Melbourne Graduate School of Education

Adults Learning Mathematics: Transcending Boundaries and Barriers in an Uncertain World

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July 2018

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Presentation Outline

In this presentation I will:

- address the possible interests that adults might have in learning mathematics in a fractured and fragmented world with constantly changing horizons in terms of politics, economics, technology, the environment, etc.
- discuss different aspects of mathematics and numeracy in relation to democracy and work
- draw on Bernstein's theories to stress the importance of understanding its underlying structures and relationships, in order to support numeracy curriculum, teaching, & assessment

Outline [2]

- critique the use of outcomes-based frameworks
- use music theory and performance to offer some illustrations
- draw some conclusions and implications from the above
- emphasise the importance of keeping adult mathematics and numeracy practitioners and researchers professionally informed through having access to high quality research related to their interests, such as ALM's own journal.

My focus will be on linking people, practices and research

What are Adults' Interests in Learning Mathematics? [1]
PAST: Unfinished Business

... arising from restricted access to mathematics education due to:

socio-economic reasons

- relative poverty in their formative years leading to missing school, changing schools frequently, leaving school early ...
- social & cultural traditions & expectations [especially women & girls]
- being part of a social or cultural minority group
- family immigration choices
- unexpected pregnancy in school years
- ...

What are Adults' Interests in Learning Mathematics? [1] PAST: Unfinished Business ctd.

- **political views**
  - of individual worth of students vs. political expediency in decision making [at all levels of education]
  - outdated conservative beliefs in education [curriculum, pedagogy, assessment]
  - preference for funding favoured social classes/cultures of voters
- **acts of human aggression & destruction**
  - war, ethnic cleansing, forced relocations, ... environmental disasters
  - individual teachers' negative discrimination, mental & physical abuse [racial abuse, intentional bullying, etc.]

What are Adults' Interests in Learning Mathematics? [2] PRESENT: More contemporary reasons

Curiosity:

- the **joy** of wanting to learn more mathematics [techniques, big ideas, history, etc.] for its own sake and finding it **making sense!!!**
- **Helping others:**
- friends & family members [e.g., children at school, partner's work, social or political groups, ...]

Compulsory requirement:

- condition of receiving government or other benefits
- preparing for further study or employment: entry test or hurdle requirement *

PRESENT: More contemporary reasons ctd.

Finding a new direction, often after significant life change:

- relationship breakup, children all left school/home, release from carer's duties, ...
- realising & attempting to overcome limited options in work/life
- needing to keep up with technology, especially new mathematical & learning technologies
- [re] learning mathematics in English [or other language]
- seeking alternative, meaningful & respectful adult teaching approaches
- seeking personal enrichment & new friendships

Contemporary Issues: GLOBALISATION

The phenomenon of globalisation has been characterised as a series of inter-related flows including knowledge, capital, jobs, people and cultures.

It is also associated with **increasingly rapid developments in ICTs, along with transport — facilitating cultural and economic exchange.**

One consequence of globalisation is that the historical model of full-time education followed by full-time work until a dignified retirement no longer applies to the vast majority of people.

Contemporary Issues: GLOBALISATION ctd

The likelihood is that there will be

- **several changes of jobs and even occupations, in different geographical locations**
- **periods of unemployment or under-employment**
- **casualised / contract labour or relatively more secure employment**

Contemporary Issues: The 4th Industrial Revolution [1]

- The **1st Industrial Revolution** used **water and steam power** to mechanize production.
- The **2nd** used **electric power** to create mass production.
- The **3rd** used **electronics and information technology** to automate production.
- The **4th Industrial Revolution, builds on the 3rd, the digital revolution** that has been occurring since the middle of the last century.
- It will bring **advanced robotics and autonomous transport, artificial intelligence and machine learning**, advanced materials, biotechnology, etc. (Gray, 2016)

Contemporary Issues: The 4th Industrial Revolution [2]

Automation and the technologically mediated global movement of people, knowledge, and capital, is profoundly changing work and working lives.

The demand for highly skilled workers has increased while the demand for workers with less education and lower skills has decreased.

By 2020

- **35% of skills that are considered important in today's workforce will have changed.**

Some jobs will disappear, others will grow and jobs that don't even exist today will become commonplace.

Contemporary Issues: The 4th Industrial Revolution [3]

People working in sales and manufacturing will need new skills, such as technological literacy. Workers will have to become more creative.

By 2020 the top three skills needed by workers will be:

- **Complex problem solving**
- **Critical thinking**
- **Creativity**

***What does this mean for ALM? For us as teachers in vocational and further education? For us as researchers? For our students in this changing world?**

What is Mathematics? [1]
A cognitive perspective

Mathematical thinking develops through three worlds of mathematics:

- the ***practical mathematics*** of shape and number, with experiences in shape, space, and arithmetic (embodied operations);
- ***theoretical mathematics*** with a focus on properties, leading to Euclidean proof and algebra, and definitions based on known objects and operations; &
- ***formal mathematics***, working with properties proved from given axioms and definitions, and formal objects based on formal definitions.

Each world is interlinked with the others and valuable in its own right.

(David Tall, 2013)

What is Mathematics? [2]
A sociocultural perspective

Anna Sfard (2017), in her conceptualisation of **mathematics "as a certain well-defined form of communication,"** asserts that:

"to think mathematically means communicating — with others or with oneself" — in the special way generally endorsed by the mathematical community.

What is Mathematics? [3]
A philosophical perspective

The duality of mathematics as a means and a system:

Mathematics provides a *means* for individuals to explain and control complex situations of the natural and of the artificial environment and to communicate about those situations.

Mathematics is also a *system* of concepts, algorithms and rules, *embodied in us*, in our thinking and doing; we are subject to this system, it determines parts of our identity. This system runs from everyday quantifications to elaborated patterns of natural phenomena to complex mechanisms of the modern economy.

(Roland Fischer, 1993)

Democracy and Mathematics Education [1]

Bernstein (2000) advocates **three pedagogic rights** which enable democracy to function: enhancement, inclusion, and participation.

- At an ***individual*** level, the **right to enhancement** is the right to the means of critical understanding and to new possibilities and a condition for ***confidence***
- At the ***social*** level, the **right to be included**, socially, intellectually, culturally, and personally, is a condition for ***communitas***
- At the ***political*** level, the **right to participate** must be about practice which has outcomes; it is the condition for ***civic practice*** or **discourse**

Democracy and Mathematics Education [2]

In formal mathematical pedagogic situations:

- **arbitrary selections are made from the discipline of mathematics** which provide different forms of consciousness to different social groups, with
- **differential access to 'unthinkable' knowledge** in the possibility of new knowledge creation **[e.g., curiosity, creativity, innovation]**
- as distinct from **'thinkable' knowledge** which takes the form of **official knowledge [e.g., rule following].** (Bernstein, 2000)

*

Doing Mathematics at Work [paid & unpaid] [1]
[FitzSimons & Boistrup, 2017]

In society & across a wide range of industries and occupations people are required to **use, develop, and communicate mathematical ideas and techniques in a diversity of ways with others** who have differing expertise, experience, and interests, including in mathematics itself.

