A re-design research project on implementation at scale of dialogic teaching of school mathematics

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Dialogic teaching

- *Dialogic teaching* gives a central place to small-group and whole-class discussion in which pupils are encouraged to talk in an exploratory way and to consider different points of view, so as to think deeply about a knowledge domain.
- Such *peer interaction between pupils* provides ‘symmetrical’ opportunities for pupils to explore and develop their current understandings and relate them to their everyday world.
- The resulting classroom talk can give the teacher insights into pupils' thinking which can help in supporting their development of key concepts relating to the domain.
- Such *teacher-led interaction with pupils* plays a crucial role in socialising pupils’ understandings through inducting them into the accepted discourse of the knowledge domain.

The *epiSTEMe* project

- This ESRC-supported project aimed to develop and analyse
  - a research-informed pedagogical intervention in early-secondary physical science and mathematics
  - incorporating a dialogic teaching approach
  - suited to implementation at scale in the English educational system.
- Its adoption of a 're-design' research stance recognised
  - that design for pedagogical improvement at scale must take account of the existing state of the system
  - notably the people, structures, resources and practices already in place
  - Including drawing on important contributions from collaborating teachers during the design phase.
- http://www.educ.cam.ac.uk/research/projects/episteme/

Scoping the *epiSTEMe* intervention

- To provide support for teachers/departments to develop their pedagogical approach without significant reorganisation or substantial investment of time
- By developing an intervention of modest scope, packaged as a viable substitute for existing modules, with
  - classroom materials explicitly targeting curricular objectives within the typical period of time allotted to the topic
  - lessons structured as sequences of activities adjustable to session length and lesson pace
  - required equipment limited to items known to be widely available and easily usable.
- Focusing on Year 7, the first year of secondary education
  - where teachers shape new norms of classroom participation
  - far from the constraining backwash of external assessment

The *epiSTEMe* apparatus

- An *Introductory Module* intended:
  - To build teacher and student understanding of the value of talk in supporting subject thinking and learning
  - To develop rules and processes that support effective small-group and whole-class discussion
- Two *Topic Modules* (in each subject) intended:
  - To support and capitalise on use of talk and dialogue
  - To instantiate key pedagogical principles and processes
  - Through educative materials designed to support teacher development as well as classroom activity
- Two *professional development* days for teachers intended:
  1) To develop understanding of dialogic teaching and of how the Introductory Module supports its development
  2) To debrief experience of teaching the Introductory Module and develop understanding of the pedagogical principles and processes underpinning Topic Modules

The development phase

- The research team worked with collaborating teachers to develop, trial and refine the introductory and topic modules.
- The trialling also generated evidence and examples which were used in designing the professional development days.
- The focus in what follows will be on the dialogic teaching aspect, illustrated by an example from probability module.
- Fuller account of development of the probability module in:
  - Ruthven, K., & Hofmann, R. (2013). Chance by design: devising an introductory probability module for implementation at scale in English early-secondary education. *ZDM*, Special Issue on Classroom-based Interventions in Mathematics Education, 45(3), 409-423. https://doi.org/10.1007/s11858-012-0470-6

An illustrative dialogic episode

- The background to a set problem has been introduced in a whole-class session.
- The pupils have discussed the set problem in small groups, and each group has decided its solution.
- These group solutions are now examined in a whole-class session.
- Earlier analysis in:
  - Ruthven, K., Hofmann, R., & Mercer, N. (2011). A dialogic approach to plenary problem synthesis. In B. Ubuz (Ed.). *Proceedings of the 35th Conference of the International Group for the Psychology of Mathematics Education*, Vol. 4, pp. 81-88. https://www.educ.cam.ac.uk/people/staff/ruthven/RHMPME11paper.pdf

The facts of earlobe life

A genetic model has been developed of how people inherit *attached* or *detached* earlobes.

In the model, this characteristic is determined by a pairing of genes, one inherited from the mother, one from the father.

Detached Attached

The spin on earlobes

Children inherit one form of the earlobe gene (one allele) from each parent.

A parent can't pass on an allele that's not in their own pairing.

