser on their iPad using the application *Popplet*.
- Students self-assessed their role in group work using a template provided.
- The teacher analysed student responses to this task and used them to plan for class 2.

Class 2:

- Students were divided into their groups once more.
- Students peer assessed graphic organisers using a marking rubric developed by the teacher.
- Students self-assessed their role in the collaborative task.
- The teacher analysed student responses to the task.

Two forty-minute classes were required for this lesson. It was important that there was a break between the classes in order for students to have time to reflect on the first class before attempting the second activity. The iPad application *Popplet* was essential in this activity as it allowed for students to create graphic organisers (or mind maps) on their iPads. This helped them to think and learn visually, all while organising their thoughts and creating relationships between different science topics. This was especially beneficial to low achieving students as it allowed for them to represent their learning pictorially. Students could make use of images and videos within this application that would not have been possible with a pen and paper graphic organiser. The *popplets* created by the students were uploaded to the class *Schoology* page (or when this was not a possibility, emailed to the teacher to upload) where they were to be peer assessed by other students in the class, this was evident from teacher instruction gathered during video analysis. This demonstrated the sending and displaying functionality of the technology in this activity.

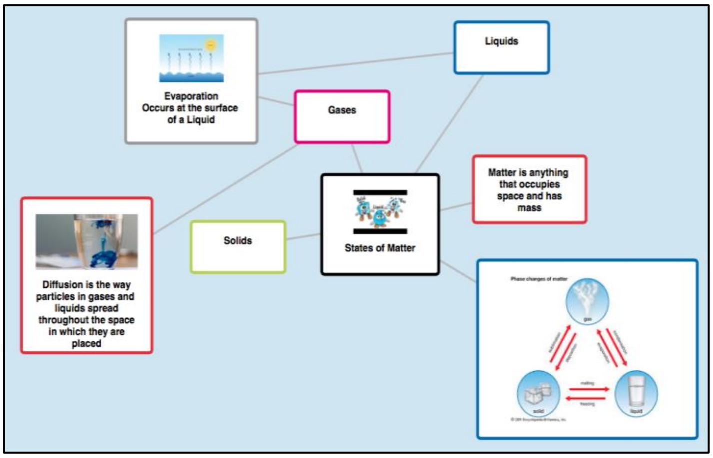


Figure 2: Sample popplet

Within A5 the students made use of *Schoology*, an interactive web based learning environment. This technology provides teachers and students with a safe place to interact and connect both in and out of school. The functionality of this technology was in creating in interactive learning environment for students to work on. Its structure is similar to Facebook whereby those enrolled in a class can post comments and resources on the class wall. There is also the facility whereby the teacher can upload different resources including marking rubrics, assessments and video links, for the students to make use of. Students had access to their *Schoology* accounts via the class set of iPads.

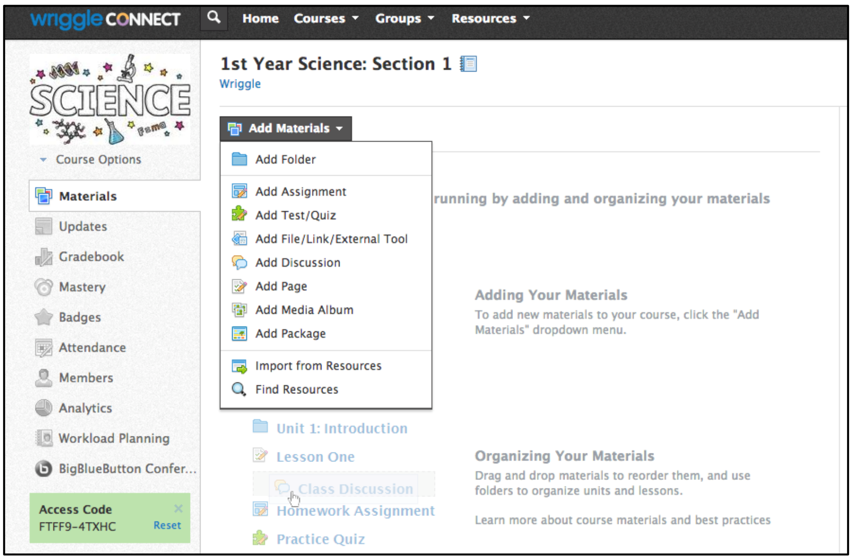


Figure 3: Sample Schoology page

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, 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.

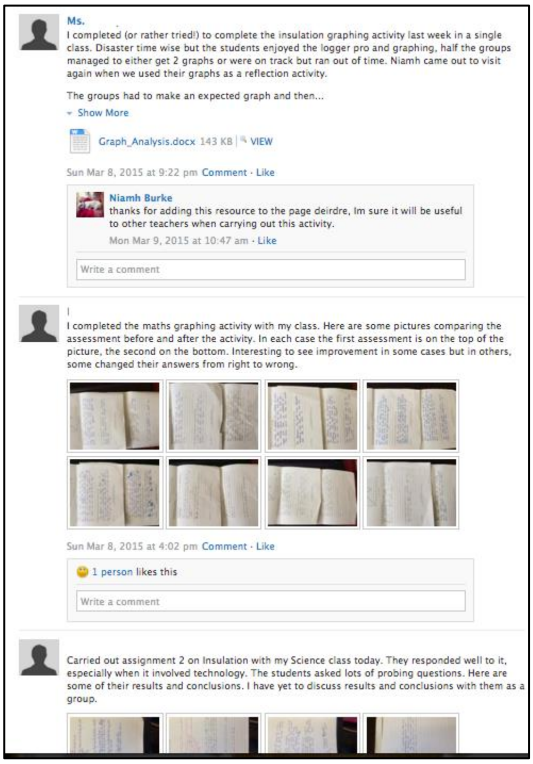


Figure 4: Screenshot of FaSMEd Schoology page

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*. This sharing of practice between sessions encourages peer support and professional sharing (see Figure 4).

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.

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 (see Figure 5).

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.

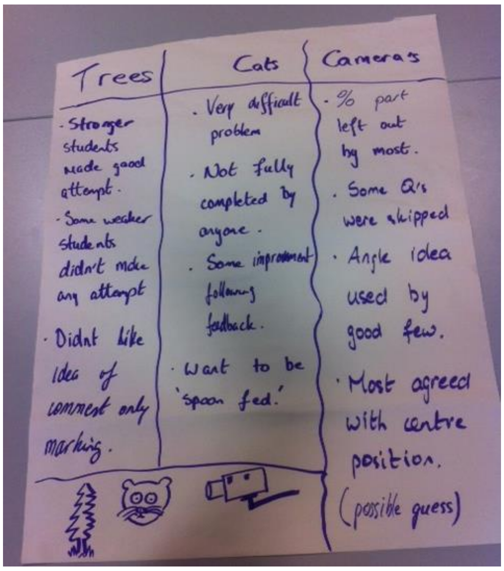


Figure 5: Poster created by FaSMEd teachers portraying their feedback on activity 1

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 with the activities, as they were uncomfortable because there was no right answer.

In the afternoon the teachers explored student misconceptions and how these might impact a science 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 science teachers were to carry out an insulation activity with students using temperature probes, data logging software and *Schoology*. This activity was adapted from materials from Discover Sensors Ireland. The aim of the lesson was to alleviate any misconceptions that students may have around graphing and insulation by completing a pre-assessment before the lesson that the teacher could review. Then following feedback on this pre-assessment the students set up an experiment to graph a cooling curve using the logger software. The students then had to record their analysis of their graphs within groups.

Figure 6: Students working on Insulation Investigation

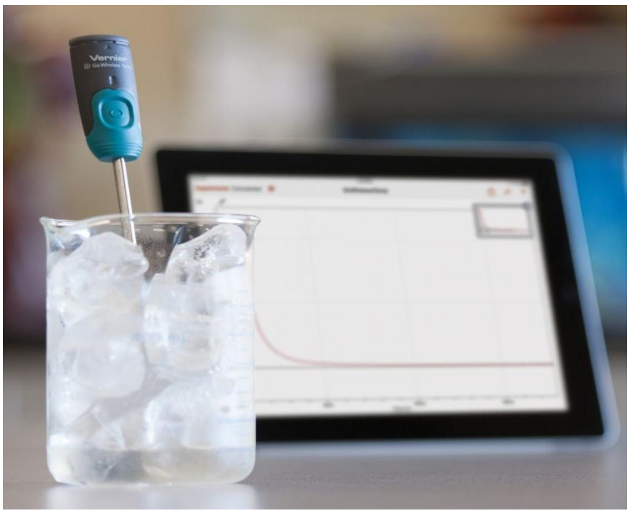


Figure 7: Bluetooth temperature probe and iPad, an example of the apparatus used by teachers in this activity

The technology in this lesson was to function in processing and analysing data. The temperature probes gathered data quickly, allowing students the time to focus on analysis of the graph rather than spending the lesson creating the graph. The students were to upload their graphs and conclusions about the experiment to their class *Schoology* page for the teacher and other students to review at the end of the lesson. Here the teacher could see if there was still any misconceptions evident and use this time to alleviate them with the help of the rest of the class.

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. They commented that the pre-assessment worksheet was unclear and needed to be simplified for students in the science activity. Teachers also noted some difficulties with the logger technology as the graphs sometimes auto-scaled, which made comparisons difficult. Teachers felt they had difficulties with students becoming disconnected in larger groups. Some teachers noted that discussing the activity with colleagues before entering the classroom was very helpful.

The researchers made use of FaSMEd professional development materials with their teachers on the topic of questioning. The teachers were asked to utilise what they learned about effective questioning in their future lessons. The teachers were also asked 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. There was also CPD on improving student collaboration. Once again the researchers made use of professional development materials provided by FaSMEd and adapted them to suit their teachers. Teachers engaged in discussions with researchers about how to manage collaborative discussions and how to create and establish ground rules for collaborative work. Science teachers were to carry out an investigation around heart rate and get students participating in co-operative group work when designing and carrying out the investigation. Technology played a role in this activity with the apps *Educreations* and *Explain Everything* aiding group work and facilitating student feedback. These applications recorded what students were saying during group work and also provided a place for students to write down their thoughts about the investigation.

