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University of Dublin

Trinity College

**Developing Mathematics Teachers' Pedagogical Content
Knowledge through Lesson Study:**

A Multiple Case Study at a Time of Curriculum Change

Book of Appendices

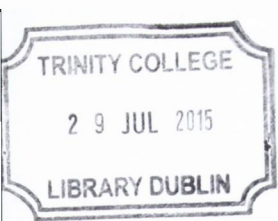
A thesis written in fulfilment of the requirements for the degree of

Doctor in Philosophy (Ph.D.)

2015

Aoibhinn Ní Shúilleabháin

Supervisor: Dr Aidan Seery



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APPENDIX A

A1 Initial Letter/Proposal to Schools

A2 Initial Presentation to Teachers

A3 Letter/Proposal to Mathematics Department

A4 Information Letter to Principals

A5 Information Note for Participating Teachers

A6 Teacher Consent Form

APPENDIX A1 – Initial Letter/Proposal to Schools



TRINITY COLLEGE DUBLIN
COLÁISTE NA TRÍONÓIDE, BAILE ÁTHA CLIATH

THE
UNIVERSITY
OF DUBLIN

Dear Principal,

I would like to invite your school to participate in an innovative and unique pilot study being carried out as part of a PhD Thesis on Mathematics Education through the School of Education in Trinity College Dublin under the supervision of Dr. Aidan Seery.

The research aims to develop a model of professional development for post-primary mathematics teachers through a task based community of practice. The project will support mathematics teachers in implementing the Project Maths curriculum content and teaching methodologies through continuous, collaborative work within the mathematics department, while also identifying the implications on student learning and classroom practice.

The pilot study will be held from September 2012 until April 2013 and will involve a maximum of six meetings lasting one to one and a half hours (or 2 classes) with the participating teachers throughout the year and a maximum of four demonstration lessons. It would be hoped that four mathematics teachers from your school would participate in the pilot study. The NCCA are kindly supporting this study and substitution for classes and meetings related to this research will be provided to the school up to a sum of €2000. It is hoped that the mathematics teachers in your school will benefit from the collegiate collaboration in curriculum content and teaching methodology while also accessing additional resources.

The data will be analysed for the purposes of my own research and confidentiality and anonymity can be ensured throughout the process. Prior consent to participation will be sought from all participants and the right to withdraw at any point will be guaranteed.

It would be very much appreciated if you could circulate this invitation to the mathematics teachers within your school. I would be delighted if these teachers would be interested in participating in the study. I will follow up contact with you by phone, or feel free to contact me at the email address below. I would propose to meet with participating teachers in May 2012 to discuss the project and answer any questions they may have.

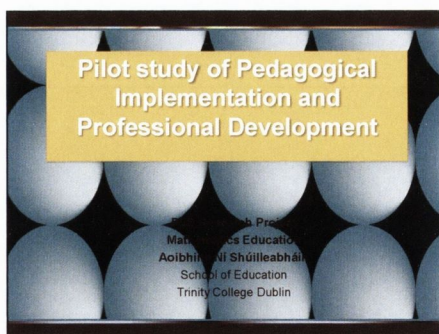
Kind regards,

Aoibhinn Ní Shúilleabháin

Email: [REDACTED]

Phone: [REDACTED]

APPENDIX A2 - Initial Presentation to Teachers



Why research Professional Development of Mathematics teachers?

- An abundance of international research on classroom practice and teacher-student interactions.
- TALIS report 2009 shows Ireland below average international norms of collaboration with colleagues, in-school professional development, peer observation & feedback.
- Academic research showing positive results of collegiate collaboration in mathematics departments in other countries.
- It is one area I felt was neglected & needed while I was teaching.

My own background...

- Teaching mathematics, physics, science & applied mathematics in St. Mark's Community School, Tallaght since 2007
- Project Maths Pilot School & PMISG
- Project Maths Facilitator in Strands 1, 2, & 3 since 2009
- Commenced PhD in September 2011 and coordinating Mathematics Pedagogy on PDE course
- Post-graduate Diploma in Education, TOD
- BSc, Theoretical Physics from UCD

What does this research propose to do?

To investigate how a model of a **task-based community of practice** may provide a **structure** for mathematics teachers as a mode of **professional development**.

Equally to investigate how this model impacts **student engagement** in the mathematics classroom.

PhD Study - Aislinn O'Sullivan

What is this research about?

A model of professional development of post-primary mathematics teachers in Ireland.

Research Questions

1. How effective an approach is a task-based community of practice in enhancing and developing teachers' professional and pedagogical practices?
2. How is shared meaning constructed within a task-based community of practice?
3. How does a task-based COP nurture the teaching and learning practices envisaged by the Project Maths curriculum?

PhD Study - Aislinn O'Sullivan

Why a Community of Practice?

- Many other countries have educational structures where collegiate collaboration is supported.
- A community of practice has been shown to provide positive peer support and feedback to teachers.
- **Content knowledge and pedagogical content knowledge** of participants have improved in other countries where communities of practice are the **NORM** (Shulman 1986)



PhD Study - A. N. Shulman

My Research Will Focus On...

- The evolution and development of the community of practice
- Providing analysis on certain themes recurrent in the practices of the community
- Identifying the structures for a sustainable COP to develop
- Highlighting the advantages/disadvantages of the study

PhD Study - A. N. Shulman

Why a Community of Practice?

- Similar to:
 - Communities of Learning
 - Communities of Inquiry
 - Teacher Design Teams (Handelzalts 2007)
 - Teacher Learning Communities (McLaughlin 2005)



PhD Study - A. N. Shulman

What I hope to emerge from the research...

- An identification of the key structures beneficial to mathematics teachers in their professional development
- Identify the benefits to classroom practice of this model of professional development
- Make recommendations on the future structures of professional development of mathematics teachers

PhD Study - A. N. Shulman

Why a "task based" Community?

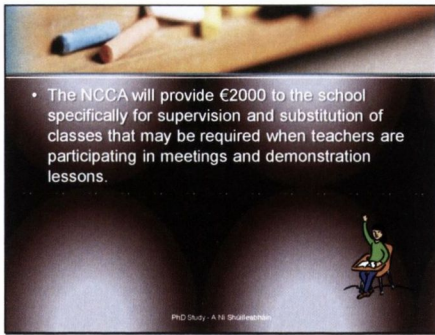
- Research literature has shown a community to be successful and sustainable when there is a specific objective.
- This task may be devising a particular lesson for a class which will then be taught by one teacher (participating teachers will decide on the specifics)
- Other members of the community will observe student engagement in the lesson (not assessing the teacher's practice)
- This practice is generally referred to as **Lesson Study**

PhD Study - A. N. Shulman

Details of the Study

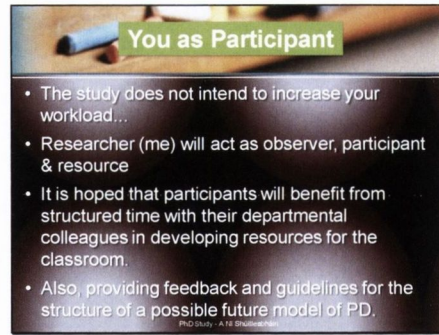
- There will be 4 members of the community from your Mathematics Department
- Between 4 and 6 meetings during the year lasting between 1 hour and 1.5 hours.
- A total of 2 or 3 demonstration lessons that will be taught and/or observed by the teachers in your community.
- The meetings will be held at a time convenient to the teachers.

PhD Study - A. N. Shulman



- The NCCA will provide €2000 to the school specifically for supervision and substitution of classes that may be required when teachers are participating in meetings and demonstration lessons.

PHD Study - A. H. Shalashin



You as Participant

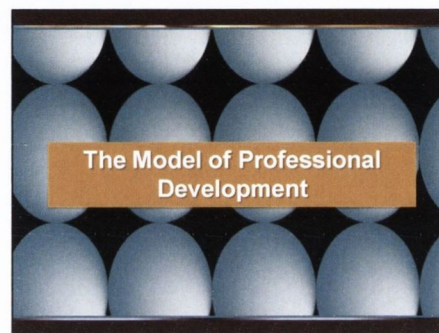
- The study does not intend to increase your workload...
- Researcher (me) will act as observer, participant & resource
- It is hoped that participants will benefit from structured time with their departmental colleagues in developing resources for the classroom.
- Also, providing feedback and guidelines for the structure of a possible future model of PD.

PHD Study - A. H. Shalashin



What would be your role as participant?

PHD Study - A. H. Shalashin



The Model of Professional Development

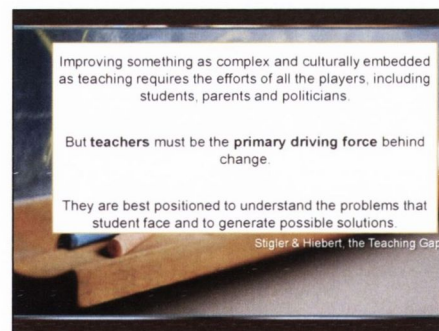
PHD Study - A. H. Shalashin



Your Role

- You are the most **important** part of this research.
- Your participation in the community, your conversations, opinions and feedback are key to the study.
- Without you, there is no research!

PHD Study - A. H. Shalashin



Improving something as complex and culturally embedded as teaching requires the efforts of all the players, including students, parents and politicians.

But **teachers** must be the **primary driving force** behind change.

They are best positioned to understand the problems that student face and to generate possible solutions.

Stigler & Hiebert, *The Teaching Gap*

Effective Professional Learning

- Is intensive, ongoing, and connected to practice
- Focuses on student learning and addresses the teaching of specific curriculum content
- Aligns with school improvement priorities and goals
- Builds strong working relationships among teachers

Darling-Hammond, Wei, Andree, Richardson, and Orphanos (2009)

PHD Study - A.N. Shults

Professional Development through a Community of Practice

Traditional In-Service	Lesson Study & Research Lessons
• Begins with answer	• Begins with question
• Driven by expert	• Driven by participants
• Communication: trainer → teachers	• Communication among teachers
• Relationships hierarchical	• Relationship reciprocal
• Research informs practice	• Teachers conducting research into their own practice

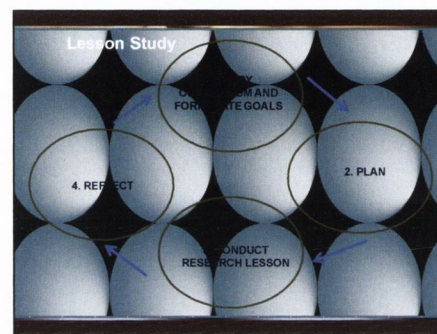
PHD Study - A.N. Shults

Community of Practice

Key Features

- Discuss the values, meaning and objectives of the community
- Joint enterprise in developing resources relevant to your staff and your school
- Collegiate collaboration of professional peers
- Shared repertoire of resources in improving student engagement in mathematics lessons
- Implementing a classroom community of learning as relevant to the Project Maths curriculum

PHD Study - A.N. Shults



Task-Based Community of Practice

- Based on Japanese Tradition of Lesson Study
- Common professional practice in Japan, also being adopted in the USA.
- Similar to professional practices in many other countries such as Finland, Belgium, Hungary etc.

PHD Study - A.N. Shults

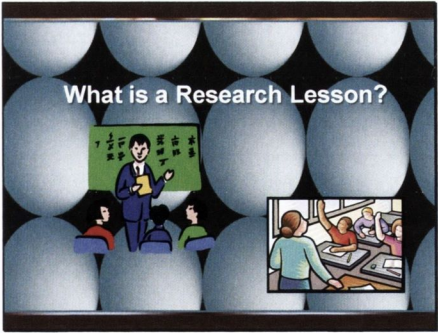
Lesson study differs from...

- Lesson planning
- Curriculum writing
- Coaching/mentoring
- Demonstration lessons
- Basic research

It is about developing a community of practice where:

- Participants develop a **shared repertoire**
- Participants **reflect** on their practice
- Participants improve their **pedagogical and content knowledge** through collaboration with their professional peers.

PHD Study - A.N. Shults



Lesson Study Provides Opportunities to...

1. Access and explore the curriculum objectives in detail.
2. Reflect on long-term aims and goals for students
3. Carefully consider the goals for particular content area, unit and lesson
4. Study the best available research evidence
5. Plan lessons that carefully consider learning in and long-term goals for students
6. Develop pedagogical content knowledge or specific teaching skills
7. Build capacity for colleague learning
8. Develop a focus on student thinking and engagement
9. Implement the Project Maths curriculum in the environment intended by the syllabus

PD Study - A16 Shulmeister

Research Lesson

1. Classroom lesson taught by one teacher
2. Lesson observed by other members of the community who gathering data on student engagement
3. Planned collaboratively
4. Brings to life a goal or vision of education
5. Recorded: video, audio, student work
6. Reflected on by participants in the community

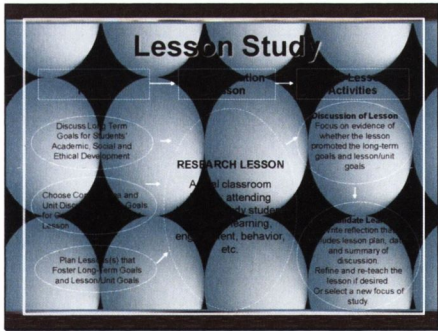


PD Study - A16 Shulmeister

Example of a Lesson Study question:



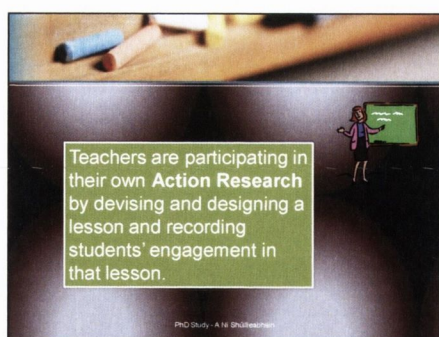
Can patterns help us find an easy way to answer the question: How many seats fit around a row of triangle tables, arranged as shown?



How might this question relate to syllabus?

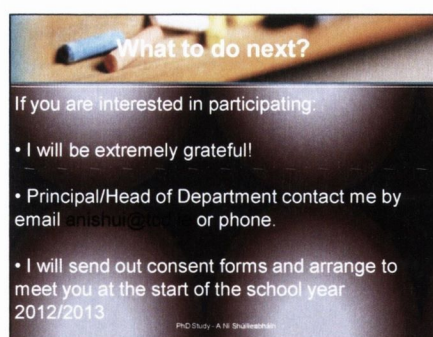


- 3.6 Synthesis and problem-solving skills
- 4.1 Generating arithmetic expressions from repeating patterns
- 4.2 Representing situations with tables, diagrams and graphs
- 4.3 Finding formulae
- 4.4 Examining algebraic relationships



Teachers are participating in their own **Action Research** by devising and designing a lesson and recording students' engagement in that lesson.

PHD Study - A Ní Shúilleabháin

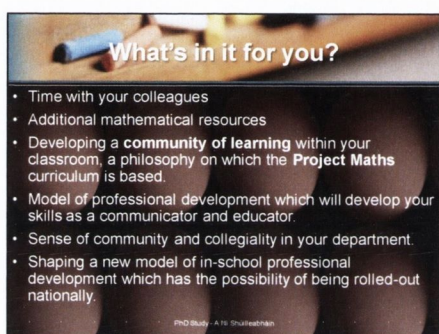


What to do next?

If you are interested in participating:

- I will be extremely grateful!
- Principal/Head of Department contact me by email anishu@tcd.ie or phone.
- I will send out consent forms and arrange to meet you at the start of the school year 2012/2013

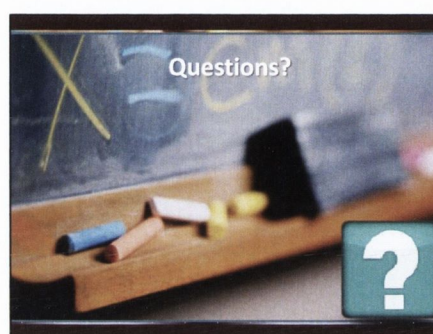
PHD Study - A Ní Shúilleabháin



What's in it for you?

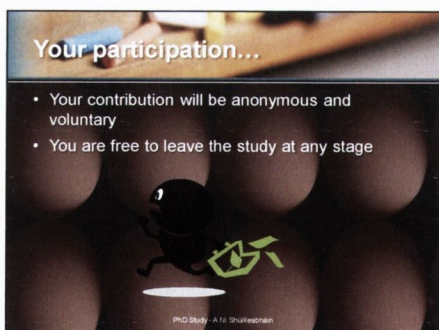
- Time with your colleagues
- Additional mathematical resources
- Developing a **community of learning** within your classroom, a philosophy on which the **Project Maths** curriculum is based.
- Model of professional development which will develop your skills as a communicator and educator.
- Sense of community and collegiality in your department.
- Shaping a new model of in-school professional development which has the possibility of being rolled-out nationally.

PHD Study - A Ní Shúilleabháin



Questions?

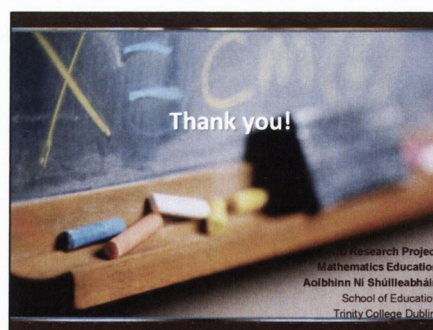
PHD Study - A Ní Shúilleabháin



Your participation...

- Your contribution will be anonymous and voluntary
- You are free to leave the study at any stage

PHD Study - A Ní Shúilleabháin



Thank you!

Research Project
Mathematics Education
Aolbhinn Ní Shúilleabháin
School of Education
Trinity College Dublin

APPENDIX A3 – Letter/Proposal to Mathematics Departments



TRINITY COLLEGE DUBLIN
COLÁISTE NA TRÍONÓIDE, BAILE ÁTHA CLIATH

THE
UNIVERSITY
OF DUBLIN

To the Mathematics Department,

I would like to invite you to participate in a study being carried out as part of a PhD Thesis on Mathematics Education through the School of Education in Trinity College Dublin.

As a mathematics teacher, my research aims to develop a model of professional development for post-primary mathematics teachers through a task based community of practice. The project will support mathematics teachers in implementing the Project Maths curriculum content and teaching methodologies through continuous, collaborative work within the mathematics department, while also identifying the implications on student learning and classroom practice. The researcher will also participate in the project as resource support for the mathematics department.

The pilot study will be held from September 2012 until April 2013 and will involve a maximum of six 1-1.5 hour meetings with the participating teachers throughout the year and a maximum of 3 demonstration lessons. It would be hoped that 4 mathematics teachers from your school would participate in the pilot study.

Substitution for classes and meetings related to the study will be funded up to €2000 by the NCCA.

Teachers should benefit from the collegiate collaboration in curriculum content and teaching methodology while also accessing additional resources with assistance from the researcher.

The data will be analysed for the purposes of my own research and confidentiality and anonymity can be ensured throughout the process. Prior consent will be sought from all participants and the findings created from this project will be used as part of my PhD thesis and for publication in educational journals and conference proceedings.

It would be very much appreciated if you could discuss this invitation with other mathematics teachers in your department and would be delighted if you would be interested in participating in the study. Please feel free to contact me by phone or at the email address below. I would propose to meet with participating teachers in May 2012 to discuss the project and answer any questions they may have.

Kind regards,

Aoibhinn Ní Shúilleabháin

Email: [REDACTED]

Phone: [REDACTED]

APPENDIX A4 – Information Letter to Principals



TRINITY COLLEGE DUBLIN
COLÁISTE NA TRÍONÓIDE, BAILE ÁTHA CLIATH

THE
UNIVERSITY
OF DUBLIN

Dear Principal,

Thank you sincerely for allowing me the opportunity to work with your Mathematics Department in the coming academic year 2012/2013 as part of my PhD studies in Mathematics Education.

I have been in contact with ... in the Mathematics Department and will hope to begin the programme with the teachers in September 2012. I hope to conduct meetings and interviews at times convenient to the teachers in order to minimise any disruption to the school day. However, as mentioned in my previous communication, there is likely to be some disruption to classroom time. In relation to this matter, the NCCA have generously offered to cover the supervision of these classes up to the amount of €2000.00. Bill Lynch of the NCCA will be in contact with you in September with the first instalment of this funding.