Problems requiring mathematical reasoning and calculations are usually

- **embedded in physical and/or intellectual tasks, rich in context,**
- **with a range of constraints that are oftentimes mutually contradictory,**
- **but always need a workable answer & within a short space of time.**

Doing Mathematics at Work [paid & unpaid] [2]

- In many jobs **problem solving** is an expected and routine part of the day's work: Every new request or order requires an **original or customised solution** within given parameters.
- Whether **using mathematics explicitly or implicitly** in these processes, no matter how trivial, the worker must also take into account all of the **relevant contextual knowledge** in their **decision making**.
- Crucially**, the kinds and complexity of problems that occur at work contrast sharply with those found in formal mathematics education texts and assessment tasks**.

Doing Mathematics at Work [paid & unpaid] [3]

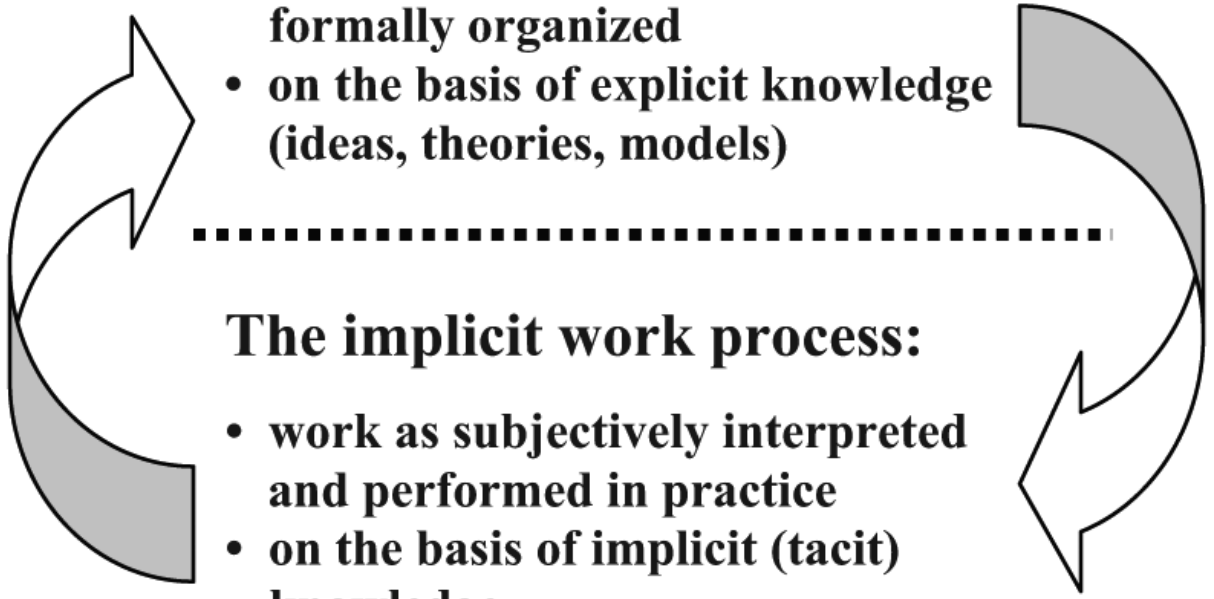
- **Doing mathematics at school and doing mathematics at work are two very different activities, epistemologically and socioculturally.**

(FitzSimons, 2013)

- **Most mathematics teachers and students who visit work sites, and even workers themselves, find it very difficult to recognise any activity they are able to judge as being mathematical beyond number and measurement.** (Williams & Wake, 2007; Nicol 2002)

Practice-based innovation as a cyclical process of learning (Ellström, 2010)

The logic of development:
Variation/ improvisation
Developmental learning
Transformation



The explicit work process:

- **work as officially prescribed and formally organized**
- **on the basis of explicit knowledge (ideas, theories, models)**

The implicit work process:

- **work as subjectively interpreted and performed in practice**
- **on the basis of implicit (tacit) knowledge**
- **variation and improvisation in interpretation and performance**

The logic of production:
Standardization
Implementation
Adaptive learning
Reproduction

Learning at Work [1]
Informal learning

Many people do not consciously recognise that learning takes place at work:

- **learning via non-formal education** may occur via specific activities
- **informal learning at work** is an ongoing process that **encompasses personal, social, and cultural knowledges and skills**

Importantly, there is **an ongoing need for communication of an educative kind** between stakeholders where information, often **mathematical**, is sought and shared.

Pedagogic relations play an important role!

Learning at Work [2]
Pedagogic relations

Mathematics-related knowledge is, or can be, transformed from the academic discipline of mathematics into the specific context of the problem at hand.

There are *pedagogic relations* at work in communications:

- between co-workers
- between managers or team leaders & workers
- between client & supplier of services or goods, etc.

Workplace mathematics is not often formally recognised as a pedagogic activity, unlike school mathematics.

Learning at Work [3]
Recontextualisation

***Recontextualisation* offers a powerful means of "bridging the gap" between theoretical and experiential knowledge.**

- **Students in formal education need to learn these skills,** for themselves, *and* to communicate effectively with other stakeholders at work, etc.
- ***Recontextualisation* combines the disciplinary knowledge of mathematics with contextual knowledge of the specific situation, including personal & sociocultural knowledges, in the form of communication.**

This is what all teachers do!

In Summary

Doing mathematics at work [& elsewhere] involves:

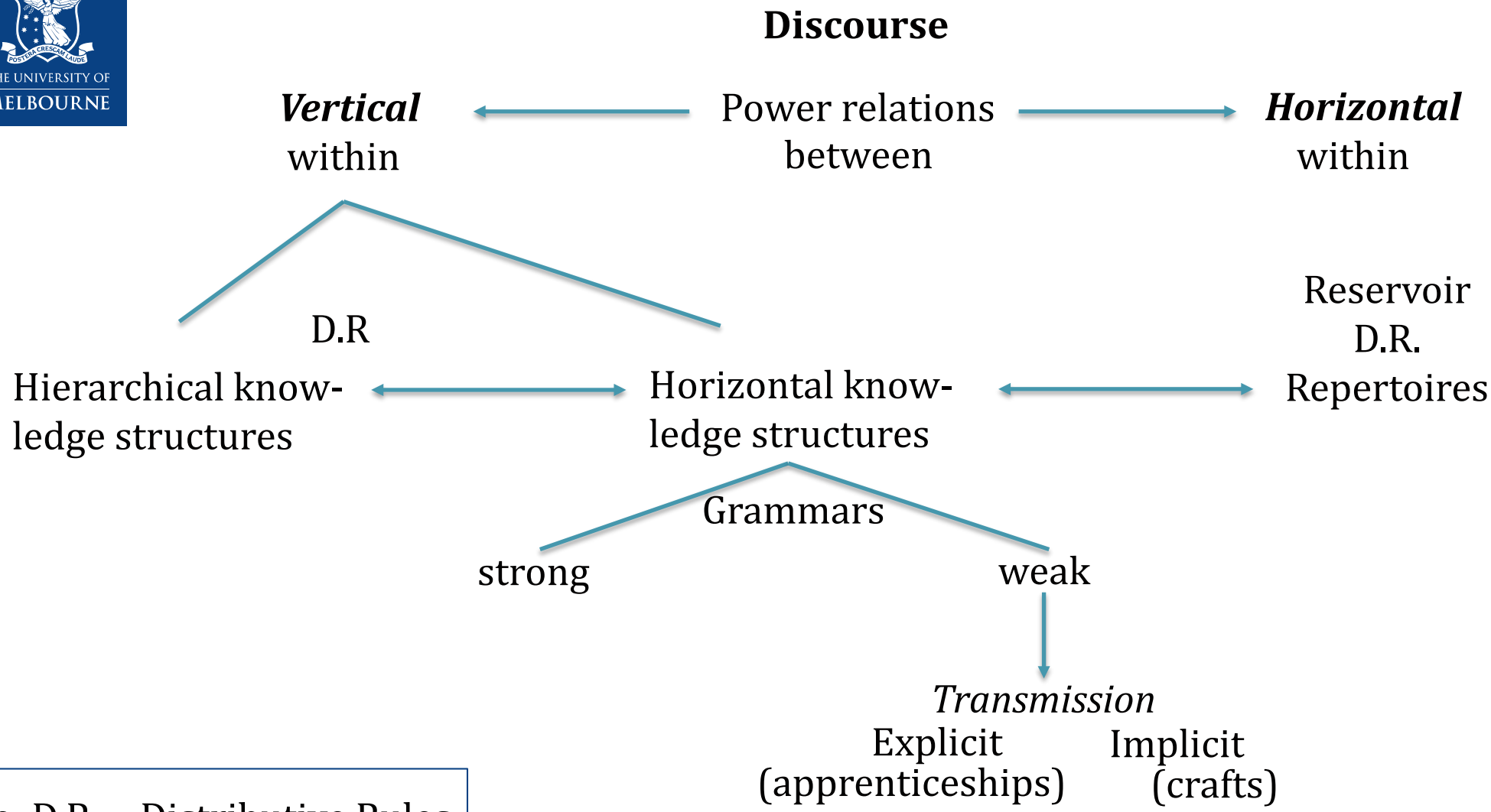
Learning at work &

Communicating *at work* (through symbols, diagrams, speech, gestures, etc.)

via ***Recontextualisation***

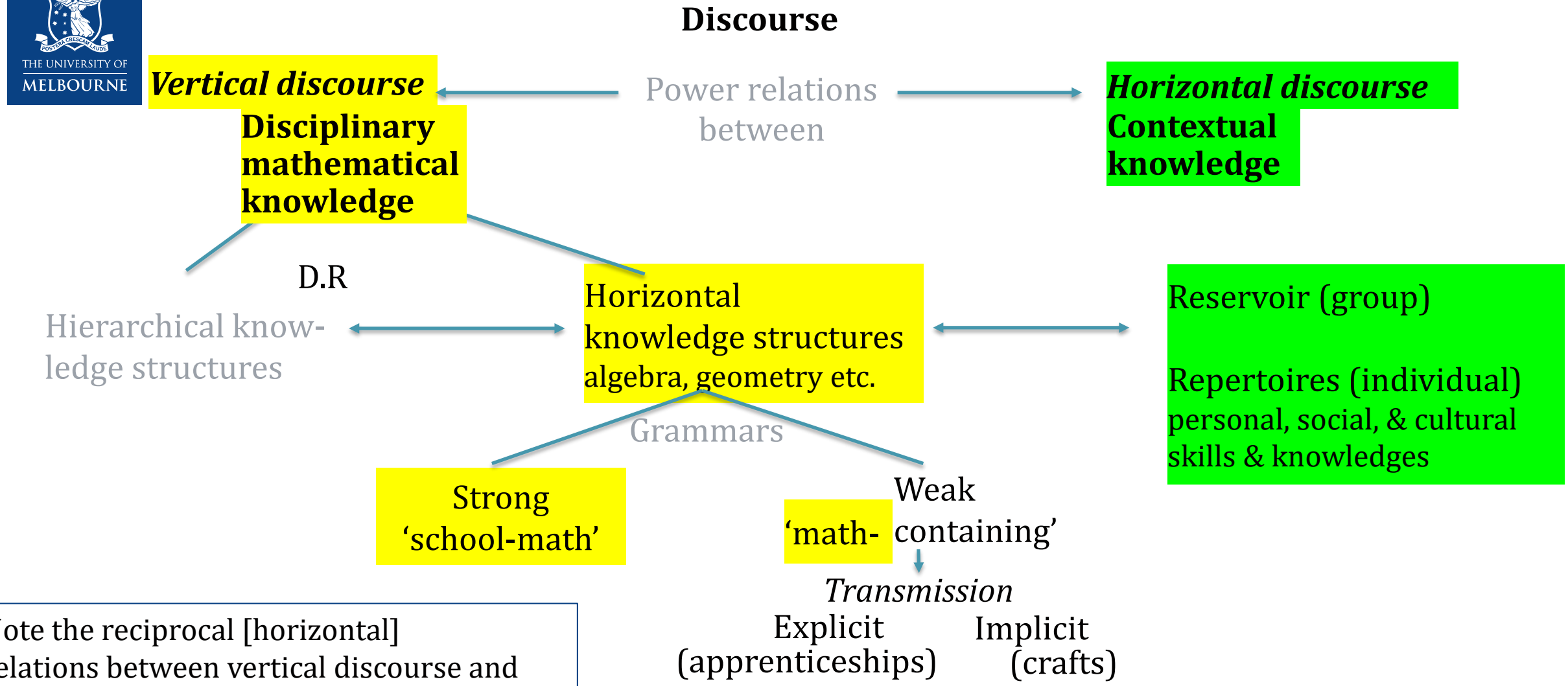
– *i.e.,* ***transforming*** what you know mathematically and contextually to find the most appropriate decision or action

Bernstein's Map of Knowledge Structures [1]



Note: D.R. = Distributive Rules

Bernstein's Map of Knowledge Structures [2]



Note the reciprocal [horizontal] relations between vertical discourse and horizontal discourse

The Importance of Both Vertical Discourse & Horizontal Discourse

While the a working understanding of the **vertical discourse of mathematics** [at whatever level the person has reached in each of its sub-disciplines] is essential

- knowledge of the **horizontal discourse within the particular context** is absolutely necessary to make sense of the task at hand.

When employers complain that new graduates cannot use their mathematical knowledge and skills, this is because they have not yet comprehended the horizontal discourse at the worksite.

- There are specific ways of being a research scientist, a mathematics teacher, a plumber, etc.

Outcomes-Based Frameworks: A Critique [1]
(Allais, 2014)

Outcomes-based frameworks & qualifications rest on a notion of knowledge as information that can be divided into little bits that can be selected and combined at will.

This ignores:

- **that scientific knowledge is necessarily organized in bodies of hierarchical conceptual relationships,**
- **the value of such bodies of knowledge, and**
- **the necessary conditions for their acquisition [i.e., sequencing]**

Outcomes-Based Frameworks: A Critique [2]

In qualifications frameworks, **knowledge must be selected:**

- [only] **because it leads to the required learning outcome**
- **and <u>not for any other reason</u>, such as its intrinsic value and interest,**
- **or to provide a foundation for further knowledge development**.

Knowledge* does not need to be assessed but can be *inferred from competent performance, implying that ...

