Teaching-learning strategies for ill-structured problem solving in engineering

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August 26, 2014
1. Overview of Work Done

2. Literature Review

3. My focus: Field Studies in Ill-Structured Problem Solving
   - Delayed Guidance
   - Guided problem solving and group programming

4. Other Projects
   - Representational Competence
   - Think-pair-share

5. Future Directions
During World War II, the city of South London was hit by 537 bombs. For the sake of analysis, the total area of the city was divided into 576 squares, each with area 1/4 sq. km. The statistics of the actual hits/square is below:

<table>
<thead>
<tr>
<th>Number of hits/sq</th>
<th>Number of squares</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>229</td>
</tr>
<tr>
<td>1</td>
<td>211</td>
</tr>
<tr>
<td>2</td>
<td>93</td>
</tr>
<tr>
<td>3</td>
<td>35</td>
</tr>
<tr>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
</tr>
</tbody>
</table>

Looking at this statistics, can you tell if the Germans were targeting specific areas or if they were bombing the city without any prior information?

Can you test your hypothesis by a computer simulation?

(from EE 746, Autumn 2013, Bipin Rajendran)
Senior engineering students, even exceptional ones, cannot solve these problems despite knowing the theoretical concepts.
The previous problem and my first year

- Senior engineering students, even exceptional ones, cannot solve these problems despite knowing the theoretical concepts.
- Engineering students can be taught how to solve such problems.
Senior engineering students, even exceptional ones, cannot solve these problems despite knowing the theoretical concepts.

Engineering students can be taught how to solve such problems.

We developed two teaching-learning strategies for this thinking skill.
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Engineering students can be taught how to solve such problems.

We developed two teaching-learning strategies for this thinking skill.

They were effective in improving certain aspects of ill-structured problem solving.
Senior engineering students, even exceptional ones, cannot solve these problems despite knowing the theoretical concepts. Engineering students can be taught how to solve such problems. We developed two teaching-learning strategies for this thinking skill. They were effective in improving certain aspects of ill-structured problem solving. Students enjoyed and learned from both strategies.
Ill-structured problems are those in which (Jonassen, ETRD, 1997)

- One or more of the problem elements are unclear or ill-defined
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- Possess multiple solutions and/or solution paths
What are ill-structured problems?

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- Possess multiple evaluation criteria
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- One or more of the problem elements are unclear or ill-defined
- Possess multiple solutions and/or solution paths
- Possess multiple evaluation criteria
- Often have to be solved with incomplete information
Why ill-structured problem solving?

- ABET learning outcome: “an ability to identify, formulate and solve engineering problems”
- Washington Accord: “Define, investigate and analyze complex problems” and “Design or develop solutions to complex problems”
- “Workplace problems are ill-structured.” (Jonassen et al, JEE, 2006)
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Graduating engineers need to be able to solve ill-structured problems.
The ability to solve well-structured problems in the classroom does not translate to the ability to solve ill-structured, engineering problems (Hong et al., JRST, 2003; Linder, PhD dissertation, 1999)
Motivation for the previous years work

• The ability to solve well-structured problems in the classroom does not translate to the ability to solve ill-structured, engineering problems (Hong, et al., JRST, 2003; Linder, PhD dissertation, 1999)

• Ill-structured problem solving ability needs to be explicitly developed via teaching-learning strategies.
April-July 2013

- Presented IDP-ET TR: “Notes on problem-solving: A literature review of problem-solving, with emphasis on ill-structured, engineering and estimation problems”

- Wrote a paper (ICER 2013) as part of TPS in CS101: “Effect of Think-Pair-Share in a large CS1 class: 83% sustained engagement” (with Rwitajit Majumdar, Sridhar Iyer, Sahana Murthy)

- Planned experimental study in EE 746 - Neuromorphic engineering: “Delayed guidance as a teaching-learning strategy for ill-structured problem solving” (with Bipin Rajendran)

- Wrote a paper (T4E2013): “PULSE: A Framework for Protocol based Utility to Log Student Engagement” (with Rwitajit Majumdar)
August-October 2013

- Conducted two experiments in EE 746. Analysed the data and revised the study based on this. Planned and conducted third experiment.

- Wrote a paper (ITiCSE 2014) as part of TPS in CS101: “Think-pair-share in a large CS1 class: does learning really happen?” (with Sahana Murthy, Sridhar Iyer)
Timeline

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- Wrote a paper (ITiCSE 2014) as part of TPS in CS101: “Think-pair-share in a large CS1 class: does learning really happen?” (with Sahana Murthy, Sridhar Iyer)

November - December 2013

- Did detailed statistical and qualitative analyses of experiment three data.