I am sincerely grateful for the opportunity to conduct this research in your school and hope that participating in the study will be of benefit to both teachers and students.

If you have any questions in relation to the research please do not hesitate to contact me.

Mise le meas,

Aoibhinn Ní Shúilleabháin

Tel: [REDACTED]

Email: [REDACTED]

APPENDIX A5 - Information Note for Participating Teachers

Post-Primary Mathematics Teachers participating in Lesson Study

Participation Information Form

This research aims to identify the features of a task-based community of practice within an Irish post-primary Mathematics Department. The research should also identify the key practices of the community of mathematics teachers in nurturing and implementing the teaching and learning practices envisioned by the Project Maths curriculum.

Members of the research will be expected to attend and participate in research meetings of the Mathematics Department. Members will also be expected to participate in Research Lessons involving teaching and observing specially planned lessons. The researcher also hopes to interview each member of the research twice, at the beginning and end of the research period.

It is expected that 8 meetings of the community of practice will be held during the academic year 2012-2013 with a total of 2 interviews per member and approximately 3 research lessons. Each meeting is expected to last between 1 and 1.5 hours. Interviews should last no longer than 30 minutes and research lessons will be held in the usual class duration.

All information provided by the members of the research will be treated with the utmost confidentiality and security. All data generated during the research will be accessed by the researcher and supervisor and participant information will only be accessed by the researcher and supervisor. Participants will not be identifiable in any published material. Primary data will be stored for a period of 18 months following publication of the thesis. Thereafter, it will be destroyed.

Participation in this research is entirely voluntary and participants are at liberty to withdraw at any time without prejudice or negative consequences.

This information sheet is a constitutive part of the consent form.

Should any members of the research wish to enquire further on any detail they may contact:

Researcher: Aoibhinn Ní Shúilleabháin

Tel: [REDACTED]

Email: [REDACTED]

Address: [REDACTED]

APPENDIX A6 - Teacher Consent Form

Participation Consent Form

Title of project:

Post-primary mathematics teachers as a task-based school community of practice

Statement:	Yes	No
I have been informed of and understand the purposes of this study		
I have been given an opportunity to ask questions		
I understand I can withdraw at any time without prejudice		
Any information which might potentially identify me will not be used in published material		
I agree to participate in this research		
I agree that data generated from this study may be used by the researcher only for a period of 5 years after the publication of the PhD thesis.		

Name: _____

Signature: _____

Date: _____

APPENDIX B

B1 Research Context as a Funding Proposal for NCCA

B2 Proposal of Costs (NCCA)

APPENDIX B1 – Research Context as a Funding Proposal for NCCA

Project Maths: A pilot study of pedagogical implementation and professional development

Post-Primary Mathematics Teachers as a Task-Based School

Community of Practice

Executive Summary of Proposal

Rationale

With the introduction of a new Project Maths curriculum to all post-primary schools in Ireland, and with the final Strand 5 to be introduced in September 2012, it is a relevant and important time to conduct research into the practices of mathematics teaching, the modes of professional development of mathematics teachers, and the implementation and introduction of mathematical skills and concepts within the classroom.

Proposed Research

This proposed pilot study aims to employ a new theoretical framework, extending certain ideas of the extant literature, for a task-based professional community of practice to engage in developing the Project Maths classroom focused on establishing a communicative classroom community where all students are engaged in their mathematical learning. This proposed model will be loosely based on the Japanese model of Lesson Study (Inoue, 2010; Peng, 2007) where mathematics teachers in a school department collaborate in planning a particular topic of mathematics. This method is seen as an important practice in establishing a constructive, collaborative teaching practice which encourages teachers to view a lesson from a student-engagement perspective. The majority of data generated in this study will be qualitative and will be recorded through the observations of teachers' meetings as a task-based community of practice, of teachers conducting and observing Action Research in their classroom and of teachers' practices in their classrooms.

Impact

- It is hoped that this investigation might become a model for further descriptive, and perhaps evaluative, curriculum research in Ireland.
- It is hoped that this investigation might become a model for future continuous professional development of mathematics teachers in discussing, collaborating and implementing a mathematics curriculum, in particular the Project Maths curriculum.
- It is hoped this model of in-school professional development will have a positive impact on classroom practice and on the engagement, interest and assessment of students in their mathematical learning.

APPENDIX B2 – Proposal of Costs (NCCA)

Project Maths: A pilot study of pedagogical implementation and professional development

Post-Primary Mathematics Teachers as a Task-Based School

Community of Practice

Proposed Maximum Costs for Substitution/Supervision

- The hourly rate payable to teachers for supervision in the 2010/2011 school year is €47.82 with effect from 1st September 2010.
- The hourly rate payable to personnel employed solely for the purpose of supervision in the 2010/2011 school year is €21.31 with effect from the 1st September 2010.

[Circular Letter Pay 0016/2011, DES]

- In total it is envisaged that a maximum of **64 supervision classes** be required for the duration of the data generation from September 2012 to April 2013.

$$€47.82 * 64 = €3060.48$$

Or

$$€21.31 * 64 = €1363.84$$

- It may be at the discretion of the principal which personnel be employed for the purpose of supervision and hence costs will not be able to be concretely established at this point without consultation with the schools involved in the pilot study.

APPENDIX C

C1 Lesson Study Teacher Booklet

Lesson Study in a Community of Practice

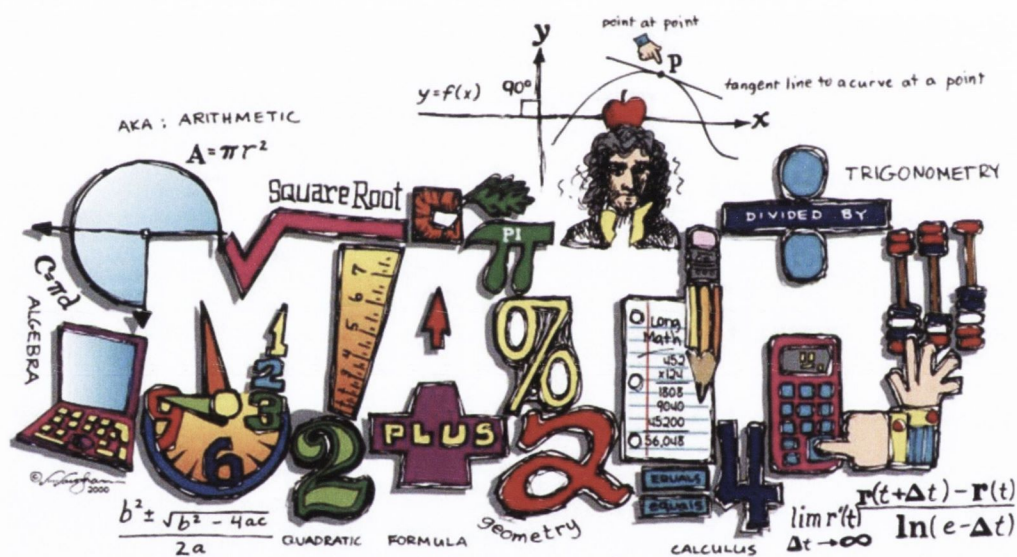


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This booklet hopes to introduce teachers to the practice of Lesson Study and should provide a template for the proceedings of the community of teachers as they participate in this research during the academic year 2012/2013.

What is Lesson Study?

Lesson study is a system of planning and delivering teaching and learning that is designed to challenge teachers, to share practices & ideas, to explore new teaching approaches, and to recognise the possibilities of independent growth of learners while fostering self-confidence in all.

Lesson study develops innovative ways of building on and improving teacher practices by sharing lesson ideas, sharing observations and reflecting on learning in the classroom. Evidence of good teaching practice is rarely explicitly witnessed by professional teachers. Lesson study provides opportunity for teachers to share and develop their personal expertise within a wider, collegiate framework through planning and observing structured lessons that have agreed lesson objectives. Lesson study also offers well-developed student activities and teacher-student interactions that are beneficial for the improvement of teaching and learning. It has been shown that through participating in lesson study, the focus of teaching transitions towards the mindset of student and allows for more creative and collaborative contributions to learning within the classroom. Teachers themselves have acknowledged an improvement in their mathematical content knowledge and pedagogical content knowledge through participating in Lesson Study.

It is important to note that Lesson Study is not about creating the best and most successful lesson plan (although it may be a very welcome outcome of the practice) but rather is about the professional and collegiate discussions evolving from engaging with a curriculum and creating ways for students to engage with a topic.



Figure 1 Image from Lewis & Hurd, 2011

Lesson Study as Action Research

Participating in Lesson Study invites teachers to establish a long-term objective or goal for their teaching and for their students during the academic year. In pursuing these objectives or goals, teachers become researchers in exploring innovative approaches to their classroom practice. While the goals and objectives for this research are established as a community, there is an opportunity for teachers to pursue their own individual Action Research within their classrooms. Performing Action Research as teachers researching in the classroom is seen as a beneficial and engaging form of professional development in education.

It is an opportunity for individual teachers participating in the study to further explore researching as an educator with a view to publishing or co-publishing their own findings or incorporating the project as part of their own academic study. It is open to any participant to discuss this with the researcher during the academic year.

In pursuing the objective of sharing and building on new approaches in classroom practice as a community, it is hoped that participating teachers will reap the benefits both as individual teachers and as a Mathematics Department.

History of Lesson Study

Lesson Study originated as a practice in Japan in the 1960s and is an embedded tradition within the educational community from 1st to 3rd level. Teachers within a school department, including those in pre-service training, participate in Lesson Study throughout the academic year. Teachers collaborate in carefully devising lesson plans with proposed student questions and student learning at the core of these lessons. The class is taught by one teacher while the rest of the group, and sometimes invited external educators, observe and take note of happenings and proceedings within the classroom. All members of the community then reflect on the lesson, the learning achieved, the objectives met etc. and discuss any changes that could be made in improving the lesson. There are many Japanese textbooks based on accumulated lesson plans devised through Lesson Study and many teacher reference books based on the activities and resources used in Lesson Study.

Mathematical inquiry in Japan usually follows a traditional problem solving approach with four key components:

1. *Hatsumon* (initial math question/problem that the teacher gives to initiate a rich conceptual discussion)
2. *Kikanjyushi* (students' individual or group-based problem solving as the teacher walks by their desks)
3. *Neriage* (whole class discussions) to compare and contrast different strategies and build consensus on the problem solving
4. *Matome* (summary)

This and other similar practices have been adopted in many other countries as a structured and innovative way for teachers to interact with a curriculum and to collaborate with one another.

Community of Practice

Participating in Lesson Study as a group of mathematics teachers establishes a community of practice in a Mathematics Department. Within this community of practice teachers determine objectives, develop resources and demonstrate activities as a group of teachers. Communities of practice are seen as important entities in establishing sustainable, collaborative and supportive working environments.

The following features of a community of practice within an educational environment have been established for the purposes of this research:



During the course of this research, it is hoped that these features will emerge through the participation of the community in the practice of Lesson Study.

The Research

The researcher's objective in this project is twofold:

1. To analyse and interpret significant moments of learning and transformation within the community of practice
2. To assess/judge Lesson study as a practice of a community of mathematics teachers and as a form of in-school continuous professional development in Ireland

In carrying out this research, the discussions, conversations and dialogue within the community of mathematics teachers will be the main focus for the researcher. While the researcher will be noting the interactions within the group, she hopes to also participate with and assist teachers in their community of practice meetings in providing classroom resources, curriculum materials etc. as they see fit.

It is well recognised that there are many positive practices present in Irish post-primary mathematics classrooms and it is hoped that this research will highlight and share these with the wider teaching and academic community. The research may also present the beneficial outcomes of affording in-school departmental hours towards teaching methodologies and pedagogy within a subject topic.

Research Questions

In this early stage of the research, it may be of interest to the participating teachers to be aware of the questions of focus for the purposes of this Ph.D. thesis. To date, they are as follows:

1. How do the features of a community of practice manifest through dialogue within a task-based community of practice?
2. How effective an approach is a task-based community of practice in developing and transforming teachers' professional and pedagogical practices in an Irish post-primary context? How are these transformations evident in community interactions?
3. How does a task-based community of practice establish and cultivate the teaching and learning practices envisaged by the Project Maths curriculum?

Participating Teachers' Roles in this Research

The participating teachers are the most important agents in this research. The generous offering of a teacher's time and their involvement in this project is greatly appreciated. As a researcher, I would like to offer my sincere thanks in allowing me to participate in and observe in the planning, teaching and reflecting on classroom practice within your mathematics department. It is a unique and valuable opportunity as an educational researcher to gain such privileged access and this is very much appreciated.

Participating teachers are free to opt out of the research at any stage during the year, but it is hoped that teachers will both enjoy and feel rewarded by the experience of participating for the full academic year. It is also hoped that your participation will be of benefit to you as an individual mathematics teacher and member of an innovative, engaging community of mathematics educators.

As part of your role in this research it is hoped that you will participate in the practice of Lesson Study by attending and engaging in the meetings of the Community of Practice and in the Research Lessons. Each meeting should last approximately 1 to 1.5 hours and will be held at a time agreed upon by the teachers.

It is also requested that you participate in an individual interview with the researcher at the beginning of the research and again at the end of the research. The content of these interviews will be based on the processes and practices involved in the research.

Time-Frame

It is hoped to commence the research and meetings of the Community of Practice in September 2012 and to conclude the research in April 2013. While the time-frame of the Lesson Study cycles will be agreed upon by the community, the researcher will suggest conducting two Research Lessons before the end of the first term and two Research Lessons before the end of the second term in 2012/2013. The schedule and details of the meetings and research lessons will be agreed upon by the teachers and researchers early in the academic year.

Lesson Study as a model of Professional Development

“Improving something as complex and culturally embedded as teaching requires the efforts of all the players, including students, parents and politicians. But teachers must be the primary driving force behind change. They are best positioned to understand the problems that student face and to generate possible solutions.” Stigler & Hiebert, The Teaching Gap

Lesson Study has been established as a practice of professional development in many countries. It aligns with many features of professional development, such as those outlined below:

- Is intensive, ongoing, and connected to practice
- Focuses on student learning and addresses the teaching of specific curriculum content
- Aligns with school improvement priorities and goals
- Builds strong working relationships among teachers

Lesson Study is a professional development strategy that is deceptively simple on the surface and remarkably complex once participants begin to probe beneath the surface. It is said to become as much a cultural as a professional development activity since it requires teachers to be comfortable sharing resources and ideas with one another and also be comfortable in observing each other teaching.

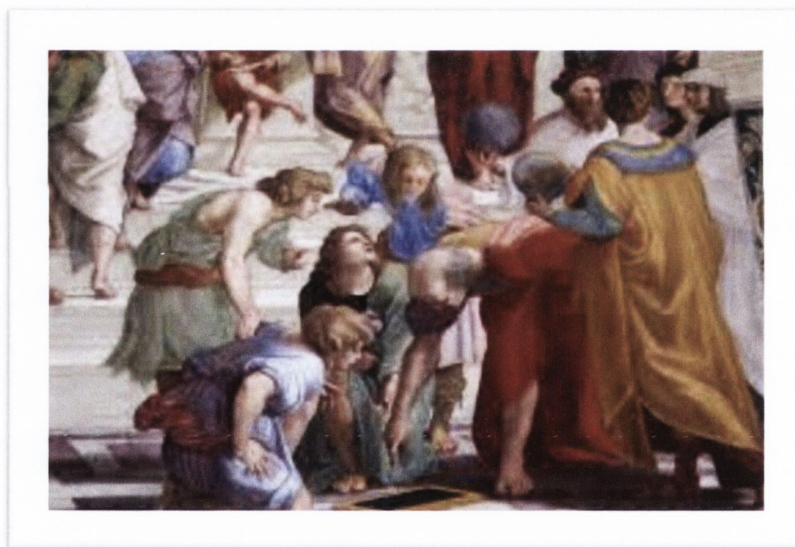
Teachers who have participated in Lesson Study have acknowledged positive changes in their classroom practice but have also indicated that both their mathematical content knowledge and pedagogical content knowledge have improved due to their participation.

Within the Irish context, it is hoped that Lesson Study will allow teachers to:

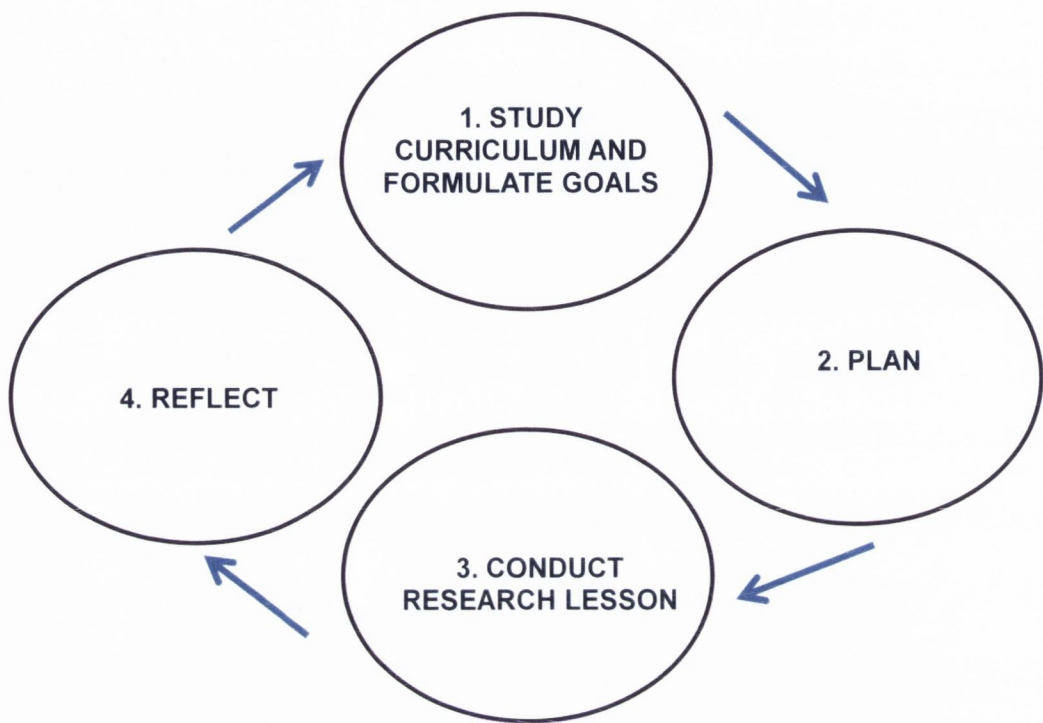
1. Access and explore curriculum objectives in detail.
2. Reflect on long-term aims and goals for their students
3. Carefully consider the goals of a particular strand, content area, unit and lesson
4. Study the best available international lessons and ideas
5. Plan lessons that identify and achieve short-term and long-term goals
6. Deepen subject matter and content knowledge
7. Develop pedagogical content knowledge or specific teaching skills
8. Build capacity for collegiate learning
9. Develop a focus on student thinking and engagement

10. Implement the Project Maths curriculum in an environment intended by the syllabus

Note: Developing processing skills while also developing innovative ways of problem solving are much desired within many international curricula and education systems. Mathematics is a powerful subject since it develops creative and critical thinking in general, and mathematical and logical thinking in certain situations. In the painting *Scholars of Athens* by the Renaissance painter Raphael, Euclid is showing constructions to his students. At the centre of the picture, a student is explaining his findings to his fellow classmates. It is this objective of students enjoying mathematical conversations among themselves that is a key to creating a community of learning within the mathematics classroom.



Model of Lesson Study



(Lewis, Perry, & Murata, 2006)

1. Study Curriculum and Formulate Goals

Initial Meeting

During the first meeting of the community of practice the following agenda is suggested:

- i. Choose roles for the initial meeting of the community of practice
- ii. Examine ideas about professional development and lesson study
- iii. Consider long-term goals and/or research theme
- iv. Build a timeline for the Lesson Study Cycle
- v. Review the curriculum and areas or topics which may be of interest
- vi. Review key decisions and/or insights made during the meeting
- vii. Agree upon assignments to be completed or followed up in the next meeting.

In considering long-term goals and/or research theme teachers may ask themselves:

- What is a gap between the ideal and the actual that you would really like to work on as an educator?
- Think about the students you serve. What qualities would you like these students to have 5-10 years from now?
- What qualities do they have now and what could be improved upon?