- **everyday knowledge is equivalent to structured bodies of knowledge.**

i.e., vertical and horizontal discourses are interchangeable!

Structured bodies of knowledge are important. They allow us to:

account for and explain the natural and social world in systematic ways,

participate in, and reflect on key human experiences [cf. *Bernstein & Democracy*] such as the literary, visual, or musical domains.

Disciplines such as mathematics [& music] enable abstraction, reflection, prediction, and application across time and local contexts.

Music performance: Like mathematics, playing music requires mastery of **simple pieces**, gradually **building up to a reflective and more original practice,** offering **insight into musical conventions & boundaries**, even if only in order **to violate them**!

Music & Mathematics [1]

Jubal, Pythagoras and Philolaus engaged in theoretical investigations, in a woodcut from Franchinus Gaffurius, *Theorica musicæ* (1492).

Music & Mathematics [2]
Mathematics and music have many similarities

They are both pancultural, with historical & cultural variations, including ethno-mathematics or ethno-music, & something available to all of us [in theory at least e.g., rhythmic clapping, singing]

Mathematics and music each have:

- a **structured body of knowledge** which is ever evolving
- a **codified set of symbols** with universally accepted meanings within the discipline
- **several different sub-fields** [instrumental and vocal specialisations, genres etc in music], **each with their own rules**

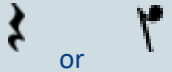
Music & Mathematics [3]
Mathematics and music each have …

the possibility of knowledge and skills leading to performance **being passed on through an oral tradition, often culturally specific, and displayed/performed in <u>contextually appropriate settings.</u>**

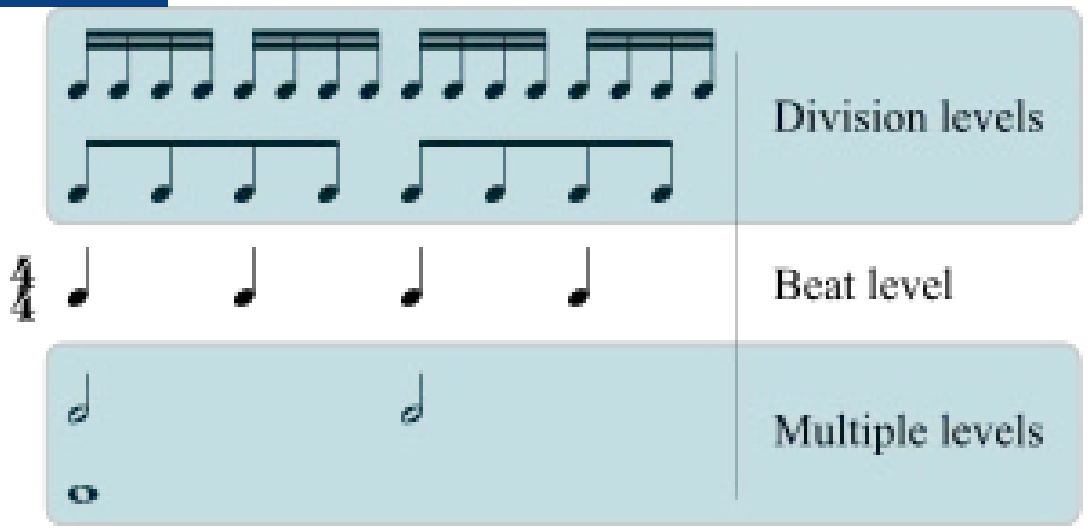
In music, popular social and cultural songs are sung on appropriate occasions, & are a valuable means of social cohesion:

- **Happy Birthday**
- **Auld Lang Syne**
- **Danny Boy [Londonderry Air]**
- **Will Ye Go Lassie Go?**

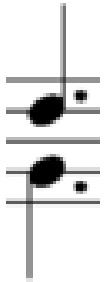
Both vertical & horizontal discourses exist in music & mathematics.

Note	Rest			Relative value	*Dotted value
		whole note	semibreve	1	1 + 1/2 = 1 1/2
		half note	minim	1/2	1/2 + 1/4 = 3/4
	 or	quarter note	crotchet	1/4	1/4 + 1/8 = 3/8
		eighth note	quaver	1/8	1/8 + 1/16 = 3/16
		sixteenth note	semiquaver	1/16	1/16 + 1/32 = 3/32

Music & Mathematics [4]

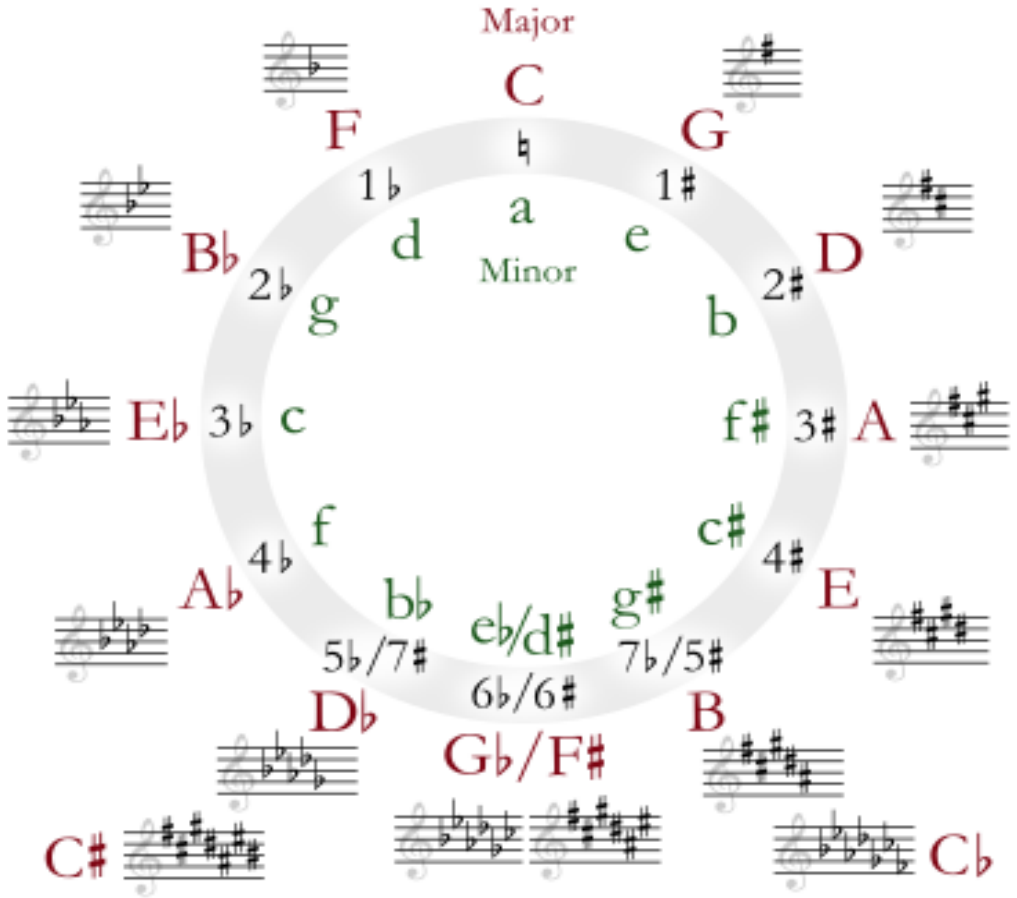


‘Equivalent’ note values cf. equivalent fractions



*A **dotted note** is a note with a small dot written after it. The dot increases the duration of the basic note by half of its original value.

