Learning by app

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Universiteit Leiden
Studying Mobile

A Comenius Leadership Fellow program at Leiden University (2019-2023)

Applicant: dr. Ludo Juurlink

associate professor Physical Chemistry at Leiden Institute of Chemistry

Research group: Catalysis and Surface Science

Research fields #1: Surface Science and Chemical reaction dynamics

Research fields #2: Chemical pedagogy and mobile learning

Co-applicants:

prof. dr. Han de Winde (Biology)

prof. dr. Marco de Ruiter (Medicine)

dr. Maarten van de Ven (ICLON)
The hurdle race

1. Lack of insight into its structure makes an academic curriculum to its students look like as a series of more or less unrelated courses and assignments (hurdles).

2. Financial incentives make students want to study efficiently.

➔ Many students adopt studying techniques that are efficient in passing assessments but inefficient in building long-term retention, e.g. ‘cramming’.
Cerego

a mobile phone-based application that uses push technology to remind students to study at the optimal time.

Cerego’s engine uses

• distributed learning (spaced repetition)
• retrieval practice (testing effect)
and
• it adapts itself to each individual student
• can be integrated with, a.o., Brightspace
• runs on all smart phones
• is reasonably affordable

“Adaptive learning platform”
Distributed learning

The Forgetting Curve

\[ R = e^{-t/s} \]

Hermann Ebbinghaus
1850 - 1909

Retrievability
Stability of memory

aka “Spaced repetition”
Retrieval practice

“The finding that taking a test on previously studied material leads to better retention than does restudying that material for an equivalent amount of time.”

APA Dictionary of Psychology

aka “Testing effect”, “active recall”, ..
How does it work?

1. Professor (or student assistant) creates content, e.g. flash cards, ordering assignments, clickable images, ... in “sets” that can be studied in rather short study sessions.

2. Sets are added to a “course”.
   • Retention level
   • Availability (start and end date/gated)

   The first time they see/read everything in a new set. Thereafter, they are only tested to build retention.

3. Student signs up for your course and receives notifications to study the material.

   They continue to study throughout the course while an AI algorithm tracks each student performance and optimizes parameters (what and when).
What we suggested to study

1. “Implementation effects”, e.g.
   a) How easily is a platform like this implemented?
   b) Do students appreciate the availability of the platform?

2. Whether the use of Cerego affects long-term retention

3. Whether it lowers test anxiety

4. Whether it increased time spent studying
What have we learned so far? part 1a

2019-2022 Logistics of implementation

1 AVG/GDPR issues

2 The difficulty of convincing others to get involved (both teachers and support)

3 Funding to pay for continuation of license

4 Training of teachers and student assistants
What have we learned so far?  

Monitor *date of registration* for Cerego as an optional study tool.

Technology acceptance varies between programs?!
What we suggested to study

1. “Implementation effects”, e.g.
   a) How easily is a platform like this implemented?
   b) Do students appreciate the availability of the platform?

2. Whether the use of Cerego affects long-term retention

3. Whether it lowers test anxiety

4. Whether it increased time spent studying

main pedagogical issue

side issues
What have we learned so far? part 1b

Student experience tested through 30 second SURVEY at 5 different programs (Dec-2020).

- ENJOYED using Cerego in this course
- think it HELPED with studying this course
- wish for more Cerego CONTENT in this course
- think MORE COURSES in program should use Cerego
What have we learned so far? part 1b

Student experience tested through general SURVEY after “Anatomy - Motion” (March 2021), N ~300.

Likert scale van “slecht” (1) tot “zeer goed” (5)

- De Cerego app is een fijne aanvulling voor het leren van de anatomische structuren, av. = 4,7.
- De Cerego app is een aanvulling op het bestaande onderwijs, av. = 4,6.
- Ik zou de Cerego app aanbevelen aan medestudenten, av. = 4,7.
- De Cerego app was gebruiksvriendelijk, av. = 4,5.
- Ik vond het fijn dat Cerego aangeboden werd als extra studiemiddel bij Vraagstukken Bewegen, av. = 4,8.
- Ik denk dat het studeren via Cerego me heeft geholpen bij Vraagstukken Bewegen, av. = 4,6.
- Ik had graag méér studiemateriaal aangeboden gekregen via Cerego bij Vraagstukken Bewegen, av. = 4,4.
- Het zou goed zijn als studeren met Cerego bij méér vakken van mijn opleiding wordt aangeboden, av. = 4,8.
What we suggested to study

1. “Implementation effects”, e.g.
   a) How easily is a platform like this implemented?
   b) Do students appreciate the availability of the platform?