For example: *For students to be curious about mathematical patterns, and develop the capacity to identify and represent mathematical patterns.*

- It may be useful for teachers to focus on a teaching approach rather than a curriculum unit at this stage, e.g. successful group work within the mathematics classroom.

2. Plan

Planning Meeting

- i. Choose roles for the planning meeting of the community of practice
- ii. Decide on the class group and curriculum area on which to focus
- iii. Select or revise the research lesson
- iv. Write a teaching and learning plan
- v. Devise an observation strategy for collecting data
- vi. Review key decisions and/or insights made during the meeting
- vii. Agree upon assignments to be completed or followed up in the next meeting.

Teaching and Learning Plan

The teaching and learning plan should include:

- Long term goals
- Anticipated student thinking
- Data collection plan
- A 'model of learning' trajectory
- The rationale for this chosen approach

In commencing the teaching and learning plan teachers should ask themselves:

(Questions 1 – 4 may be un-necessary in planning a single isolated lesson)

1. What do students currently understand about this topic?
2. What do we want them to understand at the end of the unit or sequence of lessons?
3. What's the sequence of experiences (lessons) that will propel students toward the learning objective?
4. What will make the unit/sequence of lessons and each individual lesson motivating and meaningful to students?
5. Which lesson in the unit will be selected as the research lesson?
6. What will students need to know before this lesson?
7. What will they learn during this lesson?
8. What is the sequence of experience through which they will learn it?
9. How will students respond to the questions and activities in the lesson?
10. What problems and misconceptions will arise and how will teachers respond to them?

11. What evidence should we gather and discuss about student learning, motivation, and behavior?
12. What data collection forms are needed to do this?

Each member of the planning team should independently do the activity intended for the research lesson. Usually in a group of teachers, there will be a variety of strategies in attempting an activity and each teacher should have an opportunity to share how they approached the activity. It will be important to discuss the successes and difficulties the students will encounter and also the successful process(es) and outcomes for this task.

The point of anticipating student responses is not to design the activity so that student’s won’t struggle or so that misconceptions won’t emerge, but rather to give teachers an opportunity to plan how they will respond and to think about what kind of struggles and misconceptions may be an intentional element of the lesson. It is important to discuss the instructional strategies and options that might facilitate the student learning as struggles and misconceptions emerge.

Record the anticipated student responses and teacher responses in the lesson plan.

Approximate Time Guide	Student Learning Activities	Anticipated Student Responses	Anticipated Teacher Responses	Points to notice & evaluate

[See end of document for Lesson Plan template]

Collecting Data

It will also be important for teachers to reflect on what data collected during the lesson will assess the learning and engagement of students.

NB: It may be useful for observing teachers to have both a copy of the lesson plan and seating map of the room with students’ names during the lesson.

In designing and observation sheet teachers should ask:

1. What data will help you understand your students’ progress on your lesson goals and long-term goals?
2. Would a prepared data collection form facilitate observation or should conversations between students be recorded?
3. What student work (if any) will be collected at the end of the lesson?
4. How will material that is presented on the board or in other locations be captured? (photographs etc.)

5. What are the individual assignments of the lesson study team? Will one person transcribe the lesson and keep a timeline of lesson events? Will observers be assigned to observe specific students or groups?

6. If the lesson is to be video-recorded, who will be in charge of the video equipment during the lesson?

[See suggested templates at end of document]

Note: during the Research Lesson the researcher will be observing the teachers' various roles and interactions during the lesson.

3. Conducting Research Lesson

Teaching the Lesson

The teacher who will be instructing the lesson should follow the Teaching & Learning plan or may construct a Lesson Flow for themselves [See end of document]. The teacher may introduce the class to the observing teachers but otherwise should not interact with his/her colleagues during the lesson.

Observation

Recommendations for observing teachers:

- Minimise side conversations during the lesson
- Remain in the classroom during the entire lesson to capture how the lesson is set up, its flow, and its conclusion
- Do not block the students' view of the blackboard or any area where the teacher is writing and posting materials or demonstrating an activity
- Do not block the video camera
- Circulate freely when students are working individually or in groups but move to the side or back of the classroom during whole class discussions.
- Minimise interactions with students. Refrain from teaching or assisting the students. Occasional interaction is permissible if done discreetly and with the purpose of understanding student thinking.

Suggested Observations to Note:

- Comments that come to your mind as you observe
- Critical things that are happening in the classroom
- Types of questions the students ask
- Types of questions the teacher asks
- Evidence of higher-level thinking
- Evidence of confusion
- Number of times students refer to and build on classmates' comments
- Evidence of engagement

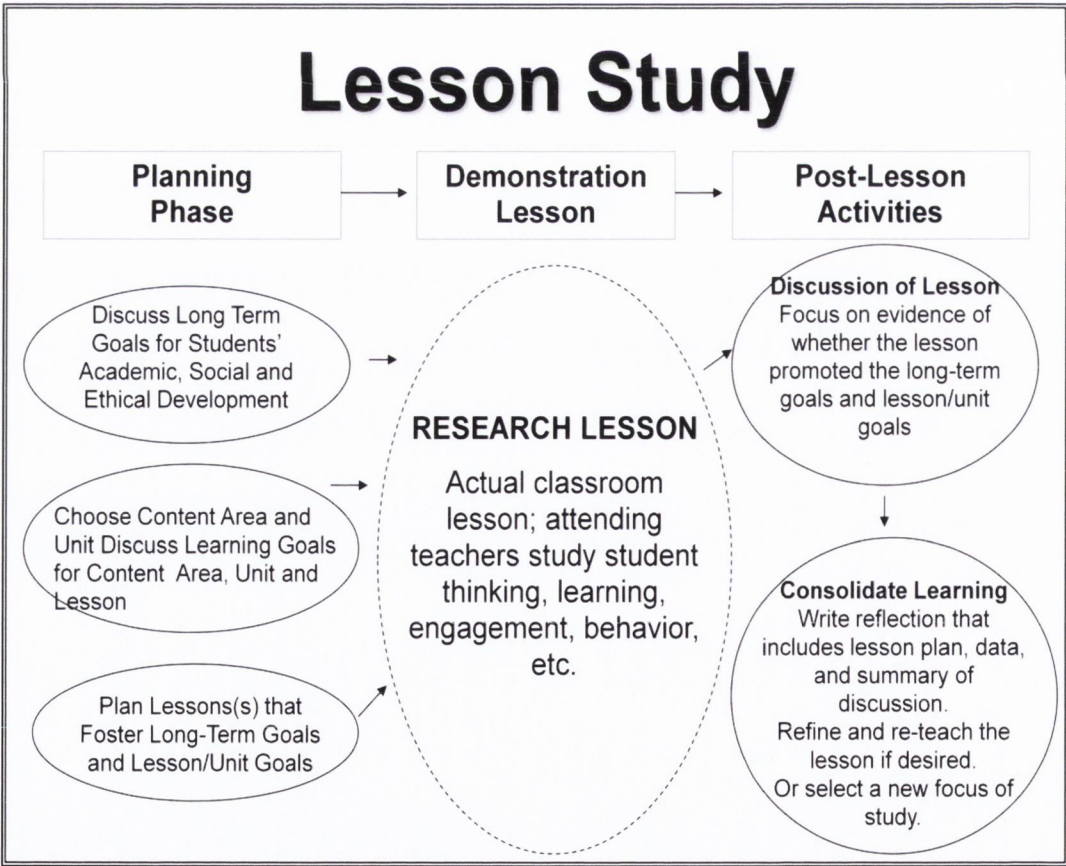
Observing teachers should choose specific behaviours or actions to focus on during the lessons. Teachers may wish to address specific research questions during the lesson and/or use observation forms. [See end of document]

4. Reflect

Reflection Meeting

- i. Choose roles for the planning meeting of the community of practice
- ii. The lesson teacher should first share their reflections on the lesson
- iii. Observing teachers should share data and reflections from the lesson (each person should have an opportunity to share their opinions and provide evidence for their observations)
- iv. Use the data to highlight student learning, lesson design and any broader issues in the teaching & learning
- v. Reflect on any changes that should/not be made to the Teaching & learning template and decide whether or not to teach this adjusted plan or embark on a new cycle
- vi. Review key decisions and/or insights made during the meeting
- vii. Agree upon assignments to be completed or followed up in the next meeting.

Note: If community agrees to revise and re-teach the lesson, what changes affected the student learning? How was the learning affected?



Sample Lesson Template

These plans have been amended from other groups and are merely suggestions of how a Community of Practice may wish to layout teaching & learning plans for Lesson Study:

Suggested Template for Teaching-Learning Plan 1

Meeting Number: ...

Date: ...

School: ...

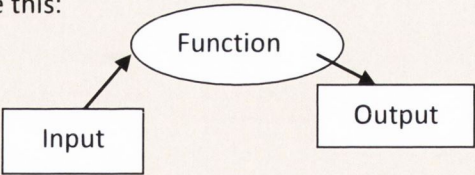
Participating Teachers:	
Instructor:	
Date:	
Intended Class & Year Group:	

Lesson Title	Inventing Function Notation
Goal of the Lesson	a. For students to understand why it is useful to name functions b. For students to appreciate the merits of function notation as a concise way to express the relationship between a function, its input, and the corresponding output. c. For students to grow in their ability to analyse, critique, and discuss mathematical ideas with each other.
Lesson Rationale: Why focus on this topic? What is difficult about learning or teaching this topic? What is currently noticed about students learning	Using the context of prices at two different shops, the lesson will motivate the need to give functions names and to create an efficient notation for functions. Students will be challenged to devise their own notation and then to compare theirs with other notation proposals. They will then learn the standard mapping and $f(x)$ notations. There is no direct reference to domain and range in the syllabus but students will be able to refer to functions using this terminology.

this topic?	Students have usually accepted function notation and not had many difficulties with it. Many other students however do have trouble with the $f(x)$ notation, confusing it with multiplication or having difficulty when $g(x)$, $h(s)$ etc. are introduced. Also, $f(x) = 3x$ plays a different role than in equations students have seen before. Arrow notation may be used on board notation even though it is not referred to directly in the syllabus, as it might remind students what a function is.
How does students' understanding of this topic develop?	Some of the students may have been informally exposed to the idea of functions as input-output previously. Students should be aware of the relation where a unique output is determined by an input. Students are accustomed to (x, y) tables. For this lesson, students will be asked to invent their own function notation, an authentic mathematical task. The discussion will then focus on evaluating the different proposals (with the different mapping notations mixed in) based on clarity and brevity. We will then tell them which are the standard notations, and ask them to practice using them. Following this unit, 5.2 (drawing and interpreting graphs) can be addressed and can be expanded to interpreting expressions for exponential functions.
Where does this lesson relate to the curriculum (Project Maths)	3.1 f – investigate models to help think about the operations of addition, subtraction, multiplication and division of rational numbers 3.1 g – consolidate the idea that equality is a relationship in which two mathematical expressions hold the same value 3.1 k – use the equivalence of fractions, decimals and percentages to compare proportions 4.4 c – use representations to reason about the situation from which a relationship is derived and communicate their thinking to others 4.7 a – consolidate understanding of the concept of equality 5.1 a – engage with the concept of a function, domain, co-domain and range 5.1 b – make use of function notation $f(x) =$, $f : x \rightarrow$, and $y =$
Why we have designed the	To encourage discussion we will use 3 strategies: 1. Where it makes sense, we will have multiple

lesson as shown.	solutions or ideas – ideally, conflicting answers or ideas – clearly posted on the board before we ask for discussion. We will then ask students to compare the posted solutions following a think-pair-share structure. 2. We will routinely ask students to restate the comments of their peers. This will serve two purposes: it holds students accountable for listening to each other, and it will also give students more than one opportunity to hear and understand the ideas, giving them more time to consider whether they agree or disagree. 3. We will often write student observations on the board, with the student’s name, to communicate the importance of the contribution.
How will the learning be assessed?	Students learning will be assessed according to their expression of the functions and on their ability to use the various notations.

Flow of the Lesson:

Lesson Flow	Learning Objectives
1	Students discuss a situation in which a shop charges different customers a different price for the same item. In contrast to this, they learn that a function connects an input (e.g. an item) to exactly one output (its price). Student practice this concept by distinguishing functional and non-functional relationships from contexts. Students see a diagram like this: 
2.	Students learn that many functions in mathematics can be expressed with a rule. They are challenged to come up with a rule for a function with a multi-step situation, and learn the value of working first with concrete numbers.
3.	
4.	
5.	Students play “guess the rule” for in-out tables and learn strategies for doing so, such as “divide the output by the input” (to test for proportion) Research Lesson: Students learn that functions can be named (with words or letters); they learn how to use the name in mapping (arrows) and Euler ($f(x)$).

Write for several examples: “Function __ connects input of __ to output __” T: is anyone else’s hand getting tired?	decipher what’s happening to the price in each of the shops.	A function is an operation on a number. We do something to the input to get a different output.	to have more examples ready.
	S: yes, because for any input, you know exactly what the output will be. Input: wholesale price. Output: retail price	T: Are these functions? Why? What’s the input? What’s the output?	Can Ss express why these are functions? (refer to unique outputs here also)
	S: which store	T: Which store? = which function?	
	S: Ss can double or triple the price etc. according to the function rules.	Suppose we give them names? Function B (Big box) and Function F (Fred’s). Using Function B what is the output?	Does this example motivate giving functions names?
	Ss think of names for the	T makes a	

	functions.	point of long names...	Does this motivate students to find shorthand?
2. Posing the task Compare to notations for numbers, addition, subtraction etc. "People invented these symbols"	Ss: think quietly for 2 minutes, jot down as many ideas as they can	T: Let's invent a shorter way to clearly express an idea like "Function F connects input €2.20 to the output €4.40"	
3. Anticipated Student Responses Variations on arrow diagrams		Identify the three things to be represented (Fn, input, output). Suggest a simple picture or abbreviations.	Do students' representations contain all three elements?
4. Comparing and discussing Now, we are going to compare our notations and choose the best ones. Let's focus on two criteria: to be clear and short. Post all notations on the board. Mix in the conventional arrow and Euler notation.	Each group chooses one of their suggestions and writes it on A3 paper. (Ask Ss to write big enough!)	All of the suggestions are posted on the board. And some correct options too (they may not be included in student suggestions) T: Why did you choose this?	Do students use the criteria? Do students

Remove all but the two conventional ones.	Groups discuss what is on the board and Ss vote for the one they think is best.	After each group has picked a favourite, as for justifications from 2-3 of them.	just choose their own?
		T: If we are going to communicate with the rest of the world, we will need to use a notation that other people understand. People have agreed on two notations.	Is the lesson helping students defend their choices?
Explain how to say them.		On board: 2.20 → 4.40 F maps 2.20 to 4.40 $F(2.20) = 4.40$ F of 2.20 equals 4.40 F of any number = multiply it by 2. $F(x) = 2x$	
	Students repeat the functions aloud.		
Repeat for a number of examples:	Students should say the	What would the following functions do? $f(x) = 3x$ $h(x) = 2x - 4$	Do all students understand

	functions and explain what they do Have students set functions for one another to decipher in pairs. e.g. $f(x) = 1.8x$ $g(x) = 2x$	Repeat	what the functions are doing? Are students discussing the function meanings with one another?
5. Practice and Extension Ask students to rewrite each of the sentences from the introduction using this notation. Ask a student to read each of these.	Ss can now practice using function notation on problems.	Ts decide in advance of further activities here.	Can students use these notations?
6. Summing up Main points from today • Functions have names like f, g etc. • New ideas require new notations, so we don't have to write so much • Functions can be expressed using mapping or $f(x)$ notation			

Evaluation:

- Did the context of the two shops help students appreciate the value of naming functions?
- Did students appreciate the value of shorthand for expressing the relationship between a function, an input, and the corresponding output?

- Did the opportunity to try to invent their own notation for that relationship help them understand and appreciate the standard $f(x)$ and mapping notations?
- Did the lesson provoke students to think critically about their own and their classmates' ideas, and did it help them express their reasoning?

Other Lesson Ideas:

- Haga's Theorems (paper folding/origami) – Euclidean Geometry, linear algebra & word problem
- How Fast do Trees Grow? – Using Tables & Graphs to Explore Slope
- Number Golf – numbers and operations

Acknowledgements

I would like to offer my sincere thanks to the participating Mathematics teachers in allowing me to participate in and observe in the planning, teaching and reflecting on classroom practice within their Mathematics Department. It is a unique and valuable opportunity as an educational research to gain such privileged access and this is very much appreciated.

I would like to sincerely thank the Principals of the schools involved in this research for facilitating this project within their school's Mathematics Department. I would also like to thank each school's teaching and additional staff for providing opportunity for their colleagues to participate in this study.

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Agenda: Initial Meeting

Date:

Meeting 1:	
Introductions	
Roles (discussion of as opposed to assigning)	Facilitator: Note takers: Timekeeper: Researcher of materials: Lesson Plan recorder: Updating and circulating lesson Plan: Convener to send out reminders and arrange room:
Discussion of Long-Term Goals and Research Objectives	Personal objectives Group objectives:
Decide on a Research Theme	Research Theme or long-term goal
Building a shared understanding of Lesson Study	Questions on lesson study Book and DVD available to be viewed. YouTube channel and/or internet resources
Building a Timeline	
Sharing of resources	Dropbox or email to share teachers' resources
Observation Techniques	
Review and Reflection	
Study curriculum and identify topic(s) of interest (Time permitting)	Project Maths curricula

Initial Meeting

Long-term Goals and Research Objectives of participating in Lesson Study
2012/2013

Personal Objectives	
Teaching Objectives	
Classroom Objectives	
Objectives for Students	

Teaching-Learning Plan Template

Meeting Number:

Date:

School:

Participating Teachers:	
Instructor:	
Date:	
Intended Class & Year Group:	

Lesson Title	
Research Theme/ Subject Matter Goals/ Lesson Goals	
Lesson Rationale: Why focus on this topic? What is difficult about learning or teaching this topic? What is currently noticed about students learning this topic? Why we have designed the lesson as shown.	
How does students' understanding of this topic develop?	
Where does this lesson relate to the curriculum	
How will the learning be assessed?	

Lesson Design

Lesson Title:

Year Group:

Lesson Objectives:

Long term objectives:

Approximate Time Guide	Student Learning Activities	Anticipated Student Responses	Anticipated Teacher Responses	Points to notice & evaluate

Lesson Flow for instructing Teacher

Lesson Flow	Role of Teacher (s)

Observing the Research Lesson

Observers may wish to take these actions while observing:

1. Make notes on individual student comments and conversations, noting the names of students
2. Note situations in which students are collaborating or choosing not to collaborate
3. Look for examples of how students construct their understanding through their discussions and activities
4. Document the variety of methods that individual students use to solve problems, including errors.

Observer Questions	Notes
Was the goal clear? Did the supporting activities contribute effectively to achieving the goal?	
Was the flow of the lesson coherent and did it support students' learning of the concept?	
Were the activities and the materials helpful in achieving the goal of the lesson?	
Did the classroom discussions help promote student understanding?	
Was the content of the lesson appropriate for students' level of understanding?	
Did students apply their prior knowledge to understand the content of the lesson?	
Did the teacher's questions engage and facilitate student thinking?	
Were student ideas valued and	

incorporated into the lesson? Did the lesson summary refer to student theories or ideas?	
Was the lesson summary consistent with the lesson goal?	
How could the teacher reinforce what the students learned during the lesson?	

Lesson Observation Log

Lesson Title:

Goals of the Lesson:

Observation objectives:

Activity/Student	Observation	Significance

Conclusions:

Further questions raised:

Observation & Reflection Sheet

What surprised me:

Wow!

I'm wondering:

Pretty exciting:

Not sure about this:

A little confusing:

Other:

APPENDIX D

D1 Semi-structured Interview Guide: 1

D2 Semi-structured Interview Guide: 2

D3 Semi-structured Interview Guide: 3

APPENDIX D1 – Semi-structured Interview Guide: 1

1. How long have you been teaching mathematics?
2. How long have you been teaching at this school?
3. Why did you decide to become a mathematics teacher?
4. How would you describe your own approach to the teaching of maths?
5. What has been your experience of CPD to date?
6. In your opinion, how useful have these sessions been?
7. Have you spoken with colleagues about the content of these sessions in the days following the CPD? If so, what are the conversations about?
8. In your view, what are the characteristics of effective professional development?
9. Have you implemented resources or lesson plans from professional development sessions?
 - a. If yes, were you afforded the opportunity to review these resources or lesson plans?
10. Have you been offered follow-up support or further resources after a professional development session?
11. What, if any, changes would you make to the CPD currently available?
12. How often, if ever, do other teaching professionals observe your classroom practice?
13. How do you feel about another teaching colleague observing your classroom practice?
14. How do you feel about another teacher observing your classroom practice?
15. If you have scheduled or formal meetings with other maths teachers in your school what issues are generally discussed? (textbooks, students, methodology, topics, student allocation, assessments etc.)
16. Do you regularly converse with your mathematics colleagues in an informal manner? If so, what is generally the content of these conversations?
17. What are your expectations of participating in this research?
18. Do you have any worries about participating in this research?