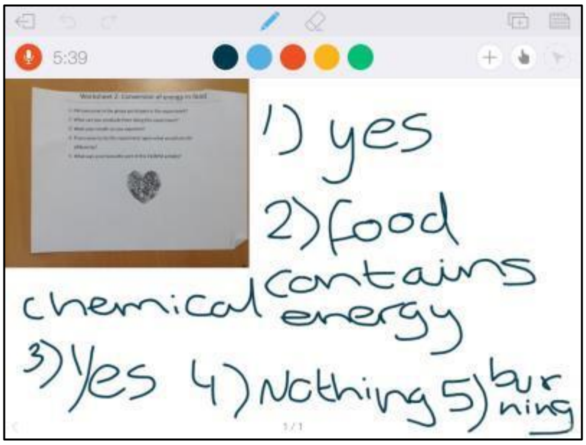


Figure 8: Example of student work on Explain Everything

The students were then to post these videos on *Schoology* or email them to the teacher for feedback. This allowed for formative feedback to take place as the teachers could use this information to plan for the next lesson. It also provided students with an interactive environment in which to work, as they had to work together to complete the task set on their iPads. Teachers could also make use of heart rate monitors and data logger software provided by the researchers for this activity in processing and analysing any misconceptions that students may have concerning the circulatory system.

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 gave feedback on the previous two activities. The teachers felt that the applications used in this activity were very useful in keeping students on task and motivated during group work. They also felt that the

Figure 9: FaSMEd teachers and researchers engaged in discussion about their questioning practices

heart rate monitors helped to alleviate misconceptions some students had around the number of beats per minute. 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 student's questions with teachers placing an emphasis on the importance of body language in the classroom. 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 and self-assess by filling out reflection sheets at the end of every 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. The teachers were equally given the option to get the students to create pen and paper graphic organisers.

4. Classroom Teaching

The Science Case Teacher (YSA) was interviewed on two occasions. She was initially interviewed at the beginning of the project (T1) and at the end of the initial implementation of the toolkit (T2).

Before participating in FaSMEd, YSA described her teaching style as predominantly active and collaborative. With her junior students (12-14) she put a lot of emphasis on mixed ability group work, she differentiated her lessons depending on the needs of the students, she made use of prompts and higher order questions to evoke student interest, and she additionally created time for students to participate in discussions around science. From participation in the project, it was felt that the teacher's co-operative learning techniques and feedback practices could be, to some extent, enhanced. The school in which this teacher is working in is beginning to integrate iPads with their students. The school has a class set of iPads that are available for any teacher to make use of. In conversations with the researchers, YSA commented that she had not previously integrated iPads within her lessons and her use of technology in class had been minimal before involvement in the project.

Examining the whole picture at T2, YSA felt that the biggest changes in her practice came from her modified feedback practices; from her recognition that her planning for teaching needed to start from where the students were in their learning. This was discussed in post interview:

> "…It just makes you more aware that you need to get that feedback from the students, after a few years of teaching you can fall into a bit of a routine and forget about it… it has definitely pushed me to become more self aware and to be aware of how the students are responding in the classroom. But it's also beginning to get the students to look at how they're learning in the classroom, take responsibility for it, which is important." (YSA_T2)

In the above comment, she attributes her improved feedback practices to her participation in the project. Not only is she using feedback to inform her own teaching, she is using it to build on student knowledge and to help them to inform their own learning.

Post interview also confirmed that the teacher was promoting student self-awareness through modified feedback during class. Within interviews, she commented that it is important that she is not only the supplier of answers but that she pushes students to look for the answers themselves rather than looking to her for help. This is especially beneficial to low achieving students to build on their self-efficacy and reduce their reliance on the teacher for guidance. This change in practice is evident from the initial interview where her feedback practices were somewhat unclear and inconsistent:

> "…sometimes I do the ticket to leave, they write down what did you like about the class, what didn't you like, what did you learn, is there anything

you'd like me to go back over, and they can hand those back up to me then."

(YSA_T1)

Following on from this comment, the teacher failed to mention how she made use of this feedback or if it was used at all. When probed about the types of feedback she gives to students, she commented that:

> "I'd probably give verbal or written feedback, I try to be positive in the feedback always, even when it's this is done really well but maybe next time lay it out with just a little bit more space between it, or the diagram was really good but the labels were a little bit small, can we just make them a little bit bigger next time for my eye sight, so it's not you it's me, would you mind just doing it for me?" (YSA_T2)

Although in these comments the teacher is portraying that she finds feedback necessary, her practices are very different both pre and post intervention. In this remark it is apparent that the teacher is placing a strong emphasis on the students completing work accurately, there is no evidence that feedback is moving the learning forward. From participation in the project, she now relies strongly on students assessing themselves, for themselves:

> "…making sure to not always give feedback to the students, that they don't always look for me for feedback, that they get a discussion going between the students, it's very easy when a student asks a question for me just to give the answer to them, but to make them think about it is more difficult".

(YSA_T2)

YSA attributed her modified feedback practices to participating in FaSMEd and was aided by her use of technology within lessons. She made use of the iPad application *Educreations* to gather information on student understanding and use this information to plan structured feedback for her students. The teacher had great praise for this application and highlighted how she would be using it again in the future with her classes. She felt that using the application was of benefit to her and her students because:

> "…they can write the answer on it but you're also hearing what they're saying, you can hear how the discussion is going, if a student is dominating a

discussion, or even how they come around to an idea. What's their logic behind the answer, because sometimes we're getting the right answer but the logic behind it wasn't necessarily sound and it's just that you can address that." (YSA_T2)

In the above comment the teacher is conveying the importance of process over product. This is particularly pertinent in relation to low achieving students as she is able to track their train of thought and help them to move forward with their learning through structured feedback. Moreover, she emphasised how the application kept students on task while completing group activates and field notes from A4 reconfirmed this.

Resulting from the teacher's enhanced feedback processes; the teacher's questioning style underwent significant improvements. Examining the teacher's opinions pre-intervention it emerged that the teacher placed significant importance on the use of questioning in class. It became apparent that the teacher made use of questioning in class to find out what students were thinking and if they were learning. She spoke about differentiating questions for students, getting students to explain their reasoning and probing for understanding. However she believed there was issues with her higher order questioning techniques, one being that she felt they were not suitable for all students in class. This opinion at T1 was indicative of a judgement being made by the teacher about the ability of some students to deal with higher order thinking.

> "There are certain weaker ones that I would avoid asking some higher order questions to because if they can't answer they tend to freeze up but I'll have a look at that". (YSA_T1)

Emphasis was placed on improving higher order questioning techniques with teachers during professional development sessions particularly to help low achieving students engage in lessons. Following the intervention period, the teacher highlighted how her questioning skills had developed by participation in the FaSMEd project. During post-interview, she commented how she now allocates thinking time to all students and she also has begun to rephrases her questions so that all students including low achievers will be able to contribute to the learning.

> "...just waiting for some of the students that just need a little bit longer to think about a question rather than if they don't know the answer straight away, jumping right in there to answer to help them, give them the time to think".
>
> (YSA_T2)

The comment below illustrates how the teacher is now incorporating all students of all levels during questioning; alleviating the issue she was having with higher order questioning that she highlighted at T1.

> "...use the word might, how might you do this rather than how do you do this, and that has definitely helped some of the weaker students I think find a voice in the classroom". (YSA_T2)

During the interview process it became apparent that the teacher had also made significant enhancements to her use of co-operative learning within class.

Prior to the project the teacher alluded to the notion of co-operative learning (referring to it as group work) in her lessons however she demonstrated a superficial knowledge of the process. At T1 she discussed how she uses group and pair work regularly in class and is careful to set mixed ability groups so that students don't become discouraged by group work participation by feeling overwhelmed by other group members. She commented that she accomplishes this using careful planning of the groups she constructs:

> "You can have quite good achievers but they don't like to work with weaker students, and the weaker students then become quite easily intimidated…I'll get to know the students, their different levels, and what I will try to do is if I've got a weak student, pair them with someone who is a little bit above their level and who they have a rapport with. Likewise with the high achievers, I will try to pair them with a student who's maybe achieving a mid level grade and again try to use them to help bring up students, because those students that are in the middle range won't be as easily intimidated as a weaker student." (YSA_T1)

Although it was communicated by the teacher that the students were participating in group work, the teacher also commented how she was using this time to check previous understanding. This was accomplished by talking to the students individually while they were in groups. This highlighted a mismatch between what the students were accomplishing in groups and what the teacher was discussing with them individually. This suggested a naive understanding of effective co-operative learning implementation due to a lack of quality in the group's interactions.

The teacher did not comment exhaustively on her improved co-operative learning skills at T2 however she mentioned how the use of the application *Educreations* helped her to structure co-operative learning and how it kept students engaged in her science lessons. She commented that she felt that the use of the application made students stay on task longer than they normally would in an activity like this.

> "It also helps keep some of the students on task because they know you're listening." (YSA_T2)

As the student's co-operative learning skills were being developed, this led to the student's capacity for peer assessment being heightened. Data gathered from post interview demonstrated that the FaSMEd student's peer assessment skills had greatly improved from participation in the A5 (students as assessors) activity. The teacher drew comparisons between the students involved in FaSMEd and other students that she taught who had little experience of peer assessment; she commented that:

> "Another class that I tried to do the same thing with they were more just making sure that they were giving nice comments to everybody, while they didn't want to really analyse what was there they wanted to make sure that everybody got fours and I said well did they really get a four, and they said yeah they did, rather than actually going well no they didn't do that, whereas the FaSMEd class they were definitely more critical, positive but critical." (YSA_T2)

This conveys the positive impact the project had on the students and how incorporating different formative assessment techniques in class was building the students capacity to self regulate their learning. However, more cycles of plan, do and review would be needed to ascertain if the practices were deeply embedded with the teacher.