- Presented credit seminar based on this work.
January - February 2014

- Planned grounded theory study of student perceptions of learning with productive failure
- Planned and began study in EE590 - Foundations of Projects as secondary researcher/mentor: “Guided problem solving and group programming” (with Abhinav Anand and Bipin Rajendran)
## Timeline

### January - February 2014

- Planned grounded theory study of student perceptions of learning with productive failure
- Planned and began study in EE590 - Foundations of Projects as secondary researcher/mentor: “Guided problem solving and group programming” (with Abhinav Anand and Bipin Rajendran)

### March - April 2014

- Conducted interviews for the grounded theory study, began transcription and analysis.
- Concluded EE 590 study and data analysis.
- Began project: “Development of representational competence using an enactive computer interface” (with Rwitajit Majumdar, Prajakt Pandey, Harshit Agarwal, Ajit Ranka and Sanjay Chandrasekhan)
May - July 2014


- Completed interface development, conducted a pilot study and submitted a paper to T4E2014: “The enactive equation: exploring how multiple external representations are integrated, using a fully controllable interface and eye-tracking” (with Rwitajit Majumdar, Prajakt Pandey, Harshit Agarwal, Ajit Ranka, Sanjay Chandrasekharan and Sahana Murthy)

- Planned closure on project TPS in CS101: Journal paper (with Shitanshu Mishra, Rwitajit Majumdar, Sridhar Iyer and Sahana Murthy)
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The guiding questions for the literature review were . . .

- What are ill-structured problems and how are they solved?
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- What is ill-structured problem solving ability?
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- What are ill-structured problems and how are they solved?
- What is ill-structured problem solving ability?
- What are the teaching-learning strategies for ill-structured problem solving?
Problem Solving

- Of well and ill-structured problems
- Involves a 5 step process
- Behaviour of experts and novices is very different.
  - Individual ability depends on
  - Is taught in the classroom as
  - Is taught using
- The nature of the problem
  - Internal factors
What we learned from the literature survey.

1. Problem solving can be described as a three step process: Problem framing, solution generation and evaluation.

2. Expert problem solving behaviour differs greatly from novice behaviour.

3. Problem solving ability has several different dimensions. Individual problem solving ability = f(familiarity, knowledge base, problem solving strategies, metacognition, epistemic cognition, affective abilities, practices of the domain)

4. Individual problem solving ability + Learning → Expert problem solving ability

5. Learning can happen on the job. Here we focus on instruction in school/college.

6. A six-step design is suitable for ill-structured problem solving.

Each step has several activities and scaffolds involved.
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5. A six-step design is suitable for ill-structured problem solving.

6. Each step has several activities and scaffolds involved.
This can be represented in the following framework:

![Diagram showing the progress from student to expert with 5 dimensions of learning environment: 1. Domain knowledge, 2. Problem solving strategies and heuristics, 3. Epistemic cognition, 4. Metacognition, 5. Affective elements and domain practices.](image)
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Study the effect of some instructional strategies/scaffolds discovered in the literature review in field settings.
Moving forward from the literature review...

- Study the effect of some instructional strategies/scaffolds discovered in the literature review in field settings.
- Two strategies selected based on the requirement of the classrooms in which we were working.
  - The role of delayed guidance on ill-structured problem solving.
  - The role of question prompts and peer interactions on ill-structured problem solving.
What is Delayed Guidance?

- Delayed guidance improves conceptual understanding (Kapur, CI, 2008; Schwartz and Bransford, 1998; vanLehn et al, 2003; Schwartz and Martin, 2004).

Premise: Allowing students to explore the domain without direct instruction at the beginning $\rightarrow$ Prime and differentiate prior knowledge, attention to critical features $\rightarrow$ Build upon this in the following structure/feedback/instruction.

Our Argument

- Allowing students to explore a problem without telling them how to approach it $\rightarrow$ Exploration leads to greater priming and differentiating of prior knowledge than direct instruction $\rightarrow$ Students understand what is relevant and what is not, attend to critical features $\rightarrow$ Do problem framing in terms they know $\rightarrow$ Follow this up with instruction on problem framing.
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Broad Research Goal

To study the effect of delayed guidance on student learning and perceptions of ill-structured problem solving.
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Specific Research Questions

1. Does delayed guidance lead to improved ill-structured problem solving performance?
   - To what extent does delayed guidance affect the ill-structured problem solving performance?
   - To what extent does delayed guidance affect the development of ill-structured problem solving competencies?

2. What are student perceptions of learning through delayed guidance?

3. What are the differences between the problem solving strategies of students who learn through delayed guidance vs. those who learn via direct instruction?
# Overview of the study

<table>
<thead>
<tr>
<th>About</th>
<th>Contributions</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motivated by literature review done in technical report</td>
<td>Some dimensions of students problem solving ability improved</td>
<td>Ongoing</td>
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<tr>
<td>Conducted in EE746 - Neuromorphic Engineering, Prof. Bipin Rajendran</td>
<td>Students problem solving strategies with/without delayed guidance being explored</td>
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<tr>
<td>Quasi-experimental study, 3 interventions</td>
<td>New teaching-learning strategy for problem solving ability: currently in use in EE 746</td>
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<td>Two conference papers planned</td>
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**Direct Instruction**
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### Experiment design