APPENDIX D2 – Semi-structured Interview Guide: 2

1. How have you found participating in research meetings during this process?
2. Have there been fruitful ideas in these meetings of the group? (How did they come about?)
3. Have there been moments of frustration during these meetings?
4. How are you finding the group dynamics?
5. Can you see changes in the group?
6. Do you feel comfortable enough airing all of your opinions during a meeting?
7. Do you think other members of the group are being open and forthcoming with their opinions during meetings?
8. Did topics come up in the meetings that you think you may not have otherwise addressed?
9. Have the topics of meetings changed during other scheduled meetings or informal conversations?
10. How did you find it teaching in front of your peers? (only relevant to some teachers)
11. How did you find the experience of observing in a class where one of your colleagues was teaching?
12. Did you notice any change in the research lessons in how students engaged in the lesson?
13. Is there any change in how students were engaged in the research lesson?
14. Has participating in the group changed how you teach?
15. Has participating in this community of practice changed you personally? If so, how?
16. (Crannog only) Has participating in the project maths RDO programme affected your involvement with this community or these meetings?

APPENDIX D3 – Semi-structured Interview Guide: 3

1. Have you enjoyed the conversations within the lesson study meetings? Why?
2. Did you enjoy the engaging in lesson study as a practice with your colleagues?
3. Did you feel that the planning meetings and meetings after a lesson dealt properly with the lesson objectives / content / long term goal?
4. In what way did your observations of the research lesson assist the process?
Could/Should this be improved?
5. Do you feel there is respect within the group?
6. Do you see trust as an important part of the workings of the community?
7. Do you feel that there is a mutual engagement by everyone in the group? (No one leader or one strong voice)
8. Do you feel there is a communal responsibility for the activities of the group and meetings?
9. Do you feel ownership of the shared repertoire for everyone in the group? – resources developed during the year and others?
10. Do you think you've built up shared terminology (shared meaning, shared language) within the group?
11. How do you think differences of opinion and tensions have been resolved during the year? (collective mediation)
12. Has there been more sharing of resources since the beginning of the year?
13. Is there more talk about content of lessons? (in and out of meetings)
14. More talk about teaching methodologies? How you teach something? (pedagogy)
15. Do you feel participating in the community and lesson study has increased your mathematical knowledge?
16. Do you feel that participating in the community and lesson study increased your awareness of teaching approaches?

17. Do you feel that participating in the community and lesson study has increased your own confidence with the mathematics content? Teaching new curriculum? Engaging with your colleagues?
18. Do you feel you've engaged more with project maths curriculum and approaches?
19. Do you think this model of professional development benefits classroom practice and how students engage in mathematics class?
20. Do you feel you're thinking more about how students think in class? How they're engaging with the lesson?
21. Do you think there is a distinct identity for this community of teachers within the school?
22. How well has the school supported the project? Principal? Other staff? Has this made a difference?
23. Do you feel this community has developed as it has because of the environment and staff in the school?
24. Has it made a difference having funding available for supervision & substitution?
25. Would you recommend this as a form of professional development to other teachers? Other subjects? Why? Do you think it's sustainable?

APPENDIX E – Data Samples

E1 - Samples of Transcripts from Lesson Study Meetings

E1 Lesson Study Meeting Transcripts Sample 1: Doone

E1 Lesson Study Meeting Transcripts Sample 2: Crannog

E2 Samples of Transcripts from Teacher Interviews

E2 Teacher Interview Sample 1: Doone

E2 Teacher Interview Sample 2: Crannog

E3 Samples of Summary of Researcher Log

E3 Researcher Log Sample 1: Doone

E3 Researcher Log Sample 2: Crannog

E4 - Researcher Field Notes Sample

APPENDIX E1 - Samples of Transcripts from Lesson Study Meetings

E1 Lesson Study Meeting Transcripts Sample 1: Doone

18/2/2013 Cycle 3 Post-lesson Meeting

65 A: By the second one and third, he was just going off and doing the graph, you know, he even felt
66 confident in doing that.

67 B: Even that, that's huge.

68 S: Is yours cold?

69 A: No.

70 B: Mine is roasting.

71 K:... Mine's cold.

72 B: It's just the same with Stephen in the group that I was watching, he was the guy I was
73 saying...He said, nah, I, there's just not enough information there for me to do that question, and,
74 but he was calculating how high the ball would go and all that stuff and then the guys who were
75 straight into the maths were like, "oh yeah, that makes sense". So everybody was offered...

76 P: Everyone made a contribution, yeah, from their own strengths, yeah.

77 K: I was really impressed when I gave them this out and majority of groups, bar two I think, didn't
78 even draw a graph. They went straight into, they obviously got the table of values and went, "ok,
79 well this is complete symmetrical, so we have the answer". Another one solved this and then
80 solved this, so...

81 A: Yeah, there were good lead-ons, I think that was a great one.

82 K: That was a great question. Well done you, 'cause you

83 P: It was, yeah...

84 K:... and it is so relevant and they were even laughing, I could hear them saying, George Hook's not a
85 mathematician...

86 B: Oh yeah yeah yeah.

87 P: George Hook doesn't know.

88 K:... but it's good as well because the numbers aren't symmetrical, so it's not as easy, you have to do
89 the graph.

90 A: Yeah.

91 B: Yeah, yeah.

92 K: This one, you don't, but I'm glad I chose one with that, I am glad I didn't have five there.

93 A: They still did a graph, like, most of them.

94 B: Like, in both instances, like, particularly in C there, like, if you go to any training in any job, like,
95 you know if you do group work and...

96 A: Yes.

97 B:... you know, like, you're always sitting around chatting, or the first chance to not talk about what
98 they're on task to do or something that's related to...

Doone

138

180

801 K: So definitely the third lesson, I think...

802 E: Mmm.

803 K:...so they know square root and...

804 E: The other thing about learning for the students is they can learn the theorem, but then it is

805 confusion when the diagrams are labelled in any given way. So, how do I say that better?

806 D: So what is it?

807 E: You know, we discussed it.

808 D: They can learn it, but...

809 E: We think it's saying, $A^2 + B^2 = C^2$, but it's meaningless to them when you give them a thing and

810 D: Yeah.

811 E:...and A is the hypotenuse and then you go, $A^2 + B^2 = C^2$.

812 D: Yeah.

813 E: They don't actually understand...

814 D: So that's rote learning.

815 K: Yeah, concept rather than formula.

816 B: That's what I was saying about your man in sixth year.

817 E: Concept rather than formula.

818 B: He said it to me and "I remember", he just rattled it off. I asked him, "what does it

819 mean?". It didn't mean anything.

820 E: Yeah, exactly.

821 K: We want them to know the English sentence.

822 D: Yeah.

823 E: Yeah.

824 K: In their own words.

825 E: To be like, "hypotenuse is on its own" 03:48

826 D: Yeah

827 E: So, recognising the hypotenuse. Well, that might come down further here. We just want to

828 know what is difficult about it so that they...

829 K: That's the main one, I think...

830 E: ...they know the formula, but they can't conceptualise it.

831 E: Yeah.

NNB &

teachers clearly

(perhaps for

the first time)

what they want

so to

understand.

130225_001
180

NP SL Breakthrough in Ts recognising Her S. low.

181

- 832 D: Mmm. What about teaching it?
- 833 E: What's difficult about teaching it?
- 834 D: I've never taught it. * ~~QNT~~ NQT - no experience.
- 835 K: I think...
- 836 E: I think because we have focused too much on that.
- 837 K: Yeah.
- 838 E: We know it. We know that this is the formula, but we don't look at it from the kids... *
- 839 D: The concept around the formula rather than the formula.
- 840 E: And it's only that you, talking about that today, if they label the hypotenuse A, I hadn't actually
- 841 realised that that is what's causing the problem. They don't... I keep... *NB
- 842 K: I always just label it X or...
- 843 E: Yeah.
- 844 K:...just some random letter.
- 845 E: So...
- 846 K: I never use A, B, C or H...
- 847 E: We... I think we... always teach by formula.
- 848 K:...and I never use H because H is sometimes height of a pole...
- 849 D: Yeah.
- 850 K:... H hypotenuse. So I'd always label X the...
- 851 E: Ok. So, my problem teaching it is that I focus too much on the formula.
- 852 K: I used to. This year, though, I actually am really happy with the way I did it this year because I was
- 853 just doing it as in I wasn't writing... You know the way you would, normally, "Ok, solve the problem".
- 854 We get them to write down the formula, $A^2 + B^2 = C^2$ and underneath sub in. Lisa reflecting on what has been in her teaching and how important it?
- 855 E: Yeah. 05:04
- 856 K: I was skipping that stage altogether and just going straight to...
- 857 B: Mmm.
- 858 K:... $5^2 + X^2 = 10^2$
- 859 B: That's what I do, yeah.
- 860 K: I was completely skipping... They weren't writing down any formula. There was no formula to
- 861 learn.
- 862 E: So, ok.

130225_001

181

E1 Lesson Study Meeting Transcripts Sample 2: Crannog

8/11/2012 Cycle 1 Post-lesson discussion

		248
1	F: What is this guy sitting here?	
2	D: Eh, Joe...	
3	F: He is very good...	
4	D: Yes	
5	W: He is the top class...	
6	D: No...	
7	F: He looked at it and he had it worked out. He said "No, no, no...get the square, and then add	ST.
8	one onto your answer and then square that", he had it all sussed out after a relatively short time, he	
9	had worked out the answer...	← T missed out on S getting answer
10	D: I didn't even know that...	
11	F: After I would say about...	
12	W: I think it was more exciting for them than I thought it would be...	SE
13	E: Yeah...	
14	F: Well I think the way you started it off was brilliant. I think you got them interested by talking	Re-entry was useful or wanted.
15	about the competitive Pharaohs and as they came up with all the answers you wanted, which was	
16	great...	
17	D: They came up with the questions themselves!	
18	W: Their imagination of it, they just sort of plugged into that more...	
19	F: No, it was great...	
20	D: It was a good classroom to do it...	
21	F: It is...	
22	D: Did you like the way I had it set up this morning?	
23	F: It is so bright, like my room is just dark and dull and dreary... And the other thing I love about	CE.
24	this is I don't have a remote control... No I have to stand up on top of a chair or a desk to use mine...	
25	A: Are they not used to building bricks like that?	
26	(All conversing at once)	
27	A: Do they sit like this usually?	
28	D: Pairs, pairs, pairs.	
29	F: It worked. Those guys over there I was watching, they really helped each other. They hugely	Classroom conversing
30	helped each other, they were listening to each other...	
31	D: They are used to that because they talk the whole time in the class, and it is always that	
32	loud.	
33	F: But they are actually, they had great discussions...	
Crannog		248

- 696 W: A suggested exercise to do...
- 697 S: And then they graphed it...
- 698 W: It is quite linear, isn't it?
- 699 E: Yeah...
- 700 F: You want to try to get some motion in this...
- 701 W: Some rate of change.
- 702 S: It is, the difficulty is in timing. That they find it very difficult to time it properly and that is your issue there...
- 703
- 704 E: Yeah...
- 705 F: You would probably need to start off actually with a linear situation and look at a constant rate of change... just to get them into the idea of a rate of change...
- 706
- 707 E: And the fact that it is a slope...
- 708 F: Yes, you would possibly need to start off with that at the very beginning, something linear; and connecting the rate of change to slope, and then do that quite reasonably briefly, maybe with a couple of examples...
- 709
- 710
- 711 W: You could drop... there is a physics experiment where they have a, like a trap door that you drop a ball onto it, it hits the trap door, there is a timer on it so it tells exactly how long it took to drop over a certain distance, and that would be linear, well it should be linear, your slope should be nine point eight... *context.*
- 712
- 713
- 714
- 715 A: Yeah... *Cost curriculum.*
- 716 W: If you graph what is what...
- 717 F: Distance...speed against time...
- 718 A: Speed against time...
- 719 F: Not distance against time...
- 720 W: Yeah, so speed against time...
- 721 A: I never got the right numbers for that though...
- 722 W: No it is very difficult...
- 723 F: That would have to be speed against time, not distance against time...
- 724 A: I did that with classes and you have to give them results, I don't know what, but they were never able to get ten, it was always crazy numbers...
- 725
- 726 W: So that wouldn't hold...
- 727 A: But it might be a nice one to do as part of a unit, with the TYs, to give them, you know, an introduction...
- 728
- 729 W: I am sure we could borrow that from science...

APPENDIX E2 – Samples of Transcripts from Teacher Interviews

E2 Sample 1: Doone

Michael Interview 3

240 M: Em just a lot yeah. Ehhh I mean eh you're bringing in different methodologies there's
241 loads of different way that you're utilising in in classes. I mean like everyone just goes group
242 work default, you know it's not just group work it's em paired work, it's reading, it's active
243 engagement with tools. And by doing that you're getting people saying, oh well we could do
244 this, there's just so many ideas going on you know?

245 A: Yeah. And do you think it engages, it benefits how students engage in those lessons?

246 M: I think so yeah.

247 A: Why?

248 M: Well there's no definitive, there's no definitive for this but I guess if you're bringing more
249 in and you're more engaged and there's a more focussed approach to it, you're more
250 certain about what it is that you're doing and what you want to achieve and you have a
251 planned structure, well they're going to be more involved with it as well. Whereas the
252 opposite is if you have someone who comes in and is all over the place. The kids are all over
253 the place as well, you know you lead them.

254 A: Mhmm okay. Do you think that you're thinking more about how students are thinking in
255 the class?

256 M: Em no I don't think so.

257 A: Were you always?

258 M: I always, yeah I always try to think of it from their point of view.

259 A: Okay.

260 M: It's just the way I always look at it.

261 A: Right so this has just enhanced or

262 M: It just reinforces to me that it's really really important to always think how do kids see it?

263 A: Yeah.

264 M: You know em we're doing final accounts there on the board and for me in school you
265 know you get lost in there, so I'm always conscious of the fact that this is how I felt at that
266 time. How do they feel, where are they at? It's really important.

267 A: Yeah no it is really important and not everyone thinks like that though, so.

268 M: Well I don't know, probably not actually no.

269 A: So

E2 Sample 2: Crannog

Eileen Interview 3

- 215 A: But it would. Do you feel you are thinking more about how students think in class after
216 doing this?
- 217 E: Yeah I probably would ask myself a bit more like how would they react to this or what
218 questions will they have, like pre-empt their questions or pre-empt their confusion, em,
219 yeah I would think about that a little bit more.
- 220 A: Why do you think you would think about that a little bit more?
- 221 E: Well I suppose it was something that we always thought of when we were planning our
222 lessons and it was something that we planned for, that if this goes too quickly we'll do this
223 or if they don't get it we'll go at it this way or, you know, we always planned for the
224 eventuality, so, I suppose I do that on my own now.
- 225 A: Great, yeah, that's good. Then within the school here do you think that there is a distinct
226 identity for the maths teachers as a community?
- 227 E: Yeah I think because we are just maths teachers that might help, that we aren't shared
228 between the two departments, that we're just em, maths teachers, so I do think we are
229 seen as having our own little community and the fact that we have our own building, so we
230 are like..
- 231 A: Oh yeah, does it not do any of the other subjects?
- 232 E: Well if there's no mad teachers like myself, if these rooms are empty some people use
233 them but this is the maths block.
- 234 A: But is there like a science block or..?
- 235 E: Yeah there's a science block and then there is em, well then the classroom block is pretty
236 much everybody and then there's the English and music block.
- 237 A: Right, so it is very distinct?
- 238 E: There is, yeah.
- 239 A: It's highlighted?
- 240 E: We are the maths block yeah.
- 241 A: And do you think then it made a difference how the Principal supported this project and
242 the other staff supported you guys being involved in this research?
- 243 E: Em, yeah well I think he is always very keen on it, he was very interested in seeing how
244 we got on, em, yeah I think he was enthusiastic about our involvement, yeah.
- 245 A: Has it made a difference having funding available for supervision and substitution? A bit
246 of an obvious question but I have to ask.

APPENDIX E3 – Samples of Summary of Researcher Log

E3 Researcher Log Sample 1: Doone

14/11/2012 Cycle 2

Date of event: 14/12/12

Length of audio fily: 00:31:11

5: Few changes made to the powerpoint between the meeting and the lesson (from researcher log). Owen happy with the class. Nora pointing out that one group wasn't able. Lisa noting that she would have liked Owen to highlight the improper fraction a bit more. Teachers very forthcoming in their feedback and Owen doesn't seem to be taking it personally. It really does feel like a team review and commentary on the lesson. This is different to the last reflection meeting where it did seem to be focused on Lisa. This is focused on the lesson and the students. Everyone using "we" did they do the same after Lisa's lesson?

Log: Great session. Class was really good. Students were problem solving and the teachers were recognising where they need to improve in giving roles to students. Good students were magnificent in interpreting, drawing graphs and diagrams. Only one group got to present. Very favourable. Excellently scaffolding. Could have done more with the "why". Maybe Owen's content knowledge let him down on that. Students engaged. Show me boards very useful. Great to know they can be used like that. Groups were hard, need more teachers when you have more groups. Team teaching would be useful. Reflection was brilliant. Seem to have come to a new level with that. Everyone really honest. No-one wanting to be rude or critical but an awful lot was said that needed to be said and was critical. All wanted to get everything out. Dont' think anyone held anything back and don't think Owen thought there was anything personal in the reflection. Great move for the community. Strong progress. Overall lovely reflection. I have to do work on those lesson plans. Nora involved which was good. Michael tends to be a little negative. Would be nice to do more of the group work. There were moments in the group work where students said "now I get it"...really showing teachers how they engage. Dialogue between the students was good and the hook helped. Initial activity to get them straight into it. Overall a very good result and progress with the COP. Dialogue happening. Moments of interactions. "We" were in that table. Environment that we're sitting in has something to do with how we are interacting.

E3 Researcher Log Sample 2: Crannog

8/11/2012 Cycle 1 Post-lesson Meeting

Date of evenF: 8th November 2012

Length: 1:03

6: Teachers all very excited directly after the lesson. Surprised at students' engagement and imagination. Very interesting the observations each teacher had on their own groups. Teachers enjoying sharing their observations of the student group work and group dynamics. A lot of reflection and mentioning students individual work. Dave reflecting on his own practice. Conversations on how we can facilitate groups better.

Post Lesson LoJ: students did the group work wonderfully & first time in group. Good for teachers to have one group and to track students' thinking and progression in dealing with the question. Charts useful for the group work. Surprised that students graphed. Class could have done with 10 more minutes. Very well structured lesson since the groups didn't need as much guidance because it was scaffolded so much. Dave not nervous. Walter missed out on not observing students since he just looked at the powerpoint. Directly after class the big, enthusiastic conversation started in the classroom. Initial excited reactions. Meeting a little bit more subdued. Good debate on the content – part of the reflection in discussing the content. Teachers found the observation interesting and recording student comments instead of questions. Everyone is going to use this lesson in their own groups. Thrilled with how it all went. Good group to work with. Nothing is an issue. All teachers there for the lesson and post-discussion. Think they're all really enjoying the process. Should I interview more people at the mid-way point.

Participants:

- A: Aoibhinn
- E: Eileen
- F: Fiona
- W: Walter
- D: Dave
- S: Stephen
- M: Martin
- J: Judy

APPENDIX E4 – Sample of Researcher Field Notes

29/11/2012 Crannog Cycle 2

Geometry - theorems
factorising quadratics...

great year plan on excel.

why it has to be equal to zero

$$2x^2 - x - 3$$

$$\begin{array}{c|c} x & -3 \\ \hline x & x^2 & -3x \\ -2 & -2x & +6 \end{array}$$

Area arrays.

$$x^2 - 5x + 6$$

$$\begin{array}{c|c} x^2 & \\ \hline & 6 \end{array}$$

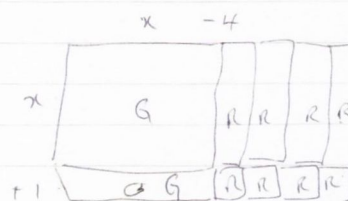
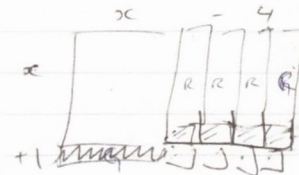
Algebra-tiles.

