Designing Inquiry-Based Learning Experiences

Inquiry-Based Learning: What, Why, & How?
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Thanks to Stan Yoshinobu for providing some of the content.
About me

• Assistant professor in Mathematics & Statistics.
• PhD from University of Colorado (2008).
• MS here at NAU (2000).
• Areas of research:
  ‣ Combinatorics of Coxeter groups and diagram algebras,
  ‣ Some math education.
• Special Projects Coordinator for Academy of Inquiry-Based Learning.
• Spent 4 years at Plymouth State University prior to NAU.
• Number of IBL classes I had as a student: 0
What is inquiry-based learning (IBL)?

- According to the Academy of Inquiry-Based Learning:
  - IBL is a teaching method that engages students in sense-making activities.
  - Students are given tasks requiring them to solve problems, conjecture, experiment, explore, create, & communicate.
  - Rather than showing facts and/or algorithms, the instructor guides students via well-crafted problems.
- Students are responsible for guiding acquisition of knowledge.
- Often involves very little lecturing, and typically involves student presentations.
What is IBL? (Continued)

Here’s a short video by Jo Boaler (Stanford) that discusses IBL in the context of mathematics.
Guiding Principle of IBL
Continually ask yourself the following question:

Where do I draw the line between content I must impart to my students versus content they can produce independently?
Our main objective

Students answering questions

How do we get here?

Students asking questions
My first IBL class

- When I started teaching, I mimicked the experiences I had as a student (i.e., I lectured).
- By most metrics, I was a successful teacher (e.g., high evaluations, several awards). Why change?
- Inspired by Project NExT Workshop, decided to try IBL.
- For 3 consecutive semesters, I taught an intro to proof course at Plymouth State University.
- 1st two iterations taught via lecture-based approach.
- 3rd time taught using IBL with emphasis on collaboration.
- When I taught an abstract algebra course containing students from both styles, anecdotal evidence suggested students taught via IBL were more independent as learners.
Some data

• 4-5 million freshmen in HS.
• 75% HS graduation rate.
• 1.2 million bachelors degrees annually (<1% of BA/BS are in math).
• 48,000 doctoral degrees annually (400-500 PhDs in math).
• Education is a self-populating institution!

(NCES & NSF)

Conclusion?

You are peculiar!!!

We need to renormalize.
Talking About Leaving

• About half of STEM majors switch to non-STEM.
• Top 4 reasons for switching are teaching related.
• Good ones leave, too.
• Loss of interest.
• Curriculum overload.
• Students dissatisfied with teaching of STEM classes.
• Weed-out culture.
The good news
Evidence from the math ed literature suggests that active, learner-centered instruction leads to improved conceptual understanding, problem solving, proof writing, retention, habits of mind, and attitudes about math.


Other disciplines?
I am guessing/assuming that educational research in your respective disciplines bears this out, as well.
The Colorado study

- Comparing IBL vs non-IBL university mathematics courses.
- Sandra Laursen, CU Boulder.
- Statistically significant advantages for students in IBL vs traditional courses.
Instructor Obstacles

• “That’s how I learned, and it worked for me…”
  ▶ But you are peculiar!
• “I like inspiring lectures.”
  ▶ Inspiration is necessary, but not sufficient.
• “I’m afraid the students won’t like it.”
  ▶ My kids like Gummi Bears, but that doesn’t mean they are good for them.
• Control!
  ▶ If I lecture, then I dictate pace.
  ▶ If I write something on the board, then there is a good chance that it will be done correctly.
Student Obstacles

The main obstacle:

Most students do not enjoy direct instruction, but it is what they are used to. They expect to be passive, & they have had 14+ years of experience to develop deep-rooted beliefs about how STEM classes should operate & what is expected of them.
Marketing!

- Most students do not come equipped with the skills and interests that we have.
- Students need to know what their role is.

Students are asked to solve problems they do not know the answers to, to take risks, to make mistakes, and to engage in fruitful struggle.