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<tr>
<th>Constructs</th>
<th>Ill-structured problem solving instructional strategy</th>
<th>Student achievement in ill-structured problem solving</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Variables</strong></td>
<td>Instructional strategy with 2 levels-</td>
<td>Scores on ill-structured problem solving test;</td>
</tr>
<tr>
<td></td>
<td>1. Delayed Guidance</td>
<td>Development of ill-structured problem solving</td>
</tr>
<tr>
<td></td>
<td>2. Direct Instruction</td>
<td>competencies</td>
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<tr>
<td><strong>Confoundning variables</strong></td>
<td>Affective and conative abilities, prior knowledge,</td>
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<td></td>
<td>metacognition, epistemic cognition, general problem</td>
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<tr>
<td></td>
<td>solving skill</td>
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<tr>
<td><strong>Sampling Technique</strong></td>
<td>Convenient sampling; Matched (on the basis of pre-test</td>
<td></td>
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<tr>
<td></td>
<td>for prior knowledge, motivation and general problem</td>
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<td></td>
<td>solving skill) and random assignment to experimental</td>
<td></td>
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<tr>
<td></td>
<td>and control groups.</td>
<td></td>
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<tr>
<td><strong>Research Design</strong></td>
<td>Quasi-Experimental: Mr X1 02(Experimental)</td>
<td></td>
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<tr>
<td></td>
<td>Mr X2 02(Control)</td>
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</table>
At level 1, the experimental group presents more successful design solutions than the control group.

Table: Success rate of both groups

<table>
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<tr>
<td>Expt</td>
<td>31%</td>
</tr>
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<td>Ctrl</td>
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\(^1p\ (\text{Mann-Whitney}) = 0.4\)
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But the difference is not statistically significant.

\[ p \text{ (Mann-Whitney)} = 0.4 \]
At level 0, the experimental group performs better than the control group on all constructs.

Table: Ill-structured problem solving performance

<table>
<thead>
<tr>
<th>Construct (0-3)</th>
<th>Expt Group Mean (SD)</th>
<th>Ctrl Group Mean (SD)</th>
<th>p (Mann-Whitney)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inputs</td>
<td>2 (1.2)</td>
<td>1.8 (1)</td>
<td>0.64</td>
</tr>
<tr>
<td>Time scales</td>
<td>2.4 (0.8)</td>
<td>1.9 (0.9)</td>
<td>0.19</td>
</tr>
<tr>
<td>Network structure</td>
<td>2.3 (0.8)</td>
<td>2.2 (0.8)</td>
<td>0.98</td>
</tr>
<tr>
<td>Adjusting parameters</td>
<td>2.8 (0.8)</td>
<td>1.9 (1.2)</td>
<td>0.017 (r=0.45)</td>
</tr>
<tr>
<td>Complete, justified design proposed</td>
<td>2.6 (0.6)</td>
<td>2 (0.9)</td>
<td>0.095 (r = 0.4)</td>
</tr>
<tr>
<td>Complete, working design</td>
<td>1.4 (1.2)</td>
<td>1.1 (0.8)</td>
<td>0.64</td>
</tr>
<tr>
<td>Quality of solution</td>
<td>1.6 (1.1)</td>
<td>1.2 (1.1)</td>
<td>0.49</td>
</tr>
</tbody>
</table>
At level 0, the experimental group performs better than the control group on all constructs.

The difference is statistically significant for the construct of “Adjusting Parameters” and approaches significance for the construct of “Proposing a complete, justified design”.

**Table:** Ill-structured problem solving performance

<table>
<thead>
<tr>
<th>Construct</th>
<th>Expt Group Mean (SD)</th>
<th>Ctrl Group Mean (SD)</th>
<th>p (Mann-Whitney)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inputs</td>
<td>2 (1.2)</td>
<td>1.8 (1)</td>
<td>0.64</td>
</tr>
<tr>
<td>Time scales</td>
<td>2.4 (0.8)</td>
<td>1.9 (0.9)</td>
<td>0.19</td>
</tr>
<tr>
<td>Network structure</td>
<td>2.3 (0.8)</td>
<td>2.2 (0.8)</td>
<td>0.98</td>
</tr>
<tr>
<td>Adjusting parameters</td>
<td>2.8 (0.8)</td>
<td>1.9 (1.2)</td>
<td>0.017 (r=0.45)</td>
</tr>
<tr>
<td>Complete, justified design proposed</td>
<td>2.6 (0.6)</td>
<td>2 (0.9)</td>
<td>0.095 (r = 0.4)</td>
</tr>
<tr>
<td>Complete, working design</td>
<td>1.4 (1.2)</td>
<td>1.1 (0.8)</td>
<td>0.64</td>
</tr>
<tr>
<td>Quality of solution</td>
<td>1.6 (1.1)</td>
<td>1.2 (1.1)</td>
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At level -1, the experimental group shows more evidence of ill-structured problem solving competencies in the solution than the control group.