2. Whether the use of Cerego affects long-term retention

3. Whether it lowers test anxiety

4. Whether it increased time spent studying

(\textit{main pedagogical issue})

\{ \textit{side issues} \}
What have we learned so far? part 2

2019-2022 Learning Effects

Testing for retention effects within BSc Chemistry program.
Involved courses “General Chemistry” (Q1, yr 1) and “Inorganic Chemistry” (Q4, yr 1)

“General Chemistry” (Q1, yr 1)
- 6 EC taught in 8 weeks + 2 weeks (Sept-Nov)
- Enrollment ~180 students
- Classes and ‘workshops’
- Content based on a teacher-written book
- Midterm and a final exams
- Cerego use is optional
- Cerego content mostly serves topics leading up to the midterm exam.

“Inorganic Chemistry” (Q4, yr 1)
- 6 EC taught in 8 weeks + 2 weeks (April-July)
- Enrollment ~140 students
- Classes and ‘workshops’
- Content based on a commercial book
- Repeats and elaborates on some of the topics form General Chemistry.

➔ Entrance level (retention) test is useful in itself
Retention test characteristics

• Voluntary but unannounced
• 30 questions offered sequentially in random order in a BrightSpace quiz:
  21 questions relate to study material also offered within Cerego during “General Chemistry”
  9 questions did not have Cerego-related content
• Grading: 1 or 0 points per question
• Timed: 15 minutes max

• Question types:
  3 multiple answer (3 in Cerego-related questions + 0 in non-related)
  17 multiple choice (15+2)
  8 true/false (2+6) ← note this potential for bias!
  2 ordering (1+1)
What have we learned so far?

2021-2022

- $N = 102$ students
- 134 of these also registered for Cerego when taking AAC
  - 51 did not start // 83 started
  - 23 reached > 50% progress goals
- Same general observations in both years
  - Cerego users score higher.
  - Scores increases with reached study goal in Cerego

Cerego users

2021-2022

2020-2021

class average

average progress to Cerego retention goals on all content

normalized retention test score
What have we learned so far?  

2020-2021

• Focus on non-Cerego related questions

<table>
<thead>
<tr>
<th>Question #</th>
<th>Question</th>
<th>Discrimination index (%)</th>
<th>Average score</th>
<th>Average score Cerego users</th>
<th>Average score non-users</th>
</tr>
</thead>
<tbody>
<tr>
<td>22</td>
<td>HF is een sterk zuur.</td>
<td>43,8</td>
<td>0,375</td>
<td>0,405</td>
<td>0,370</td>
</tr>
<tr>
<td>24</td>
<td>De geconjugeerde base van een zuur met een $K_a$ waarde...</td>
<td>56,1</td>
<td>0,441</td>
<td>0,514</td>
<td>0,395</td>
</tr>
<tr>
<td>28</td>
<td>In de kristalveldtheorie staat het symbool $\Delta_o$...</td>
<td>53,1</td>
<td>0,475</td>
<td>0,676</td>
<td>0,383</td>
</tr>
</tbody>
</table>
What have we learned so far?  

2020-2021

• Compared AAC exam results

<table>
<thead>
<tr>
<th>Exam #</th>
<th>Average score Cerego users</th>
<th>Average score non-users</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>79.6</td>
<td>63.1</td>
</tr>
<tr>
<td>2</td>
<td>59.6</td>
<td>42.8</td>
</tr>
</tbody>
</table>

Relies in part directly on content also offered within Cerego

Does not rely directly on content also offered within Cerego

➡ Selection bias and/or compound effect?!
What have we learned so far?  

2021-2022

• Analyze results *in detail*:

• *Conclusion*: Avid Cerego users clearly do better (about 20% for the most avid users) on the retention test, but this is likely due to a selection bias and/or compound learning effect.
2021-2022

• Alternate comparison to remove the selection bias

**Design:**

• Compare performance of Cerego students with course progress > 50% to an equal sized group with identical results on AAC Final exam scores (exam2). *These exam results can not reflect Cerego study effects as no questions were asked that related to Cerego study content.*

• We compare scores on all and the selected 21 questions of the retention test administered after 5 months.
What have we learned so far?