5. Lessons

Overview

For the purpose of this case study a number of lessons were observed. The activities A4 (increasing student collaboration) and A5 (students as assessors) were both observed and video recorded. For the original A4 lesson, one observer both recorded the lesson and took detailed field notes of what was happening in the class. For A5 and the A4 *reteach* lesson there was two observers in the classroom, Observer 1 took detailed field notes of what was happening in the lessons and Observer 2 recorded the lesson making use of both close up shots of student work and wide shots of classroom proceedings and discussions. Video was analysed using a time-indexed video analysis template developed by the researchers.

Upon analysis of the data collected from teacher and student interviews and classroom observations, a feedback loop was identified that emerged over the course of the project. Through professional development, reflection and refinement, YSA had created a cycle of feedback and questioning that encouraged students to become self-regulatory learners by participating in self and peer assessment and therefore moving their learning forward independently. This conveys how the teacher was providing feedback that moves learners forward by activating students as instructional resources for themselves and for one another. This is discussed in more detail throughout this section.

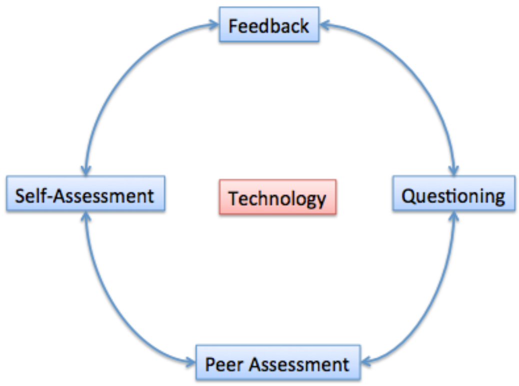


Figure 10: Feedback Loop

Technology was at the heart of this loop by providing the teacher with the opportunity to gather conceptual information about the students to assist in her feedback processes. It also functioned in sending and displaying data and providing students with an interactive environment in which to work. *Educreations* and

Schoology provided the space in which data was gathered from students and could be shared and displayed among the group to allow for self and peer assessment.

A4: Increasing Student Collaboration

Within this series of lessons the teacher tried to increase and improve students' participation in co-operative work in order to engage them in learning tasks that elicit evidence of student understanding. Students were to work collaboratively to design and carry out a heart rate investigation. While the lesson was successful in increasing student collaboration and getting students working co-operatively, it was noticed how the teacher's feedback practices had improved during this series of lessons.

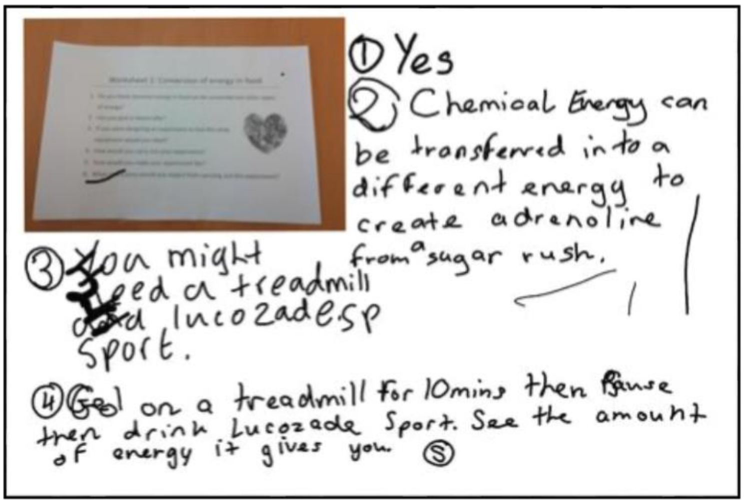


Figure 11: Sample of student work on Educreations (A4)

In the initial lesson on A4 the teacher had innovatively made use of the application *Educreations* to build structured group feedback. This fits neatly into the cuboid framework whereby the teacher was providing feedback that moves learners forward through technology functioning in the sending and displaying of student information. Within the application student's thoughts about their heart rate activities were recorded onto their iPads and the teacher used the student thinking to inform her next lesson. Figure 11 illustrates a sample of student work on the application. The questions posed by the teacher that the students have to explore as a group appear in the picture to the left and the students then have the space to write down their ideas on the right (Appendix C contains the questions that the students explored). Their comments during the task were also audio recorded through the application. Prior to the second lesson, the teacher analysed the student's work on this task and used it to build structured group feedback. In the following lesson it was observed that she made time for identifying and responding to any conceptual difficulties that the students were having about the circulatory system and addressed these misconceptions at the beginning of the lesson as displayed in Figure 12. This was particularly of benefit to low achieving students as their misconceptions may have gone unnoticed prior to integrating this technology into the lesson.

For example, video data gathered in the lesson A4 shows how the teacher was using feedback in the form of effective questioning to help a student with a misconception in relation to the energy content in sugar. Firstly the teacher provided the student with ample wait time for the student to construct their answer. When the student cannot answer she probes the student for understanding using further questioning, when the student is still unsure she makes use of a random recall application on her iPad to call on a student from the class to help with the answer. This indicates how the teacher made use of numerous effective questioning techniques sequentially in her feedback practices to help alleviate a misconception that a student was having. During this lesson students were seen to be very engaged with technology and were familiar with using it in class. The majority of groups were focused on completing their work co-operatively. The teacher discussed how the application (*Educreations*) aided co-operative learning and feedback practices during teacher interviews (discussed in section four).

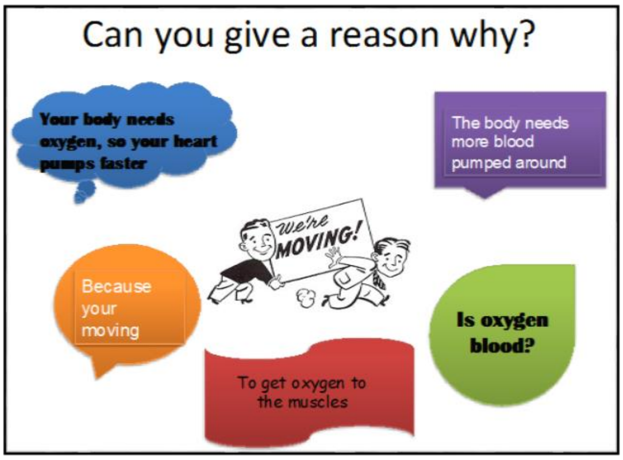


Figure 12: Science case teacher's PowerPoint Slide, an example of student answers to be used to give feedback to class (A4)


Figure 13: Students engaged during group work with Educreations (A4)

As the project is rooted in design based research it is important to examine and modify activities to make them more relevant and useful to the teachers and students who are using them. In light of this both researchers and YSA reviewed the A4 activity and a *reteach* lesson was planned. The teacher planned the following changes for the lesson:

- A whole class discussion on group work and the importance of roles when working in a group. This is important in relation to low achieving students being active in these types of activities and not being overshadowed by other students.
- Distribute the groups differently, with a fair distribution of active and non-active students.
- Planning worksheet to keep the students on task and focused before and during the activity.
- More integration of technology within the lesson.

Again at the beginning of the lesson the teacher used information gathered from the *Educreations* application to build structured feedback for the group. This was once again very effective as it helped students to move forward with their learning. As Figure 14 demonstrates, when listening back to the students work the teacher noticed that students were disputing about group roles and participation. The teacher used this information to clarify to students the need to work co-operatively in class in order to meet the learning objectives. She also reiterated the importance of not only concentrating on the individual group role, but also participating fully in group work. In addition, she provided students with the objectives of the lesson so the students could be informed about where their learning was going. Here the teacher was employing the formative assessment strategy of clarifying, sharing and understanding learning intentions for the students.

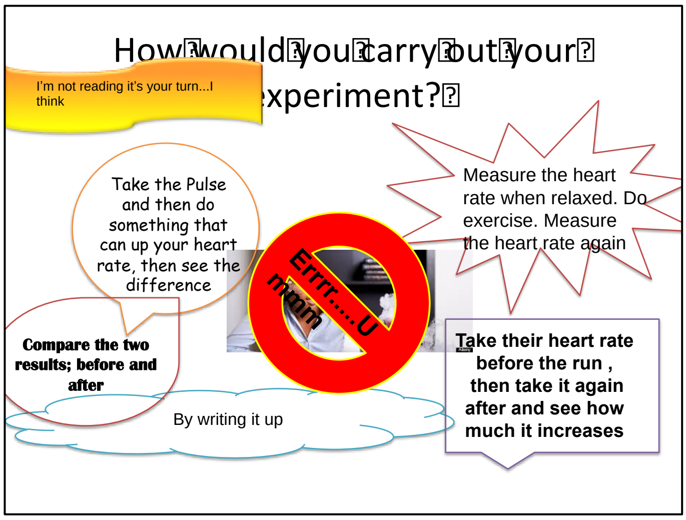


Figure 14: Science case teacher's PowerPoint Slide (reteach lesson), an example of student answers to be used to give feedback to class (A4)

Within this lesson there were some changes to the teachers questioning skills. She began the lesson using questioning directed individually at particular students and many of her questions were of a lower order. Questions such as “where do we get our energy from” and “what is carried in the blood” were directed at individual students causing other students to become disengaged with the activity and get distracted by the camera at the back of the room. This could have been detrimental to low achieving students as their lack of engagement was not moving them forward in their learning, however as the lesson progressed the teacher adapted more questions of a higher order and it was evident that she wanted students to explain their reasoning to their activity conclusions. The teacher challenged the students by asking them why their results were as they are and what would they do differently if they were to repeat the process.

