Evidence-based evaluation of the effectiveness of problem-based learning in a pre-college population

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What is problem-based learning (PBL)?

- Contextualized, student-centered instructional approach: students learn through a meaningful task.
- Concrete problems initiate learning.
- Problems describe observable phenomena that need explanation.
PBL process

2. Identify facts about problem.
3. Identify what they need to find out.
4. Discuss problem, generate problem strategies, hypotheses, possible solutions, and explanations.
5. Learn relevant concepts through brief lecture or self-directed research.
Role of teacher

- PBL students manage their learning strategies and goals.
- Teacher as coach: monitors learning, poses questions, answers student-initiated questions, facilitates group learning.
Purpose of study

- What is the effect of instructional condition on student **comprehension** and **application** of concepts?
  - Does PBL produce superior results to lecture/discussion (LD)?
  - Does PBL-team produce superior results to PBL-individual (i.e., is social context an essential component of PBL)?
Method

Participants

- n=90
- middle-school students
- 3 classes at alternative, public middle school
- ethnically and socioeconomically diverse
- 6 50-min class periods
Design

Crossed, within-subjects

Independent variables:
1. Instructional format: PBL vs. LD
2. Grouping condition: PBL-team vs. PBL-individual

<table>
<thead>
<tr>
<th>Topic 1</th>
<th>Topic 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1</td>
<td>PBL-individual</td>
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<tr>
<td>Class 2</td>
<td>PBL-team</td>
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<tr>
<td>Class 3</td>
<td>LD</td>
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<tr>
<td>PBL: team &amp; solo</td>
<td>Lecture/discussion</td>
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**Session 1**

**Problem-formulation**
- Intro to topic (5 min)
- Identify problem & related facts (15 min)
- Address PBL problem (15 min)
- Intro to all concepts (5 min)

**Session 2**

**Problem analysis**
- Mini lecture on all concepts (20 min)
- Utilize concepts to solve problem (20 min)

**Session 3**

**Problem resolution**
- Final problem resolution (35 min)
- Concluding discussion (5 min)*

* Lecture/discussion on all concepts and new examples (35 min)
- Concluding discussion (5 min)
Topic 1: groupthink

1. Groupthink
2. Cognitive diversity
3. Conformity
4. Cohesion
5. Diffusion of responsibility
6. Obedience
7. Group Size
Groupthink problem

- Why do you believe the team members didn’t collect more information and try to find out everything they could to make the right decision about the Columbia? What characteristics of this particular group made it not work well and what could have helped them function better as a group?
Topic 2: memory

1. Survey
2. Question
3. Recite
4. Review
5. Reduce interference
6. Spaced learning
7. Associative links
Memory problem

What are they doing wrong in their studying? What advice can you give them on effective studying and memorization skills and why do you believe these will work? What practical strategies should our students and current surgeons use to memorize important procedures, in the right order, like this checklist?
Assessments

- 9 weeks after intervention
  - Application assessment
  - Comprehension assessment
Application assessment: groupthink

How will you select your committee members, and how will you run your committee, to make sure they’ll come up with a successful plan?
Application assessment: memory

How can you make sure that the article you write when you get home is as accurate as possible, reflecting everything you learned?
Comprehension assessment: groupthink

Please define and fully explain the following groupthink terms:

1. Groupthink
2. Cognitive diversity
3. Conformity
4. Social cohesion
5. Diffusion of responsibility
6. Obedience
7. Group size
Comprehension assessment: memory

Please define and fully explain the following memory terms:

1. Survey
2. Question
3. Recite
4. Review
5. Reduce interference
6. Space learning
7. Associative links
Coding
2 levels of coding/analysis for each assessment

Coding: 2 levels of coding/analysis per assessment
1. Total number of concepts defined/applied: 0-7
2. Depth of explanation:
   • What level of explanation did the student reach on each concept?
   • What was the highest level of explanation reached by the student, on any of the concepts?
   • What was the modal level of explanation reached?
Coding: application