2021-2022

• Alternate comparison

<table>
<thead>
<tr>
<th>alternate comparison</th>
<th>AAC score final</th>
<th>Cerego progress</th>
<th>AAC score final</th>
<th>Cerego progress</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>96%</td>
<td>10</td>
<td>24%</td>
<td></td>
</tr>
<tr>
<td>9,53</td>
<td>98%</td>
<td>9,29</td>
<td>n.a.</td>
<td></td>
</tr>
<tr>
<td>8,82</td>
<td>99%</td>
<td>8,82</td>
<td>4%</td>
<td></td>
</tr>
<tr>
<td>8,35</td>
<td>68%</td>
<td>8,24</td>
<td>4%</td>
<td></td>
</tr>
<tr>
<td>8,35</td>
<td>55%</td>
<td>8,24</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>7,65</td>
<td>55%</td>
<td>7,77</td>
<td>n.a.</td>
<td></td>
</tr>
<tr>
<td>7,06</td>
<td>60%</td>
<td>7,06</td>
<td>42%</td>
<td></td>
</tr>
<tr>
<td>6,71</td>
<td>73%</td>
<td>6,71</td>
<td>5%</td>
<td></td>
</tr>
<tr>
<td>6,12</td>
<td>99%</td>
<td>6,18</td>
<td>n.a.</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>52%</td>
<td>6</td>
<td>n.a.</td>
<td></td>
</tr>
<tr>
<td>5,65</td>
<td>79%</td>
<td>5,71</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>5,65</td>
<td>54%</td>
<td>5,65</td>
<td>n.a.</td>
<td></td>
</tr>
<tr>
<td>5,59</td>
<td>99%</td>
<td>5,59</td>
<td>24%</td>
<td></td>
</tr>
<tr>
<td>5,24</td>
<td>51%</td>
<td>5,53</td>
<td>n.a.</td>
<td></td>
</tr>
<tr>
<td>4,77</td>
<td>53%</td>
<td>4,77</td>
<td>33%</td>
<td></td>
</tr>
<tr>
<td>4,53</td>
<td>82%</td>
<td>4,47</td>
<td>n.a.</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>61%</td>
<td>4,06</td>
<td>n.a.</td>
<td></td>
</tr>
<tr>
<td>1,77</td>
<td>91%</td>
<td>1</td>
<td>7%</td>
<td></td>
</tr>
</tbody>
</table>

Average score AAC Final = 6.43
StDev = 2.10

Average score AAC Final = 6.39
StDev = 2.17
What have we learned so far?  

2021-2022

• Alternate comparison

• Observation: From two identical groups, “Avid Cerego users” (here defined as scoring >50% on Cerego-defined learning goals)) score considerably better than others after 5 months on the retention test.

<table>
<thead>
<tr>
<th></th>
<th>Score “avid Cerego users”</th>
<th>Score “non/poor Cerego users”</th>
<th>Cerego improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>complete test (30 questions)</td>
<td>18.3</td>
<td>15.3</td>
<td>+20%</td>
</tr>
<tr>
<td>limited test (21 questions)</td>
<td>12.2</td>
<td>10.8</td>
<td>+13%</td>
</tr>
</tbody>
</table>
What have we learned so far?

2021-2022

• Many more comparison groups (500 per data point) using two varying intervals
  • AAC final exam score interval
  • Cerego learning goal cut off

• Observation: From two identical groups, “Avid Cerego users” score considerably better than others after 5 months. This is especially so for users of Cerego exceeding 50% of the learning goals.
Started with implementation in Summer 2019

2019-2020
1 Introductory Chemistry (BSc Molecular Science & Technology/Maths & Natural Sciences)
2 Anatomy (Medicine/LUMC)
3 Material Science (BSc Archeology/Archeology)

Added in 2020-2021:
4 Celbiology and Biochemistry (BSc Life Science & Technology/Maths & Natural Sciences)
5 Biochemistry 1 (BSc Biopharmaceutical Sciences/Maths & Natural Sciences)
6 Metals and Life (MSc Chemistry/Maths & Natural Sciences)
7 Introductory in programming in Python (BSc Computer Science/Maths & Natural Sciences)
8 Developmental Biology (BSc Biology/Maths & Natural Sciences)
9 Introductory Chemistry (BSc Biopharmaceutical Sciences/Maths & Natural Sciences)
...

Sept 2022: Vocabulary building (BSc Law, Faculty of Law) + 1200 potential students!

In April 2022:
1700 active users
2700 registered users
Conclusions

Implementation
1. GDPR issues, license costs, and the limited period of a pilot study negatively affect implementation.
2. Students and teachers are very positive about the availability
3. *Technology acceptance variation* between programs is likely affecting the intended outcome (better long-term retention).

Learning effects
1. Strong indications of a selection bias and/or compound effect in retention data.
2. Circumventing the selection bias, we find a positive effect on long-term retention (~10% improvement for avid Cerego users over a 5-month time span).
Een gewilde app waarmee je beter leert!

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