Digital technology in mathematics education

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False hopes?

School technology has raised “too many false hopes”

Performance gets worse?

Poorer school performance through increased computer use


-> CCC!
Little solid evidence?

Despite considerable investments in computers, internet connections and software for educational use, there is little solid evidence that greater computer use among students leads to better scores in mathematics and reading. (OECD, 2015, p. 145)

What is known about the effects of using digital technology in mathematics education on student performance?
Outline
Outline

✓ Problem statement

- Reviewing review studies

- An exemplary (?) study

- The wrong question? New answers?

- Conclusion
Reviewing review studies
Li & Ma 2010

- 46 studies, 85 effect sizes
- K-12 classrooms
- Statistically significant positive effects
- Effect sizes: $d = 0.28$ (weighted), $d = 0.71$ (unweighted)
- Additional findings: higher effect sizes in
  - primary education;
  - special education;
  - studies that used a constructivist approach to teaching;
  - studies that used non-standardized tests.

- Focus on algebra; technology tools and technology curricula
- Strict criteria for inclusion
- 109 effect sizes.
- Statistically significant positive effects
- Weighter effect sizes: $d = 0.151$ (tools) and $d = 0.165$ (curricula)

Additional findings:
- Interventions on conceptual understanding provide twice as high as procedural;
- Short interventions may have significant effect;
- No difference whole school – single teacher.
From Rakes et al. (2010)
Cheung and Slavin (2013)

- 74 effect sizes
- K-12 classrooms
- Statistically significant positive effects
- Effect size: $d = 0.16$ (weighted)
- Additional findings:
  - Effect not improving over time;
  - Higher effect sizes in primary education;
  - Lower effect sizes in randomized experiments;
  - Effect sizes in large studies smaller than in small-scale studies.
“Educational technology is making a modest difference in learning of mathematics. It is a help, but not a breakthrough.” (Cheung & Slavin, 2013, p. 102).
Overview of review study results

<table>
<thead>
<tr>
<th>Study</th>
<th>Number of effect sizes</th>
<th>Average effect size</th>
<th>Global conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Li &amp; Ma 2010</td>
<td>85</td>
<td>0.28 (weighted)</td>
<td>Statistically significant positive effects.</td>
</tr>
<tr>
<td>Rakes et al. 2010</td>
<td>109</td>
<td>0.151 – 0.165</td>
<td>Positive, statistically significant results.</td>
</tr>
<tr>
<td>Cheung &amp; Slavin 2013</td>
<td>74</td>
<td>0.16</td>
<td>A positive, though modest effect</td>
</tr>
</tbody>
</table>

Table 1: Effect sizes reported in three review studies

(Drijvers, submitted)
Mixed conclusions (1)

“Over the last four decades, research has led to consistent findings that digital technologies such as calculators and computer software improve student understanding and do no harm to student computational skills.”
(Ronau et al., 2014, p. 974)
Mixed conclusions (2)

“Research findings from experimental and quasi-experimental designs – which have been combined in meta-analyses – indicate that technology-based interventions tend to produce just slightly lower levels of improvement when compared with other researched interventions and approaches.”

“Taken together, the correlational and experimental evidence does not offer a convincing case for the general impact of digital technology on learning outcomes. “

“We need to know more about where and how it is used to greatest effect.”

(Higgins, Xiao, & Katsipataka, 2012, p. 3)
Possible explanations and remarks

1. ICT simply doesn’t work!

2. The claim is too general; it is the how that counts!

   - Results seem difficult to replicate
   - Scaling up is problematic
An examplary (?) study
Drijvers et al. (2014)

- RQ: What is the effect of learning and practicing of algebraic skills in a digital environment as compared to a traditional learning environment?
- Topic: linear and quadratic equations in grade 8
- ICT: Freudenthal Institute’s Digital Mathematics Environment (DME)
- Sample: 842 13-14 year old high-achieving students
\[
8 + \frac{4}{4 \cdot x - 12} = 9
\]

\[
\frac{4}{4 \cdot x - 12} = 1
\]

\[
4 \cdot x - 12 = 4
\]

\[
4 \cdot x = 16
\]

\[
x = 4
\]

De vergelijking is correct opgelost.
7. Extra practice 2

Choose the right strategy and carry it out

In this activity you can use the red buttons to select the next step, but you have to carry it out yourself.

Afterwards you can press Enter to check.

A short description of the buttons can be found here:

Example use answer box:

Exercise 1

Solve the equation below step by step.

\[ \frac{x^2 + 3x - 10}{x + 5} = 0 \]

\[ (x + 5)(x - 2) = 0 \]

\[ x + 5 = 0 \quad \text{or} \quad x - 2 = 0 \]

\[ x = -5 \quad \text{or} \quad x = 2 \]

The equation is solved correctly.
Four possible explanations

1. Spill-over effect?
2. Too superficial learning?
3. Too limited, mainly strategic, feedback?
4. Lack of integration of computer work and paper-and-pen work?
The wrong question? New answers?
"Pen and paper is good for mathematics education."
What is known about the effects of using digital technology in mathematics education on student performance?

How to exploit the potential of using digital technology for student performance in mathematics?
Answering the “how” question: Instrumentation

- Mental scheme
- Technique
- Type of tasks
- Artefact
- Solve an equation

Instrument
The intertwinnement of doing and understanding: instrumentation

Artefact and instrument:
- Artefact: the object or ‘thing’ good artefact does not imply nice music!
- Cognitive scheme = Technique + Concepts
- Instrument = Artefact + Schemes
Example instrumentation: the solve scheme on a CAS calculator

(Drijvers, 2003; Drijvers, Godino, Font & Trouche, 2013)
Orchestration: A symphony orchestra conductor? Rather a jazz band leader...

The teacher: orchestration

- The challenge for the teacher: to facilitate students’ instrumentation.

- Three-level model for that: instrumental orchestration

Diagram:

- Didactical performance
- Exploitation mode
- Didactical configuration
ICT for PD on ICT: a MOOC

[VIDÉO 3.1] ORCHESTRATION

Configurations didactiques des artefacts
Conclusion
One more quote:

One interpretation of all this is that building deep, conceptual understanding and higher-order thinking requires intensive teacher-student interactions, and technology sometimes distracts from this valuable human engagement. Another interpretation is that we have not yet become good enough at the kind of pedagogies that make the most of technology; that adding 21st-century technologies to 20th-century teaching practices will just dilute the effectiveness of teaching.

(OECD, 2015, p. 3)
Conclusion

- Evidence for the benefit of the use of ICT in mathematics education not yet overwhelming;
- The question is the “how” rather than the too general “can”
- We need to take into account methodological rigor
- In the mean time, focus on subtleties reflected in the notions of instrumentation and orchestration
Thank you for your attention!

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