1. Total number of concepts applied: 0-7
2. Depth of explanation: each concept is coded under one of 5 categories
   - **No reference.** Does not apply the concept, either in content or by name.
   - **Mention.** Applies the concept, either in content or by name, but does not define.
   - **Definition.** Applies the concept, either in content or by name, and provides definition.
   - **Explanation.** Applies the concept, either in content or by name, and provides definition and explanation.
   - **Elaborated explanation.** Applies the concept, either in content or by name, provides definition and explanation, and also elaborates on the application or explanation, or establishes meaningful relationships between concepts.
Coding: comprehension

1. Total number of concepts defined: 0-7
2. Depth of explanation: each concept is coded under one of 5 categories
   - **No relevant response.**
   - **Basic Definition.** Provides only vague or very basic definition.
   - **Elaborated Definition.** Provides basic definition and elaborates on definition.
   - **Basic Explanation.** Provides basic definition, elaborates on definition and provides basic explanation.
   - **Elaborated Explanation.** Provides basic definition, elaborates on definition and provides basic explanation. Also elaborates on explanation or relates the concept to the main topic or related concepts.
Results: reliability

- Assessments coded by 2 coders, blind to condition
  - Primary coder coded 100%, secondary coder coded 20%
- Cohen’s kappa coefficient used to measure inter-rater reliability
  - Reliability = 86-91%
  - Cohen’s kappa = .704-.866
Results: no instruction group baseline performance

- Students had **little prior knowledge** of concepts
- Two topics were **equivalent in difficulty**
  - Mean no. concepts defined
    - Groupthink: 0.56 (sd= .797; range 0-3)
    - Memory: 0.52 (sd= .901; range 0-5)
    - **No sig difference**, $t(186) = .343, p = .732$
  - Modal no. concepts defined
    - Groupthink: 0
    - Memory: 0
- Of the students who were able to define any concepts, most defined only one
Results - groupthink comprehension

PBL-team vs. PBL-individual

- No. of concepts defined
  - PBL-team: 5.19 (sd= 1.331; range 2-7)
  - PBL-individual: 4.84 (sd= 1.179; range 2-7)
  - No sig difference, \( t(50) = .987, p = .329 \)

- Highest explanation level
  - No sig difference, \( \chi^2(2, N = 52) = 2.209, p = .331 \)

- Modal explanation levels
  - No sig difference, \( \chi^2(2, N = 52) = 7.889, p = .05 \)
Results - groupthink comprehension
PBL (team and individual) vs. LD

- PBL defined more concepts than LD
  - PBL: 5.02 (sd= 1.260; range 2-7)
  - LD: 3.33 (sd= 1.373; range 1-6)
- Sig difference, $t(74) = 5.271, p = .001$
Results - groupthink comprehension
PBL (team and individual) vs. LD

- PBL: higher explanation levels than LD, \( \chi^2(3, N = 76) = 14.996, p = .002 \)
- PBL: higher modal explanation levels compared to LD, \( \chi^2(3, N = 76) = 12.584, p = .006 \)
# Results - groupthink comprehension

## PBL (team and individual) vs. LD

<table>
<thead>
<tr>
<th></th>
<th>No relevant response</th>
<th>Basic definition</th>
<th>Elaborated definition</th>
<th>Basic explanation</th>
<th>Elaborated explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>PBL-team</td>
<td>0</td>
<td>3.7</td>
<td>25.9</td>
<td>33.3</td>
<td>37.0</td>
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<tr>
<td>PBL-individual</td>
<td>0</td>
<td>4.0</td>
<td>12.0</td>
<td>52.0</td>
<td>32.0</td>
</tr>
<tr>
<td>LD</td>
<td>0</td>
<td>20.8</td>
<td>45.8</td>
<td>25.0</td>
<td>8.3</td>
</tr>
</tbody>
</table>
## Results - groupthink comprehension