A5: Students as Assessors

During this activity, improvements in the teachers questioning and peer assessment practices were evident. Classroom observation provided the researchers with the opportunity to witness the teacher’s improved questioning. Field notes gathered from the lesson directly preceding A5 demonstrate how students were provided with the opportunity to rethink answers that may have been incorrect. The teacher facilitated this by providing the students with *thinking time* in class and using higher order questioning to probe for understanding. In the lesson A5 where students were using graphic organisers to assess both themselves and each other, field notes illustrated that the teacher was making use of questioning repeatedly to give feedback on answers and to scaffold students to problem solve and find the solution. Scaffolding is especially important for low achievers as it allows for them to build on their previous knowledge and not become overwhelmed by problem solving. Through improvements YSA made to her co-operative learning techniques, her ability to activate students as instructional resources for one another was heightened. This fits into the cuboid whereby the technology functioned in sending and displaying and providing students with an interactive environment in which to work.

During the project the teacher improved her co-operative learning practices and not only accomplished the students working as teams, but used this group work to promote peer assessment within class. During lessons where the teacher was working on promoting students as assessors (A5), the teacher made use of technologically enhanced co-operative learning to develop student's teamwork and peer assessment skills. The teacher made use of the iPad application *Popplet* to incorporate technology in the lesson, the completed *popplets* were shared and displayed among students so that they could peer assess each other's work on *Schoology*.

Figure 15: Student working with the iPad application Popplet (A5)

Prior to the lesson, the teacher had organised the students into groups by ability levels, she had discussed this in initial interviews. At the beginning of the class the students were assigned group roles, however the teacher did not tell them what these roles were and they had to assign themselves a letter, A, B, C or D. This tackled the issue of students choosing roles based on their ability levels, for example, stronger students being the reporter and weaker students being the timekeeper. This method of group design had not been explored during sessions with teachers and demonstrates the teacher taking the initiative to push her co-operative learning planning to a higher level and being particularly mindful of low-achieving students.

Video analysis of A5 illustrated student engagement in the activity throughout the lesson. This engagement was supported by the teacher who was seen to be constantly monitoring group work, probing students for understanding through questioning and engaging in discussions with students about their

Figure 16: Science case teacher engaging with different groups during the activity (A5)

work. The teacher was seen to keep the students on task during group work by providing them with the criteria for success for the graphic organiser at the beginning of the lesson. During the co-operative learning activity it was observed that the teacher repeatedly referred back to the success criteria for making the mind maps. It was noticeable through observation in A5 that this helped to keep the students focused on their group task and to self apply success criteria to it.

Once students had completed their graphic organisers in groups, they were to upload them to the class *Schoology* page for them to be peer assessed in the next lesson. This allowed for the sending and displaying functionality of the technology whereby the graphic organisers could be shared among all the students in the following lesson. During the subsequent lesson on A5 the class made use of the success criteria uploaded on *Schoology* for peer assessment of their graphic organisers. Teacher reflections gathered after the lesson explained how the students enjoyed this lesson. In particular thy enjoyed both giving advice to and receiving feedback from their peers. The teacher also noted how the technology had an impact on the lesson as the students communicated to her that they wished to use the application in other subjects in school.

6. Pupil Perceptions

Data Collection:

Data were gathered from the science students participating in the FaSMEd project during a Q-Sort activity and by them completing questionnaires. During the Q-Sort activity students individually sorted 48 statements onto a placemat, see Figure 17. During the activity the students were engaged in discussions with the interviewer about their perceptions of science 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 or needed relevant examples of. 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.

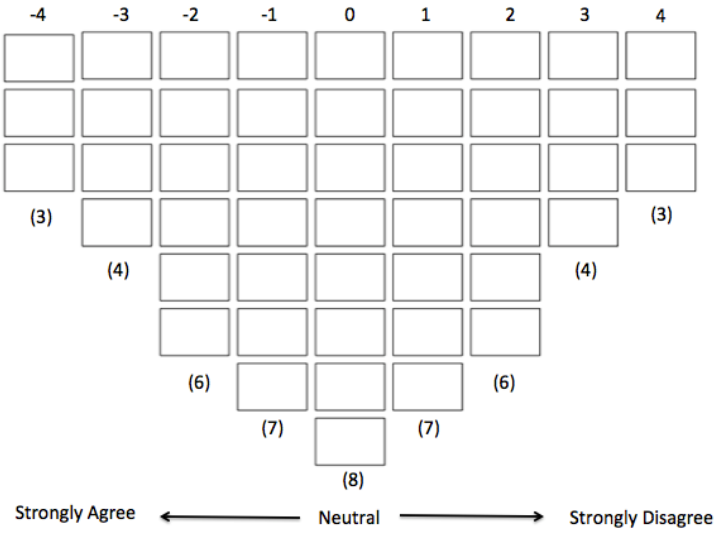


Figure 17: Placemat in Fixed Quasi-Normal Distribution. Ranking values range from -4 to +4. Numbers in brackets indicate the number of items that can be assigned to any particular rank. A total of 48 items can be sorted in the distribution illustrated.

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 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. 124 science students participating in the project completed a 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 were carried out followed by varimax rotations. Data gathered from both tests did not differ significantly. This case will report on the results of the principal component analysis with varimax rotation. During the Q-Sort activity students were interviewed about their perceptions of science and their views of the FaSMEd activities they had participated in. Data were audio recorded, transcribed and analysed using MAXQDA. Finally the questionnaires that were distributed to science students participating in FaSMEd (n=124) were analysed using SPSS software.

Theme	**Example**	**Number of Statements**
Views of science (VOS)	*I am good at science*	9
Use of technology in learning (UOT)	*Using technology helps me understand science better*	12
Perceptions of examinations (POE)	*Doing exams motivates me to work harder in science*	3
The usefulness of science (UOS)	*Science helps us to understand the world around us better*	7
Ideas about science teaching and learning (STL)	*It best way to learn science is by working with others*	12
The nature of science (NOS)	*Science 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 analysis of the questionnaire data was carried out in the same manner as described in the mathematics case study. For the science students, the correlation between the Christmas and summer exam marks was higher than that of the mathematics students at 0.844. Both exam marks were significantly correlated with VOS and UOS measures. In fact the measures for VOS and UOS were significantly correlated with all other variables.

Analysis of regression (trying to predict the summer marks using the Christmas mark and the 4 attitude measures) found that the predictors were the Christmas mark and the POE measure, and that the R-square was 0.716, so 71.6% of the variations in summer marks are accounted for by these two variables. Considering the answers to some of the questions relating to technology and formative assessment provided interesting results:

Question	Definitely Agree	Agree a bit	Not sure	Disagree a bit	Definitely Disagree
Using technology helps me understand science better.	25.2%	35.0%	24.4%	11.4%	4.1%
Our science teacher has a better idea of how we are doing when s/he uses the technology to record our answers.	22.1%	23.8%	46.7%	3.3%	4.1%
Technology helps me find out for myself how I am doing in a science activity.	22.0%	37.4%	26.8%	8.9%	4.9%
The technology we use in science class helps me see where I am going wrong.	20.2%	28.9%	34.2%	13.2%	3.5%
Our science teacher always uses some kind of technology in class.	30.4%	38.3%	16.5%	10.4%	4.3%
We use a lot of technology in our science classes.	15.8%	30.8%	25.8%	20.0%	7.5%

Table 3: Responses to Technology and Formative Assessment questions

The students were more likely to agree that the teacher uses a lot of technology in class than to agree that they use it themselves however the difference is not as great as in the maths classes. Once again it is seen that students are often unsure how to answer these questions but that on the whole they are positive about the role of technology in their learning.

There were no significant differences in the mean measures of the science and maths groups on the UOM/S or POE scales. There was a statistically significant difference on the VOM/S and the UOT scales ($p<0.001$ in both cases). In both scales the maths groups had significantly higher means, which signifies that the science group had a better view of themselves in relation to the subject and a more positive view of technology. (Recall strongly agree was coded as 1 and strongly disagree as 5 so low scores relate to more positive attitudes). Looking at the differences between the students on different questions supports this finding about science.

Question	Subject	Definitely agree	Agree	Not sure	Disagree	Definitely Disagree
We use a lot of technology in our maths/science classes.	Maths	9 6.4%	35 24.8%	30 21.3%	30 21.3%	30 21.3%
	Science	19 15.6%	37 30.3%	32 26.2%	24 19.7%	10 8.2%
Our maths teacher always uses some kind of technology in class.	Maths	42 30.4%	41 29.7%	24 17.4%	19 13.8%	12 8.7%
	Science	37 31.6%	44 37.6%	19 16.2%	12 10.3%	5 4.3%
Using technology helps me understand maths/science better.	Maths	21 15.1%	32 23.0%	47 33.8%	23 16.5%	16 11.5%
	Science	32 25.6%	43 34.4%	31 24.8%	14 11.2%	5 4.0%
Our maths/science teacher has a better idea of how we are doing when s/he uses the technology to record our answers.	Maths	19 13.6%	32 22.9%	70 50.0%	12 8.6%	7 5.0%
	Science	27 21.8%	30 24.2%	58 46.8%	4 3.2%	5 4.0%
Technology helps me find out for myself how I am doing in a maths/science activity.	Maths	21 15.3%	30 21.9%	54 39.4%	24 17.5%	8 5.8%
	Science	27 21.6%	47 37.6%	34 27.2%	11 8.8%	6 4.8%
The technology we use in maths/science class helps me see where I am going wrong.	Maths	25 18.2%	39 28.5%	52 38.0%	14 10.2%	7 5.1%
	Science	23 19.8%	35 30.2%	39 33.6%	15 12.9%	4 3.4%

Table 4: Comparison of answers to technology related questions in the maths and science questionnaires.

A chi-square test showed that the answers to the use of technology in class were not independent of subject (p=0.004) with more technology in the science classrooms.