### Table: Number of competencies evident in the solution

<table>
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<th>EXPT Mean (SD)</th>
<th>CTRL Mean (SD)</th>
<th>p (Mann-Whitney)</th>
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<tbody>
<tr>
<td>Pre Prompts Mean (SD)</td>
<td>14.7(7.3)</td>
<td>10.9(4.9)</td>
<td>0.187</td>
</tr>
<tr>
<td>Post Prompts Mean (SD)</td>
<td>15.3(6.6)</td>
<td>9.1(6.3)</td>
<td><strong>0.02</strong></td>
</tr>
<tr>
<td>p (Wilcoxon)</td>
<td>0.816</td>
<td>0.285</td>
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At level -1, the experimental group shows more evidence of ill-structured problem solving competencies in the solution than the control group.

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And the difference is statistically significant in the post-prompts stage.
At level -1, the experimental group does more problem framing at the start and the control group does problem representation.

Table: Frequency of first competency category

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<tr>
<th>Competency Category</th>
<th>Expt Group (%)</th>
<th>Ctrl Group (%)</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Pre-prompts</td>
<td>Post-prompts</td>
</tr>
<tr>
<td>Problem Representation</td>
<td>31.25</td>
<td>12.5</td>
</tr>
<tr>
<td>Problem Framing</td>
<td>43.75</td>
<td>6.25</td>
</tr>
<tr>
<td>Generating Solutions</td>
<td>25</td>
<td>81.25</td>
</tr>
<tr>
<td>Evaluation and Monitoring</td>
<td>0</td>
<td>0</td>
</tr>
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Pre prompts, \( p(\text{chi-squared}) = 0.167 \) and post prompts, \( p(\text{chi-squared}) = 0.513 \)
At level -1, the experimental group does more problem framing at the start and the control group does problem representation.

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<td></td>
<td>Pre-prompts</td>
<td>Post-prompts</td>
</tr>
<tr>
<td>Problem Representation</td>
<td>66.67</td>
<td>0</td>
</tr>
<tr>
<td>Problem Framing</td>
<td>11.11</td>
<td>11.11</td>
</tr>
<tr>
<td>Generating Solutions</td>
<td>22.22</td>
<td>88.89</td>
</tr>
<tr>
<td>Evaluation and Monitoring</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

But the difference is not statistically significant.

\[^2\text{Pre prompts, } p(\text{chi-squared})=0.167 \text{ and post prompts, } p(\text{chi-squared})=0.513\]
1. Problem framing is significantly lesser post-prompts for both groups.
2. Evaluation is significantly higher post-prompts for experimental group only.
3. The difference between the two groups in solution generation approaches significance.
Relative frequency of competency evidence

1. The percentage of problem framing is significantly lesser post-prompts for experimental group and approaches significance for control group.
2. The percentage of evaluation is significantly higher post-prompts for both groups.
3. The percentage of problem representation is significantly lower post-prompts for the control group, constant for experimental group.
Students perceived that they learned problem-solving.

Students found the problems interesting and want to do more such problems in other classes.
There are differences in the problem solving performance and behaviour of both groups

<table>
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<tr>
<th>STUDENTS IN THE EXPERIMENTAL GROUP:</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Choose parameters, propose solutions and justify them better (based on rubric).</td>
<td>Attention to critical features during ill-structured problem solving phase Engage in discussions to explain and refute These are corroborated by (Kapur, C&amp;I, 2008)</td>
</tr>
<tr>
<td>Show more evidence of using ill-structured problem solving competencies.</td>
<td>Students tried multiple representation and solution methods for a given problem during the ill-structured problem solving phase (^3)</td>
</tr>
<tr>
<td>Started with problem framing while those in control group started with problem representation.</td>
<td>Students try to define and understand the problem by themselves during the ill-structured problem solving phase</td>
</tr>
</tbody>
</table>

\(^3\) This warrants further investigation of in-class work and discussions of students in the delayed guidance group
There are differences in the problem solving performance and behaviour of both groups

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</tr>
</thead>
<tbody>
<tr>
<td>Were able to use the prompts better to do more evaluation and monitoring</td>
<td>Students engaged in discussions, elaborations and critiquing during the ill-structured problem solving phase.</td>
</tr>
<tr>
<td>Do as much problem representation post prompts as pre prompts</td>
<td>Students tried multiple representation methods for a given problem in the ill-structured problem solving phase.</td>
</tr>
<tr>
<td>Show more evidence of the competency category of generating solutions</td>
<td>Students tried multiple solution methods for a given problem in the ill-structured problem solving phase.</td>
</tr>
<tr>
<td>Found the problems interesting, but smaller percentage of students perceived to have learned problem solving compared to the control group</td>
<td>The delay in guidance.</td>
</tr>
</tbody>
</table>
1. Overview of Work Done

2. Literature Review

3. My focus: Field Studies in Ill-Structured Problem Solving
   - Delayed Guidance
   - Guided problem solving and group programming

4. Other Projects
   - Representational Competence
   - Think-pair-share

5. Future Directions

Extend the scaffolds into the computational part of problem solving, implementing the numerical solution (Chabav and Sherwood, Matter & Interactions, 2001).
What is Guided problem solving and group programming?


