The dialogic bases of effective inquiry-based science and mathematics education

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The sociocultural turn in pedagogical theory

• Starts from common constructivist position that learners must think for themselves to truly know and understand, and that teaching must provide opportunities and encounters that enable them to do so.

• Moves away from Piagetian model of the learner as a ‘lone scientist’ who develops cognitively by interacting with stimulating materials, towards Vygotskian view that development depends crucially on interaction with adults, other children and wider culture.

• Views learning not only in cognitive terms of learners developing understanding of school knowledge but in terms of their developing a social identity in relation to such activity.

• Sees teaching (and other interpersonal interaction within the classroom) as playing an active part in ‘mediating’ development and learning that goes beyond indirectly ‘facilitating’ them.

(adapted from Alexander, 2008)
Spoken language in learning and development

• While in some domains implicit learning can take place, higher-order cognitive activities of the kind that characterise formal schooling require both conscious effort and direct intervention.

• From a sociocultural perspective, spoken language constitutes the ‘master tool’, providing the primary medium for collective representation and regulation of joint activity and reflection on it.

• From a neuroscientific perspective, talk plays a key part in fuelling the building of the brain as a physical organism via synaptogenesis.

• However, from a sociolinguistic perspective, conventional patterns of classroom talk are cognitively impoverishing:
  – highly structured question and answer sequences at a low cognitive level funnel pupils towards an expected answer;
  – pupils work in groups but rarely think together as a group.

(adapted from Alexander, 2008)
Learning as appropriation of social languages

• Extending the Vygotskian analysis of inter-mental activity on the social plane, the Bakhtinian notion of social language recognises that different modes of discourse are used in different parts of society.

• A special social language has developed within the mathematics and science community, based on the use of special concepts that establish a distinct ontology, and that are organised in terms of key epistemological principles such as development of general theories.

• A social language may incorporate semiotic practices other than language. As well as discourse, symbolic and figural representations are central to the social language of mathematics and science.

• Learners are constantly exposed to an everyday social language. Studying mathematics and science requires them to reconstruct the sense of the talk and activities that surround them, reorganising their existing ideas and ways of thinking accordingly.

(adapted from Ruthven et al., 2009)
Emergent conceptions of dialogic teaching

• A ‘mutualist and dialectical’ pedagogy in which understanding is fostered through discussion and collaboration (Bruner, 1996)

• ‘Dialogic inquiry’ in which collective dialogue mediates open-ended and exploratory classroom activity (Wells, 1999)

• Development of classroom communication as a reciprocal process of ‘interthinking’ involving exchange of ideas (Mercer, 2000)

• Linked processes of conflict discussion and collective metacognition to promote ‘cognitive acceleration’ (Shayer & Adey, 2002)

• ‘Dialogic teaching’ through classroom communication which is collective (in pupil group or whole class), reciprocal (through considering all viewpoints), supportive (of free expression and mutual assistance), cumulative (in chaining and developing ideas) and purposeful (towards particular curricular goals) (Alexander, 2008)
Deconstructing ideas of classroom ‘dialogue’

• Classroom ‘dialogue’ can be broken down into two dimensions:

  • Authoritative/Dialogic
    – In authoritative discourse, an authority figure (normally the teacher) controls the direction of the talk, to focus it on one point of view (normally the accepted mathematical/scientific view).
    – In dialogic discourse, the discourse is open to different points of view, both everyday and scientific.

  • Interactive/Non-interactive
    – Interactive talk involves more than one speaker
    – Non-interactive talk involves just one speaker.

• Authoritative talk is more appropriate when new meanings are being introduced to the classroom, whereas dialogic talk is more appropriate when students’ everyday views are being explored.

(Mortimer & Scott, 2003)
Interactivation of mathematical knowledge

- Mathematical knowledge is only indirectly communicable and locally constructible through classroom interaction focusing on the epistemic relations between reference context, sign system and concept.

