Research-informed pedagogical innovation at scale in school mathematics and science education

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The National Strategies:
Pedagogical experiment at systemic scale

• A systemic school improvement programme
  – Introduced to primary schools from 1998
    (informally) and 1999 (formally)
  – Extended to lower secondary for student cohorts
    entering 2001 (mathematics) & 2002 (science)

• Independent evidence of impact provided by regular
  international study series such as TIMSS and PISA
  – Data gathered about attitude as well as attainment
  – Comparison across systems and between subjects
The National Strategies:  
The influence of pedagogical research

• Main basis was a predominantly American body of “process-product” research on effective teaching
• Core model of “active teaching” had been validated in relation to basic mathematical knowledge and skills
• Other research suggested that “additional classroom processes… needed to enhance higher order thinking:
  – a focus on meaning and understanding…,
  – direct teaching of higher level cognitive strategies and problem-solving,…
  – co-operative small group work.”

  (Reynolds & Muijs, 1999, p. 281)
The National Strategies:
Key features of the pedagogical model

• Derived from “active teaching” linked to “target setting”, placing emphasis on:
  – A detailed schedule of objectives to guide lessons
  – A three-part template for lesson structure
  – Whole-class interaction for pace and progress
  – A system of attainment levels to describe progress
  – Regular target setting, assessment and feedback
The National Strategies: Impact on student attainment

**Mathematics**

- Proportion of students attaining KS3 L6+
- TIMSS LH+
- PISA L4+

**Science**

- Proportion of students attaining KS3 L6+
- TIMSS LH+
- PISA L4+
The National Strategies: Impact on student attitude

**Mathematics**

**Science**

Proportion of students reporting
- Enjoy/Like
- Value
- Confident

<table>
<thead>
<tr>
<th>Cohort by year of secondary entry</th>
<th>1996</th>
<th>2000</th>
<th>2004</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mathematics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Science</td>
<td></td>
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</tbody>
</table>
A controlled international overview: Systemic change between cohorts

TIMSS result
- 1996 entry
- 2004 entry
A controlled international overview: Systemic reform in Massachusetts

• Systemic improvement programme
  – based on establishing common professional standards and ambitious achievement targets
  – backed by extensive professional development and strong accountability mechanisms

• Normative pedagogical model
  – influenced by more recent research addressing development of higher-order thinking
Approaches to research synthesis

• Basic pedagogical model for National Strategies formulated through politicised process that filtered out more innovative and recently researched approaches

• Future policy and practice would benefit from taking account of more rigorous approaches to synthesis:
  – Systematic review
  – Best evidence synthesis iteration
  – Meta-analytic approaches
Approaches to research synthesis: Systematic review

- Programme established by UK Department for Education via the Evidence for Policy and Practice Information and Coordination Centre (EPPI-Centre)
  - Follows standard stages
  - Aims to use explicit, transparent methods
  - Involves range of users to ensure relevance
- Example of the review of *Strategies to raise pupils’ motivational effort in Key Stage 4 Mathematics*
  - Very specific focus over limited time period
  - 25 relevant studies identified
  - Only one study provided high weight of evidence
Approaches to research synthesis: Iterative best-evidence synthesis

- Programme established by NZ Ministry of Education
  - Uses research literature to identify what is effective in education for diverse learners
  - Adopts health-of-the-system view that requires dialogue across professional constituencies
- Example of *Effective Pedagogy in Mathematics*
  - Drew on NZ literature complemented by work from other countries with similar characteristics.
  - Identified seminal “landmark” studies to pinpoint how quality teaching might be characterised
  - Derived a common pedagogical principles that appear to hold good across people and settings
Approaches to research synthesis: Meta-analysis incl. best-evidence synthesis

• Meta-analysis is a well-established approach to summarising studies of the effects of teaching processes on student learning
  – systematically searches for relevant studies and screens them according to explicit criteria
  – classifies the types of teaching process and learning outcome in each accepted study
  – estimates effects through statistical aggregation
• Meta-analytic best-evidence synthesis (Slavin, 1986) adds summary description of each contributing study
Recent research synthesis on pedagogy: Triangulating the meta-analytic studies