Slide

Earlobe problems to pierce

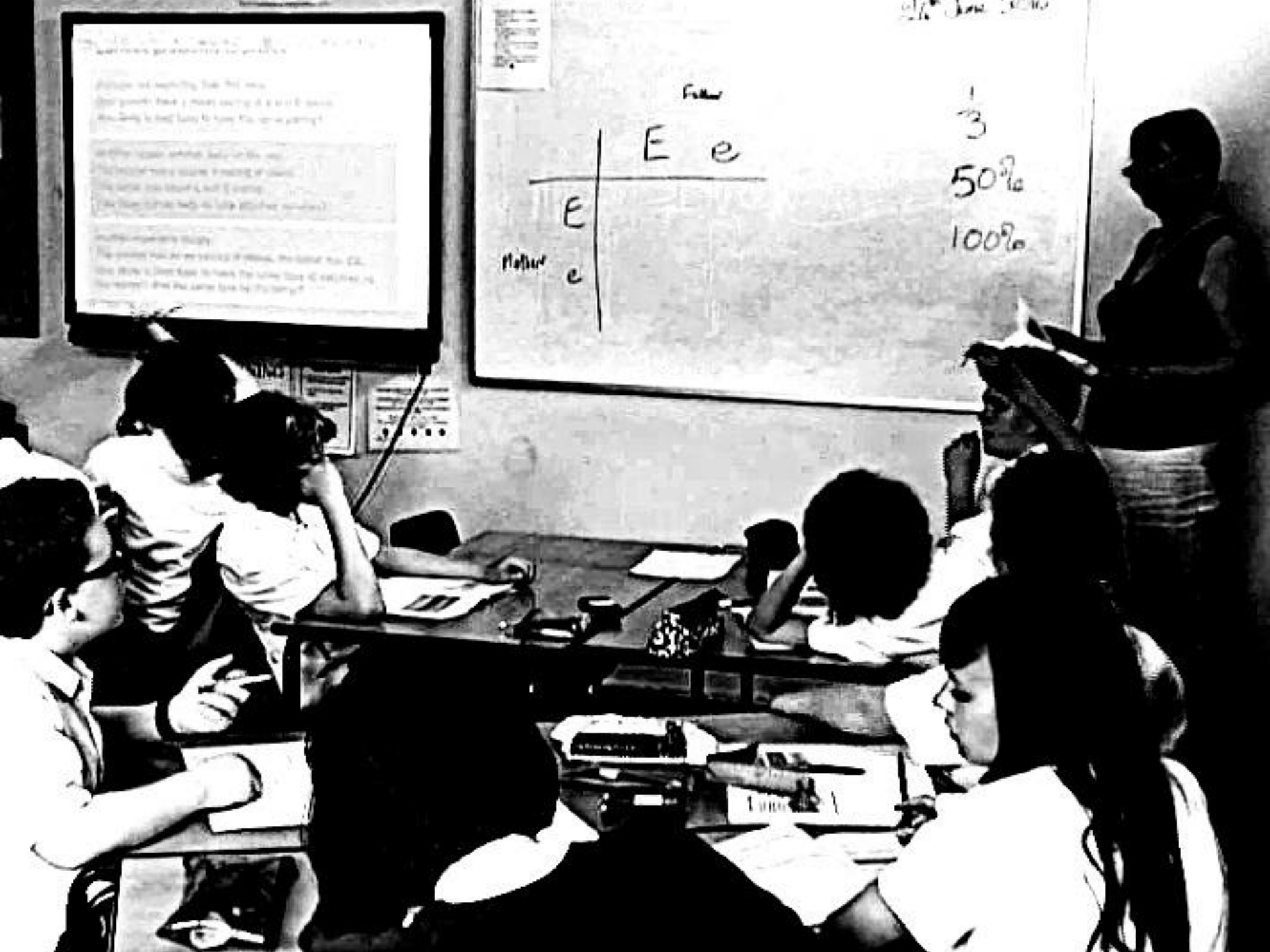
A couple are expecting their first baby.
Both parents have a mixed pairing of **e** and **E** alleles.
How likely is their baby to have this same pairing?

Preview of the opening parts of the episode

- The episode starts with the teacher instigating a sequence of subepisodes which not only establish the basis for subsequent discussion but, by establishing the presence in the class of different perspectives, demarcate a dialogic space.
- In these opening subepisodes the teacher employs a teacher-solicitation pupil-response interaction pattern to identify what answers groups have proposed (I), and to elicit initial arguments for the proposed answers (J, K).