PBL (team and individual) vs. LD

<table>
<thead>
<tr>
<th>Modal levels of Explanation by Percentage</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
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</thead>
<tbody>
<tr>
<td>PBL-team</td>
<td>18.5</td>
<td>33.3</td>
<td>25.9</td>
<td>11.1</td>
<td>11.1</td>
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<tr>
<td>PBL-individual</td>
<td>44.0</td>
<td>8.0</td>
<td>36.0</td>
<td>8.0</td>
<td>4.0</td>
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<tr>
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<td>70.8</td>
<td>16.7</td>
<td>12.5</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Results - groupthink application
PBL-team vs. PBL-individual

- No. of concepts defined
  - PBL-team: 2.59 (sd= 1.824; range 0-6)
  - PBL-individual: 2.88 (sd= 1.966; range 0-6)
  - No sig difference, \( t(51) = -0.561, p = .577 \)

- Highest explanation level
  - No sig difference, \( \chi^2(3, N = 53) = 2.022, p = .568 \)
Results - groupthink application
PBL (team and individual) vs. LD

- PBL defined more concepts than LD
  - PBL: 2.74 (sd= 1.883; range 0-6)
  - LD: 1.17 (sd= 1.523; range 0-5)
  - Sig difference, $t(74) = 5.271, p = .001$
Results - groupthink application
PBL (team and individual) vs. LD

- **PBL: higher explanation levels than LD,**
  \[ \chi^2(3, N = 77) = 15.157, p = .002 \]
# Results - groupthink application

PBL (team and individual) vs. LD

## Highest level of Explanation by Percentage

<table>
<thead>
<tr>
<th></th>
<th>No reference</th>
<th>Application</th>
<th>Definition</th>
<th>Explanation</th>
<th>Elaborated explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>PBL-team</td>
<td>18.5</td>
<td>0</td>
<td>25.9</td>
<td>25.9</td>
<td>29.6</td>
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<tr>
<td>PBL-individual</td>
<td>15.4</td>
<td>0</td>
<td>30.8</td>
<td>38.5</td>
<td>15.4</td>
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<tr>
<td>LD</td>
<td>45.8</td>
<td>12.5</td>
<td>25.0</td>
<td>8.3</td>
<td>8.3</td>
</tr>
</tbody>
</table>
Results – memory comprehension
PBL-team vs. PBL-individual

- No. of concepts defined
  - PBL-team: 4.70 (sd= 1.601; range 2-7)
  - PBL-individual: 4.00 (sd= 1.713; range 0-7)
  - No sig difference, $t(59) = -1.648$, $p = .105$

- Highest explanation level
  - No sig difference, $\chi^2(3, N = 61) = 1.237$, $p = .744$

- Modal explanation level
  - No sig difference, $\chi^2(3, N = 61) = 1.151$, $p = .756$
Results – memory comprehension
PBL (team and individual) vs. LD

- **PBL defined more concepts than LD**
  - PBL: 4.34 (sd= 1.682; range 0 -7)
  - LD: 2.75 (sd= 1.404; range 1-6)
- **Sig difference**, $t(87) = 4.362, p < .001
Results – memory comprehension
PBL (team and individual) vs. LD

- **PBL: higher explanation levels than LD**
  \[ \chi^2(3, N = 89) = 12.018, p = .007 \]

- **PBL: higher modal explanation levels than LD**, \[ \chi^2(3, N = 89) = 15.672, p = .001 \]
### Results – memory comprehension
PBL (team and individual) vs. LD

**Highest level of Explanation by Percentage**

<table>
<thead>
<tr>
<th></th>
<th>No relevant response</th>
<th>Basic definition</th>
<th>Elaborated definition</th>
<th>Basic explanation</th>
<th>Elaborated explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PBL-team</strong></td>
<td>0</td>
<td>13.3</td>
<td>20.0</td>
<td>40.0</td>
<td>26.7</td>
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<tr>
<td><strong>PBL-individual</strong></td>
<td>6.5</td>
<td>3.2</td>
<td>32.3</td>
<td>35.5</td>
<td>22.6</td>
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<tr>
<td><strong>LD</strong></td>
<td>0</td>
<td>14.3</td>
<td>60.7</td>
<td>10.7</td>
<td>14.3</td>
</tr>
</tbody>
</table>
# Results - memory comprehension