Music & Mathematics [5]
Patterns & Relations - Circle of Fifths



A Musical Example

As in mathematics, there are obvious differences between professional, amateur, & novice musicians.

- The more skilled and knowledgeable the musician, the easier it is for them to confront and solve unexpected problems that may arise in the form of being asked sight-read and perform an unseen piece of music, or even to perform it in a different key [*transpose* it up or down].

- Look at this short piece of sheet music. What do you see? Does it have any meaning for you?

What meaning you make depends on where you are on the continuum.

Public Domain

What meaning did the previous slide, hold for you?

- You might see little other than hieroglyphics, you might see some **familiar patterns**, or you might immediately **recognise** what it is.
- If you are **highly skilled**, and can immediately see the **underlying structures**, you could even **perform** this on a keyboard or sing the song after a minute or less.
- If you are **semi-skilled**, you may be able to put something together after a longer, even lengthy period of time.
- If you are only able to join in with community singing, there is little likelihood that the music script will help you at all, and you are **powerless in this situation**.

If you felt a sense of incomprehension:

- Is it too much of a stretch to imagine that this is how mathematics appears to many adults ?
- What are the consequences for people with a limited, interrupted, or discontinuous mathematics education?
- How will learning only “the maths you need” for a certain job at a certain moment in time help?

[*contextualised* curricula vs. *coherent* curricula]

[Horizontal discourse vs. vertical discourse]

Towards developing structural knowledge in numeracy

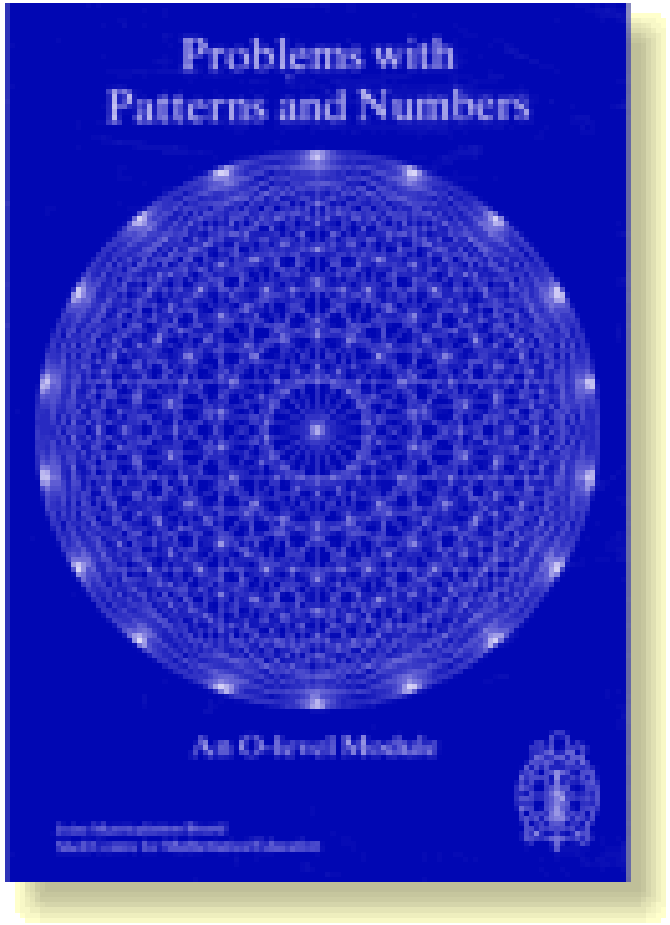
Teachers and students need access to high quality mathematics education materials to help support & develop **more secure and connected content knowledge** aimed at

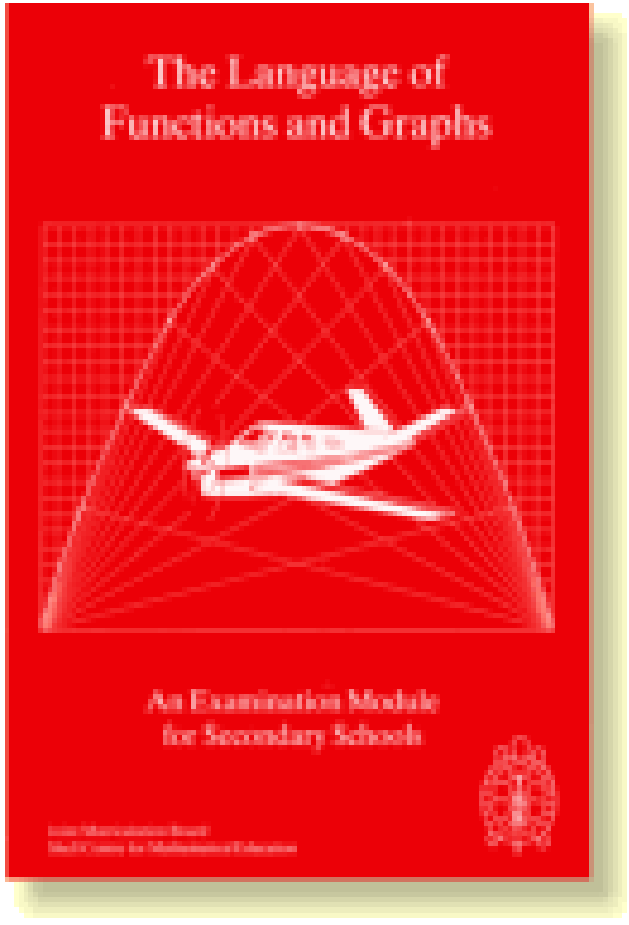
- **Complex problem solving**
- **Critical thinking**
- **Creativity**