Transcript of subepisode I

I1	T	So we have, both parents have one of each. [*Writing in margins of table drawn on board*] So the father has a big ee and a little ee, and the mother has a big ee and a little ee. And the question is, how likely is their baby to have the same pairing.
I2	Ps	[*Overlapping responses including*] Very very likely. / Fifty per cent. / A hundred per cent. / One third.
I3	T	So, we've been offered what. [*Recording on board*] A third. What else?
I4	Ps	[*Overlapping responses including*] A half. / A whole.
I5	T	[*Recording on board*] Shall we write fifty per cent? [*pause*] And what was the other one?
I6	Ps	[*Overlapping responses including*] One whole. / One hundred per cent.
I7	T	[*Records on board*]


Father
E e
E
Mother e
1/3
50%
100%

Transcript of subepisode J

J1	T	Okay. Would somebody like to sell us on a third please. So one of the groups that thought a third. Who thought a third?
J2	Ps	[Overlapping]: We did. / We did.
J3	T	You did. And you did. So we've got two groups. Who have we not heard from really. Vin. Can you tell us why you think a third, please.
J4	P	Because there's really three ways of forming pairs, a small ee and a big ee, two big ees, and two small ees [inaudible] So it'll be a third that they've got the same pairing, small ee big ee.
J5	T	Okay. What's this reminding you of? Anything? Coins. Who said coins?

Transcript of subepisode K

K1	T	Who thought fifty per cent?
K2	Ps	[*Overlapping*] I do now. / We thought it.
K3	T	Hex.
K4	P	Both parents have a mixed ee, a little ee and a big ee, and so you could either have a big ee or a little ee, it depends. Two big ees or a little ee and a big ee.
K5	P	You what? [*Other similar pupil comments overlapping*]
K6	T	Nan.
K7	P	You can get a big ee, like the, whatever sort of earlobe it is you have, and you could have like two big ees and two small ees [inaudible].
K8	T	Okay. Tia, do you want to add to that?

Transcript of subepisode K (continued)

K9	P	I'm starting to think it's a third because we've got a big ee and a small ee, that's one possibility and then you've got a big ee and a big ee, that's another possibility, and then you've got a small ee and a small ee, that's another possibility, so three possibilities. You've got to have one of those.
K10	T	Are those three equally likely?
K11	Ps	[Overlapping] No. / Yes.
K12	P	Because they've got [inaudible].
K13	P	No, no they're not.
K14	T	Hold on a minute
K15	P	Because you've got a big ee and a big ee and a small ee and a small ee. So there's not more big ees than small ees, and there's not more small ees than big ees.
K16	P	But you only need one big ee to get the big ee type but you need two little ees. *[Other student comments overlapping inaudibly]*.

Overview of subepisode K

- As before, having set the focus (K1), and identified potential contributors (K2), the teacher nominates a speaker (K3).
- But, unlike the preceding subepisode, an appropriate argument is not quickly forthcoming.
- The teacher continues to orchestrate pupil particiption by simply nominating another pupil to speak (K6), or inviting a further pupil to "add to" what has gone before (K8), without herself mediating any of their contributions.
- However, in the face of limited progress, the teacher follows up one contribution by making a short probe which highlights a crucial issue (K10).
- Having intervened in this succinct way, the teacher then steps back to resume a role orchestrating pupil contributions (K14).

Transcript of subepisode L

L1	T	[*Pointing to table drawn on board*] We have here the mother and the father so can this help us do you think?
L2	Ps	[*Overlapping*] No. / Yes. / I don't know.
L3	T	[*Pointing to table drawn on board*] So the mother can give us a big ee and the father could give us a big ee. The mother could give us a big ee and the father could give you a little ee. The mother could give us a little ee and the father a big ee.
L4	Ps	[*Overlapping*] Oh, there's four there.
L5	T	And the mother could give us a little ee and the father could give us a little ee.
L6	P	So it's a quarter.
L7	P	No, it's a half.
		[*Lesson is interrupted*]

Transcript of subepisode L (continued)

L8	T	So, the question is, what is the probability that they will have the same pairing as their parents.
L9	P	A half, because a half of them have got a small ee and a big ee.
L10	P	So we were right.
L11	T	[*Pointing to table on board*] So does this help?
L12	Ps	[*Overlapping*] Yeah. / Maybe. / Yes. / Sort of. / No, I already had that conclusion.
L13	T	Vin, does this make any difference to you?
L14	P	[*pause*] It's actually four possibilities instead of three possibilities.
L15	T	There's a difference isn't there between the combinations we've got here, the genes they might have, and what sort of earlobes they might have. Although in theory [*pause*] there's only three different ones, [*pause*] three different ones, there are two ways to get this one. So does that affect the probability of it turning up, of it happening.

