Does an explicit general problem solving teaching strategy improve elementary pre-service teachers’ ability to solve heat transfer problems?

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Rationale

• Elementary science program must produce problem solvers (NSTA, 2002)

• Elementary teachers can be taught problem solving in their content courses such as chemistry

• Some studies have also shown that explicitly teaching problem solving improves students’ performance (Bunce et al., 1991, Kumar, 1993; Schmidt, 1994).

• This study investigates the effects of an explicit general problem solving strategy on pre-service elementary school teachers’ ability in solving heat transfer problems.
Research questions

- How do the scores, on heat transfer problems, of pre-service teachers taught using an explicit general problem solving approach compare with those of students taught without this approach?

- How do pre-service teachers taught using an explicit general problem solving strategy and those taught without this strategy approach solving heat transfer problems?
Subjects

<table>
<thead>
<tr>
<th></th>
<th>Treatment</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>( N )</td>
<td>20</td>
<td>22</td>
</tr>
<tr>
<td>83 % Female</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Explicit PS

- **Problem:** to find the specific heat capacity of the metal ($c_m$)
- Given: mass of metal ($m_m$) = 2.40 g
  - Initial temperature of metal ($T_m$) = 200°C
  - Final temperature ($T_f$) = 18°C
- We know: specific heat capacity of water ($C_w$) = 4.2 J/g/°C

- **Plan:** Heat gained by water is given by $q_w = m_w C_w \Delta T$
- Heat lost by water is given by $q_w = m_m c_m \Delta T$
- Heat lost by metal = heat gained by water (law of conservation of heat)

Conventional PS

- Given: mass of metal ($m_m$) = 2.40 g
  - Initial temperature of metal ($T_m$) = 200°C
  - Final temperature ($T_f$) = 18°C
- We know: specific heat capacity of water ($C_w$) = 4.2 J/g/°C
  - $q_w = -q_m$
  - $m_w C_w \Delta T = - m_m c_m \Delta T$
Research design

- Explanatory mixed method

  - Quantitative data followed by qualitative data.

  - Used quantitative data to answer research question 1 and qualitative data research question 2.
Research question 1

How do the scores, on heat transfer problems, of PSET taught using an explicit general problem solving approach compare with those of students taught without this approach?
Experimental design

- Pretest-posttest nonequivalent control group design (Quasi experiment).

- Pre/posttest:
  
  ➢ 8 same questions; taken before and after heat/temperature topic.

  ➢ Written by researcher, validated by 2 science educators.
Results

<table>
<thead>
<tr>
<th>Group</th>
<th>Treatment</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>52%</td>
<td>47%</td>
</tr>
<tr>
<td>SD</td>
<td>13</td>
<td>20</td>
</tr>
</tbody>
</table>

\[ t_{28} = 0.84 \quad p = 0.41, \quad \text{Cohen} \; d = 0.30 \]

Pretest: No grade for subjects
Individual question comparisons

![Bar chart showing individual question comparisons between Treatment and Control groups. The chart displays the scores for each question number (1 to 8). The Treatment group is represented by blue bars, and the Control group is represented by red bars. Significant differences are marked with **.](image-url)
Quantitative data conclusion

Research question 1: How do the scores, on heat transfer problems, of pre-service teachers taught using an explicit general problem solving approach compare with those of students taught without this approach?

Answer: No improvement in performance using EGPSTS.
Question 2

- How do pre-service teachers taught using an explicit general problem solving strategy and those taught without this strategy approach their problem solving on heat transfer problems?
## Interviews subjects

<table>
<thead>
<tr>
<th></th>
<th>Subjects</th>
<th>A, B, C, D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher Performers (HP)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower Performers (LP)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment section</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>Control section</td>
<td>C</td>
<td>D</td>
</tr>
</tbody>
</table>

- **Subjects A, B, C, D**
- **Higher Performers (HP)**
- **Lower Performers (LP)**
- **Treatment section**
- **Control section**
Questions for Think-aloud interviews