Can only do positive numbers
⇒ just use as an
introduction

Different representations of the same function.

$$x^2 - 3x - 4$$

$$(x - 4)(x + 1)$$



* Check if research has been done on
factorising using algebra-tiles &
area models *

APPENDIX F – Lesson Study Artefacts

F1 Planning Materials

- F1 1: Doone Lesson Plan Cycle 3
- F1 2: Crannog Teacher Goals
- F1 3: Crannog Series of Lessons
- F1 4: Crannog Planning Notes
- F1 5: Crannog Doing Mathematics Questions
- F1 6: Crannog Lesson Plan Cycle 3

F2 Research Lesson Curriculum Materials

- F2 1: Doone Lesson 1 Questions
- F2 2: Doone Lesson 2 Differentiated Questions
- F2 3: Doone Lesson 2 Problem Solving Worksheet
- F2 4: Doone Lesson 4 Presentation
- F2 5: Doone Lesson 4 Questions
- F2 6: Crannog Lesson 1 Worksheet
- F2 7: Crannog Lesson 3 Worksheet

F3 Observation Notes

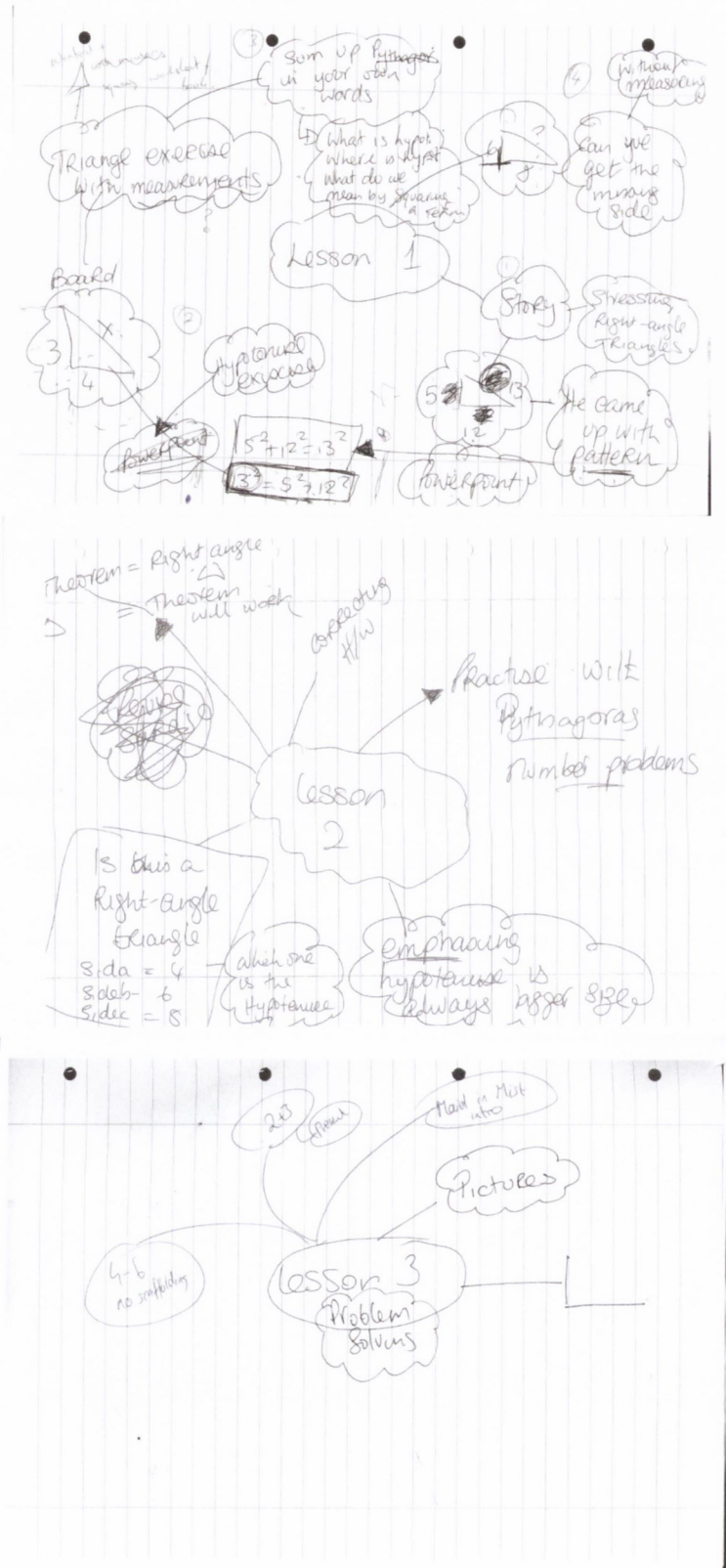
- F3 1: Doone Lesson 1 Sample Observation Sheet
- F3 2: Crannog Lesson 1 Sample Observation Sheet
- F3 3: Crannog Lesson 2 Sample Observation Sheet

F4 Samples of Student Work

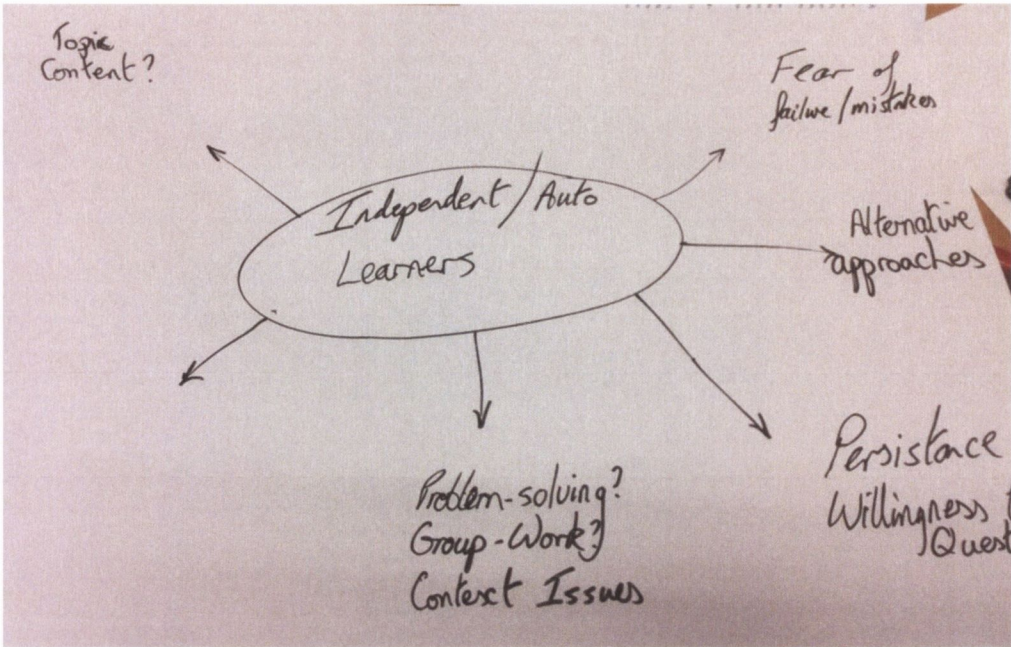
- F4 1: Doone Lesson 1 Student Work Sample
- F4 2: Doone Lesson 2 Student Work Sample
- F4 3: Doone Lesson 3 Student Work Sample
- F4 4: Crannog Lesson 1 Student Work Sample

APPENDIX F1 – Planning Materials

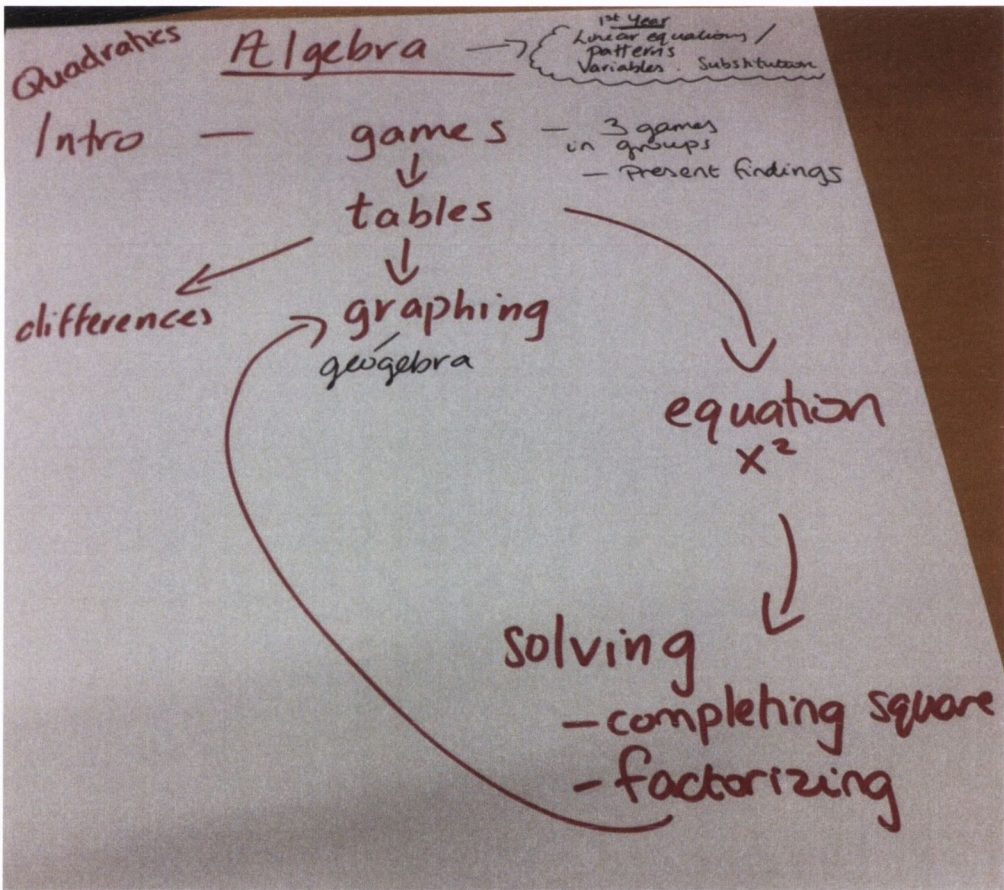
F1 1: Doone Lesson Plan Cycle 3



F1 2: Crannog Teacher Goals

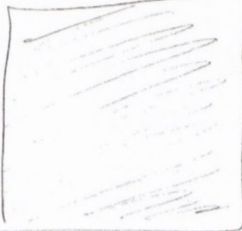


F1 3: Crannog Series of Lessons



F1 4: Crannog Teacher Planning Notes

$$x^2 + 5x + 6$$

	x	3
x		
2		

Blank

$$(x+2)(x+3)$$
$$6x$$
$$x^2 + 7x + 10$$

$x^2 + 4x + 3$ $x^2 + 5x + 6$ $x^2 + 8x + 7$ $x^2 + 12x + 11$

	x
x	x^2
	1

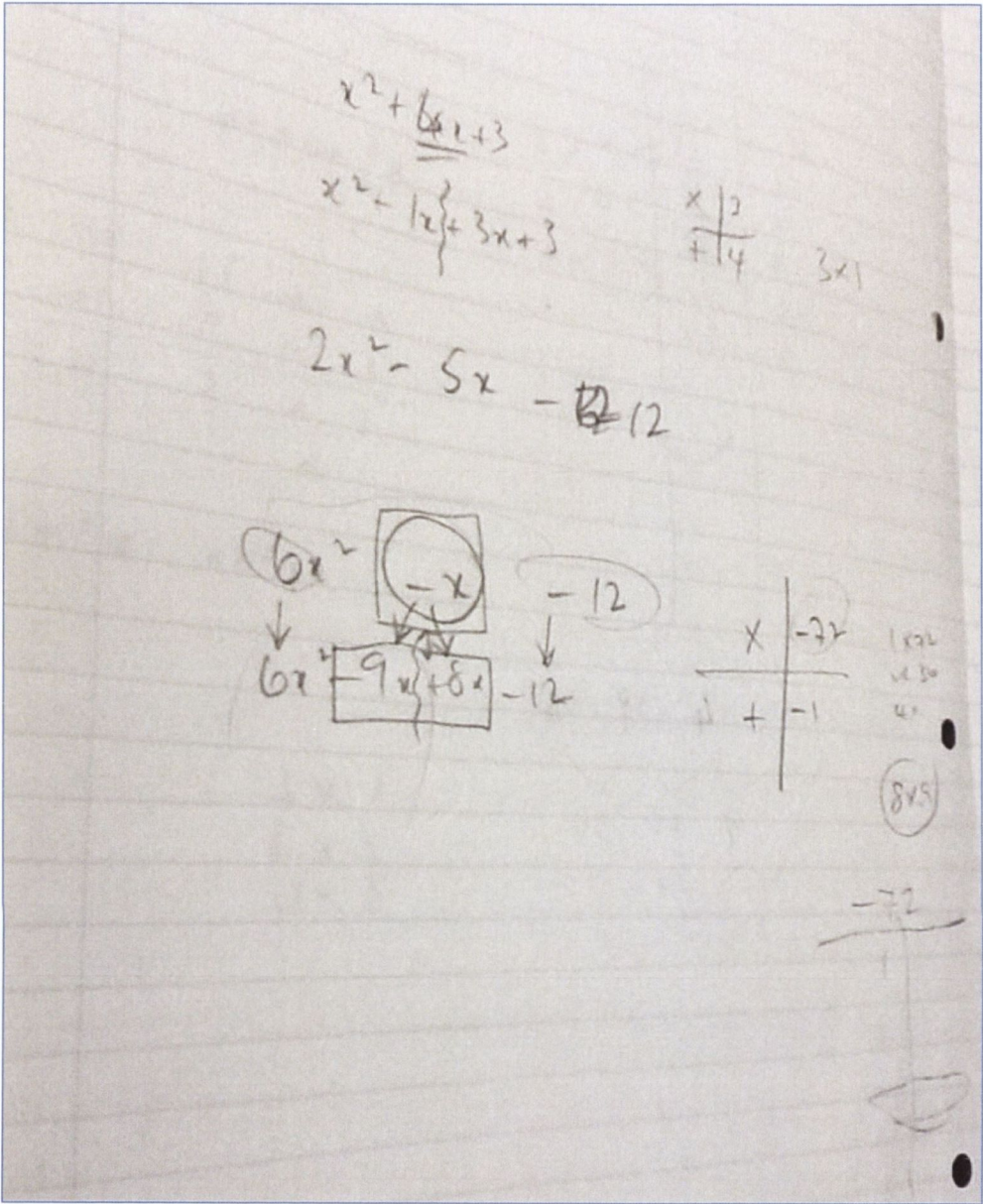
$x^2 + 6x + 5$

$x^2 + 4x + 3$

Only Prime nos

75

F1 5: Crannog Doing Mathematics Questions



F1 6: Crannog Lesson Plan Cycle 3

Introducing Calculus

Participating Teachers:	
Instructor:	
Date:	March 2013
Intended Class & Year Group:	Transition Year

Lesson Title	Introducing Calculus
Goal of the Lesson	Introduce instantaneous rate of change and associate to slope. Discovery learning of how to find an instantaneous speed
Lesson Rationale: Why focus on this topic? What is difficult about learning or teaching this topic? What is currently noticed about students learning this topic?	Traditionally, calculus fundamentals have been misunderstood/overlooked in favour of procedure. Students don't really understand the average versus the instantaneous speed. Students don't recognise that finding the slope of the line or tangent to a curve between points that are closer and closer together is represented by differentiation. Students also need a more concrete understanding of limits in order to come to this conclusion
How does students' understanding of this topic develop?	Through practical experience of the difference between instantaneous and average speed. First, students measure their own distances and times in a grand scale experiment involving a tractor on a pitch. Students graph this data and try to find the speed of the tractor. Students guided towards an understanding that the instantaneous speed can be found by finding the slope of the line at a certain point.
Where does this lesson relate to the curriculum	5.2 a Find first derivative of linear and quadratic functions (but not by rule) b Associate derivatives with slopes and tangent lines c apply differentiation to rates of change

(Project Maths)	5.2 (HL) a differentiate linear and quadratic functions from first principles 5.3 Explore patterns and formulate conjectures concerned with linear graphs. Justify conclusions of finding rate of change represented by a slope. Communicate mathematics verbally and in written form.
Why we have designed the lesson as shown.	Giving calculus a context and rationale. Why the need for calculus arises.
How will the learning be assessed?	Feedback from groups' answers. Assessing their understanding through questioning. Homework sheets.

Student Learning Activities	Anticipated Student Responses	Anticipated Teacher Responses	Points to notice & evaluate
Lesson 1: Tractor Class Meet and give students instructions of what will take place: 2 people at each station recording time of tractor to that point. 1 stopwatch, 1 recorder. 6 TY Classes involved: At least one person from each class should record the time at each station for each trial up to a maximum of 6 per	Where do we record the data? At what point do we measure the time for the tractor crossing the line?	Show students worksheet When tyre hits the line on the pitch (between two cones) There should be at least 2	Not just taking 1 results but an average (mean) of all 6 results.

station per trial. Start your stopwatch when you hear the whistle blow. Stop the stopwatch when the tyre touches the line. Teacher: Look at times, discuss and discount any outliers. Homework: What type of graph do you expect? Why?	Pupils should then return to class and record all the information into their own sheets. Students in groups discuss any outliers in the data and discount them (to avoid inaccuracies) Students calculate the mean time for each station and record on their worksheet. Graph the data. - Time on long horizontal axis. - Distance on short vertical axis. Note: dependent variable is usually on the horizontal axis but not practical here to measure distances.	students with information from each station. This needs to be shared.... (Possibly on a spreadsheet on board?) Why discounting outliers? Students may find this difficult and so have been given graph paper with time and distance intervals indicated on the sheet. Students should expect to find a straight line.	Discounting any outliers from the results.
Lesson 2: How might you find the speed of the tractor from the graph you did for homework? Video of cylinder filling: Homework:	Students will hopefully realise that the slope of the graph will give them speed (from distance over time) Students graph the changing height of the cylinder with time.	Emphasise 'rate of change' Again, emphasise rate of change of height with time.	

Students complete questions of cylinders filling with water (linear graph). Extension questions: cone filling with water.			
Lesson 3: What did you find that was unusual about the cone filling with water? Show video of Usain Bolt in Olympics....hand out graph with questions. GeoGebra graph of Usain Bolt shown on board: 1. How fast do you think he ran during the race? Give your answer correct to 2 decimal places. 2. Do you think he ran at this speed throughout the whole race? Give two reasons for your answer. 3. How do you think we could calculate Usain's speed at precisely 1 second into	Not a linear graph... From tractor class, students should recall finding the slope between two points in order to find the rate of change of distance over time. Some discussion here: students may not that the graph is not fully linear, he speeds up at the start. This should lead students into thinking about limits....finding two points that are extremely close to the 1 second data point.	Emphasise: linear graph, slope giving rate of change. Does it matter what two points I choose?	

the race? Victoria Pendleton: Quadratic graph of cyclist's race. 1. What is her speed? 2. Is her speed changing? How would we find the speed at exactly 3 minutes? Leading students to the concept of a limit – gap between points tend to 0. Homework: further sheet with 2 quadratic distance/time curves and getting the speed at particular points. Leading to differentiation by first principles?	Students working in groups. What speed when? Students should hopefully realise that her speed isn't constant. Students working in groups. Guide students to finding speed from 3 to 10, 3 to 9 etc. Speed from 2 to 4? Students to find instantaneous speed at certain points.	Guide students to the average speed over journey is total distance/total time. Or getting speed over a period of time by working between 2 points. Students should begin to realise that the closer the points are, the more accurate the speed. Possibility of leading students to tangents and graphing slopes of tangents (which will give us a straight line) If required here, refer to frog jumping across a desk. Each hop is only half the length of the previous hop. Does it reach the other side? Comment.
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APPENDIX F2 – Research Lesson Curriculum Materials

F2 1: Doone Lesson 2 Questions

Do your best to solve this problem in your group.