- Students need to know that it is ok to be stuck and that you will support them in this endeavor.
- Students need to know what the instructor’s role is.
- Expectations & goals need to be reiterated throughout the course.
Delivery vs acquisition

• For content that is to be imparted to students, how will it be delivered?
  ▶ Assigned readings?
  ▶ Lectures? Pre-planned vs. by request?
  ▶ Worksheets?
  ▶ Screencasts (Flipped Classroom)?

• For content that students produce, how & when will it be acquired?
  ▶ Task/problem sequences?
  ▶ In-class vs. homework?
  ▶ Worksheets?
  ▶ Collaboration vs. independence?
An Example

What does this all look like in practice?
The big picture

- 5-10 “tasks” assigned each class meeting (Daily Homework). Due at beginning of next class.
- Students are responsible for digesting most new material outside of class.
- Nearly all class time devoted to students presenting proposed solutions to assigned tasks.
- My job: Facilitate discussion, keep us on track, Mr. Super Positive.
- Students may request mini-lectures or screencasts.
- Typical grade determination:

<table>
<thead>
<tr>
<th>Category</th>
<th>Weight</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homework</td>
<td>25%</td>
<td>Mix of Daily &amp; Weekly Homework</td>
</tr>
<tr>
<td>Presentations &amp; Participation</td>
<td>30%</td>
<td>Students present problems from Daily Homework</td>
</tr>
<tr>
<td>3 Exams</td>
<td>45%</td>
<td>Typically take-home exams</td>
</tr>
</tbody>
</table>
**Student presentations**

- Must present at least 2x prior to each exam in order to receive a passing grade for Presentation category.
- I take notes during presentation & add to spreadsheet:
  - Who & what problem/topic
  - Difficulty level
  - Miscellaneous notes
  - Score 1-4

<table>
<thead>
<tr>
<th>Grade</th>
<th>Criteria</th>
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<tbody>
<tr>
<td>4</td>
<td>Completely correct and clear proof or solution. Yay!</td>
</tr>
<tr>
<td>3</td>
<td>Solution/Proof has minor technical flaws or is lacking some details.</td>
</tr>
<tr>
<td>2</td>
<td>A partial explanation or proof is provided but a significant gap still exists.</td>
</tr>
<tr>
<td>1</td>
<td>Minimal progress has been made.</td>
</tr>
</tbody>
</table>
Daily Homework

- These problems form the backbone of the class.
- Problems from task sequence are assigned based on where we ended previous class.
- Felt tip pens!!!
  - Each student grabs a felt tip pen on way into class.
  - Students use pens to annotate homework in light of presentation & related discussion.
  - No penalty for use of pen.
- Graded on ✔-system. What did they have done before class?
Advantages of felt tip pens

• I know what happened before class vs during class.
• Students annotate work in ways they never did before.
• Students have a record of what happened in class together with their homework.
• When students look back at notes, they see their comments about what they were thinking & they see corrected mistakes.
• Student feedback is extremely positive.
• Grading of the Daily Homework is fast!
Weekly Homework

- On week $n+1$, students choose 2 *-problems from Daily Homework from week $n$ to write up carefully.
- Solutions must be typed, email me PDF, graded on iPad.
- Students forced to reflect on previous week’s work by reviewing Daily Homework.
- Incorporates multiple rounds of revision.
- Graded harshly on 1-4 scale (credit: Ted Mahavier):

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</thead>
<tbody>
<tr>
<td>4</td>
<td>This is correct and well-written!</td>
</tr>
<tr>
<td>3</td>
<td>This is good work, yet there are some errors that need addressing.</td>
</tr>
<tr>
<td>2</td>
<td>There is some good intuition here, but there is at least one serious flaw.</td>
</tr>
<tr>
<td>1</td>
<td>I don't understand this, but I see that you have worked on it.</td>
</tr>
</tbody>
</table>