1. What will be the final temperature of water when 100 g of water at 80°C is mixed with 200 g of water at 20°C?

3. A piece of metal weighing 25.50 g is heated in boiling water for 40 minutes. Then it was removed from the boiling water and dropped into an insulated Styrofoam cup containing 150 ml of liquid water at 22°C. Assuming there was no loss of heat to the surrounding, what was the final temperature of the system? (the specific heat capacity of the metal is 0.91 J/g/°C)
Qualitative data analysis

- Two researchers analyzed data from the interviews independently and developed codes.
  - Inter-coder reliability (Cohen’s Kappa) = 0.83, (percent agreement = 0.92).

- From the codes, three themes were developed.
  - (1) Conceptual understanding; (2) organization skills and (3) confidence in solving problems.
## Conceptual understanding - Equilibrium

<table>
<thead>
<tr>
<th>Student A (HP-Treatment)</th>
<th>Student B (LP-Treatment)</th>
</tr>
</thead>
<tbody>
<tr>
<td>“I knew the temperature of the metal was 100°C because when it is in boiling water for an extended amount of time it gathers that temperature ...because it reaches equilibrium so it balances up…”</td>
<td>“The water is at 22°C but it doesn’t say what the metal is. I would assume that the metal would be hotter.”</td>
</tr>
</tbody>
</table>

Only higher performers (A and C) understood and applied the concept of equilibrium to solve question 3 than lower performers (B and D).
**Conceptual understanding- heat capacity**

<table>
<thead>
<tr>
<th>Student D (LP-control)</th>
<th>Student C (HP-control)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Interviewer:</strong> “What is so special about what you mentioned, the specific heat, why is it important?”</td>
<td><strong>Interviewer:</strong> “I agree with you we have two different substances, what is the implication when we have two different substances?”</td>
</tr>
<tr>
<td><strong>Subject:</strong> “ammm I really don’t know. I mean I know it’s important because it’s the temperature of like of metal or water, whatever, we are using it for, I mean all I think ... just like a constant.”</td>
<td><strong>Subject:</strong> “I suppose because you have different conductors and metal has lower specific heat capacity and it transfers the heat away from it quicker while for water it takes long to heat up.”</td>
</tr>
</tbody>
</table>
### Organization during problem solving

**Interviewer:** “how did you solve problem 1?”

<table>
<thead>
<tr>
<th>Subject B (LP-Treatment)</th>
<th>Subject D (LP-Control)</th>
</tr>
</thead>
<tbody>
<tr>
<td>“First thing I did was to write down what was already stated in the problem; that is 100g of water at 80°C and 200g of water at 20°C…”</td>
<td>“Well, I learned the formula for finding the temperatures like if you mix two temperatures of a certain way together and I know that it was like temperature 1 of the first thing over the total…”</td>
</tr>
</tbody>
</table>
### Confidence

<table>
<thead>
<tr>
<th>Subject A (HP-Treatment)</th>
<th>Subject D (LP-Control)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject A: “Ok, first, I started of with organizing everything and I knew the temperature of the metal was 100°C because when it is in boiling water for an extended amount of time it gathers that temperature.”</td>
<td>Subject D: “aamh, just looking at this now I am not sure if I did this right, I don’t know if you had to have the double sided formula because I did it wrong…”</td>
</tr>
</tbody>
</table>

Higher performers (A and C) were more confident than lower performers in solving complex problem (No 3).
Qualitative data conclusion

Research question 2: How do pre-service teachers taught using an explicit general problem solving strategy and those taught without this strategy approach their problem solving on heat transfer problems?

Answer: No difference on how participants approached problems.

- Differences seemed to emerge due to differences in abilities not due teaching strategy
Limitations

- Selection of interviewees did not go as planned.
  - More interviewees needed in future study

- Hence for further, research we propose
  - A longer treatment time and a robust sample selection.