As part of your answer include on your Show Me boards:

- a diagram/model
- the maths you worked out
- greater than/less than/same as
- explanation of your answer

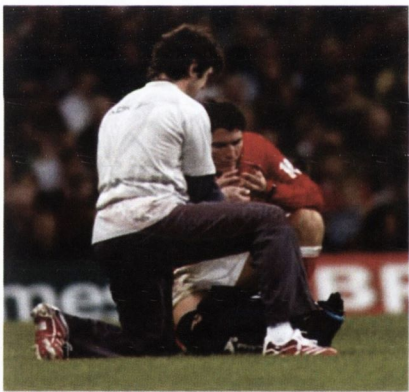


Problem:

Brian had a birthday party yesterday. A quarter of the birthday cake remained the party. This morning, Brian ate a third the remaining quarter cake. What fraction the whole cake did Brian eat this morning?



after
of
of



Problem:

The Ireland rugby squad played Argentina two weeks ago. One fifth of the players had eye problems. Of this one fifth, half wore contact lenses. What fraction of the squad wore contact lenses?

Problem:

There are 30 students in a class. 16 are sent for the MMR needle but one quarter of 16 students are terrified of needles, what fraction of the whole class will be afraid?



down
these

Problem Solving Questions for Students: Functions & Calculus

1. In your own words what are you being asked to do? Will a diagram help us?

2. What information have you been given that may help you do your calculations?

3. Can what you have learnt in previous classes help you? If so, how?

4. What method will you use for solving this problem?

5. What is the best possible solution?

F2 3: Doone Lesson 3 Questions

Problem

During the recent Ireland v England match in the Aviva Stadium as part of the Six Nations competition, Jonathan Sexton kicked a Garryowen before he went off with an injury. A Garryowen, also known as an "Up and Under", allows the attacking team to disrupt the defensive line, take the defence's pressure off themselves and put offensive pressure on their opponents. However, the kicking team risks losing possession of the ball, after which the opposing team may counter attack.

George Hook and Brent Pope, as well as being famous for their rugby commentary are also keen mathematicians who have calculated that the height of the ball above ground during the Garryowen can be described by

$$H = 25t - 4.9t^2$$

where H gives the height of the rugby ball above the ground at any time, t , in seconds.

a) How long is the ball in the air for?



b) What is the maximum height reached by the ball?

c) If Jonathan runs at a speed of 7m/s and is not tackled or hindered in any way. The ball will land 26m away. Will he catch the ball?

Problem

After years of research and clinical trials, 2 biologists have shown that the temperature of a person suffering from the flu can be modelled by the function:

$$T = -0.1t^2 + 1.2t + 98.6$$

Where T is the temperature in degrees Fahrenheit, at time t , in hours.

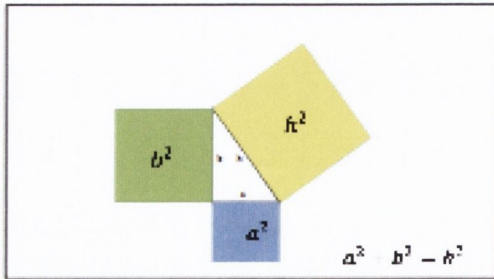
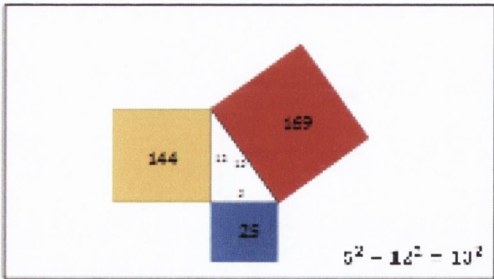
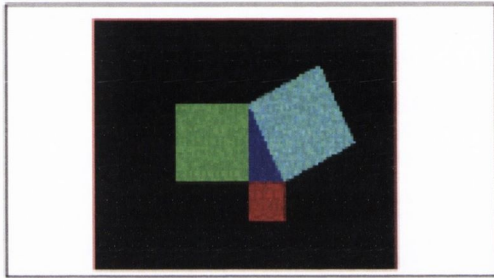
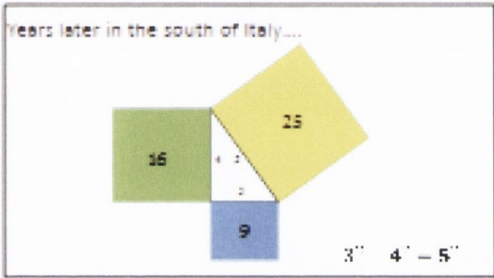
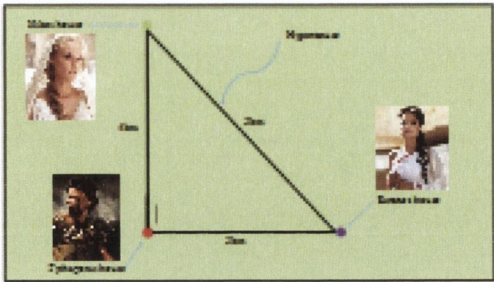


Una is feeling unwell and visits Dr. Nolan's surgery. Dr. Nolan diagnoses her with the flu.

- Predict her temperature after 1 hour.
- Predict her temperature after 2 hours.
- After how many hours will her temperature peak?
- Body temperature is 98.6°F (37°C). How long until Una's temperature returns to normal?

F2 4: Doone Lesson 4 Presentation

Pythagoras Theorem



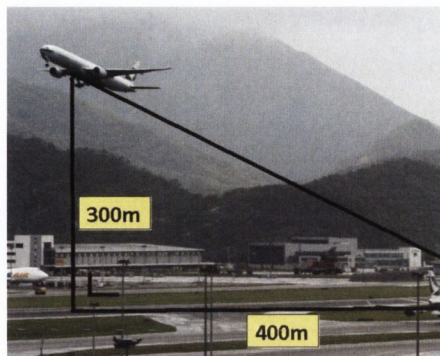
F2 5: Doone Lesson 4 Questions

Problems Involving Pythagoras' Theorem

Question 1

The aeroplane in the picture is departing Hong Kong airport. After leaving the ground it climbs along a steep, straight line.

At a certain point, the aeroplane has travelled 400m in straight line distance on the ground and has climbed 300m vertically.



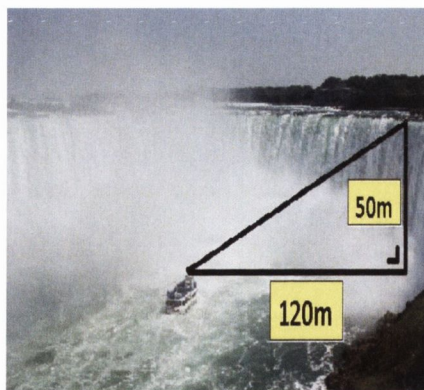
(i) If you were to give a mathematical name to the steep, straight line that the aeroplane has followed, what would that name be?

(ii) Using Pythagoras' Theorem, can you calculate how far the aeroplane has travelled in a straight line?

Question 2

The "Maid of the Mist" is a boat that brings tourists up to the Niagara Falls, on the border between Canada and America.

It goes up the river and stops 120m from the Falls, which are 50m in height.



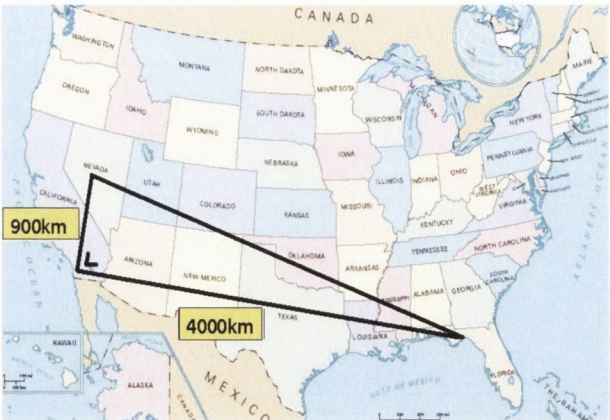
(i) If you were to estimate how far it is from the front of the boat to the top of the Falls, how far you think it might be?

do

(ii) Measure the distance from the front of the boat up to the top of the Falls using Pythagoras' Theorem. How far would it be?

Question 3

Rory Mc Elroy lives in Florida. He has a personal jet and pilot to fly him around America. He flies 4000km to play a golf tournament in California. After this, he flies 900km to meet his girlfriend (tennis player Caroline Wozniacki) in Las Vegas for a few days. He then flies home from Vegas to Florida.



(i) Measure the distance from the Las Vegas to Florida using Pythagoras’ Theorem. How far would it be?

Question 4

Susan is looking to buy an iPad. She goes to the Apple store and prices up the different options. She decides on the WIFI and mobile internet version. It is 24cm tall and 7cm wide. But Susan wants to know how the measurements diagonally from corner to corner.

- i) Can you identify the right angle for her?
- ii) Can you use Pythagoras’ Theorem to help her calculate the missing length?

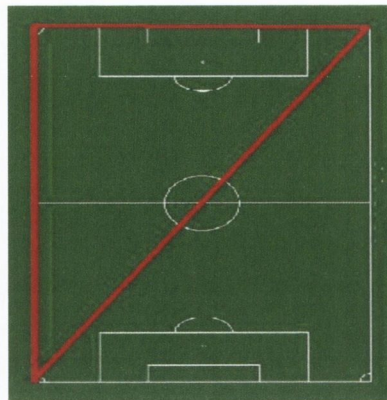


Question 5

James is doing some training drills by running triangular laps of the pitch. The pitch is 84m long and 13m wide.

Using your knowledge of Pythagoras' Theorem, can you:

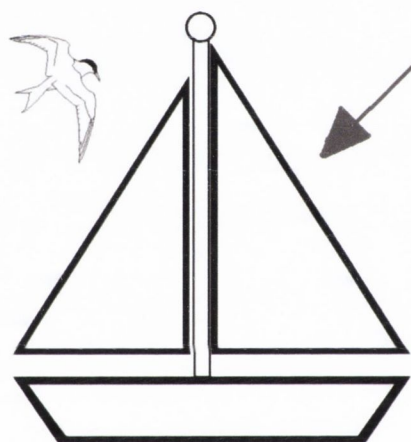
- (i) Identify the right angle in the triangle?
- (ii) Calculate the length he runs diagonally from one corner flag to the other corner flag?



Question 6

The larger sail on a boat is the most important for getting up a good speed. It is 3m wide across the bottom and 4m tall.

- (i) Mark in the length of the sides.
- (ii) Identify a right angle within the triangle of the sail.
- (iii) Can you calculate the length of the sail from the bottom corner to the top point?

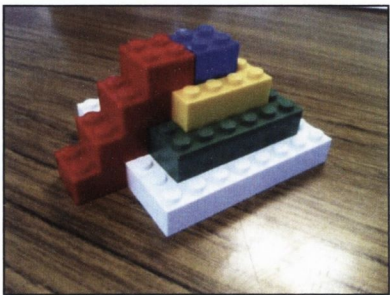


F2 6: Crannog Lesson 1 Worksheet

Homework Worksheet

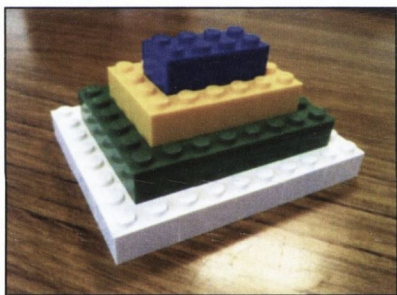
For each of the following situations, generate a table showing the number of square blocks used per layer.

1. A **square based pyramid** with steps of one block width along one side.



Number of layers	Number of bricks
1	
2	
3	
4	
5	
6	

2. A pyramid with **two blocks as the top layer** where the length and width of each layer increase by one block.

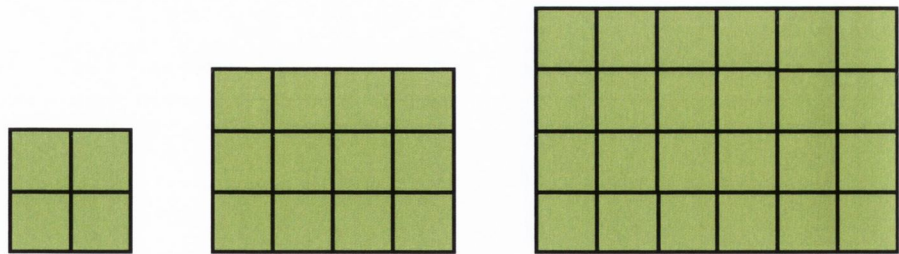


Number of layers	Number of bricks
1	
2	
3	
4	
5	
6	

3. The pyramid in question 2 with steps of one block width along one side.



4. A pyramid with the layers shown here.



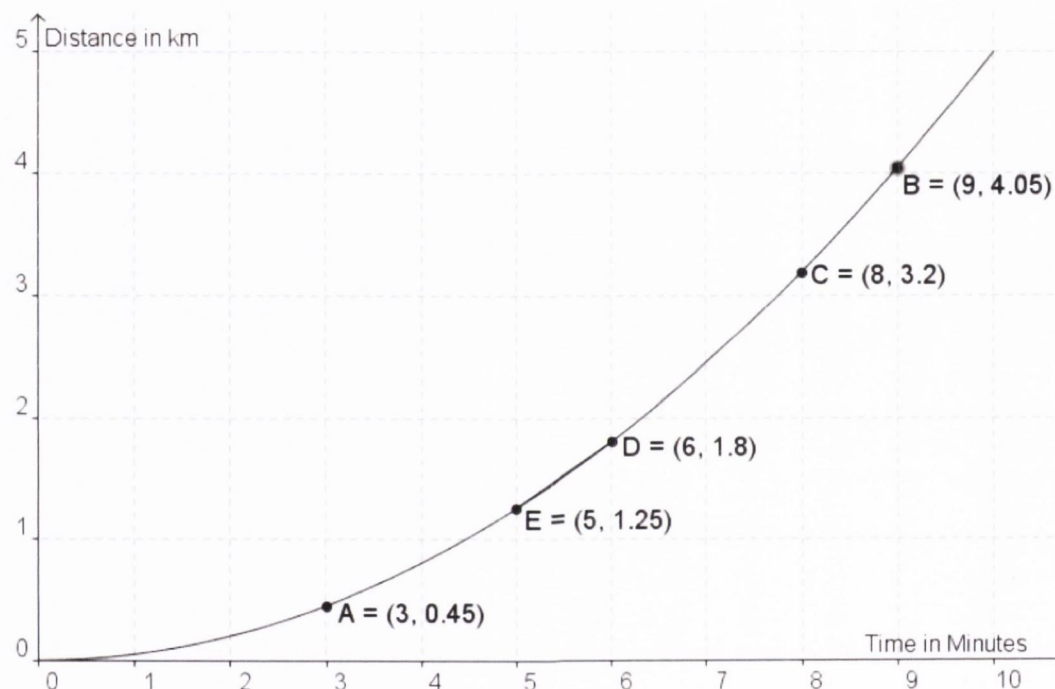
Can you find a general formula for any of the above?

F2 7: Crannog Lesson 3 Worksheet

Victoria Worksheet (modified from PMDT curriculum materials)

1. What is her speed?
2. Is her speed changing?

Below is a distance-time graph of the first ten minutes of a warm up cycle by Olympic Gold medallist Victoria Pendleton.



3. What is her speed at exactly 3 minutes?

APPENDIX F3 – Observation Notes

F3 1: Doone Lesson 1 Sample Observation Sheet

9

Observation & Reflection Sheet

What surprised me: the prior knowledge of squared term.
- all students were willing to give answers to $x=4$, $x=8$, 4^2 , 8^2 .

Wow!
- Sides all the same
- Students engaged.

I'm wondering: - about $1^2=1$
- X times X - good observation as opposed to $X \times X$
 $X \times X$

Pretty exciting:
- ways of drawing it - 5×5 are up 5 and across 5.
- X factor - relating to unknown talent/taker from maths

Not sure about this:
- The term squared - where have I heard it?
- symbol representing squared term.
- What a squarce number shaded is!

A little confusing: - $7+7$ or 7×7 for 7^2 ?
- What to do with worksheet
- using x^2 to find area.
- x^2 or x^3 ??

Other:
- 1 student lost AS
- Mixed ability evident
- great recall of Lesson
- positive atmosphere

Aolbhinn Ní Shúilleabháin School of Education Trinity College Dublin

Questions asked:

Thinking and
Can you use squared?
Can it be something square?
Spongebob
Is it always gonna be 2 up in the top corner?
Is there a way you write it differently?
Can we use it?
Our teacher told use to do it like x
~~2~~

F3 2: Crannog Lesson 1 Sample Observation Sheet

11/10/10 10:10

F.2007

Recording Students' Questions

Point in the lesson	Student Question	Significance
1. <u>INTRO</u>	You need to know whether it is square Is it all of the bottom, not just the outside? What no. of boxes are in next layer? NEED TO FIND OUT HOW MANY ARE AROUND THE EDGE What's the area of..... Is that every single block counted?... How do we know what the height is? The amount of boxes on the top is 1, then the next is 4 It's like a sequence We should use the the thing The second difference is 2! The next layer has 16 It's going 1x1, 2x2, 3x3, 4x4, 5x5, 6x6...	
-3. <u>DISCOVERY</u>		

F3 3: Crannog Lesson 2 Sample Observation Sheet

Recording Student Talk		
Point in the lesson	Student Question	Significance
ON TABLE TOP	x^2 $3x$ What would be side of the square be?	Factors created using diagram or whiteboard

$$x^2 + 7x + 6$$

- Get ideas out but don't
put the square in the top
left corner
After a few minutes without help
- square is moved to top left.
- pointed out to them
you can't break lines
- David give us a hint
- James - brings in another green
as he is thinking??
Relevant to now is apart from
4 and 3 and 3 and 4
combinations -

STUDENTS MAKE GOOD USE OF THE SHEETS LOOKING FORWARD
and BACK TO CHECK PREVIOUS EXAMPLE WHEN FILLING OUT TOP
AND SIDES OF THE RECTANGLE (FACTORS).

APPENDIX F4 – Student Work

F4 1: Doone Lesson 1 Student Work Sample

In the table below, the top line, x , lists a range of numbers from 1 to 10.

You must square each number in order to find x^2 and then fill this in beneath.

For example, where if $x = 5$, then $x^2 = 5^2$ which is $5 \times 5 = 25$.

x	1	2	3	4	5	6	7	8	9	10
x^2	1	4	9	16	25	36	49	64	81	100

Shade in the square numbers in the box below.

For example, $3^2 = 3 \times 3 = 9$. This has been shaded in.

1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48	49	50
51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70
71	72	73	74	75	76	77	78	79	80
81	82	83	84	85	86	87	88	89	90
91	92	93	94	95	96	97	98	99	100

Below is a table containing the lengths of different squares.

When you "square" the length of the side, this gives you the area. For example, $3^2 = 3 \times 3 = 9$.

Calculate the area of the remaining squares.