There was no significant difference between the groups on teacher use of technology even though there was a difference for the question *we use a lot of technology in our science/maths classes.* A chi-squared test showed that the answer to technology helping students to understand was not independent of the subject (p=0.006) and the table shows that the science students were more positive about technology helping them to understand. *Our maths/science teacher has a better idea of how we are doing when s/he uses the technology to record our answers* – there is no significant difference between the groups on this question. *Technology helps me find out for myself how I am doing in a maths/science activity* – the answers to this question are not independent of the groups (chi-squared test, p=0.009). We see that science students are more likely to agree here than their maths counterparts. *The technology we use in maths/science class helps me see where I am going wrong* – there was no significant difference between the groups here. Both groups are more likely to agree than disagree but there are a sizeable proportion of both groups who are not sure.

Within Case Analysis

Two factors were observed when analysing the data, four out of the five students were contained in factor 1, and the remaining student 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

Four out of the five students were loaded on Factor 1; three were male (S17, S5, S3) and one was female (S6). In the summer examinations, none of the students grades had increased, their grades all decreased by between five and 13 per cent. One student's grades remained unchanged (S6). None of these students have any special education needs.

S17 lives in the surrounding area of the school with both parents and one younger sibling. He has generally good grades across all subjects. He had very positive feedback from all his teachers about his performance at the end of 1st Year. S5 lives close to the school with both parents, his parents are not Irish born or educated. He had good grades that tend to fluctuate between subjects. Again all his teachers had very positive feedback about his performance throughout 1st Year. S6 was born in Romania and moved to Ireland when she was very young. All of her education has been through the Irish system. She had very positive feedback from all her teachers at the end of 1st Year. S3 lives with both of his parents in the same town as the school. He is an above average student and his teachers are all very happy with his performance in 1st Year.

Factor interpretation

The students on this factor saw great relevance of science in the wider world. They saw the science classroom as a place for expressing one's own opinions and very much enjoyed their science lessons. During the Q-Sort activity this group of students agreed the most with the following statements:

Statement	**Theme**	**Z-Score**
It is easier to learn science by doing practical activities	STL	-1.640
Science is fun	VOS	-1.556
It is important to study science	UOS	-1.542
Science is used in everyday life	UOS	-1.410
Science helps us to think systematically and logically	NOS	-1.392

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

It is observed here that the students have strongly positive views of science. They can clearly see the importance of the subjects outside of the classroom and highlight how the practical nature of science i.e. participating in experimentation and group work, can make it more enjoyable. During interviews, students commented that:

> "There's a lot of different ways to learn science and one of my ways is to hear it, but when you're doing it with others you can hear other people's opinions and sometimes they're not the same as to yours and it's fun to learn

about how other people think about the topic or the chapter."

(YSA_S6)

"I don't think that you can really learn science from a textbook because science is something that's all around us and you need to do experiments as well and stuff to get a better understanding of the actual experiment than just reading about it." (YSA_S3)

These findings were consistent with those of the entire cohort of science students who completed the questionnaire. 80.4% of all students agreed with *it is easier to learn science by doing practical activities*, 83.7% agreed with *science is fun*, 87% agreed with *it is important to study science* and 77.3% and 69% agreed with *science is used in everyday life* and *science helps us to think systematically and logically* respectively.

The factor 1 students all disagreed strongly with the following statements:

Statement	**Theme**	**Z-Score**
I hate science	VOS	1.981
I don't see the point in doing science	UOS	1.905
I can do without science	UOS	1.759
Science is only for the science classroom and has nothing to do with real life	UOS	1.680
In science classes there is no room for expressing your own ideas	STL	1.445

Table 6: Statements that the students in factor 1 strongly disagreed with

Again the relevancy and practicality of science is strongly evident in the student's opinions here. They also highlight the inclusive nature of their classroom where students can express their opinions and views about science freely without the fear of being wrong. This was also seen during classroom observations of Activity 4 (A4) where the students expressed their opinions freely in class without fear of their suggestions being rejected by the teacher. However during interview one student illustrated that the other students in the class need to express their opinions more during lessons.

"They're a bit shy of saying something that could be wrong." (YSA_S3)

This highlights the confidence the high achieving students have in their views and opinions and how this confidence may be lacking in other less academically able students.

This group of students strongly disagreed with *I hate science*, conveying they enjoy their science lessons and the teaching pedagogies utilised by the teacher during class is a factor in this enjoyment. This could also be clearly seen during classroom observation (A4 and A5) whereby the teacher used a range of different teaching strategies including co-operative learning and investigative work, to keep the students engrossed in their science lessons.

Again findings from the Q-Sort were consistent with the questionnaires. 78.4% of students disagreed with *I hate science* while 78.3% disagreed with *I don't see the point in doing science*. 82.1% of students disagreed with *science is only for the science classroom and has nothing to do with real life*. Slightly lower levels of disagreement were observed with the statements *I can do without science* and *in science classes there is no room for expressing your own ideas*, with their level of disagreement being only at 60.9% and 58.5% respectively. This highlights the point made by YSA_S3 whereby other students may be lacking in the confidence to express their opinions in class, as they may fear being interpreted as wrong.

Factor 2

Demographic Information

The student (S20) in factor 2 is an average student. Her grade dropped by 2% in her summer examination compared with her Christmas examination. She lives near to the school with both her parents and has younger siblings. Her mother is very keen for her to perform well in school and pushes her very hard to achieve *A* grades. She struggles with languages. Her teachers are very happy with her progress through 1st Year and she does not have any special education needs.

Factor Interpretation

This student differed from the other students on her beliefs about technology and her strong reliance on the teacher for guidance.

She strongly agreed with the following statements:

Statement	**Theme**	**Z-Score**
I prefer to talk to the teacher rather than find out for myself using technology	STL	-1.808
Science makes sense in the real world	UOS	-1.808
I pick things up quickly in science	VOS	-1.808

Table 7: Statements that the student in factor 2 strongly agreed with

The student here is illustrating how she relies heavily on the teacher to help her move forward in her learning. During interview she commented that:

> "If something doesn't look right I put my hand to see if I was wrong or right."
>
> (YSA_S20)

She also commented that she preferred the guidance from the teacher rather than using technology to figure a problem out on her own:

> "I prefer to talk to my teacher because she makes the definitions more sensible and more easy to understand where if you use the iPads sometimes I don't get them." (YSA_S20)

When asked about the FaSMEd feedback activity she completed in class (A1), the student did not see how the teaches feedback was benefiting her own learning, she commented that she had to retry doing the activity the teachers way, putting the onus back on the teacher. She also expressed how she went up to the teacher after getting the feedback to get further help with the activity.

The Q-Sort activity also demonstrated this student's enjoyment of science with her agreeing to the statements *I love science* and *science is fun*. The student also saw benefit in using technology in class by agreeing with *using technology in science is fun* and *using technology in science is useful*. During interview she commented that:

> "For the technology, sometimes it does help you find out how you're doing or what you got wrong and what you got right and what you can fix."
>
> (YSA_S20)

The technology that the student used can be seen to have benefitted her learning however her strong reliance on the teacher is overshadowing the advantages of using technology in class.

> "Sometimes technology does help, but I prefer knowing it off the board, from the book, and my teacher." (YSA_S20)

Formative Assessment and Technology

In relation to the technology the case students used in class, quantitative analysis of the Q-Sort did not demonstrate any significant impact on the use of technology in the students own learning, however when asked about technology, the students had largely positive attitudes about utilising it in class.

> "It's different than just doing exercises but it's also a good way to learn from and it's easier to use." (YSA_S3)
>
> "It's more interesting than having to learn loads of stuff from a book." (YSA_S3)

Students saw the advantage of using technology within co-operative learning and peer assessment, but felt that other uses of technology for example to play games was not benefiting their learning.

> "It probably would help me if we were doing a revision sheet and I got something wrong and other people were marking it, it would show me where I went wrong, and if we were playing a science game on it and I got something wrong in that, I wouldn't really learn from it." (YSA_S17)

It is also very interesting to note that the students noticed the advantages the technology had in providing them with feedback from their teacher. The students commented that apart from examinations, it is very difficult for the teacher to monitor how they are doing in class however the technology aided greatly in this.

> "Well they 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 except by exams." (YSA_S3)

With regards to the questionnaire data gathered, students felt strongest about the technology related statements *when we work together it makes sense to use the technology* and *using technology in science is fun* with 73.2% agreeing with the former and 78.9% of students agreeing with the latter. This demonstrates again the significance the students placed on using technology in co-operative learning activities, highlighting how it helps them in their learning. The fun aspect of the technology was noted in all data gathered with students conveying their enjoyment of using technology such as iPads and data loggers in science class.

Cross Case Analysis

A total of 14 science students (including the case study students) from the three participating FaSMEd schools engaged with the Q-Sort activity. Of these 14 students, seven were male and seven were female. Upon analysis of Q-Sort data, three factors emerged. Similar opinions were shared among all students and the case study students. Data in the cross case were analysed using principal component analysis with a varimax rotation.

Factor 1

Factor Interpretation

Factor 1 in the cross case analysis was very similar to factor 1 observed in the within case analysis. Nine out of the 14 students interviewed were within this factor including three students from the within case analysis. Students strongly disagreed with the statements below:

Statement	**Theme**	**Z-Score**
I hate science	VOS	1.908
Science is only for the science classroom and has nothing to do with real life	UOS	1.673
I don't see the point in doing science	UOS	1.645

Table 8: Students in factor 1 of the cross case analysis strongly disagreed with these statements

As it can be seen, these statements are common with the statements strongly disagreed with in the within case analysis of factor 1. However within this factor the students also conveyed the impact that technology had on their learning by also strongly disagreeing with the statements *I do not like using technology in science* (Z=1.464) and *for me, the technology does not work or help* (Z=1.383). This is conveying that the larger cohort of students saw the benefit that technology had in the classroom with students commenting that:

> "I do like using technology in science because it makes it more fun and easier for people to interact and ask questions rather than just studying by only using the book." (XSA_S20)

This cohort of students also perceived how the technology was helping their teacher to provide them with effective feedback while simultaneously giving the shy students in the class the opportunity for their voice to be heard.