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<thead>
<tr>
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<tbody>
<tr>
<td><strong>Subject</strong></td>
<td>Science</td>
<td>Both Ma &amp; Sc</td>
<td>Mathematics</td>
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<tr>
<td><strong>Conceptual framework</strong></td>
<td>Science teaching</td>
<td>Cognitive modelling</td>
<td>Instructional interventions</td>
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<td><strong>Teaching construct</strong></td>
<td>Teaching strategies</td>
<td>Learning components</td>
<td>Instructional programs</td>
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<tr>
<td><strong>Field location</strong></td>
<td>Restricted: Only US</td>
<td>Unrestricted: Mainly US, Eur</td>
<td>Unrestricted: Mainly US</td>
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<tr>
<td><strong>Duration</strong></td>
<td>Unrestricted</td>
<td>Unrestricted</td>
<td>At least 12 wks</td>
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<tr>
<td><strong>Outcomes examined</strong></td>
<td>Achievement</td>
<td>Achievement Attitude</td>
<td>Achievement</td>
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Recent research synthesis on pedagogy: Triangulating meta-analytic screening

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<thead>
<tr>
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<tbody>
<tr>
<td>Experimental comparison or evaluation</td>
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<td>Correlational survey or experimental comparison</td>
<td>Randomised or matched experimental comparison</td>
</tr>
<tr>
<td>Prior control not required</td>
<td>Prior control</td>
<td>Prior control</td>
<td>No large gaps</td>
</tr>
<tr>
<td>Effect sizes included</td>
<td>Relative Absolute</td>
<td>Relative only</td>
<td>Relative only</td>
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<tr>
<td>Outcome measures accepted</td>
<td>Unrestricted: Generally researcher developed</td>
<td>Unrestricted: Standardised &amp; researcher developed</td>
<td>Screened for intervention bias: Mainly standardised</td>
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Recent research synthesis on pedagogy: Meta-analytic findings on attainment effects

<table>
<thead>
<tr>
<th>Method</th>
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<th>Science</th>
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<tbody>
<tr>
<td></td>
<td>Slavin et al.</td>
<td>Seidel &amp; Shavelson</td>
</tr>
<tr>
<td>Domain-specific inquiry</td>
<td>No cognate category</td>
<td>0.37 [22]</td>
</tr>
<tr>
<td>Co-operative groupwork</td>
<td>0.36 [17]</td>
<td>-0.04 [42]</td>
</tr>
<tr>
<td>Enhanced context</td>
<td>No cognate category</td>
<td>No cognate category</td>
</tr>
<tr>
<td>Active teaching</td>
<td>0.43 [10]</td>
<td>No cognate category</td>
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<td><strong>Domain-specific inquiry</strong></td>
<td>____ [&lt;5]</td>
<td>0.35 [7]</td>
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<tr>
<td><strong>Co-operative groupwork</strong></td>
<td>0.02 [9]</td>
<td>0.41 [14]</td>
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<tr>
<td><strong>Enhanced context</strong></td>
<td>No cognate category</td>
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Recent research synthesis: Triangulating wider findings on identity and attitude

BES iteration on effective mathematics teaching
• Teaching that takes students’ mathematical thinking seriously is underpinned by principles such as:
  – all students being empowered to develop mathematical identities and knowledge
  – interpersonal respect, sensitivity, fairness and consistency being shown to all students

EPPI review on motivational effort in mathematics
• Effective pedagogical strategies are characterised by:
  – a caring and supportive classroom climate
  – activities which pupils find challenging and enjoyable
  – pupils gaining deeper understanding of mathematics
  – opportunities for pupils to collaborate
Recent research synthesis: Triangulating wider findings on co-operative groupwork

**BES iteration on effective mathematics teaching**
- Small-group work can support engagement
- Students may need opportunities to think quietly
- Many students are reluctant to share their thinking

**EPPI review of group discussions in science teaching**
- Students often struggle to express coherent arguments, and demonstrate a low level of engagement with tasks
- Groups function best, understanding improves most:
  - with groups constituted so that differing views voiced
  - when students receive training on group processes
  - when “cues” support the structuring of discussions
Research-informed conclusions for pedagogical improvement at scale

• In mathematics, varied sources agree that the active teaching model promoted by the Strategies is effective in securing content knowledge and skills but less so in developing higher-order and functional thinking.

• There is little support for this teaching model in science.

• Domain-specific enquiry that takes students’ thinking seriously strengthens attainment and (plausibly) attitude.

• Co-operative groupwork strengthens attainment and (at least in science) attitude, as long as students are properly prepared and activity well supported.

• Enhanced context, linked to student experiences and interests, is beneficial (at least for science attainment).
effecting principled improvement in STEM education