- Extend the scaffolds into the computational part of problem solving, implementing the numerical solution (Chabav and Sherwood, Matter & Interactions, 2001).

- Nature of question prompts different for each phase of problem solving like problem framing, solution generation, programming and evaluation.
What is Guided problem solving and group programming?


- Extend the scaffolds into the computational part of problem solving, implementing the numerical solution (Chabav and Sherwood, Matter & Interactions, 2001).

- Nature of question prompts different for each phase of problem solving like problem framing, solution generation, programming and evaluation.

- From well-structured problems to ill-structured problems.
Broad Research Goal

To study the role of question prompts and peer interactions on student learning of ill-structured problem solving.
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To study the role of question prompts and peer interactions on student learning of ill-structured problem solving.

Specific Research Questions

1. Does Guided problem solving and group programming strategy improve engineering students’ problem solving skills?
2. What are students’ perceptions of learning problem-solving via Guided problem solving and group programming strategy?
### Overview of the study

<table>
<thead>
<tr>
<th><strong>About</strong></th>
<th><strong>Contributions</strong></th>
<th><strong>Status</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Guided by literature review done in TR</td>
<td>• Some dimensions of students problem solving ability improved</td>
<td>Closed</td>
</tr>
<tr>
<td>• Conducted in EE 590 - Foundations of Projects, Prof. Bipin Rajendran - with Abhinav Anand</td>
<td>• Scaffolds for engineering problem solving and group programming identified</td>
<td></td>
</tr>
<tr>
<td>• Pre-experimental study, 3 interventions</td>
<td>• Activity resources to be made available on ET website soon</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• 1 conference paper</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Mentored a first year research scholar through this project</td>
<td></td>
</tr>
</tbody>
</table>
### Experiment design

<table>
<thead>
<tr>
<th>Constructs</th>
<th>Ill-structured problem solving instructional strategy</th>
<th>Student achievement in ill-structured problem solving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variables</td>
<td>Instructional strategy with 1 level Guided problem solving and group programming</td>
<td>Scores on Ill-structured problem solving test; Student perceptions</td>
</tr>
<tr>
<td>Confounding variables</td>
<td>Affective and conative abilities, prior knowledge, metacognition, epistemic cognition, general problem solving skill</td>
<td></td>
</tr>
<tr>
<td>Sampling Technique</td>
<td>Convenient sampling; Single group</td>
<td></td>
</tr>
<tr>
<td>Research Design</td>
<td>Pre-Experimental: O1 X 02</td>
<td></td>
</tr>
<tr>
<td>Criteria</td>
<td>Evidence</td>
<td>Instrument/Method of analysis</td>
</tr>
<tr>
<td>--------------------------------</td>
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</tr>
<tr>
<td>Ill-structured problem solving performance</td>
<td>Written solution + MATLAB program</td>
<td>Rubric grading (0-3)</td>
</tr>
<tr>
<td>Student perceptions</td>
<td>Survey Responses</td>
<td>Frequencies, Content analysis (emergent codes)</td>
</tr>
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Students ill-structured problem solving performance improves

<table>
<thead>
<tr>
<th>Skills</th>
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</tr>
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<tr>
<td></td>
<td>Mean</td>
<td>Std. Dev.</td>
<td>Mean</td>
<td>Std. Dev.</td>
<td></td>
</tr>
<tr>
<td>1. Problem framing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Define the problem</td>
<td>2.7</td>
<td>1.5</td>
<td>4.5</td>
<td>1.1</td>
<td>0.004</td>
</tr>
<tr>
<td>b. Generate sub goals</td>
<td>1.3</td>
<td>0.9</td>
<td>2</td>
<td>0</td>
<td>0.015</td>
</tr>
<tr>
<td>c. Identify relevant information</td>
<td>0.7</td>
<td>0.5</td>
<td>1.1</td>
<td>0.6</td>
<td>0.083</td>
</tr>
<tr>
<td>d. Seek needed information</td>
<td>0.8</td>
<td>0.4</td>
<td>1.5</td>
<td>0.6</td>
<td>0.008</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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And the difference is statistically significant for the construct of “Problem framing”.