> "When he (the teacher) records our answers he'll be able to know what we don't really know and more people can ask a questions rather than just keeping it to themselves and being scared to talk." (XSA_S20)

The above quote relates to the teacher use of the application *Explain Everything* that is similar to *Educreations* discussed previously in this case study.

With the statements that students strongly agreed with, again all students including the case study students shared similarities with their level of agreement about the following statements:

Statement	**Theme**	**Z-Score**
Science is used in everyday life	UOS	-1.619
It is important to study science	UOS	-1.529
Science helps us to think systematically and logically	NOS	-1.311

Table 9: Students in factor 1 of the cross case analysis strongly agreed with these statements

This cohort of students had stronger opinions about the relevance of science than just the case study students. Other statements that these students agreed with strongly conveyed this, with students placing *science makes sense in the real world* (Z=-1.242) and *science helps us to understand the world around us better* (Z=-1.361) also in their top five statements that they strongly agreed with.

Factor 2

Factor Interpretation

A new factor emerged from the cross case analysis. Students loaded on this factor put a lot of emphasis on the importance of examinations to gauge success in science class. Three students in total were loaded on this factor. These students agreed strongly with the following statements:

Statement	Theme	Z-Score
I learn science best when I work on my own	STL	-1.991
If I don't understand something in science, I work on it until I get it right	STL	-1.780
Doing exams motivates me to work harder in science	POE	-1.735
I like exams because the results show me how I am doing	POE	-1.660
It is important to study science	UOS	-1.561

Table 10: Students in factor 2 of the cross case analysis strongly agreed with these statements

These students here are also conveying their preference to work independently in class. These students reiterated this when they strongly disagreed with the statement *the best way to learn science is by working with others* (Z=1.372). Interestingly within the cross case analysis, YSA_S6 moved from factor 1 to factor 2. This is demonstrating how this high achieving student not only sees the strong relevance of science in the wide world; he believes that exams are a very important aspect of learning science.

> "Without exams I feel like there would be no stress, and without a bit of stress you won't be motivated to do something." (YSA_S6)

Factor 3

Factor Interpretation

Only two students loaded on this factor. The student who was contained in factor 2 in the within case analysis moved to factor 3 in this analysis. These two students did not have strong opinions about the emergent themes identified during the research. They strongly disagreed with the following statements:

Statement	Theme	Z-Score
You can learn science best with just a textbook	STL	1.714

I am good at science	VOS	1.615
In science classes there is no room for expressing your own ideas	STL	1.609
Using technology in science is fun	UOT	1.416
If I don't understand something in science, I work on it until I get it right	STL	1.311

Table 11: Students in factor 3 of the cross case analysis strongly disagreed with these statements

This shows some similarities with factor 2 of the within case analysis as this student also disagreed with the statement *in science classes there is no room for expressing your own ideas* in that factor. The statements that the factor 3 students agreed with are as follows:

Statement	**Theme**	**Z-Score**
Science makes sense in the real world	UOS	-2.013
I prefer to talk to the teacher, rather than find out for myself with the technology	STL	-2.013
When we work together, it makes sense to use the technology	UOT	-1.714
Doing exams motivates me to work harder in science	POE	-1.510
Science helps us to understand the world around us better	UOS	-1.221

Table 12: Students in factor 3 of the cross case analysis strongly agreed with these statements

Here it is observed that there are very strong opinions about science in the real world. Furthermore these results are consistent with factor 2 from the within case analysis where a strong reliance on the teacher for guidance is evident.

7. Key Findings

Within the FaSMEd Framework, the researchers observed evidence for the teacher's capacity to *provide feedback that moves learning forward* and to *engineer effective classroom discussions and other learning tasks to elicit evidence of student understanding.* The teacher, through the use of technology in *sending and displaying* and in *processing and analysing* student information, was able to accomplish this and integrate technologically enhanced assessment practices into her lessons. Technology featured in providing an interactive environment for students, which was used to some extent during the project; however, this practice was not embedded in the teaching and learning. *Activating students as instructional* *resources for one another and as owners of their own learning* were also important formative assessment strategies implemented by the teacher throughout the course of the project, with the functionalities of technology listed above aiding in formative assessment. There were notable differences in the teacher's approach to *displaying and understanding learning intentions and criteria for success* however technology did not have a strong impact on this formative assessment approach.

In summary, data gathered indicate that the teacher's ability to organise co-operative learning and peer assessment is building more autonomous, self-regulated learners in her classroom. She made substantial improvements to her use of group work in the classroom and due to participation in the project; the students are now functioning more effectively in groups and have developed their peer assessment skills. Providing students with effective feedback to move their learning forward was a formative assessment skill greatly improved by the teacher during the course of the project aided by her use of pre-assessment tasks. Due to her modified feedback techniques, her students are becoming more autonomous in their learning and her feedback practices are informing her own teaching and learning. Although these students are still somewhat reliant on the teacher for guidance, small improvements in self-regulated learning were still perceived.

Findings from the Q-Sort data and the questionnaires are indicating that similar to the FaSMEd maths students, the science students have strongly positive opinions about the relevance of science outside of the classroom. They also expressed their enjoyment of science lessons and held more positive views about technology in lessons than the maths students. The Q-Sort conveyed how science students felt they could express their opinions openly in class, this links to the peer assessment strategies promoted by the teacher in A5.

Bibliography

Reid, A. (2006). Key competencies: a new way forward or more of the same? *Curriculum Matters*, *2*, p.43-62.

Schmolck, P., & Atkinson, J. (2002). *PQMethod (version 2.35).* Available at: http://schmolck.userweb.mwn.de/qmethod/downpqmac.htm (accessed 13th December 2015).

Timperley, H., Wilson, A., Barrar, H., & Fung, I. (2007). Best evidence synthesis iterations (BES) on professional learning and development. *Wellington, NZ: Ministry of Education*.

Appendix A: Themes and Statements from Q-Sort and Questionnaires

Scale	Statement	Number
View of Science (VOS)	I find science difficult.	1
	I hate science.	3
	Science comes naturally to some people.	7
	Science is fun.	14
	Science is frustrating.	16
	I love science.	19
	I am good at Science.	35
	I pick things up quickly in science.	45
	Using technology in science is useful.	26
Use of technology in learning (UOT)	Using technology helps me understand science better.	6
	I do not like using technology in science.	11
	Our science 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 science 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 science activity.	34
	Our science teacher always uses some kind of technology in class.	39
	Using technology in science is difficult.	43
	The technology we use in science class helps me see where I am going wrong.	44
	Using technology in science 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 science.	28

The usefulness of science (UOS)	Science is used in everyday life.	5
	Science makes sense in the real world.	21
	Science is only for the science classroom, has nothing to do with real life.	22
	I can do without science.	25
	Science helps us to understand the world around us better.	36
	I don't see the point in doing science.	8
	It is important to study science.	38
Ideas about science teaching and learning (STL)	The best way to learn science is by doing loads of exercises from the book.	9
	If I don't understand something in science, I work on it until I get it right.	10
	You can learn science best with just a textbook.	13
	In science classes there is no room for expressing you own ideas.	15
	I learn/understand science best when I work on my own.	18
	Doing well in science depends on having a good science teacher.	20
	It is easier to learn science by doing practical activities.	33
	In science classes there is no time for reflecting on my work	37
	In science we're always doing the same exercises over and over again.	40
	The best way to learn science 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 science classes.	27
The nature of science (NOS)	Science means exploring and experimenting.	17
	In science the answer is either right or wrong.	23
	Science helps us to think systematically and logically.	41
	Science means seeing connections.	48
	Science is something everybody can learn.	47

Appendix B: Comparison of the Mathematics and Science Groups

We use a lot of technology in our maths/science classes. * Subject Cross tabulation

			Subject		
			Maths	Science	Total
We use a lot of technology in our maths/science classes.	Definitely Agree	Count	9	19	28
		% within Subject	6.4%	15.6%	10.6%
	Agree a bit	Count	35	37	72
		% within Subject	24.8%	30.3%	27.4%
	Not Sure	Count	30	32	62
		% within Subject	21.3%	26.2%	23.6%
	Disagree a bit	Count	37	24	61
		% within Subject	26.2%	19.7%	23.2%
	Definitely Disagree	Count	30	10	40

		% within Subject	21.3%	8.2%	15.2%
Total		Count	141	122	263
		% within Subject	100.0%	100.0%	100.0%

Our maths/science teacher always uses some kind of technology in class. * Subject Cross tabulation

			Subject		Total
			Maths	Science	
Our maths teacher always uses some kind of technology in class.	Definitely Agree	Count	42	37	79
		% within Subject	30.4%	31.6%	31.0%
	Agree a bit	Count	41	44	85
		% within Subject	29.7%	37.6%	33.3%
	Not Sure	Count	24	19	43
		% within Subject	17.4%	16.2%	16.9%
	Disagree a bit	Count	19	12	31
		% within Subject	13.8%	10.3%	12.2%
	Definitely Disagree	Count	12	5	17
		% within Subject	8.7%	4.3%	6.7%
Total		Count	138	117	255
		% within Subject	100.0%	100.0%	100.0%

Using technology helps me understand maths/science better. * Subject Cross tabulation

			Subject		Total
			Maths	Science	
Using technology helps me understand maths/science better.	Definitely agree	Count	21	32	53
		% within Subject	15.1%	25.6%	20.1%
	Agree a bit	Count	32	43	75
		% within Subject	23.0%	34.4%	28.4%
	Not sure	Count	47	31	78
		% within Subject	33.8%	24.8%	29.5%
	Disagree a bit	Count	23	14	37
		% within Subject	16.5%	11.2%	14.0%

	Definitely disagree	Count	16	5	21
		% within Subject	11.5%	4.0%	8.0%
Total		Count	139	125	264
		% within Subject	100.0%	100.0%	100.0%