<u>towards</u> **Confidence**

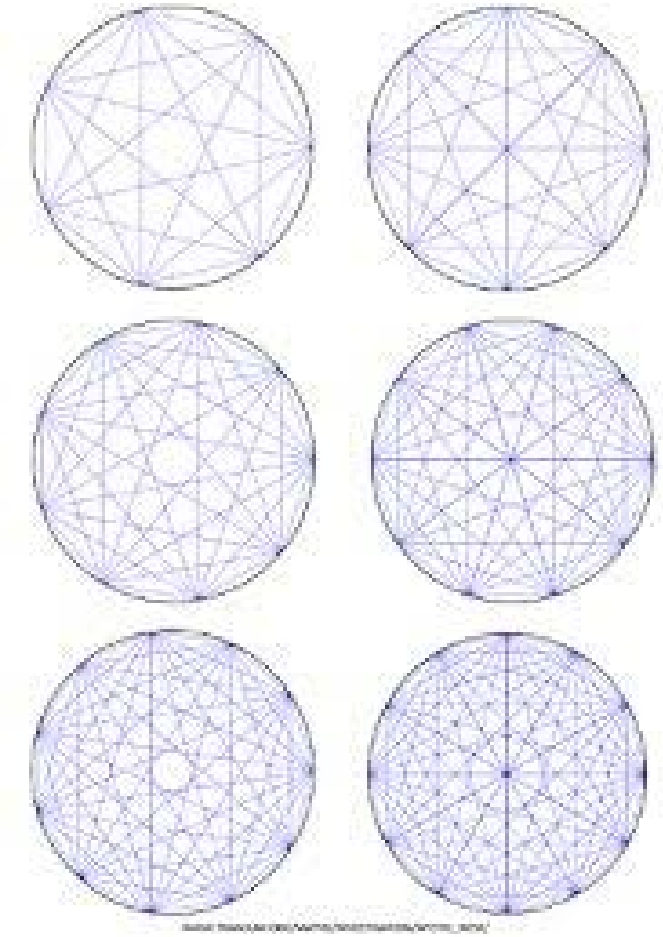
Inclusion

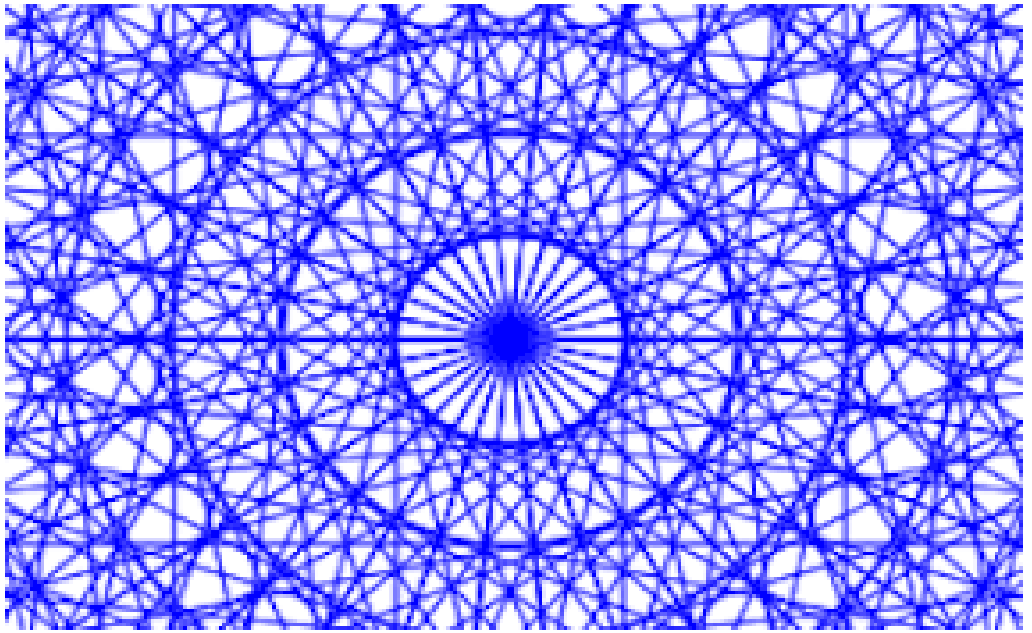
Participation


Problems with
Patterns and Numbers
An O-level Module

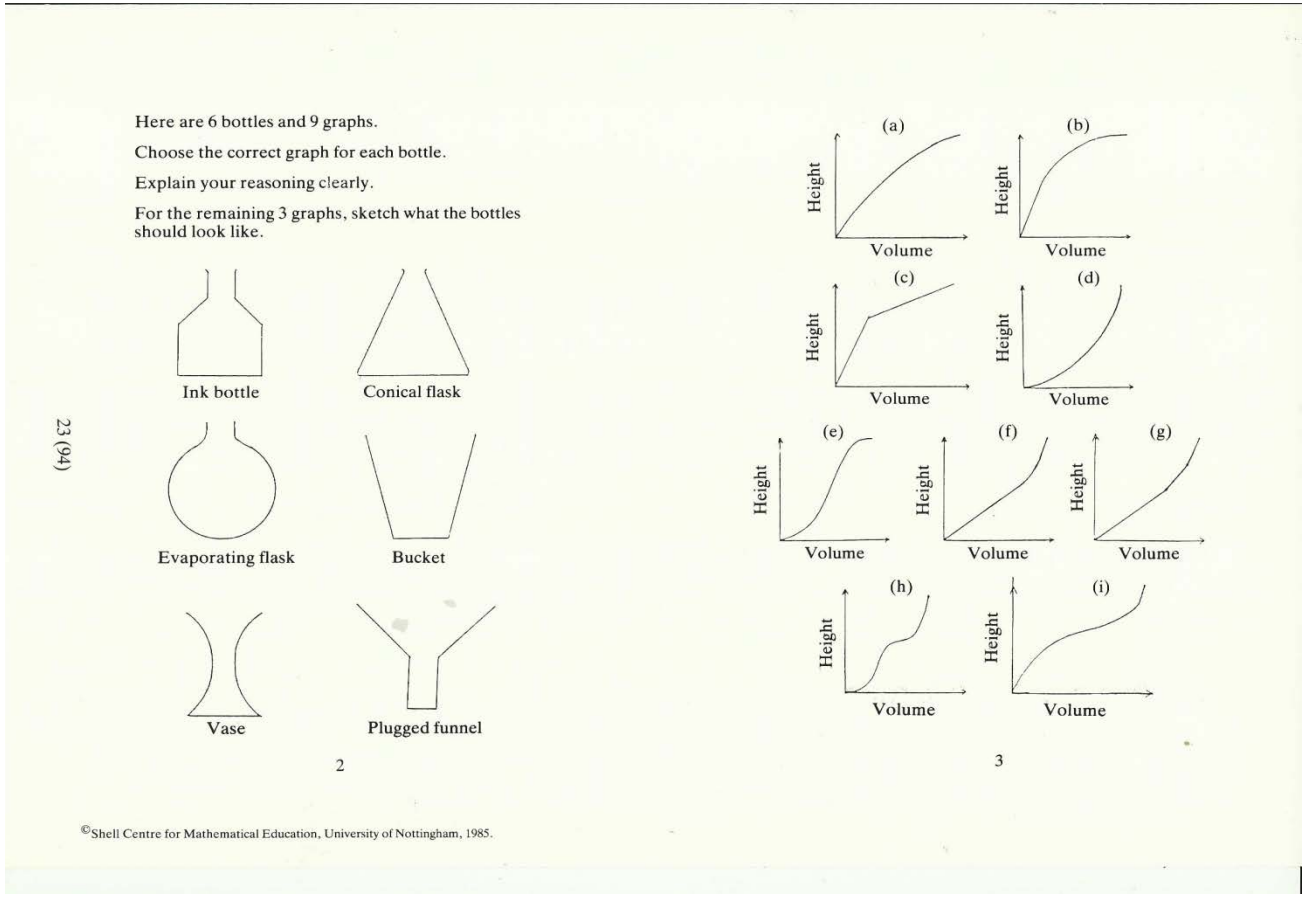

The Language of
Functions and Graphs
An Examination Module
for Secondary Schools

Mystic Roses: Looking for patterns and relationships *try simple cases *make a table *alternative methods





Exploring the relationship between graphs & events
Combining language with visual representations



Here are 6 bottles and 9 graphs.

Choose the correct graph for each bottle.