Side of the square	Area of square	=
1	1^2	1
2	2^2	4
3	3^2	9
4	4^2	16
5	5^2	25
6	6^2	36
7	7^2	49
8	8^2	64
9	9^2	81
10	10^2	100
11	11^2	121
12	12^2	144
16	16^2	256
23	23^2	529



F4 2: Doone Lesson 2 Student Work Sample



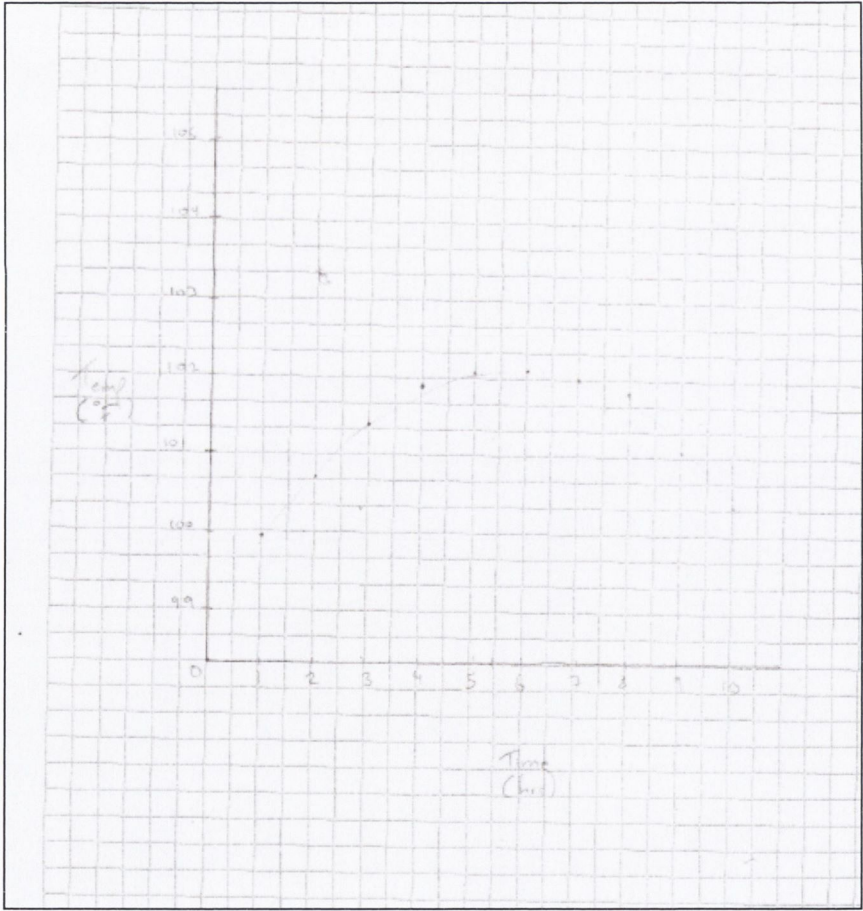
F4 3: Doone Lesson 3 Student Work Sample

L		H	
0		0	
1		20.1	
2		30.4	
3		30.9	
4		21.6	
5		2.5	
6			
7			
8			

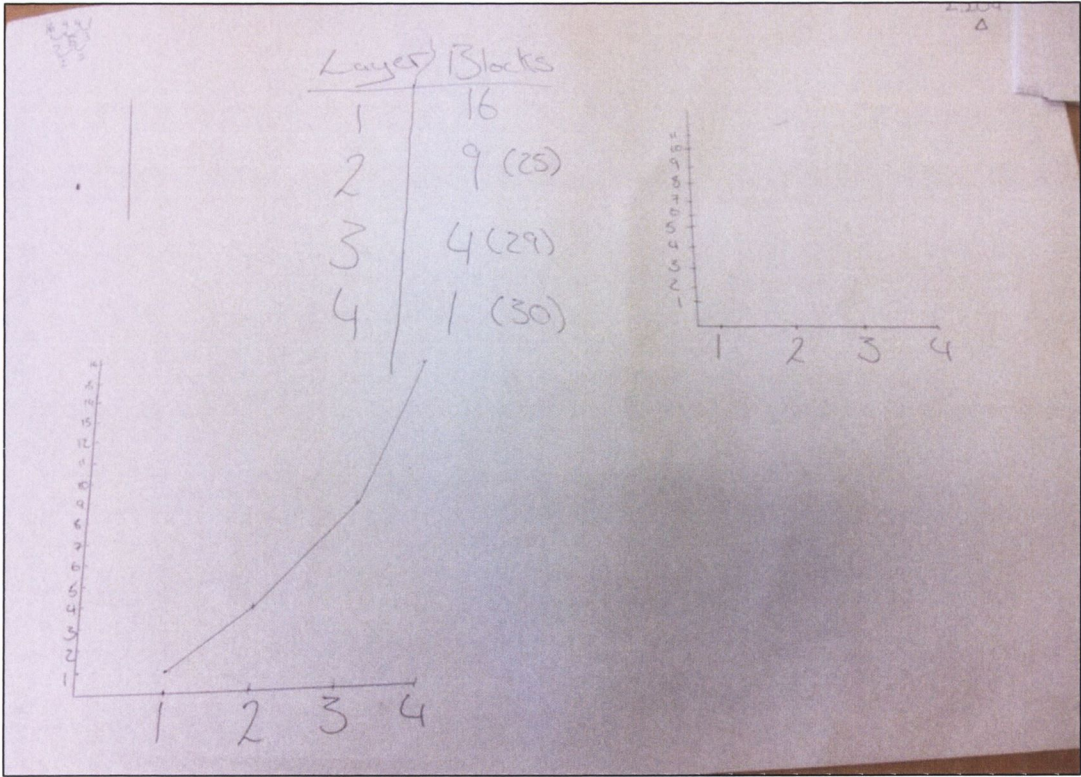
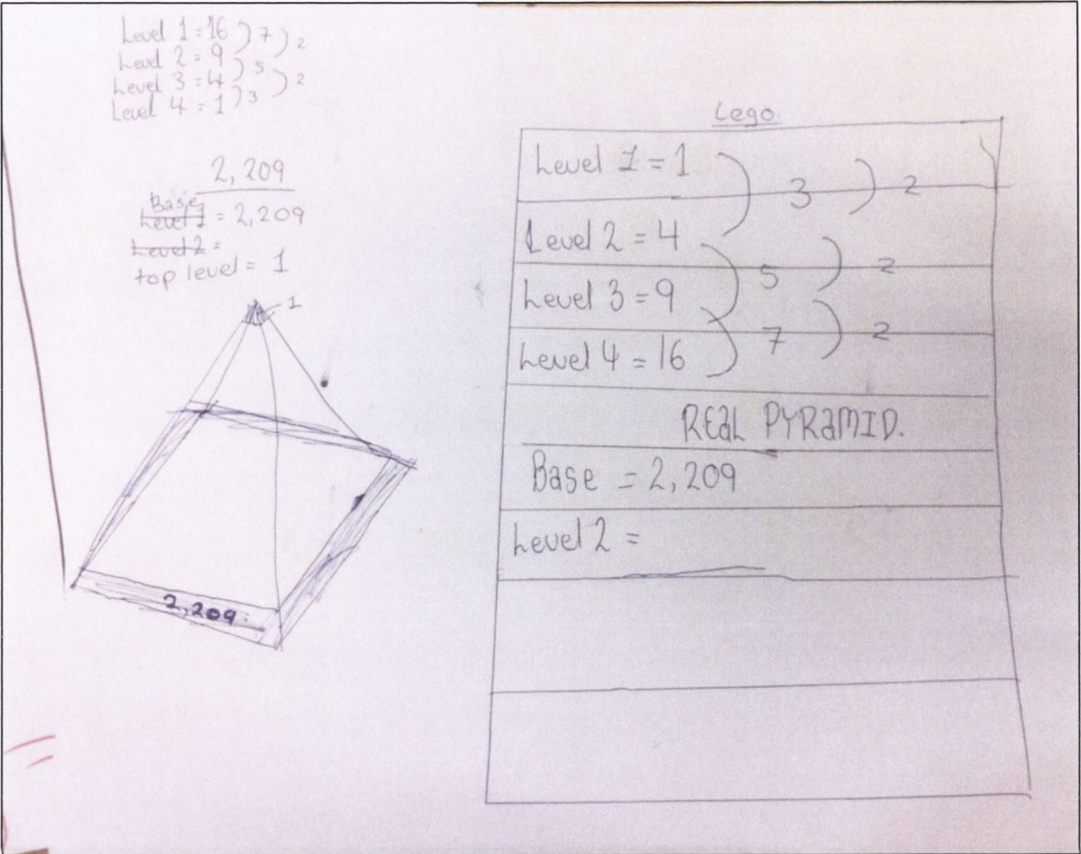
0.5K

Time	Temp
0	0
1	99.9
2	100.6
3	101.3
4	101.8
5	102.1
6	102.2
7	102.1
8	101.8
9	101.3
10	100.6
11	99.9
12	98.6

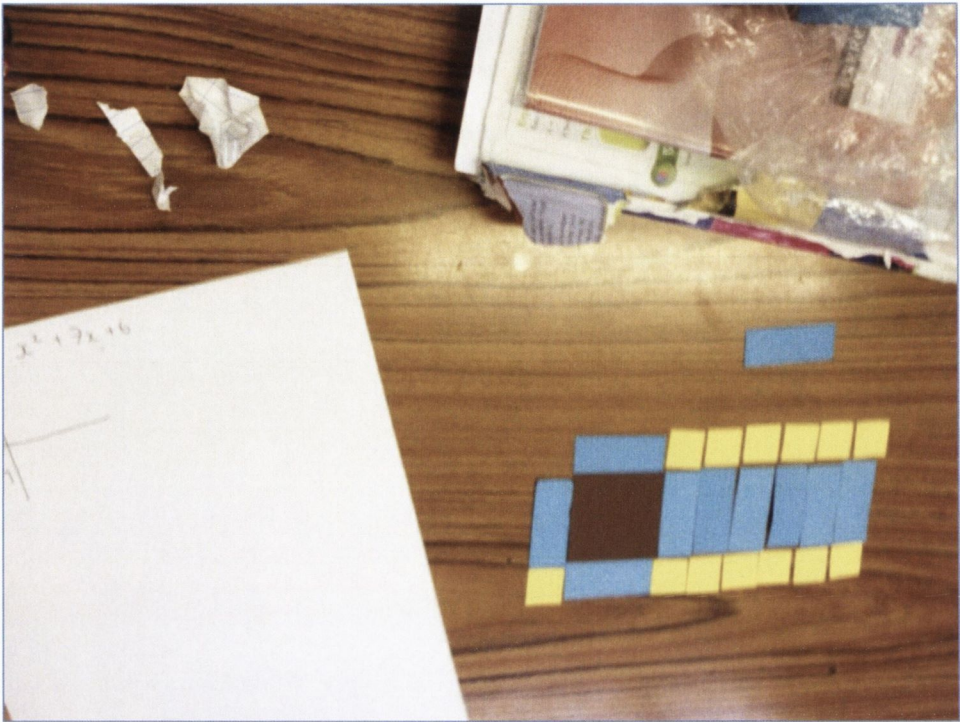
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	



F4 4: Crannog Lesson 1 Student Work Sample



F4 5: Crannog Lesson 2 Student Work Sample



APPENDIX G – Data Analysis

G1 Shallow Description of Teacher Meetings

G2 Notes on Teacher Meetings

G3 Refining Coding Themes

G4 Suggesting Initial Codes

G5 Coding in Phase 3 of Analysis

G6 Final Open Codes in Phase 4 of Analysis

APPENDIX G1 – Shallow Description of Teacher Meetings

G1 Sample 1: Doone

399

Transcript 8 **Doone 26/11/2012**

Cycle 2 **Meeting 2**

Date of Transcribing:

Length of audio file: 1:27

2: Looking through the articles and resources that I brought for the fractions. Teaching reading and reacting to them. Kate re-defines where this lesson is beginning at the end. Michael has found a nice piece explaining that people in general have no concept of what function they're using with fractions. Lisa agrees they could work this into a worksheet multiplying by one, less than, or greater than. Nora then highlights the order of the multiplication. Teachers really focusing on what should be the objective of the lesson. Real shift in their focus from the last one. Lisa brings the idea of measure into the lesson. Kate wants the 'show me boards'. Owen is now very nervous about the lesson, whether his students have understood what he has taught. Idea of number line, highlighted by Michael, has come directly from one of the research literature pieces brought in by the researcher..... Owen very worried about teaching it, really quiet in the meeting. Other teachers assuring him that the lesson ideas and plan are the utopia, not the reality. Also assuring him that not all students every 'get' everything. Agreement reached on what the lesson should look like and progress as.

LiteraturY: Colin Foster, 50 Mathematics Lessons, page 70 (Foster, 2008)

(Li, 2008) types of questions

(Petit, Laird, & Marsden, 2010) Lisa – they get fractions as pizzas!

(Coughlin, 2011) divisor role

(Son, 2012) visual examples fin discussion

(Cramer, Monson, Whitney, Leavitt, & Wyberg, 2010) – samples of types of student work

(Tsankova & Pjanic, 2009) – birthday cake example

(Johanning, 2011) – estimation on the number line

(Taber, 2007) – alice in wonderland questions referenced in the discussions

Log: never as relaxed. Not used to working together and don't have the same physical space. Nothing has been based really on problem solving. The use of "we" will be interesting to see if there's that development. They're getting more comfortable working together but they're nervous at the thought of teaching in front of each other. I'll have to stay calm and focused and relaxed at the next meeting.

G1 Sample 2: Crannog 18/10/2012

Date of Transcribing: 15th October, 2013

Date of EvenF: 18/10/2012

Length of audio file: 01:23:17

5: Trying to find the other patterns that students might find with the lego. All of the teachers attempting the activities together around the table. Fiona has come up with another extension problem for students that's exponential. Huge amount of thought going into the patterns and the sequence of homework questions scaffolding the problems. Interesting how a shared LEGO language developed in that meeting. Everyone knows what a four by two is etc. Teachers worried about what they need to observe in particular for this lesson and how they'll gauge if students know what they're doing.

ds. No work done outside of meetings not like
Facilitator to do extra work in organising
resources. Leads to cubic equations, visual, story all to the lesson.

APPENDIX G2 – Notes on Teacher Meetings

G2 Sample 1: Doone 27/2/2013

27/2/2013

7 ~~XXXX~~ referencing an in-service – she felt like one of the students!

24 interest in the other school.

28 I use this resource for my next meeting with Wesley – sharing resources across schools!

100 ~~XXXX~~ interested in the research*

108 will miss the sessions

127 ~~XXXX~~ and ~~XXXX~~ cooperating outside of the classroom now due to the lesson study!!!! NB Sharing resources :)

138 we've started. ~~XXXX~~

199 discussing syllabus content in relation to mock exam

249 hook for the lesson. ~~XXXX~~ annoyed it was poopooed last week?

278 deciding on the numbers for students

301 pre-empting students' responses and quoting students.

320 mindmap instead of template.

347 students will think they're consecutive numbers. Disagreeing with ~~XXXX~~ that they'll spot a pattern *

355 reflection from previous teaching this lesson

G2 Sample 2: Crannog 7/3/2013

7/3/13

537 Notes taking a lot of time

547 articulating the objective/purpose of the lesson.

560 filling out lesson plan taking a lot of time too.

601 need to re-do the workshop in order to find slope. Teachers spot this now
- pre-empting meeting the objective.

688 practical to the theoretical

720 pre-empting difficult task for students

848 want real life as opposed to animated for the students.

858 planning class discussion

878 teachers doing the question

880 facilitator suggesting textbook as a resource. Teachers never do.

892 the class activity

894 talk about slope

901 discussion when you come back into class.

921 modifying the activity again.

991 ~~planning~~ planning out the lesson 2 in the module.

1030 getting the students to think. they're puzzled.

1049 teachers now looking for notes.

APPENDIX G3 – Analysis Codes Phases 1 & 2

APPENDIX G3a - Phase 1 Codes

Curriculum Reform: Awareness of Curriculum

Attitude to Curriculum

Engagement with Curriculum

Implementing PM Curriculum approaches:

- Increased communication in the classroom
- Problem solving
- Decreased reliance on textbooks
- Student talk

Teacher Learning/Professional Development

Changing Practices in Classroom:

- Wait time
- Discovery learning
- Changing environment

Attitude to current Professional Development

Reflecting on Lessons

Development of the community

Teacher Confidence

Teacher Collegiality

Focus on students:

Focus on student thinking

Students talking about maths

Student engagement

Greater classroom interaction

Learning for understanding

APPENDIX G3b - Phase 2 Codes

Curriculum

- Awareness of new curriculum
- Attitude to new curriculum
- Engagement with the curriculum
- Reflecting on lessons/practice

Teacher learning

- Lesson planning
 - Content
 - Differentiation
 - Scaffolding
 - Asking questions of the others – pedagogy

New Approaches:

- Causing student's confusion/frustration for learning / Discovery learning
 - Using graphing/modelling as another form of solving
 - Building on resources and modelling/concrete resources
 - Different approach to teaching/learning a topic introduced to students / Teachers sharing new mathematical strategies
 - Teachers creating new questions
 - Utilising research articles / Researching a new method as a teaching tool.
 - Manipulating resources (as suggested by Manchester study, Hanley 2010) / Introducing new resources
 - Focus on language and on notation
-
- Implementing PM Curriculum approaches:
 - Increased communication in the classroom
 - Problem solving
 - Decreased reliance on textbooks
 - Observing students in class
 - Noting student misconceptions / Where students are having difficulty

- Reflecting on students' learning & Describing students reactions
 - Referencing student talk
- Reflection on own practice (Difficult to observe and not teach)
 - Observing other teachers' practices.
 - Following up the lesson – sequence of learning

Changed practice: Classroom environment - desks

Project Maths

1. To create a learning environment which engages students. Students participate in learning environments that are open to new ideas and gain confidence in expressing their mathematical ideas and considering those of others. (*Expressing Ideas*)
2. An approach to teaching and learning which gives prominence to learners able to develop their skills in communicating and working with others with teachers facilitating discussions. Students are encouraged to work together in groups to generate ideas, problem solve and evaluate methods. Learners communicate mathematics verbally and in written form. (*Social Aspect*)
 - Planning group work
 - Changing classroom layout
 - Whole Class discussion
 - Facilitating group work
 - Students presenting their work
3. A focus on learners understanding the concepts, building from the concrete to the abstract and from the informal to the formal. Fostering students' sense of creativity, they will be confident and able to apply their mathematical knowledge in a range of contexts (Jeffes et al., 2012) (*Relational Understanding*)
 - A focus on the 'why'
 - Scaffolding worksheet questions and homework questions.