Overview of subepisode L

- This subepisode takes the form of an interactive exposition led by the teacher: while most of her turns are extended, only one by an individual pupil is.
- By framing discussion in terms of helpfulness of the diagram (L1, L11), the teacher introduces a reflective dimension.
- This is reinforced by her return to Vin to see whether he has changed his earlier view in response to the diagram (L13).
- Indeed, most of the teacher solicitation and pupil reponse pairs are framed in reflexive terms.
- Through these devices, the teacher succeeds in comparing the two proposed answers that have been highlighted.
- However, although the main elements of a valid argument have now been advanced, the teacher leaves the issue open by concluding with a question (L15).

Overview of the remainder of the episode

- The teacher maintains awareness of the dialogic space through publicly monitoring which answers participants are supporting, and whether/how their position has changed (M, N) leading to a polling of opinion across the class (O).
- The teacher avoids evaluating proposed solutions, and declines an invitation to provide "the actual answer" (N).
- As the attention of some pupils flags, the teacher reminds them of class norms for discussion (O, P) and explicitly states that an answer needs to be *"worked out"* with *"mathematical heads"* and *"believed by all"* (O).
- The teacher concludes with: *“We’re going to leave it unresolved for the minute, so all of you need to give it some thought, please, before the next lesson.”* (P)

Teacher orchestration of discussion

- After the short opening subepisodes (I, J) and the start of the next subepisode (K), the orchestration of discussion becomes less overtly structured by the teacher.
- The pattern shifts to one in which teacher simply nominates another pupil to speak, or invites a further pupil to "add to" what has gone before (K).
- In the later subepisodes there is a further evolution in this pattern, first to refer a question from one pupil to be answered by another (M), then to revoice pupil contributions and mediate indirect exchanges between them (P).
- This passes initiative to pupils, reflected in the flourishing of pupil contributions: not only does around half the talk come from pupils, but around half of these contributions are extended ones of at least 10 words.

Teacher contribution to discussion

- However, there are occasions when the teacher steps forward, particularly to nudge the discussion through making substantive contributions which probe or react to pupil propositions (K, M, N, P).
- In addition, subepisode L, which takes the form of a short teacher exposition about using a diagrammatic tool, seems to develop out of very brief intervention that the teacher makes towards the end of subepisode K to highlight a crucial issue on which this tool can throw light.
- However, these substantive contributions by the teacher are always indirect, in the sense that none of them points directly to the answer to the problem.

Challenges for teachers in embracing and realising dialogic teaching

- Realising the dialogic element of the *epiSTEMe* pedagogy proved challenging for many teachers
- The goal of developing thinking, not simply securing performance, requires significant shifts beyond the received ideas and habitual reflexes of established practice:
  - Aiming to express reasoning not just produce answers
  - Giving time to multiple extended student contributions
  - Allowing extended student contributions that are fallacious
  - Interanimating the reasoning behind student responses
  - Making contributions that are reflexive not regulative
  - Steering discussion to secure progression in reasoning but not closing it down through authoritative intervention

The field trial

- The field trial was designed as an experimental study randomised between intervention and control groups, each consisting of around 12 intact classes from different schools.
- Judgements about effectiveness were based on:
  - Learning gain by pupils (inferred from proficiency tests administered before and after undertaking each topic module)
  - Pupil opinion (inferred from opinion questionnaires administered after completion of each topic module)
- Fuller account of the field trial in:
  - Ruthven, K., Mercer, N., Taber, K., Guardia, P., Hofmann, R., Ilie, S., Luthman, S., & Riga, F. (2017). A research-informed dialogic-teaching approach to early secondary school mathematics and science: the pedagogical design and field trial of the epiSTEMe intervention. *Research Papers in Education*, 32(1), 18-40. http://dx.doi.org/10.1080/02671522.2015.1129642

Evaluation results

- Both intervention and control groups showed learning gains for the mathematics modules.
- These gains were slightly higher in the intervention group
  - *Probability*: ES +0.09
  - *Ratios:* ES +0.17
- Both intervention and control groups expressed positive opinions about their experience of the mathematics modules
- These opinions were slightly lower in the intervention group
  - *Probability*: ES -0.04
  - *Ratios:* ES -0.12

Observational markers of dialogic talk

- A sample of intervention group lessons were observed with 4-minute units of whole-class activity coded.