PBL (team and individual) vs. LD

<table>
<thead>
<tr>
<th>Modal levels of Explanation by Percentage</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>PBL-team</td>
<td>82.1</td>
<td>3.6</td>
<td>14.3</td>
<td>0</td>
</tr>
<tr>
<td>PBL-individual</td>
<td>36.7</td>
<td>13.3</td>
<td>30.0</td>
<td>20.0</td>
</tr>
<tr>
<td>LD</td>
<td>41.9</td>
<td>19.4</td>
<td>19.4</td>
<td>19.4</td>
</tr>
</tbody>
</table>
Results - memory application
PBL-team vs. PBL-individual

- No. of concepts defined
  - PBL-team: 2.10 (sd= 1.749; range 0-6)
  - PBL-individual: 2.42 (sd= 1.747; range 0-7)
  - No sig difference, \( t(59) = -0.713, p = .478 \)

- Highest explanation level
  - No sig difference, \( \chi^2(4, N = 61) = 4.595, p = .331 \)
Results - memory application
PBL (team and individual) vs. LD

- PBL defined more concepts than LD
  - PBL: 2.26 (sd= 1.741; range 0-7)
  - LD: 1.24 (sd= 1.154; range 0-5)
  - Sig difference, $t(78) = -3.302, p = .001$
Results - memory application
PBL (team and individual) vs. LD

- **PBL**: higher explanation levels than LD,
  \[ \chi^2(4, N = 90) = 11.312, p = .023 \]
### Highest level of Explanation by Percentage

<table>
<thead>
<tr>
<th></th>
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<th>Explanation</th>
<th>Elaborated explanation</th>
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<tr>
<td>PBL-team</td>
<td>23.3</td>
<td>23.3</td>
<td>3.3</td>
<td>33.3</td>
<td>16.7</td>
</tr>
<tr>
<td>PBL-individual</td>
<td>19.4</td>
<td>12.9</td>
<td>19.4</td>
<td>29.0</td>
<td>19.4</td>
</tr>
<tr>
<td>LD</td>
<td>27.6</td>
<td>37.9</td>
<td>20.7</td>
<td>6.9</td>
<td>6.9</td>
</tr>
</tbody>
</table>
Comparison of groupthink vs. memory topics - comprehension

- **No. of concepts defined**
  - Groupthink: 4.49 (sd= 1.51; range 1-7)
  - Memory: 3.84 (sd= 1.76; range 0-7)
  - Sig difference, $F(1, 163) = 6.26, p = .03$
    - the only sig comparison of two topics

- **Highest explanation level**
  - No sig difference, $F(1, 163) = 2.261, p = .135$

- **Modal explanation level**
  - No sig difference, $F(1, 163) = .682, p = .41$
Comparison of groupthink vs. memory topics - application

- No. of concepts defined
  - Groupthink: 28.08% (sd= 23.92; range 0-75%)
  - Memory: 27.62% (sd= 23.44; range 0-100%)
  - No sig difference, $F(1, 165) = .016, p = .899$

- Highest explanation level
  - No sig difference, $F(1, 165) =1.191, p = .277$
PBL-individual vs. PBL-team within-subjects analysis

- Analyses of individual patterns confirm results of between-subjects comparisons:
  - No sig difference between PBL-individual and PBL-teams
Conclusions: how does PBL work?

- Engagement with problem
  - Goal-based, authentic
    - = higher motivation and engagement?
  - Contextualized
    - A story-line for information
  - Activation of prior knowledge
    - tackling the problem “cold”
    - ideas more meaningful and more accessible
  - Elaborations and explanations
    - Metacognitions: reflecting on one’s own learning

- Not social component
  - (cognitive load sharing through social collaboration)