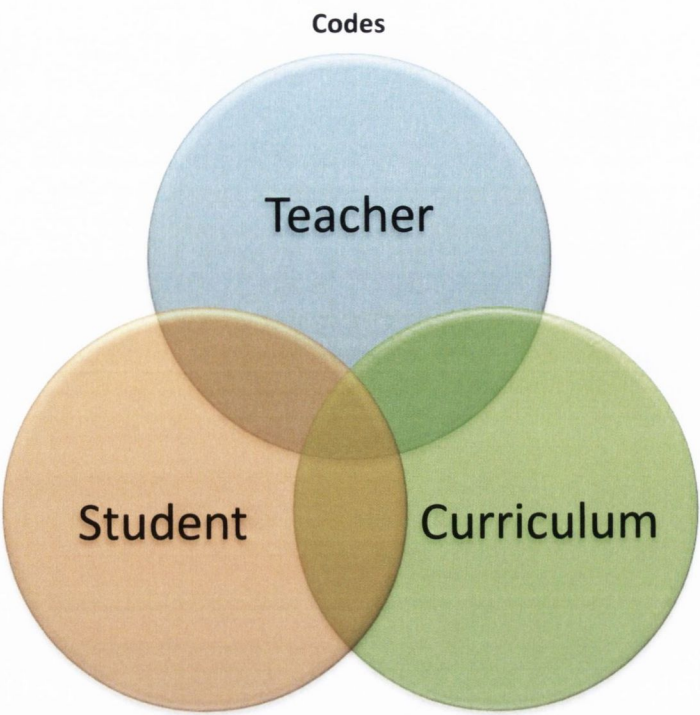
- Giving students time to process the topic (quadratics 1 post lesson)
4. Investigative, problem-focused approach to learning mathematics with emphasis on application in real-life settings and contexts where students become active participants in developing their mathematical knowledge and skills (Cosgrove, Perkins, Shiel, Fish, & McGuinness, 2012) (*Problem Solving*)
 - a. *Want the students to get stuck.*
 - b. Allow students time to construct and ask questions
 - c. Modelling a question
 5. Teachers are encouraged to use supplementary resources instead of a traditional over-reliance on textbooks as a curriculum source (Cosgrove et al., 2012) (*Textbooks as a resource*)
 - a. *Creating questions*
 - b. *Utilising new resources*
 - c. *Creating worksheets*

Teacher Confidence

Teacher Practice

- * changed due to observation
- * Teacher Collegiality
- * Focus on student thinking
 - * doing the activities
 - * what will students ask
 - * anticipating student responses
- * Attitude to current Professional Development

APPENDIX G4 –Initial Codes Phase 3



Teacher Lens

- PTRc Personal teaching reflection after conducting
- PTRo Personal teaching reflection after observing
- TRst Teacher reflection on student talk and questions
- TR Teacher as researcher in lesson study

Student Lens

- ST anticipating student talk
- SUp anticipating student understanding in planning
- SUm reflecting and interpreting student mathematical strategy
- SUr reflecting a student response
- PEM Pre-empting Mistakes/Answers

SCe	articulating common student errors
PK	Prior knowledge
SE	student engagement
SA	Student ability
IS	identifying students by name and particular circumstance

Curriculum Lens:

CA	Concrete to abstract sequence
CC	Contextualising content
Seq	Sequencing activities and lessons
WC	Planning whole class discussion
EncST	Encouraging student talk
L	A focus on language
GW	Planning/discussing group work
CE	Changing classroom environment
Fac	Teacher guiding students and student communication

RTB	Resource textbook
CR	Concrete resources developed or modified
RBW	Board Work
RL	Resource Literature

APPENDIX G5 – Coding in Phase 3 of Analysis

Code	Sub-code		Descriptor	Quotation
Question 1: How does this model of professional development encourage the teaching and learning approaches envisaged in Project Maths?				
Teacher perspective		PCK		
Teacher Reflection	<i>Personal Teaching Reflection</i>		Teacher reflecting on how they conducted the research lesson and what they learned	Judy “it was interesting like, in terms of I know that I would rush them along.....”
			Teacher reflecting on what they learned from observing the research lesson	
			Reflecting on students' questions	Kate “It was brilliant and I just looked down at the questions that were asked.....’is it always going to be two up in the top corner?’” p200[1]
Teacher as researcher	<i>Researcher lens</i>		Teacher viewing the lesson as a way of researching an aspect of mathematics teaching	Walter - "Which is the more interesting class to observe? p364

Doing Mathematics Activities	Evaluating mathematics questions and activities	KCS (evaluating examples)	Teachers doing activities in planning and evaluating them on merit of building student understanding	Doone cycle 4, doing and sequencing questions according to scaffolding learning.
Student perspective				
Student talk (planning)	<i>Teacher quoting student in planning</i>	KCS (interpret student talk)	Teachers speaking utilising student voice	24 as perimeter, research cycle 1.
Student mathematical thinking	<i>Student Understanding (anticipation and interpretation)</i>	KCS (anticipate student production)	Teacher referencing students' understanding of a topic	Kate "What does 2 over 7 mean.... They know what 2/7ths is...But do they know what 2 divided by 7 is? Why are they the same thing?"
		KCS (interpret student production)	Teacher deciphering why students did something incorrectly on something specific in class.	Kate "But we lose the division symbol.....and they're like "Well, it's not divided by anything, like""That is divided by". I was horrified" p345

	<i>Reflecting on student responses</i>		Teacher reflecting on what surprised them about students during observation	Nora “And Lisa, I’m sorry, I have to tell you another very interesting observation. The little fella beside me, he was squaring them up to five and that was grand, but when he got to six, he started to multiply……for perimeter!……” p197[1]
	<i>Pre-empting student mistake/answer/difficulty</i>	KCS (anticipating student misconception)	Teacher predicting what might confuse a student.	Kate “They’re like ‘but it’s not the same thing’ Oh no!” p347[1]
	<i>Common student errors</i>	KCS (anticipating students’ common computation or conceptual errors)		<i>Changing 2^2 to 3^2 in cycle 1 of Doone - Nora</i>
Prior Knowledge	<i>Identifying student prior knowledge</i>		Teacher articulating what they expect the student to already know.	Kate “They’ll know that from primary school” p83

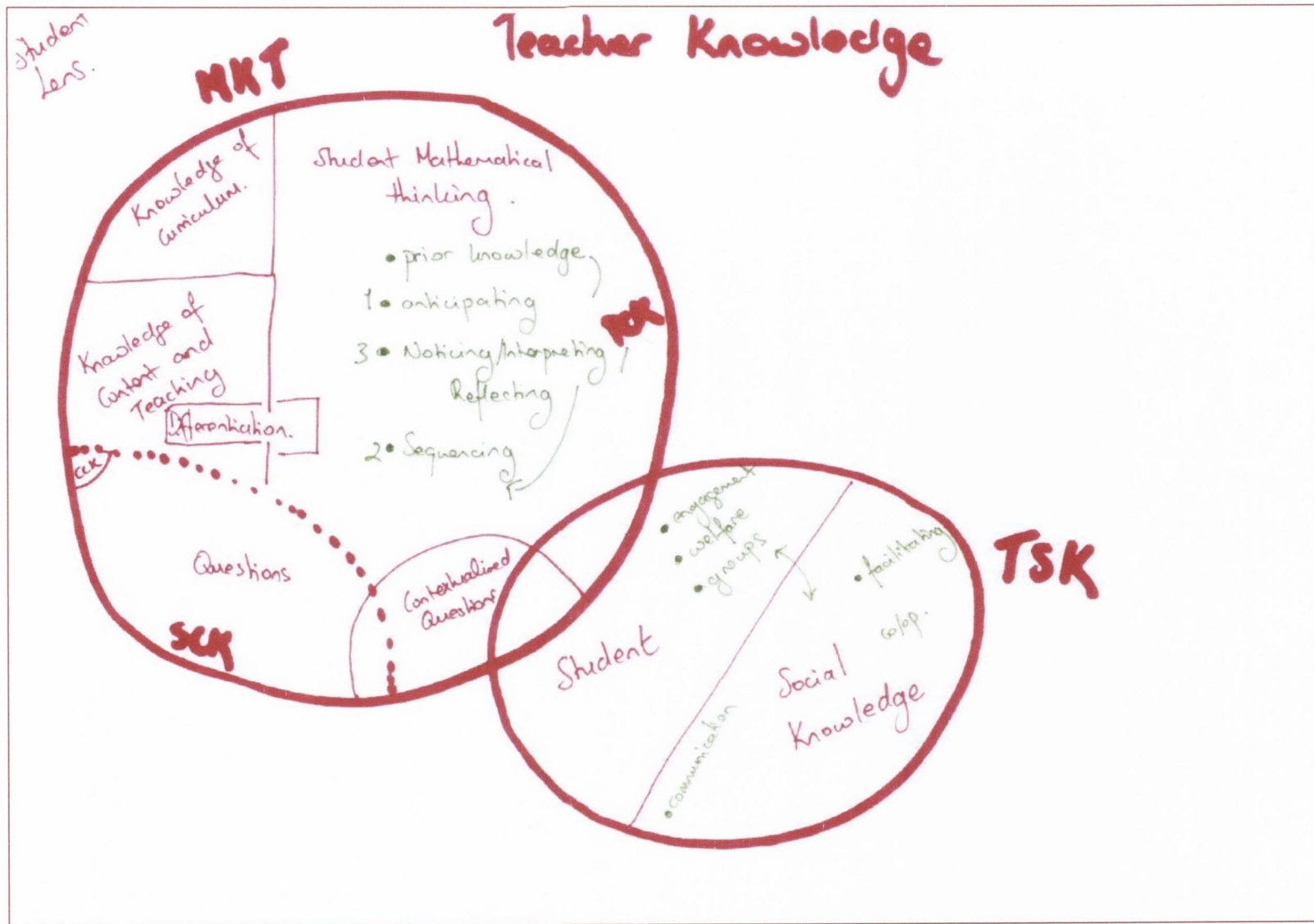
Student engagement		KCS (motivating students)	Teacher referencing how student will /were engage(d) with a particular activity	Walter "I think it was more exciting for them than I thought it would be" p248
Student ability			Teacher reflecting on how 'able' a student may be in answering a question.....	Owen "I brought the weaker ones up and they just, it's like, they don't get it"
Identifying students			Teacher identifying particular student by name	Lisa "There's the guy who was colouring in the whole square at the start, look it, in blue, Stephen. Yeah, he'd be, he'd be weak enough as well"
Curriculum lens (teaching approach)				
Concrete to Abstract		KCS (sequencing content)	Teacher articulating going from concrete to abstract concept	Nora "It's very easy to see on a diagram that $\frac{1}{3}^{\text{rd}}$ of 2 is exactly the same as $\frac{2}{3}^{\text{rds}}$ " p344

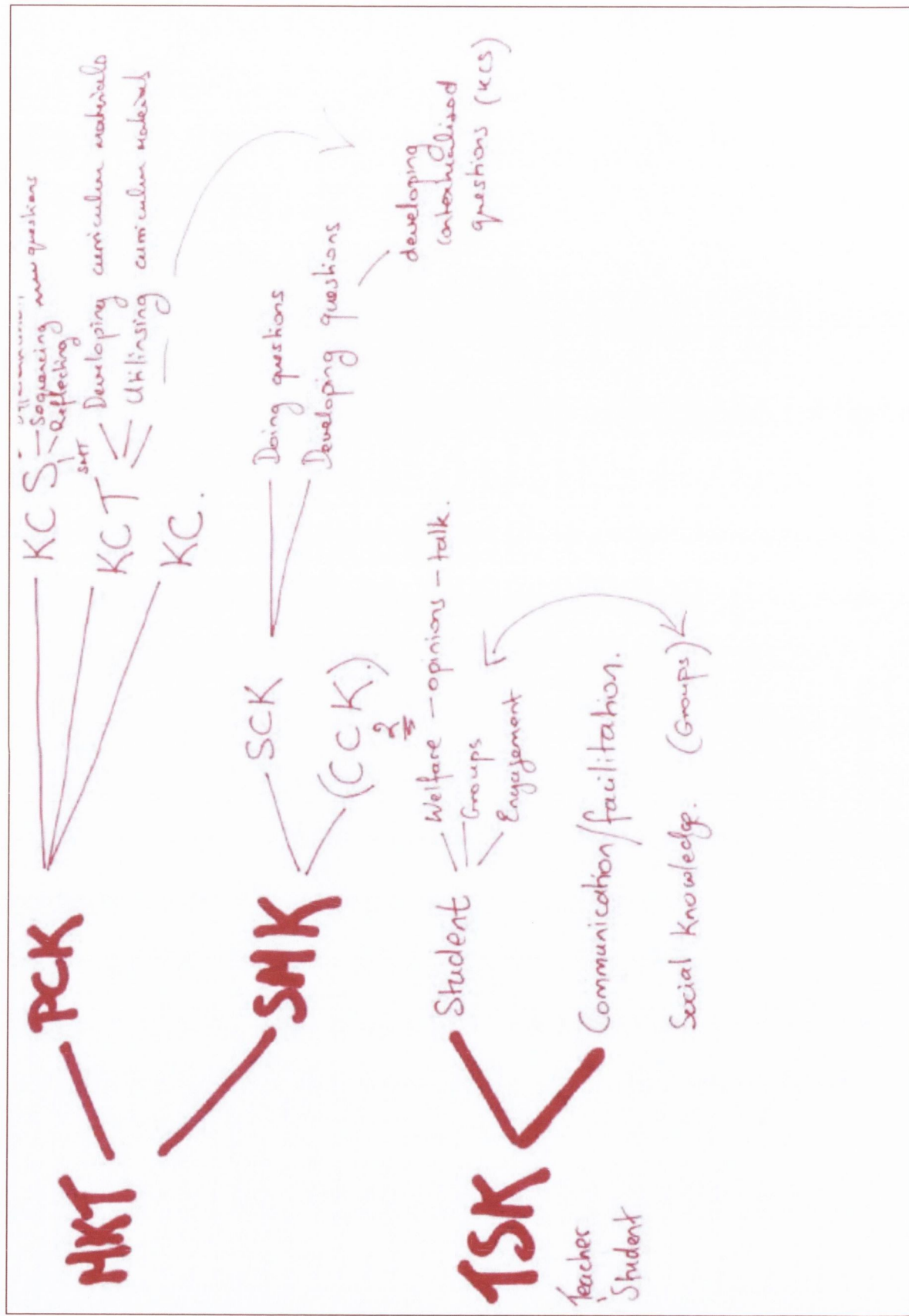
Contextualising content			KCS (interesting and motivating for students)	Teacher providing context relevant to student for a question	<i>Michael: "And I've said linked to reality, and maybe you are right, like. I think the way you put it, it's not always about reality, it's about contextualisation.....It doesn't have to be 'the' reason that makes it amazing, it's just, it's a reason that makes them comfortable enough to do it". P46</i>
	Sequencing activities		KCS (sequencing content)	Detailing what activities students will engage in what order	
	Sequencing lessons		KCS (sequencing content)	Detailing what will come before and after in terms of building students' knowledge	<i>Nora "Yeah, I just feel strongly. I'd just like to know each, what was coming after it, you know, what to emphasise or how much they will hear square root" p261</i>
Communication within class	Whole class			Teacher encouraging discussion and communication as a whole class	<i>Fiona "this is what they need to do, to speak it and say it"</i>

	<i>Encouraging Student questions and Student talk</i>		Teacher encouraging discussion and communication of students with each other	Fiona "Yeah, I like them, it's the questioning that's the key thing I think to....'cause getting them, 'cause giving them all the information of even quite a bit of information..." p145
	<i>A focus on language</i>		Teachers focusing on the specific language used in class	Walter "the word 'model' is important" p153 and Doone p349[1]
			Critique or wariness of group work	Owen "So, my objective for the lesson is to tolerate group work" p386[1]
			Altering classroom environment for group work	Lisa changing desks in her room
Facilitator of learning			Teacher guiding student learning but not directing it, Not 'telling' the student	Fiona "Okay, still our biggest challenge is, how do we generalise, how do we get them to actually think of doing that" p159
			Choosing students to present to the class	Dave "I'll need to pick one group that got it the way we wanted it..." p160
Curriculum Lens				

Classroom Resources	<i>Textbook</i>		Referencing the textbook as a teaching/learning resource	Brian "...because that's the nature of a lot of schools, you just go through the book, and it's Chapter 5"
	<i>Board</i>		White board used during lesson	Lisa post lesson 1
Curriculum materials	<i>Modification of or developing classroom resources</i>		Teachers modifying curriculum materials, classroom resources or ideas from resource literature for use within their own classroom. Including worksheets etc.	Lisa "...Now, can I just say there isn't the, there's a very good Project Maths 'Introduction to Fractions'" p360[1]
External materials	<i>Research literature</i>		External research literature: teacher magazines, education literature	Owen "I liked this example here with cake.....like the diagram here shows it well, I think" p409[1]

APPENDIX G6 – Developing a Framework for Phase 4 of Analysis





APPENDIX G7 – Final Open Codes in Phase 4 of Analysis

Code	Sub-code	Descriptor	Quotation
1) How is teacher knowledge, particularly pedagogical content knowledge, enhanced through lesson study?			
Knowledge of Content and Students			
Prior Knowledge	<i>Identifying student prior knowledge</i>	Teacher articulating what they expect the student to already know.	Kate “They’ll know that from primary school” p83
	<i>Incorporating students’ prior knowledge</i>	Teachers incorporating what prior knowledge they expect of students into the research lesson plan.	Stephen <i>They do it in first year actually. We do it with them, it comes up</i> Fiona <i>So we could just give them a number, a simple one, one like that and then go onto $n+2$ by $n+3$ or something...</i> Walter <i>And then do multiplication with algebra tiles?</i> Fiona <i>Yeah, just to show that these are the factors.</i>
Anticipating student mathematical thinking	<i>Pre-empting student mathematical thinking</i>	Teacher anticipating what student might think about and how they might understand a mathematical idea.	Michael <i>You’re going to be saying to them...”Why is the room square?” And they’re going to say, “well, because the length and the width are the same thing.”</i>
	<i>Anticipating students’ mathematical response: strategy</i>	Teacher predicting how a student might respond in terms of their strategies attempting an activity.	Stephen <i>Because some would look... if it is 1, 4, 9 some will look at it as being squared; some will look at it as being...</i> Fiona <i>Add 3 and 5...</i>

	<i>Highlighting Common Conceptions</i>	<i>Teachers highlighting in their planning what mistakes or interpretations are commonly made by students.</i>	Nora Can I just suggest that rather than 4 there Lisa Yeah Nora I prefer to go for 9 because an awful lot of people half things and double things.
Noticing student mathematical thinking	<i>Noticing students' mathematical strategies</i>	Teacher commenting on how student reflected on an activity/answer	Kate "There was the guy who got the mistake first, but then he corrected himself..." p291[1]
	<i>Interpreting student mathematical response</i>	Teacher interpreting/making sense of why students did responded in a specific way	Nora "And Lisa, I'm sorry, I have to tell you another very interesting observation. The little fella beside me, he was squaring them up to five and that was grand, but when he got to six, he started to multiply.....for perimeter!....." p292[1]
	<i>Attending to student talk</i>	Observing and reflecting on students' questions in the research lesson	Kate "It was brilliant and I just looked down at the questions that were asked.....'is it always going to be two up in the top corner?'" p200[1]
		Observing and reflecting on student talk within the research lesson	Lisa p463[1]
Knowledge of Content and Teaching			
Sequencing mathematical content	<i>Sequencing activities within research lesson</i>	Detailing what activities students will engage in what order	

	<i>Sequencing lessons</i>	Detailing what will come before and after in terms of building students' knowledge	<i>Nora "Yeah, I just feel strongly. I'd just like to know each, what was coming after it, you know, what to emphasise or how much they will hear square root" p261</i>
Developing contextualising content	<i>Contextualising mathematical content</i>	Teacher providing context relevant to student for a question	<i>Brian: "And I've said linked to reality, and maybe you are right, like. I think the way you put it, it's not always about reality, it's about contextualisation.....It doesn't have to be 'the' reason that makes it amazing, it's just, it's a reason that makes them comfortable enough to do it". P46</i>
	<i>Developing questions/activities</i>	Teachers develop specific activities relevant to the research lesson objective and relevant to students.	p524[1] conducting teacher should be familiar with the content.
Evaluating mathematics questions	<i>Evaluating mathematical activity</i>	Teachers engaging in problem solving themselves/answering questions	p26[2] fly question
Teacher Knowledge of Student			
Student engagement	<i>Engagement of specific class groups and specific students</i>	Teacher referencing how particular student will /were engage(d) with a particular activity	Walter "I think it was more exciting for them than I thought it would be" p248

	<i>Games within class</i>	Teachers including games within class in order to further engage students.	p471[1] Last Man Standing
Student ability		Teacher reflecting on how 'able' a student may be in answering a question.....	Owen "I brought the weaker ones up and they just, it's like, they don't get it"
Identifying students		Teacher identifying particular student by name	Lisa "There's the guy who was colouring in the whole square at the start, look it, in blue, Stephen. Yeah, he'd be, he'd be weak enough as well"
	<i>Differentiating for students</i>	Teachers differentiate activities for students according to their perceived ability	p561[1] Owen "I'll give this to my strongest group"
	<i>Modifying content</i>	Changing curriculum content according to specific class/student ability	"do you think I would be better to start them off with just common factors and give them an expression and just get them to do that maybe?" p361 crannog
Communication within class	<i>Whole class</i>	Teacher encouraging discussion and communication as a whole class	Fiona "this is what they need to do, to speak it and say it"
	<i>Students communicating understanding</i>	Students encouraged to articulate 'why' something is happening	p467[1]
	<i>Student/Student talk</i>	Teacher encouraging discussion and communication of students in class groups with each other	Fiona "It worked. Those guys over there I was watching, they really helped each other. They hugely helped each other, they were listening to each other"

	<i>Students presenting their work</i>	Specific students explicitly encouraged to present their work to their colleagues as a whole class	Dave "I'll need to pick one group that got it the way we wanted it..." p160
	<i>A focus on language</i>	Teachers focusing on the specific language used in class dependent on student understanding	Walter "the word 'model' is important" p153 and Doone p349[1]
	<i>Changing classroom environment</i>	Altering classroom environment for group work	Lisa changing desks in her room p477[1]
	<i>Facilitating group work</i>	how to' facilitate group work, choosing groups etc/ giving roles / number of students.	p478 & 479[1] Kate "you might ask one or two...."

APPENDIX G8 Tallying Phase 4 Codes

Cycle 2

Coding Table		2a	2b	2c	2d	2e
KCS						
Identify and incorporate prior knowledge	Identifying PK					
	Incorporating PK					
Anticipate students responses	Mathematical Strategies					
	Mathematical Thinking					
Highlighting common conceptions						
Noticing Students' thinking	Interpreting mathematical strategies					
	Attending to student talk					
KCT						
Sequencing learning trajectories	Sequencing content within research lesson					
	Sequencing content over series of lessons					
Developing contextualised content						
Evaluating mathematical activities						
TKS						
Student engagement	Related to research lesson					
	Referencing particular class or student					
Group work dynamics						
Interpreting student interactions						

CSL