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Students ill-structured problem solving performance improves

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<td>Mean</td>
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<td>Mean</td>
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<tr>
<td>2. Developing solution</td>
<td>2.3</td>
<td>1.2</td>
<td>3.9</td>
</tr>
<tr>
<td>3. Making justification for proposed solution</td>
<td>2.8</td>
<td>1.7</td>
<td>3.5</td>
</tr>
<tr>
<td>4. Monitoring and evaluating problem space and solutions</td>
<td>0.3</td>
<td>0.7</td>
<td>0.1</td>
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And the difference is statistically significant for the construct of “Developing Solutions” but not for the constructs of “Justification” and “Monitoring.”
Students ill-structured problem solving performance improves

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And the difference is statistically significant for the construct of “Developing Solutions” but not for the constructs of “Justification” and “Monitoring”.
1. Students perceived they learned ill-structured problem solving, that question prompts played a role.
2. Students enjoyed the strategy and developed confidence in problem solving.
3. However they were mostly as to neutral to whether concepts were sufficient to solve ill-structured problems.
Students perceived these benefits of each stage of the strategy:

- **Discussion**
  - Multiple ways solving/thinking
  - New Ideas
  - Reaching conclusions

- **Programming**
  - Evaluation
  - Optimization, Parameter Variation
  - Social skills, enjoyment

- **GPGP**
  - Thinking skills
  - Adverse group dynamics

**Understanding** frequency: 10

Frequency (# Students):
- Multiple ways solving/thinking: 12
- New Ideas: 6
- Reaching conclusions: 4
- Optimization, Parameter Variation: 8
- Social skills, enjoyment: 4
- Thinking skills: 8
- Adverse group dynamics: 4

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Question prompts play a role in learning ill-structured problem solving

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<tr>
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<th>What in the intervention <em>might</em> have caused this?</th>
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<tr>
<td>All dimensions of problem framing (based on ISPS rubric).</td>
<td>Instructor prompts like “Think about it physically. What is the probability that you are going to go very far without changing directions?” Engage in discussions during group problem solving.</td>
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<tr>
<td>All dimensions of developing solutions</td>
<td>Instructor prompts like “That’s a good strategy right. But would he be able to walk that distance?” Engage in discussions during group problem solving.</td>
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Question prompts play a role in learning ill-structured problem solving

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<tr>
<td>Did not improve in evaluation and monitoring skills</td>
<td>Insufficient question prompts during the problem solving and code writing phase.</td>
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<td>Interesting problems and regular, in-class problem solving</td>
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And the role and nature of prompts warrants further study.
From literature and as corroborated by our field studies, we identify desirable features in an ill-structured problem solving learning environment:

- Task orientation- authentic, real world problems.
From literature and as corroborated by our field studies, we identify desirable features in an ill-structured problem solving learning environment

- Task orientation- authentic, real world problems.
- Delay in guidance to allow students to explore the problem, do problem framing and identify critical features.
From literature and as corroborated by our field studies, we identify desirable features in an ill-structured problem solving learning environment.

- Task orientation- authentic, real world problems.
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From literature and as corroborated by our field studies, we identify desirable features in an ill-structured problem solving learning environment

- Task orientation- authentic, real world problems.
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- Allow students to work in groups and collaborate.
- Provide question prompts after the delay to help students complete the problem framing.
From literature and as corroborated by our field studies, we identify desirable features in an ill-structured problem solving learning environment

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- Delay in guidance to allow students to explore the problem, do problem framing and identify critical features.
- Allow students to work in groups and collaborate.
- Provide question prompts after the delay to help students complete the problem framing.
- Provide question prompts to support solution development, argument construction/identifying evidence for solution and evaluation.
- Have metacognitive and epistemic prompts throughout the process.
So the learning environment would look like this now.

Learning Environment
will include scaffolding on 5 dimensions:
1. Domain knowledge
2. Problem Solving Strategies and heuristics
3. Epistemic cognition
4. Metacognition
5. Affective elements and domain practices

Some types of scaffolds:
1) Question prompts
2) Multiple representations
3) Mini-cases
4) Strategy selector

Different @ each stage

Problem Framing → Generating Solutions → Evaluation
Outline

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3. My focus: Field Studies in Ill-Structured Problem Solving
   - Delayed Guidance
   - Guided problem solving and group programming

4. Other Projects
   - Representational Competence
   - Think-pair-share

5. Future Directions
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What is representational competence and how is it developed?

- The ability to simultaneously process and integrate multiple external representations in a domain (Pande and Chandrasekharan, 2014)
What is representational competence and how is it developed?

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- Experts are good at this.
What is representational competence and how is it developed?

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- Leads to deeper conceptual understanding
- Computer interfaces having multiple representations follow information processing theories of cognition with mixed results.
- Distributed and embodied, cognition (Kirsh, AI& S, 2010; Glenberg et al, PPS, 2013) suggest more roles for multiple representations.
Broad Research Goal

To explore how representational competence develops using an embodied, enactive interface.
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To explore how representational competence develops using an embodied, enactive interface.

Specific Research Questions

1. How can eye tracker data analysis give us more insight into the process and mechanism of multiple external representation integration and the development of representational competence?

2. What is the difference in student exploration of the interface, particularly in terms of manipulation/control, in the text-guided and self-guided conditions?