Our maths/science teacher has a better idea of how we are doing when s/he uses the technology to record our answers. * Subject Cross tabulation

			Subject		Total
			Maths	Science	
Our maths/science teacher has a better idea of how we are doing when s/he uses the technology to record our answers.	Definitely Agree	Count	19	27	46
		% within Subject	13.6%	21.8%	17.4%
	Agree a bit	Count	32	30	62
		% within Subject	22.9%	24.2%	23.5%
	Not Sure	Count	70	58	128
		% within Subject	50.0%	46.8%	48.5%
	Disagree a bit	Count	12	4	16
		% within Subject	8.6%	3.2%	6.1%
	Definitely Disagree	Count	7	5	12
		% within Subject	5.0%	4.0%	4.5%
Total		Count	140	124	264
		% within Subject	100.0%	100.0%	100.0%

Technology helps me find out for myself how I am doing in a maths/science activity. * Subject Cross tabulation

			Subject		Total
			Maths	Science	
Technology helps me find out for myself how I am doing in a maths/science activity.	Definitely Agree	Count	21	27	48
		% within Subject	15.3%	21.6%	18.3%
	Agree a bit	Count	30	47	77
		% within Subject	21.9%	37.6%	29.4%
	Not Sure	Count	54	34	88
		% within Subject	39.4%	27.2%	33.6%
	Disagree a bit	Count	24	11	35
		% within Subject	17.5%	8.8%	13.4%
	Definitely Disagree	Count	8	6	14
		% within Subject	5.8%	4.8%	5.3%

Total	Count	137	125	262
	% within Subject	100.0%	100.0%	100.0%

The technology we use in maths/science class helps me see where I am going wrong. * Subject Cross tabulation

			Subject		Total
			Maths	Science	
The technology we use in maths/science class helps me see where I am going wrong.	Definitely Agree	Count	25	23	48
		% within Subject	18.2%	19.8%	19.0%
	Agree a bit	Count	39	35	74
		% within Subject	28.5%	30.2%	29.2%
	Not Sure	Count	52	39	91
		% within Subject	38.0%	33.6%	36.0%
	Disagree a bit	Count	14	15	29
		% within Subject	10.2%	12.9%	11.5%
	Definitely Disagree	Count	7	4	11
		% within Subject	5.1%	3.4%	4.3%
Total		Count	137	116	253
		% within Subject	100.0%	100.0%	100.0%

Appendix C: A4 and A5 Lesson Plans

Students Working Collaboratively

Science Toolkit

Activity 4

Heart Rate Investigation

Learning Outcomes:

<u>Content Knowledge:</u>

- Students will understand the effect of exercise on heart rate.
- Students will recall that the average pulse for an adult at rest is 70 b.p.m. Students will understand why exercise affects heart rate.

<u>Process:</u>

- Students will learn how to do a fair test.
- Students will become familiar with using a heart rate sensor.
- Students will associate increase in heart rate with the graph going up.

<u>Skills:</u>

- Information processing- recording, presenting information.
- Critical and creative thinking – examining evidence and reaching conclusions.
- Communicating
- Working with others

Questions during Activity (optional):

<u>Questions to drive student learning (directing them to the learning outcomes):</u>

- How does exercise affect heart rate?
- How does rest affect heart rate?
- Is your pulse the same as your heart rate? What is an adult's average pulse rate at rest?

<u>Questions to probe understanding:</u>

- Why does your heart beat faster when you exercise?
- Is exercise the only thing that affects heart rate?
- Questions to get students thinking about their own learning (metacognition):
- What did you learn about heart rate?

<u>Initial questions leading to the questions students will work on during the activity:</u>

- What does your heart do?
- Why does your heart beat?
- What does blood bring to all the parts of your body? Why do all parts of our body need oxygen?
- Why do all parts of our bodies need food?
- Does your heart rate stay the same all the time?
- Does exercise affect your heart rate?

Introduction:
This lesson unit is structured in the following way:

Class 1:

- Students will be divided into groups and the teacher will explain the rules of group work.
- Students will work in groups deciding how to measure their heart rate, recording their ideas on *Educreations* or *Explain Everything*.
- Teacher will analyse student responses to this task and use it to plan for class 2.

Class 2:

- A whole class discussion will allow for students to re-examine and modify (if needed) their original heart rate activity.
- Students will carry out their designed experiment working as a group.
- Students will answer the second question worksheet as a group again recording their ideas on *Educreations* or *Explain Everything*.
- Teacher will analyse student responses to the task.

Materials Required:

- iPads/Surfaces
- Heart Rate monitors
- *Educreations* app for iPad
- *Explain Everything* app for Surface
- Worksheets 1 and 2 (you may adapt these to suit your class or another lesson)

Time needed:

Two forty minute classes. It is important that you do this activity in two separate classes so you have time to analyse the student responses to the first task and plan accordingly for the next lesson.

Before the Lesson:

- Ensure that you have the apps required for this activity installed on the tablets well in advance to avoid technical difficulties in class.
- Familiarise yourself with the technology before introducing it to the class.
- Print out worksheets 1 and 2.

Class 1 outline:

- Begin the class by discussing the importance of group work with your class.
- Explain to the students how successful group activities work and how to assign group roles.

- Allow students time to come up with rules for group work and to decide on group roles. Divide students into groups.
- Give students an iPad/surface per group and get them to answer worksheet 1 on the *Educreations*/*Explain Everything* app.
- Get students to save their work.
- Either get students to upload their work to *Schoology* or email them to the teacher so that you can analyse them and give them feedback in the next class.
- (If there is no Internet in the school analyse the worksheets from the iPads/Surfaces directly.)

Class 2 outline:

- A whole class discussion or brainstorm at the beginning of class will allow for students to recap on the previous lesson.
- Teacher will use this discussion to give some feedback to students on their previous work on this task.
- Students will be put back into their original groups and try to modify or change their original method.
- Students will carry out their heart rate activities in groups recording their results as they work.

You should let the students use the heart rate monitors provided by FaSMEd for this activity where possible.

- Give the students worksheet 2 to do on their iPad/Surface.
- Get students to save their work.
- Either get students to upload their work to *Schoology* or email them to the teacher so that you can analyse them and give them feedback in the next class.
- (If there is no Internet in the school analyse the worksheets from the iPads/Surfaces directly.)

After the lesson:

You should analyse responses to worksheet 2. If there are still misconceptions or difficulties with this topic they should be addressed by the teacher in the next class. You should upload your comments or any picture from the activity to the FaSMEd *Schoology* page.

Sample procedure for using the heart rate monitor:

1. Attach heart rate monitor to computer using a GO!Link.
2. Start logger pro on computer.
3. Either set length of data collection for 100 s or get students to stop data collection at 100 s – depending on their level of comfort using the equipment.
4. At rest: student standing. Hold handgrips following palm and finger positions. Start data collection. Stop collection at 100 s. Store run.

5. Walking on the spot. Start data collection as student starts to walk on the spot. Stop collection at 100 s. Store run.
6. Running on the spot. Start data collection as student starts to run on the spot. Stop collection at 100 s. Store run.
7. Show all runs to see the three results together.
8. Save graph for effect of exercise on heart rate of a particular student.

Precautions/tips:

- The maximum distance the handgrips can be from the receiver is 80 cm.
- Mobile phones and wireless laptops can interfere with the signal.
- The receivers can pick up a signal from other handgrips so groups should be at least 2 m apart.
- For some people there will be a delay of about 15 s before the heart rate start data starts to be collected (particularly if hands are cold).

Worksheet 1: Heart Rate Investigation

1. Do you think exercise changes your heart rate?
2. Can you give a reason why?
3. If you were designing an experiment to test this, what equipment would you need?
4. How would you carry out your experiment?
5. How would you make your experiment fair?
6. What conclusions would you expect from carrying out this experiment?

Worksheet 2: Heart Rate Investigation

1. Did everyone in the group participate in the experiment?
2. What can you conclude from doing this experiment?
3. Were your results as you expected?
4. If you were to do this experiment again what would you do differently?
5. What was your favourite part of this FaSMEd activity?

Students as Assessors

Science and Maths Toolkit

Activity 5

Graphic Organisers

Learning Outcomes:

Process:

- Students will develop self and peer assessment skills
- Students will develop skills in how to critically analyse the quality of work

Skills:

- Information processing- recording, presenting information.
- Communicating
- Working with others

Questions during Activity (optional):

- What did you think about this piece of work?
- What did you think of the methods they chose?
- Which method did you like best? Why was this?
- Did you find any mistakes in their work?
- Do you agree with their conclusions?
- What advice would you give to the student to improve their work

Introduction:
This lesson unit is structured in the following way:

Class 1:

- Students will be divided into groups and the teacher will explain the rules of group work.
- Students will work in groups creating a graphic organiser either on their iPad or Surface or by hand
- Students will self assess their role in group work using the template provided
- Teacher will analyse student responses to this task and use it to plan for class 2.

Class 2:

- Students will be divided into their groups once more
- Students will peer assess graphic organisers
- Teacher will analyse student responses to the task.
- Students will once again self assess their role in group work

Materials Required:

- iPads/Surfaces (optional)
- Graphic Organisers (hardcopy or PowerPoint)

Time needed:

Two forty minute classes. It may not take up the whole two classes however it is important that it is spaced out and students have time to reflect on the first class before attempting the second activity.

Before the Lesson:

- Ensure that you have the apps required for this activity installed on the tablets well in advance to avoid technical difficulties in class (optional).
- Familiarise yourself with the technology before introducing it to the class.
- Print handouts.
- Organise groups so that there is a range of abilities in each group.
- Decide on what topics you want the students to revise.