  - Solicitation of pupil ideas by teacher
  - Articulation of ideas by pupils
  - Multiplicity of pupil ideas
  - Spotlighting of pupil ideas
  - Comparison of pupil ideas

Code	Marker of dialogic talk
TSolC	Teacher asks for explanation/clarification/reason
TSolF	Teacher collects feedback from planned small group work for at least 1 minute
PArtR	Pupil gives a reason
PArtE	Pupil takes an extended turn
PMul	Number of pupils who do any of these things is 3 or more: Takes an extended turn; Gives reason; Suggests a new idea/response to a task; Takes up another pupil's idea
TMul	Teacher collects at least 2 pupil views without evaluating them
TSpot	Teacher puts a pupil idea/question to whole class to listen or respond to
PCom	Different perspectives are discussed for at least 1 minute
TCom	Teacher draws out difference between pupil ideas

Aggregate incidence of dialogic markers

- % of observational units where marker occurred

Module	Marker								
	TSolC	TSolF	PArtR	PArtE	PMul	TMul	TSpot	PCom	TCom
Probability	45%	39%	48%	48%	32%	27%	15%	9%	13%
Ratios	48%	46%	36%	35%	11%	9%	3%	0%	5%

- Teacher Solicitation and Pupil Articulation prevalent for both.
- Multiple Pupil ideas reasonably prevalent in Probability lessons, but notably less so for Ratios.
- Teacher Spotlighting of, and Comparison of Pupil Ideas are rare; appreciable levels only in Probability lessons.

Lowest incidence of dialogic markers

- For lesson with lowest incidence, % of units where marker occurred [& number of lessons/6 with incidence of 0%]

Module	Marker								
	TSolC	TSolF	PArtR	PArtE	PMul	TMul	TSpot	PCom	TCom
Probability	30%	22%	33%	33%	10%	10%	0%[2]	0%[3]	0%[1]
Ratios	22%	30%	11%	0%[1]	0%[4]	0%[4]	0%[5]	0%[6]	0%[5]

- Teacher Solicitation pervasive across both modules.
- Pupil Articulation pervasive and Multiple Pupil Ideas present across Probability (but not Ratios).
- Teacher Spotlighting of, and Comparison of Pupil Ideas in most Probability lessons (but virtually no Ratios lessons).

Retrospective phase

- Teachers' intentions to develop their practice are often not realised if dominant sociocultural norms of classroom practice are not explicitly addressed and successfully changed.
- To investigate this issue retrospectively we analysed audio-recordings of probability lessons from the development and field trial phases of the project.
- Fuller account of this analysis in:
  - Hofmann, R., & Ruthven, K. (2018). Operational, interpersonal, discussional and ideational dimensions of classroom norms for dialogic practice in school mathematics. *British Educational* Research Journal, 44(3), 496-514. https://doi.org/10.1002/berj.3444

Classroom norms

- We conceptualise norms as recurrent and socially obligating patterns of behaviour in a particular type of social encounter.
- Norms for accepted ways of acting and interacting may go unarticulated, even unacknowledged, until broken.
- They operate both at a surface behavioural level and in terms of the rationales underlying actions and interactions.
- They regulate what actions participants consider appropriate, and how they understand those actions.
- Norms may be manifest not only in recurrent patterns of behaviour, but also in teachers' evaluative appraisals of students' actions and work.

Identifying and analysing norms

- Classroom norms are often made explicit when teachers frame and focus a lesson/task.
- Breakdown of classroom norms, particularly in the form of norm-incongruent behaviour by pupils, may lead to them being explicitly reiterated by teachers.
- Feedback given by teachers at the end of activities and lessons provides a rich source of explicit norm talk.
- Close analysis of teachers' explanations of norms within classroom talk revealed, however, that beneath similar surface expressions often lay differing types of rationale.
- A distinction, then, needs to be drawn between surface expression and deeper norm structure.

Dimensionality of norms

- Our analysis indicated that rationales for any norm can relate to four dimensions of interaction:
  - The *operational* dimension concerns what are deemed appropriate ways of carrying out classroom tasks – for example, rules specifying how responses or ideas should be presented.
  - The *interpersonal* dimension concerns expectations about how students should treat each other during activities/discussions – rooted in principles of being 'kind' and 'fair'.
  - The *discussional* dimension concerns the kind of discussion that should be taking place – involving asking questions, sharing ideas and backing them up with reasons.
  - The *ideational* dimension focuses on the role that the content of discussions should play in students' learning of mathematics – promoting the significance of the ideas produced in the discussions and encouraging critical examination of them.

Operational norms

- The clearest, and most familiar, operational norms expressed in these mathematics lessons entail that
  - everyone has to contribute
  - others should be listened to when they are speaking
  - other people and their ideas should be treated with respect
  - mere (numerical) answers are not sufficient
- As well as, particularly linking with the epiSTEMe pedagogic approach
  - Pupils need to seek group agreement during planned small-group work.