3. What is the difference between student exploration of the interface before the tasks are presented and during tasks?
Overview of the study

<table>
<thead>
<tr>
<th>ABOUT</th>
<th>CONTRIBUTIONS</th>
<th>STATUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guided by distributed, embodied theories of cognition.</td>
<td>Interface developed</td>
<td>Ongoing</td>
</tr>
<tr>
<td>With Rwitajit Majumdar, Prajak Pande, Harshit Agarwal, Ajit Ranka and Sanjay Chandrasekharan</td>
<td>Analysis methodology developed</td>
<td></td>
</tr>
<tr>
<td>Pilot, two-group, lab study - twelve, class 7 students - eye and mouse tracking</td>
<td>Interaction features for developing representational competence will be refined</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Further studies planned</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Two papers written, 1 more planned</td>
<td></td>
</tr>
</tbody>
</table>
The Simulation

**Iteration 1**
- Manipulation: click and drag the bob to increase/decrease length change angle.
- \[ \theta(t) = \theta_0 \cos \left( \frac{\sqrt{2}}{T} t \right) \]
- \[ \theta(t) = \frac{27.5}{\text{COS} \left( \frac{9.807}{1.5} \right)} \]
- Manipulation: scrubbing the numbers left-right decrease/increase value respectively.
- \[ f = \frac{1}{2\pi} \sqrt{\frac{9.807}{0.8 \text{ m}}} = 0.49 \text{ s}^{-1} \]

**Iteration 2**
- Manipulation:
  1. Left click and drag the bob to increase/decrease length.
  2. Right click and drag the bob to change angle.
- \[ \theta(t) = \theta_0 \cos \left( \frac{\sqrt{2}}{T} t \right) \]
- \[ \theta(t) = \frac{31.2}{\text{COS} \left( \frac{9.807}{0.5 \text{ m}} \right)} \]
- \[ f = \frac{1}{2\pi} \sqrt{\frac{9.807}{0.8 \text{ m}}} = 0.50 \text{ s}^{-1} \]

**Iteration 3**
- Color coded vertical sliders added to manipulate same colored numbers in equation.
- Initial Angle = 22.5 degrees
- Length of Pendulum = 1.0 m
- Slider for Initial Angle (degrees)
- Length of Pendulum (meters)
- Match the graph: next will appear when you are correct.
- Tick: Check
- Cross: Correct
- \[ \theta(t) = 22.5 \cos \left( \frac{\sqrt{2}}{T} t \right) \]

Manipulation on graph removed.
**LEVEL 4:** Process patterns, developed using a graph theoretic analysis, considering different areas on the screen as nodes on a graph.

**LEVEL 3:** Extracting markers of integration of MERs: (i) Gaze returns to a particular area of interest. (ii) Gaze transitions between spatial and numerical areas of the screen. (iii) Manipulating a particular area of the interface via mouse clicks and looking at another area of the screen.

**LEVEL 2:** Combine both data in level 1 to form sequence of events. Events are mouse click events and gaze events (in the perception-action cycle) and gaze events (simulation/imagination cycle).

**LEVEL 1:** Duration of fixations and number of mouse clicks on different areas of the screen.

Raw data from eye-tracker
Selected results

Average visit duration in each screen

Mouse clicks on each screen

Numerical - spatial transitions

Click-gaze transitions
Goal-oriented exploration better than unguided exploration, so task is needed.
Summary of results

- Goal-oriented exploration better than unguided exploration, so task is needed.
- Instructions needed on interface to promote exploration.
Goal-oriented exploration better than unguided exploration, so task is needed.

Instructions needed on interface to promote exploration.

Students do spatial - numerical transitions during perception/action and imagination cycle.
Summary of results

- Goal-oriented exploration better than unguided exploration, so task is needed.
- Instructions needed on interface to promote exploration.
- Students do spatial - numerical transitions during perception/action and imagination cycle.
- Characterized number of spatial-number transitions and click-gaze transitions, but no goodness measure yet.
1. Overview of Work Done

2. Literature Review

3. My focus: Field Studies in Ill-Structured Problem Solving
   - Delayed Guidance
   - Guided problem solving and group programming

4. Other Projects
   - Representational Competence
   - Think-pair-share

5. Future Directions
What is Think-pair-share?

- An active learning strategy
What is Think-pair-share?

- An active learning strategy
- Three phase: Individual think, pair collaboration and share discussion

Benefits from thinking time and small group collaborative learning. Can be used for different types of problems and develops higher order thinking skills.
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- An active learning strategy
- Three phase: Individual think, pair collaboration and share discussion
- Benefits from thinking time and small group collaborative learning
- Can be used for different types of problems and develops higher order thinking skills
To study the effects of think-pair-share on learning and engagement of students in a CS1 course.
Broad research goal

To study the effects of think-pair-share on learning and engagement of students in a CS1 course.

Specific Research Questions

1. What behaviours do students engage in during the Think-Pair-Share activities implemented in a large class?

2. This question has two related parts,
   1. How much student engagement occurs during the Think-Pair-Share activity?
   2. How does the amount of engagement change as activity progresses?