(adapted from Steinbring, 1997)
The *epiSTEMe* project

- A research, development and evaluation project
  - Focusing on enhancing student engagement and learning in early secondary-school physical science and mathematics
  - Researching, developing and evaluating a teaching intervention suited to implementation at scale

- Has drawn on research-based knowledge about key components of effective pedagogy:
  - Enhancing the use of classroom talk as a vehicle for thinking and learning in mathematics and science
  - Designing classroom tasks that support such use of talk and scaffold deeper mathematical and scientific thinking

- Forms part of a research initiative by the UK Economic and Social Research Council investigating ways of addressing participation and achievement gaps in science and mathematics education
The *epiSTEMe* intervention in practice

- The intervention is organised around three subject-specific Year 7 course modules in each of mathematics and science
- An Introductory Module builds student understanding
  - of the value of talk for thinking and learning
  - of rules and processes that help make talk effective for these purposes
- Two Topic Modules are designed
  - to support effective use of classroom talk
  - to promote deeper subject thinking and broader understanding
- A two-day Professional Development sequence focuses on:
  - Introducing ideas of dialogic teaching, examining Introductory Module, and discussing related examples of classroom teaching
  - Debriefing classroom introduction of dialogic teaching, and examining integration into subject-specific Topic Modules
The design brief for the topic modules

- To cover curricular requirements relating to the topic
- To build strong conceptual foundations for the topic
- To take account of students’ informal knowledge and thinking related to the topic
- To address common forms of fallacious reasoning about the topic
- To show the human interest, social relevance, and scientific application of the topic
- To develop the use of mathematical representation and reasoning as a support for developing students’ scientific understanding
- To use dialogic small-group and whole-class teaching approaches in developing student understanding of the topic
- To build in regular checks on individual student understanding with developmental feedback

(Ruthven et al., 2010)
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?

Another couple, another baby on the way.
The mother has a double e pairing of alleles.
The father has mixed e and E pairing.
How likely is their baby to have attached earlobes?

Another expectant couple.
The mother has an ee pairing of alleles; the father has EE.
How likely is their baby to have the same type of earlobes as the mother? And the same type as the father?
Eliciting alternative viewpoints

T: Can you tell us why you think a third please?
S: Because there’s really three ways of forming a pair, a small e and a big E, two big Es, and two small Es.

T: Who thought 50%?
S: Both parents have a mixed pair, a big E and a little e, and so you could either have a big E or a little e, it depends.

T: Becky?
S: I said that his Mum’s got one of each and his Dad’s got one of each, so he’s definitely going to have one of each. Because, like, say your Dad had brown hair and your Mum had brown hair, then people say you’d have brown hair.
Scaffolding collective exploration

S: I'm starting to think it's a third because got a big E and a small e, that's one possibility and then you've got a big E and a big E, that's another possibility and then you've got a small e and a small e that's another possibility, so three possibilities.
S: Yeah but (...).
T: Are those three equally likely?
S: No.
S: Yes. Because they've got (...).
S: (...) [interrupting].
T: Hold on a minute.
S: Because you've got a big E and a big E and a small e and a small e. So there's not more big Es than small es…
Interanimating progressive discussion

T: Do correct me if I'm wrong here Holly, what Holly’s saying is that this one and this one [pointing] are the same.
S: Yeah.
T: And therefore she's saying that there’s still only three different outcomes and therefore they're a third each.
T: Katie.
S: There's three outcomes, but there's two ways of getting one outcome so that outcome has a higher probability than the other two.
T: So Holly does that make, does that make any difference do you think? Katie’s saying that although there are only three outcomes… there are two different ways that this [pointing] can happen.
The development and evaluation process

- The project team worked with teachers in 5 schools to devise, trial and refine the intervention.
- The intervention recognises the challenge of teaching consistently, day in day out, to these principles.
- It has been designed to be suitable for implementation at scale across the educational system.
- The goal is to support teachers in realising such principles more consistently, and in developing practice further in this way.
- The intervention is currently being evaluated through a randomised field trial involving around 80 classes and their teachers in 26 schools within a 100 km radius of Cambridge.
The functions of the pedagogical apparatus

- The intervention provides a pedagogical apparatus consisting of classroom materials and teaching notes for lesson sequences, with guiding ideas examined during the professional development events.
- This apparatus has a multiplicity of functions in supporting pedagogical change, and in scaffolding professional development.
  - A symbolic function, giving visible substance to the approach.
  - A pragmatic function, providing worked-out examples of the use of concrete structures for classroom activity.
  - An epistemic function, crystallising central components of dialogic teaching and the other elements of the design brief.
  - A heuristic function, assisting thoughtful interpretation and local reformulation of practice.
- Successful development depends, however, on developing an adaptive understanding of, and flexible thinking about, the practice. (Ruthven, 2005)