Rationale/background

• Problem solving is highly valued in science, and is a skill required for success in our undergraduate genetics courses.

• We knew very little about the problem solving processes our students use in genetics, and how that compares to successful solvers/experts.

• However, it is uncommon for problem solving skills to be explicitly taught and assessed in our courses.
Research Questions:

• What processes/procedures do students use when solving genetics problems, and how does this compare to experts?

• Can we improve student problem solving by making it an explicit part of our course curriculum?
Study Design

- Initial think-aloud interviews were conducted, and responses coded, to determine typical student and “expert” problem solving behaviour.

- Subsequent think-aloud sessions were used to assess student problem solving behaviour.

- Student responses on quizzes, tutorial questions, and exams were also assessed for demonstration of problem solving.
<table>
<thead>
<tr>
<th></th>
<th>Control: Typical Course</th>
<th>Treatment: Problem Solving 1</th>
<th>Treatment: Problem Solving 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Class size</td>
<td>N=180</td>
<td>N=390</td>
<td>N=74</td>
</tr>
<tr>
<td>Think-aloud group size</td>
<td>N=21</td>
<td>N=11</td>
<td>N=10</td>
</tr>
<tr>
<td>Class CI pre-test mean (s.d.)</td>
<td>47 ± 20%</td>
<td>36 ± 19%*</td>
<td>46 ± 23%</td>
</tr>
<tr>
<td>Think-aloud group CI pre-test mean</td>
<td>48 ± 19%</td>
<td>31 ± 16%*</td>
<td>54 ± 16%</td>
</tr>
<tr>
<td>Teaching Problem Solving (PS) Process</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Practice PS + feedback</td>
<td>Not explicit</td>
<td>Not explicit</td>
<td>Yes, prompted</td>
</tr>
<tr>
<td>Assessed on PS steps</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

*significantly lower than the control and PS2 group
Results: Problem Solving Process

Data: What does the question tell you?

Hypothesis: What is an explanation that might be consistent with the data?

Check: Does your result (based on your hypothesis) support or explain the data given in the question?

Are there errors?

YES: Checking revealed errors or inconsistencies → Modify hypothesis & try again

NO: Checking validated hypothesis. Are there any valid alternatives?

You’re done!

Figure modified from Rosie Redfield’s
What do students typically do?

From Think Aloud Interviews (control group):
• Students rarely check their work or consider alternative solutions
• Interviews revealed that many students don’t know how to check their work
**Part c:**
A third, unique phenotype appears in the F2 (a phenotype that was not observed in the parents or the F1). This new phenotype is observed in more than one F2 individual. Provide a possible genetic explanation for this. Show your work.

<table>
<thead>
<tr>
<th>Expert/Successful</th>
<th>Unsuccessful</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revisit solution to part a and b, confirming what phenotypes and genotypes are present.</td>
<td>No apparent consultation of what genotypes and phenotypes were observed in F1 and F2.</td>
</tr>
<tr>
<td>Hypothesis formation</td>
<td>Hypothesis formation</td>
</tr>
<tr>
<td>Doing work</td>
<td>First hypothesis: random mutation.</td>
</tr>
<tr>
<td>Checking work</td>
<td>A random mutation wouldn’t account for seeing this new phenotype in more than one F2.</td>
</tr>
<tr>
<td>Evaluation. Solution accepted.</td>
<td>Erroneous solution accepted.</td>
</tr>
<tr>
<td>Lack of applying hypothesis and checking outcome against criteria given in question. Insufficient solution.</td>
<td></td>
</tr>
</tbody>
</table>

Homozygous recessive would be observed in F1, new phenotype. Does not fit criteria.

Revise hypothesis. Only one parent is heterozygous at the second locus.

Performing crosses. New phenotype only observed in F2.

No immediate likely alternatives come to mind.
Problem Solving & Success

Interviews:
- “work-checking” students were typically more successful at solving a problem, or at least recognizing errors.

Quiz answers:
- Students who demonstrated work-checking typically get a better mark.
Results: Students better at solving

- Each dot represents a student.
- Students were assigned a problem solving score, based on demonstration of identified “expert-like” behaviours.
- More of the interviewed students exhibited problem solving behaviours if they were from the full problem solving treatment group (PS2).
For this particular question, the overall increases in total problem solving score for the PS2 group are the result of increases in all behaviours, primarily work-checking.
Conclusions

• Many students do not use work-checking and considering alternatives automatically, and often they do not know how to check work.

• Engaging in “expert-like” problem solving processes is correlated with success.

• Integrating problem solving into the course curriculum may increase the number of students that engage in problem solving behaviour automatically.

• Assessment and rewards may be the key to students engaging in the desired behaviours.
Outstanding Questions

• How can we easily, and accurately, assess context-dependent problem solving skills?
  – Capture data from a larger population, without doing think-aloud interviews

• Is work-checking a metacognitive behaviour? Are there better ways to foster this behaviour (other than grades as incentive)?

• Do students transfer these skills to other courses or contexts?
Acknowledgements

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