Contributing: From maintaining fairness to sharing ideas

- Operationally, *'everyone must contribute to the discussion'*.
- Interpersonally, pupils need need to *'contribute otherwise it's not fair'* – they cannot just *'sit back and let everybody else do the work'*; equally, they must *'give everybody a fair chance'*, *'let everyone speak'*.
- Discussionally, pupils need to *'practice making contributions, I know you all have something valuable to say'* and *'carry on this kind of discussion that you're having'*.
- Ideationally, pupils need to contribute to the discussion because other people's ideas help us *'think through'* and test our own ideas, which improves our understanding, rather than *'just kind of know[ing]'*.

Listening: From attending to others to changing one's mind

- Operationally, pupils should listen when others are speaking.
- Interpersonally, pupils should *'take it in turns to speak'*, and be *'quiet when other people are speaking'.* Again this relates to fairness: '*You were just talking and everybody was quiet for you, and now we've got another group talking but you're all chatting, and that's not fair, is it?*'
- Discussionally, pupils should *'listen very carefully [so as to be able] to contribute to what [another] group says'.*
- Ideationally, listening to others' contributions creates opportunities for learning, as hearing their ideas can *'change [y]our minds' 'if you hear an argument that is convincing'.*

Respecting: From behaving kindly to exploring disagreement

- As with contributing and listening, the norm of respecting others' ideas can remain operational and interpersonal, emphasising polite behaviour and consideration of others.
- This norm acquires a discussional rationale when it is suggested that, conducted respectfully, mathematical disagreements are acceptable in classroom discussion: *'if someone doesn't agree with you, then talk it out with them'.*
- This norm acquires an ideational rationale when respecting other people's ideas is extended to giving them serious consideration and re-evaluating our own ideas: *'We are going to respect what other people say. We are not going to say oh that's a bad idea. If we disagree, mathematically about something, we can discuss it and try to persuade the other person to change their mind'.*

Demonstrating: From showing working to arguing persuasively

- In the operational dimension of this norm, it is not sufficient for students to simply express an answer (typically in numerical form) – they need to *'show some kind of working'.*
- This norm acquires an interpersonal and discussional rationale when linked to communicating with others and supporting discussion: *'Let's try and show some kind of working so that if we ask you to come and explain it to everybody else, you've got a diagram or something that you could share'*.
- Likewise this norm acquires an ideational rationale when *'[if a student thinks they know the answer, they need to] think of something that you can tell us that will convince people of what's going on, convince them of what you believe'*, because other students may *'have good reasons for not agreeing'*.

Agreeing: From forming a majority to negotiating for consensus

- This requirement in the *epiSTEMe* pedagogic approach was often stated operationally without rationale: *'Come up with a group agreement'.*
- An interpersonal rationale sought the majority view through a fair process: *'not everyone might… agree – but as long as we've got a majority, so the three of you come to a vote'.*
- A discussional rationale sought negotiation in which group members *'might end up with a different opinion to what you started with, and that's absolutely fine'.*
- An ideational rationale sought everyone coming to accept and understand the mathematics: *'There is an answer to this and we need to work out what it is. And we all need to believe it'.*

Implications of the analysis

- The behavioural norms required for an ideational dimension to be enacted in classroom talk are, on the surface, the same norms which can be expressed solely in terms of interpersonal and discussional dimensions.
- Implementing these norms in the discussional dimension in itself often represents a shift in mathematics classroom practice.
- But a further extension of these norms into the ideational dimension is required to genuinely incorporate students' ideas and thinking into the teaching and learning process.

Further interpretation of findings

- It seems a reasonable hypothesis that for a dialogic teaching approach to have a strong influence on pupil learning it must have a strong ideational dimension.
- The retrospective analysis of the discursive framing of classroom norms found the operational, interpersonal and discussional dimensions more salient than the ideational.
- Likewise the observational results from the field trial suggested that the behavioural markers corresponding most closely to an ideational dimension – Multiple Pupil Ideas, Teacher Spotlighting of Pupil Ideas, and Comparison of Pupil Ideas – were neither prevalent nor pervasive.
- This represents one potential line of explanation for the modest outcomes of the field trial.

Teacher toolkit now available online

- Following on from the *epiSTEMe* project, the ED:TALK Toolkit is a free online resource designed to help teachers devise and implement their own projects and then evaluate the results.

  http://edtoolkit.educ.cam.ac.uk/