Explain your reasoning clearly.

For the remaining 3 graphs, sketch what the bottles should look like.

Ink bottle

Conical flask

Evaporating flask

Bucket

Vase

Plugged funnel

23 (94)

2

(a) (b) (c) (d) (e) (f) (g) (h) (i)

Height

Volume

3

©Shell Centre for Mathematical Education, University of Nottingham, 1985.

Conclusion [1]

As Bernstein (2000) argues:

- **Abstract theoretical knowledge** enables society to conduct a conversation about itself, and to imagine alternative futures.
- **Access to 'unthinkable' knowledge** enables the possibility of new knowledge creation [e.g., curiosity, creativity, innovation].

With access to the underlying structural knowledge of mathematics, adults will have the possibility

- **to make the transition to address new mathematical & numeracy demands &**
- **to recognise the same mathematical structures in novel contexts?**

Conclusion [2]

Learning outcomes in adult and vocational education tend to:

- **abstract the lived experiences of adults from the power relations of work and life &**
- **negate the possibilities of understanding and criticism.**

We need to teach adults how to use mathematics to answer back to power at work and in society more generally, going well beyond the mastery of mathematical techniques.

e.g., with the prevalence of **quality control statistics**, process workers cannot be blamed for faulty machinery or lack of maintenance – but they have to **understand the mathematics of the graphs and tables** first.

Conclusion [3] …

- How can we as educators encourage and support adults to transcend boundaries and barriers at work and elsewhere in an uncertain world?
- As members of ALM, do we not have an ethical responsibility to ensure that our students, at whatever level, have the most powerful, structurally supported & connected mathematical knowledge which is at the same time flexible enough to meet contextually specific demands?

[more …]

Adults Learning Mathematics — An International Journal [ALM-IJ]

Adults Learning Mathematics: An International Journal is the only academic journal covering the field of adults who learn mathematics. This journal was first published in 2005 after many years of work.

3 Research Questions:

- **How do teachers and researchers of adults learning mathematics become familiar with the latest research in their field?**
- **What are important indicators of journal quality?**
- **What it is that a journal has direct control over**?

How do teachers and researchers of ALM become familiar with the latest research in their field? (after Nivens & Otten, 2017)

- Ours is a **practice-engaged field**, closely linking practitioners and researchers
- One **important medium for the dissemination** of scholarship is through **journals**, especially those **freely available and readily accessible**
- The **impact is likely to come through enactment of the ideas** by adult education teachers, education methods courses or return to study mathematics lecturers, & professional developers; also possible influence on policy makers
- The accumulating body of knowledge, diverse as it is, can also provide **support for current & future research students** in the field.

What are important indicators of journal quality? What it is that a journal has direct control over?

Apart from citation indexes,

the quality of the editorial and review process is important, through:

- **insightful and relevant reviews**
- **an editorial process that actively assists the authors in the revision process**
- **minimal time lapses from submission to decision and from acceptance to publication.**

Authors can bring *visibility* to their work via personalized alerts from *Google Scholar, ResearchGate,* etc. [also upload articles from ALMIJ]

Two important components of research quality

- **How useful the research is to other scholars or practitioners [citation-based methods]**
- **The opinion of scholars in the same field as to the novelty, validity, and importance of the work.**

More personal indicators of quality include whether readers considered the articles to be readable, interesting, and relevant to their current work.

The editorial board being leaders in their field is very influential.

(Williams & Leatham, 2017)

People Matter

Although a journal is, in a sense, the sum total of the articles it publishes**, a journal is also the people and processes involved in soliciting, reviewing, and making accessible those articles**, and notions of **"high quality"** should incorporate those factors.

(Nivens & Otten, 2017)

ALM-IJ is a home-grown special purpose journal dedicated to supporting the aims of ALM.

I wish to acknowledge all who have contributed in some way since the idea was first conceived.

ALM-IJ Acknowledgements [just to name a few]

Original concept and advice: thanks to **Diana Coben**, **John O'Donoghue**, & other ALM Trustees, including **Jeff Evans**, **Tine Wedege**, and especially to **Jürgen Maasz, who as Chair of ALM,** worked so hard for ALM-IJ to be established.

Original Editorial Board formulation & invitation: thanks to **Alan Bishop** for his advice

Obtaining the ISBN & other formal processes: thanks to **Jürgen Maasz**

Original Cover design & layout: thanks to **Mieke van Groenestijn**

Thanks to all other editors: Janet Taylor, Kathy Safford-Ramus, & Javier Díez-Palomar

Thanks to all the reviewers since 2004.

Last but not least**, thanks to all the authors who have submitted articles — without whom this journal would not exist!**