Class 1 outline:

- Begin the class by explaining to the students that this is a FaSMEd class and they are going to be working as assessors for the next 2 classes.
- Explain to students how graphic organisers work and show examples.
- Explain your criteria for success
- Give students time to ask questions regarding the activity.
- Organise the students into groups and assign a revision topic to each group.
- Students will work on completing their graphic organisers in their groups.
- Teacher will aid this process by asking probing questions while the students are working.
- Student will submit the graphic organisers to the teacher.
- Students' will self assess how they worked during the activity. Students do not have to give this up to the teacher.
- Teacher will reflect on this class and plan for the next class using the work the students submitted.

Class 2 outline:

- Begin the class informing students that this is the second class in the students as assessors task.

Ask students to reflect on what they wrote on their self-assessment handouts and tell them to try to improve on this.

- Teacher will hand out graphic organisers for the other science/maths class or from different groups in the class. It is important to keep the graphic organisers anonymous for the sake of this task.
- Students will work on peer assessing this piece of work.

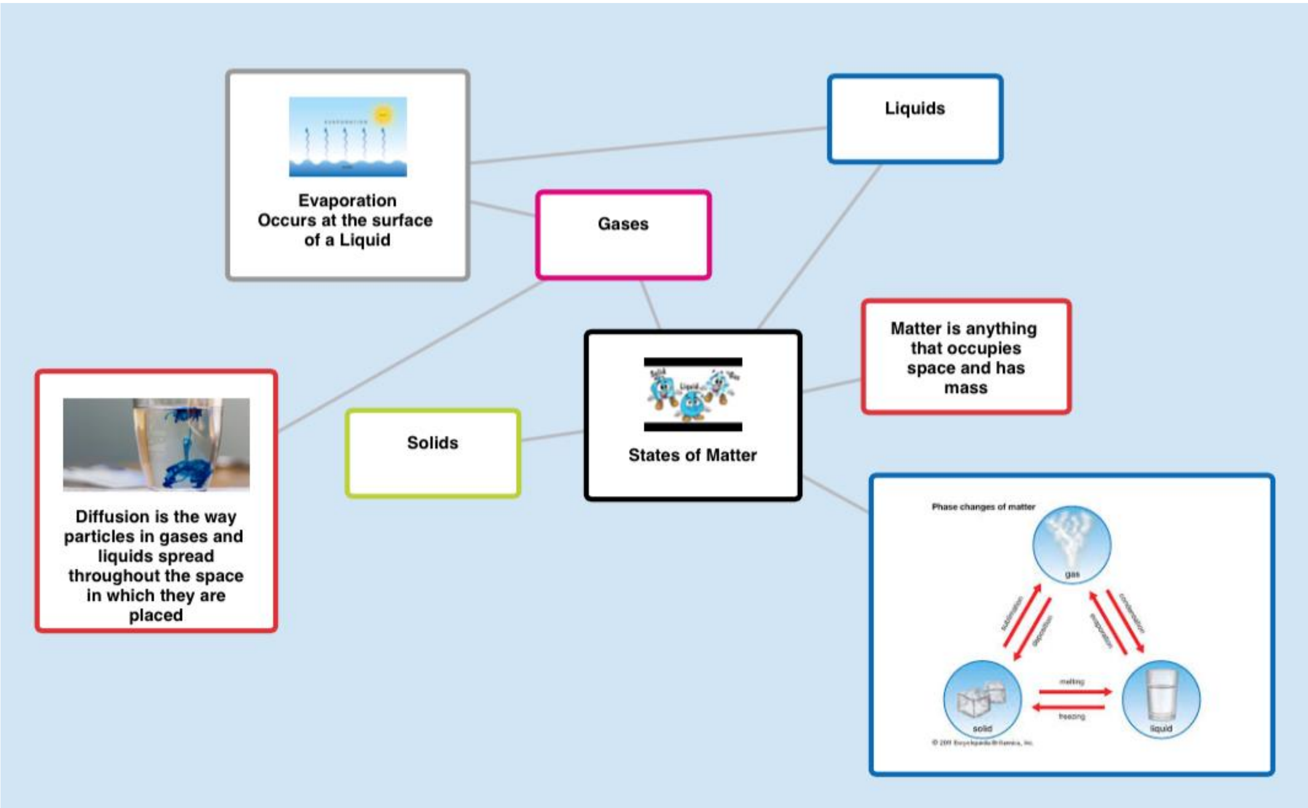
It is important as the teacher here to get the students to critically analyse the work, the questions at the beginning of this lesson plan should help you and the students to carry out peer-assessment effectively.

- Teacher will aid this process by asking probing questions while the students are working.
- A whole group discussion will allow for reflection on the activity.
- Teacher will hand out the self-assessment handouts to the students once more.
- The teacher will collect this set of self-assessment handouts.

After the lesson:

The teacher should analyse the responses to the second self-assessment handouts and make note of what worked well and what did not work well in the FaSMEd classes.

Sample Graphic Organiser:



Student Self-Assessment and Reflections

Give a brief description of the activity you have completed.	What did you like about this activity? What were you able to do well?
What did you not like about this activity? What problems did you have? Why?	What did you learn about yourself? Strengths, interests, preferences, and needs.

Adapted from the Indiana Secondary Transition Resource Center

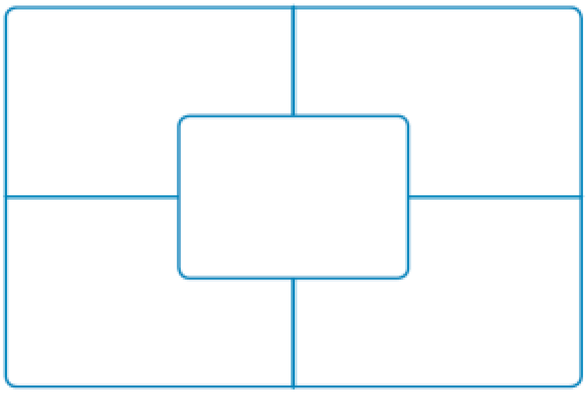
Further Activities:

In order for students to benefit fully from their role as assessors it is important for them to try a variety of different self and peer assessment activities. Some suggestions are listed and described below:

1. Mark your own work using only textbooks and exercise books.
2. Choose the best answer.
3. Self marking and target setting
4. Summarising and reflecting
5. Students generating questions for an examination or homework
6. Traffic lighting
7. Dealing with misconceptions
8. Students developing marking schemes

1. Mark your own using only textbooks and exercise books.
This is a generic strategy that can be used for peer assessment of exercises and tests. Students are put in threes and asked to mark each other's work but are not given the answers. They use their textbooks and exercise books to justify and agree answers. Teacher can circulate and help clarify disagreements. The teacher can go through just the questions that the class found most difficult or did not answer well.

2. Choose the best answer.
Another generic strategy for peer assessment. Very useful when students have been asked to explain observations or make hypothesis. Students are placed in groups and each individual explains their answer to a given question. The group selects the best answer/explanation/hypothesis and appoints a spokesperson to put the group's ideas forward to the whole class. The remaining questions are worked through in the same way. A placemat could be used for this exercise.



Sample Placemat

Examples of questions:

- Explain what happens to the particles in water when water freezes.
- Explain what happens to the volume of an object when the object's shape changes.

3. Self marking and target setting
Useful for homework. Pupils simply mark each other's work feeding back what their partner has done well together with a "mini target" for improving their work.

Examples:

- In elements mixtures and compounds students are asked to explain the differences between elements, mixtures and compounds by drawing particle representations and give examples of elements, mixtures and compounds. Depending on the outcome students could check each other's understanding of the characteristics of elements, mixtures and compounds. A mini target for the next lesson could be to describe why compounds behave differently from the elements from which they are made.
- In calculating area and volume students are asked to choose and apply a formula, manipulate that formula and give the correct answer including units. A mini target for the next lesson could be to work on including the units in all final answers.

4. Summarising and reflecting
At the end of a topic students are asked to write a list of the new things they have learned in the topic. They compare their list with others in their group and identify the bits they may find difficulty in remembering. As a group the students work together to help each person in the group remember one thing they have identified.

5. Students generating questions
This can take different forms.

Near the end of the lesson students are asked what they still do not understand or are still unclear about. The teacher collates these and the class choose the best questions that are then used for homework.

Students generate questions AND answers. The questions are given to other students and then marked by the students who generated the original questions. In this example everyone generates questions and answers and answers the questions of others.

Example:
When teaching science/maths students are asked to make up questions and provide model answers for other students to check their calculation answers. This could be

further differentiated by the nature of the question – easy or hard. Over time the challenge box could be built up and used for revision across the year group. The challenge box could be set up across the groups in a particular year, where one group provides the "challenge" for the others.

6. Traffic Lighting
A superb self-assessment tool; Traffic lighting can be used in a variety of ways:

Pairing pupils whose understanding is green and amber. The greens help the ambers to clarify their understanding whilst the teachers work with the reds.

Traffic Lighting can be used during the lesson. Whilst students are working they routinely place the traffic cards on their desk. The teacher who is circulating can then use the traffic lights to get an overview of the understanding of the class and to prioritise which students to help first, or students who show "green understanding" could be asked to explain the concepts to those who's understanding is red!"

Topic checklists are completed at the start of a topic and the information used by the teacher to re-order the planned learning (ambers first, reds later) and to check the amount of time the teacher had planned to spend on each learning outcome. Instead of traffic lights numbers could be used.

At the end of the topic students re-traffic light or re-number their understanding of the learning outcomes and list what they need to do. Teacher can collect these in and they can make the basis of a revision lesson – just going through the learning outcomes the students are still not clear about.

7. Dealing with misconceptions

Students are given a set of explanations and/or definitions that contain classic errors or misconceptions. They work in groups of four. Each group is allocated some of the misconceptions.
The groups of four split into pairs – each pair identify and correct the mistakes in the misconceptions.
They then compare what they have with the other pair and reach an agreed position. They then feed back to the rest of the class stating what the error/misconception was and how they correct it.

8. Students developing marking schemes

Students are given a sample answer and asked to develop a marking scheme for the answer. This helps them to recognise different levels of knowledge from easy to more difficult.