3. Do TPS activities lead to increased conceptual understanding and application of CS1 concepts?

4. What are the students’ perceptions of learning with TPS?

5. What are the instructors’ perceptions of teaching with TPS?
### Overview of the study

<table>
<thead>
<tr>
<th><strong>About</strong></th>
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<th><strong>Status</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>- Guided by active learning literature</td>
<td>- High engagement measured</td>
<td>Closing soon!</td>
</tr>
<tr>
<td>- Conducted in CS101 - Spring 2013, Spring 2014 - Prof. Sridhar Iyer - with Rwitajit Majumdar, Shitanshu Mishra</td>
<td>- Learning improved</td>
<td></td>
</tr>
<tr>
<td>- Observational study to measure engagement, Two experiments, Two surveys</td>
<td>- Guidelines to instructors on how to write and conduct TPS activities, resources on ET website</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Two conference papers published, One journal paper planned</td>
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</tr>
</tbody>
</table>
**Think phase.**

- Instructor presented the task.
- Students worked individually on the task for about two minutes.
- Wrote their answers in their notebooks.
TPS Strategy

1. *Think phase.*
   - Instructor presented the task.
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2. *Pair phase.*
   - Instructor gave a task related to or extended from the Think phase question.
   - Students worked with their neighbors to complete the task in three to five minutes.
   - Instructor walked along the aisles, encouraging discussion and answering queries.
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   - Students worked with their neighbors to complete the task in three to five minutes.
   - Instructor walked along the aisles, encouraging discussion and answering queries.

3. **Share phase.**
   - Instructor led a class-wide discussion related to the tasks in the Think and Pair phases.
   - Students followed the discussion to verify their solution and discuss “what-if” scenarios.
   - Open-ended, lasting from three to ten minutes depending on the depth of the discussion.
LEVEL 2: Aggregate behaviours for the entire class to report percentage engagement in each phase.

LEVEL 1: Group behaviours to generate behaviour sequences for students.

Observed behaviours of individual students in each phase.
Selected Results

Overall engagement during TPS

![Graph showing engagement levels across different problems]

Student behavior model

![Graph showing student behavior model]

Learning survey

![Bar chart showing learning survey results]

Table: Results of the experiment

<table>
<thead>
<tr>
<th>Expt Mean (SD)</th>
<th>Ctrl Mean(SD)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.91 (1.65)</td>
<td>0.88 (1.38)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Aditi Kothiyal  First APS  66/72
Students engagement oscillates around 80% in all phases, for different types of problems.
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Students learn better using TPS (moderate to high effect size).
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Students learn better using TPS (moderate to high effect size).

Students are interested in class and learning due to TPS.
Summary of results

- Students engagement oscillates around 80% in all phases, for different types of problems.
- Students learn better using TPS (moderate to high effect size).
- Students are interested in class and learning due to TPS.
- Instructor finds TPS useful for teaching different types of content and engaging all kinds of students.
Outline

1. Overview of Work Done

2. Literature Review

3. My focus: Field Studies in Ill-Structured Problem Solving
   - Delayed Guidance
   - Guided problem solving and group programming

4. Other Projects
   - Representational Competence
   - Think-pair-share

5. Future Directions
An engineer comes to your medical equipment company, claiming to have an image compression algorithm for medical images that achieves a compression ratio of 10-12x.

Previous best ratios were 3-4x. So this is going to save you a lot of memory and processing.

Does this compression ratio even sound reasonable?
• Engineers need to make these kinds of estimates in practice (Linder, PhD Thesis, 1999; Shakerin, IJEE, 2006) because:
  • Need upper and lower bounds.
  • To establish feasibility of a design
  • To eliminate candidate design solutions.
  • To plan projects or experiments.
  • When the exact calculation is too difficult
Two possible avenues to take our work

- Situate ill-structured problem solving as a thinking skill.
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- Situate ill-structured problem solving as a thinking skill.
- Develop technology enhanced learning environments for the development of this ability.
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- Electrical engineering domain- several types of ill-structured problems.
Two possible avenues to take our work

- Situate ill-structured problem solving as a thinking skill.
- Develop technology enhanced learning environments for the development of this ability.
- Electrical engineering domain- several types of ill-structured problems.
  - Technology enhanced learning environments for the development of *estimation skills* among third and fourth year electrical engineering students.
  - Technology enhanced learning environments for the development of *abstraction skills* as the first step of IS PS in electrical engineering for third and year students.
One problem selected, scoped down and delimited.
Desirable deliverables by second APS

- One problem selected, scoped down and delimited.
- Additional literature review (if necessary) complete.
Desirable deliverables by second APS

- One problem selected, scoped down and delimited.
- Additional literature review (if necessary) complete.
- Design of learning environment done, development in-progress.
Desirable deliverables by second APS

- One problem selected, scoped down and delimited.
- Additional literature review (if necessary) complete.
- Design of learning environment done, development in-progress.
- Research methodology for evaluation decided.