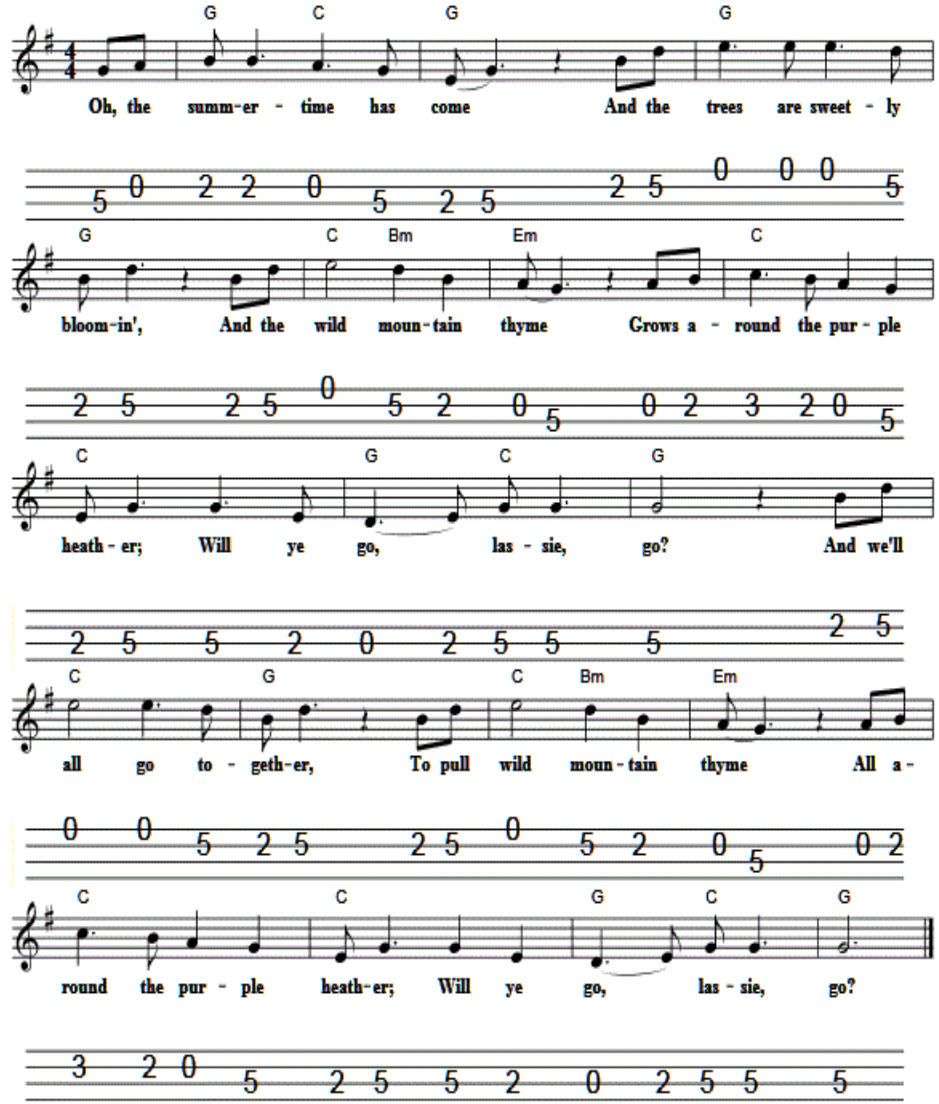
Mystery Song

https://www.youtube.com/watch?v=Sc9Ww3rmT7I

Mystery Music

Will Ye Go Lassie Go?
Lyrics & Chords

Oh the [D] summer [G] time is [D] coming
And the [G] tree's are sweetly [D] blooming,
And the[G] wild [D] mountain [Bm] thyme,
Grows[G] around the [Em] blooming [G] heather
Will you [D] go [G] lassie [D] go


G C G G
Oh, the summ-er - time has come And the trees are sweet - ly
G C Bm Em C
bloom-in', And the wild moun-tain thyme Grows a - round the pur - ple
C G C G
heath - er; Will ye go, las - sie, go? And we'll
C G C Bm Em
all go to - geth-er, To pull wild moun - tain thyme All a -
C C G C G
round the pur - ple heath-er; Will ye go, las - sie, go?

http://www.irish-folk-songs.com/will-you-go-lassie-go-lyrics-and-chords.html

Chorus

And we'll [G] all go to[D] gether,
To pluck [G] wild [D] mountain [Bm] thyme,
All a[G] round the [Em] blooming [G] heather,
Will you [D] go [G] lassie [D] go.

Selected publications [1]

- Bernstein, B. (2000). ***Pedagogy, symbolic control and identity: Theory, research, critique*** (Rev. ed.). Lanham, MD: Rowman & Littlefield.
- FitzSimons, G. E., & Boistrup, L. B. (2017). **In the workplace mathematics does not announce itself: Towards overcoming the hiatus between mathematics education and work.** *Educational Studies in Mathematics, 95*(3), 329-349.
- FitzSimons, G. E. (2015). **Learning mathematics in and out of school: A workplace education perspective.** In U. Gellert, J. Giménez Rodríguez, C. Hahn, & S. Kafoussi (Eds.), *Educational paths to mathematics. A C.I.E.A.E.M. sourcebook* (pp. 99-115). Cham: Springer. [Advances in Mathematics Education series.]
- FitzSimons, G. E. (2014). **Commentary on vocational mathematics education: Where mathematics meets the realities of people's work**. *Educational Studies in Mathematics, 86*(2), 291-305.

Selected publications [2]

- FitzSimons, G. E. (2011). **A framework for evaluating quality and equity in post-compulsory mathematics education.** In B. Atweh, M. Graven, W. Secada, & P. Valero (Eds.) *Mapping equity and quality in mathematics education* (pp. 105-121). Dordrecht: Springer.
- FitzSimons, G. E. (2010). ***Lifelong learning — Theoretical and practical perspectives on adult numeracy and vocational mathematics*.** New York: Nova Science.
- FitzSimons, G. E. (2002). ***What counts as mathematics? Technologies of power in adult and vocational education***. Dordrecht: Kluwer Academic Publishers.
- FitzSimons, G. E. (1994). ***Teaching mathematics to adults returning to study.*** Geelong, Vic: Deakin University Press. ***available on ***ResearchGate***

Useful websites [1]:**Mathematical Processes**

The Shell Centre for Mathematical Education

Problems with Patterns and Numbers (1984)

The Language of Functions and Graphs (1985)

http://www.mathshell.com/materials.php?series=tss&item=ppn

http://www.mathshell.com/materials.php?item=lfg&series=tss

Useful websites [2]

Mathematics Content, Games & Activities

Suitable for and freely available to adult learners & their teachers

https://www.mathsisfun.com

https://nrich.maths.org/

Summary: Vertical discourse & Horizontal discourse

Vertical discourse	Horizontal discourse

• refers to **disciplinary knowledge**
• is described as being **theoretical, conceptual, & generalisable knowledge**
• is **coherent, explicit, and systematically principled**
• with **strong boundaries** between itself and other disciplines.
 	
• The **procedures are linked hierarchically**
• & thus allow the **integration of meanings beyond relevance to specific contexts**.
• **Context specificity** is achieved through **recontextualisation**
• **Mathematical concepts can apply to a range of contexts beyond those available in the classroom.**
	• refers to **everyday knowledge**
	• refers to **contextual knowledge**
	• is likely to be **oral, tacit, multi-layered, & contradictory <u>across</u> but not <u>within</u> contexts**
	• **segmentation of knowledge** is the crucial feature:
	  o learning to tie one's own shoe laces
	  o learning to brush one's teeth
	  o learning to count change
	• **These knowledges are related through the <u>functional</u> relations to everyday life**
	• A **person** may build up an extensive **repertoire of strategies** chosen according to the context
	• & the **group** may likewise build up a **reservoir of strategies** of operational knowledges.
	• **There is <u>not</u> necessarily one best strategy**.

What is Numeracy? [1]

Numeracy can be used to guide actions or decisions, to consider possible hypotheses, or to question assertions of others.

Communication is likely to be multi-modal in form (through symbols, speech, gestures, etc.), and here it differs significantly from much of school-based mathematics activities and their assessment.

Numeracy has two important interlinking aspects:

structural & contextual

[Vertical discourse & Horizontal discourse]

Based on structural knowledge derived from the discipline of mathematics:

Numeracy assumes a working knowledge of the **decimal system of numbers** for various forms of counting, including

- **probability and statistics:** data handling from collection to data entry to technology assisted calculation to presentation (e.g., tables & graphs) to interpretation
- notions of **change: percentage** change & common **periodic phenomena**
- **measurement**: through developing a practical understanding of the **metric system and its links to the number system**; & **geometries of space and shape**
- **all underpinned by mathematical reasoning.**

Numeracy as contextualised communicating with oneself and others

- **in response to contextual prompts, real and virtual, both internal and external**
- **drawing on personal, social, and cultural knowledges which may be tacit**, & even acquired tacitly.
- may be **embodied** through personal experience & includes **estimations of numbers and measures**, consciously or otherwise

Note: Communicating at work where there are a multiplicity of discourses can require being able to move fluently between formal and informal mathematical discourses as needed. [cf. Barwell, 2016]

In Summary:
Numeracy at any level involves:

- **doing and communicating mathematics through interpreting & responding to the mathematics of others, in meaningful contexts**
- **communicating through a variety of modes**: verbal, written, gestures, diagrams, tables, graphs, online, etc., **often simultaneously**
- **developing contextually appropriate skills of estimation and approximation in number, shape, & space**
- **responding to & drawing on available structuring artefacts & tools**
- & **socially, culturally** etc**. informed human interactions** in any specific context.