Change Is Hard, But Not Impossible: Building Student Enthusiasm for Inquiry-Based Learning

Jill E. Jordan

Abstract Taking a course that uses an inquiry-based curriculum can be challenging for students who are accustomed to a traditional, lecture-based approach to mathematics instruction. At the end of the course, students who are not fully cognizant of the results of their many hours of hard work may conclude that the teaching approach was ineffective. This article seeks to help instructors who believe in the effectiveness of inquiry-based learning but have trouble getting students on board by giving them specific strategies to help build student confidence and enthusiasm.

1 Introduction

It is the first day of a new semester and a group of students walks into Abstract Algebra I. They're a little nervous about this class, but it's just the first day, so they anticipate getting through it just fine. They know what to expect: the teacher will start with a few definitions and a few examples, maybe a theorem or two, and then give the class an assignment from the chapter "The EDGE Program: 20 Years and Counting" of the text. Most of these students really liked algebra class in high school and are strong math students. This will be no problem for them!

After spending a few minutes going over the usual first-day details, the students have just settled in to take notes when their professor distributes X-shaped pieces of paper. "How many symmetries does this shape have? Think about it for a few minutes on your own, then discuss it with a classmate."[1] Wait, what?! This is not the way a math class is supposed to start. They haven't even learned anything and already they have an assignment!

[1] Unit 1, Lesson 1, Task 1 in the Inquiry Oriented Abstract Algebra (IOAA) curriculum [3].

J. E. Jordan (✉)
Houghton College, Houghton, NY, USA
e-mail: Jill.Jordan@Houghton.edu

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When class ends, the students have more questions than answers. Their notebooks are filled with scribbles and false starts, and to be honest, they're not sure if anything they wrote is worth keeping. One thing *is* for sure: nothing in there looks like algebra. Students asked some questions but the professor turned the questions right back around to the students instead of giving them the concise answers they were hoping for. Welcome to an inquiry-based learning class.

2 A Primer on Inquiry-Based Learning

Inquiry-based learning (IBL) is a broad term describing an approach to classroom teaching in which students are encouraged to learn through seeking answers to their own or the instructor's questions. Many teaching methods have significant overlap with IBL or refer to a specific system within the category of IBL, including problem-based learning, Moore method, student-centered instruction, discovery-based teaching, problem-solving curriculum, active learning, and cooperative learning.

The question of why I use IBL can be answered quite simply: it works! I know that my students gain a deeper understanding of the material when they confront questions about the mathematics and then struggle individually and together to discover answers to those questions. IBL works particularly well in my abstract algebra course, which draws from a population of motivated mathematics majors. This is a standard junior-level abstract algebra class with multiple pre-requisite courses, and it is typically taken during a student's junior or senior year. Anyone who has decided that mathematics questions are not worth pursuing has abandoned the major before this point. Every time I have taught this course, my students have done whatever I have asked them to do without complaining. And so they spend class time investigating my questions individually, working together, questioning each other, coming to consensus, and finally presenting their results, usually with very little help from me. Through this process, they end up with a better appreciation for each word in a definition, a better understanding of each step in proving a theorem, and better insight into the significance of each example and counterexample. I am often surprised by their deep insights into the material, and I expect that many of these insights would be missed if not for the IBL approach to the class.

As you might expect, the pace of an IBL course is much slower than a traditional lecture-based class. While it takes several class periods for my students to develop the definition of an algebraic group[2], an algebra professor who has chosen a lecture-based approach would have no trouble getting through that definition (along with several others) on the very first day of class. This can pose a problem for courses in which a certain core amount of material must be covered. IBL does not have to be an all-or-nothing proposition, however; while some professors may choose to use

[2]Unit 1, Lesson 5, Task 4 in the IOAA curriculum [3].

a comprehensive IBL curriculum, IBL methods can also be sprinkled throughout a traditionally taught course. Professors may choose a level of implementation that fits with their own preferences and the needs of their students, which makes IBL an inherently flexible approach to instruction. I have chosen to teach abstract algebra using a complete IBL curriculum [3], but in other classes, I have opted to mix in elements of IBL when I see opportunities arise.

3 The Problem

I went into my first IBL class with a mix of high hopes and apprehension, but by the end of the course, I was convinced that I had a good thing going. I was thrilled with my students' learning and I could hardly wait to do it all again the next year. Then a few weeks later, I received the student course evaluations and came crashing back to earth. The numerical scores were dismal. Ratings for "Excellent Teacher" and "Excellent Course" were well into the bottom decile. Unfortunately, the student comments were not any better. The students had little positive to say about their experience in the class, and their criticisms were centered around the very IBL methods I had so carefully put into place. I refrained from answering questions immediately, asking students to think them through on their own and then discuss their ideas with each other. When writing proofs, I wanted them to help each other figure out what was wrong and how to fix their mistakes. And yet my students suggested[3]

> Don't let the students sit in silence if they don't understand something. Help them to get to the answer that you want them to have.

and similarly

> . . . if the whole class is stuck on a proof, the best course of action may be for you to show us what is wrong, instead of having us just sit and stare at it. Then we just get frustrated and give up.

I requested that students not read ahead in the text so that they could discover the relevant definitions and theorems through inquiry. So, of course, someone pointed out that I should

> [t]ell the class which sections of the book are going to be covered previous to the actual class time. After I spent my break reading the book, I was able to understand more of the concepts that we were going over.

For the weekly problem sets, I intentionally assigned problems with new concepts so that the theme of inquiry would carry over into their work outside of class. Several students shared their thoughts on that decision:

[3]Quotes from student course evaluations used with permission from the Houghton College Institutional Review Board.

> Try making the homework on stuff we actually went over in class. There's a thought. Thisis not a 400 level course.
>
> There seemed to be a rather large disconnect between what was covered in class and what was on the homework.
>
> It is difficult to do homework on information that we have not learned.

And finally, one student cut right to the chase. His response to being asked how he would change the course:

> More teacher-led classes.

Okay. I get the point, you all hate IBL! Now what?

4 The Solution

I learned early on in my teaching career to not put too much stock in student evaluations. Recent studies (e.g. [2, 4]) have supported this practice, showing that students' evaluations of their teachers are not indicative of how well students learned course material. Despite the poor evaluations, I remained convinced that my students had learned the course material well. And so, if all that mattered to me was how much and how well my students learned mathematics, I would have felt free to ignore the evaluations and continue teaching the way I thought best, making no significant changes to my methods. But the truth is, while student learning is essential, I care about more than that. I want my students to not only learn, but to *know* that they have learned. I want them to be able to appreciate the results of their hard work. I want them to realize that their struggles in the class—yes, even those times when they felt like they were going around in circles without making any progress—made them better mathematicians. And because my goals go beyond student learning, I need to pay close attention to what the student evaluations tell me. This set very clearly told me that students needed to be taught how to appreciate the value of an IBL course. In subsequent semesters of teaching the course, I have incorporated the following into my class with the goal of making my students more aware of how the IBL approach benefits their learning.

Tip #1: Start Off Strong The first time we meet as a class, I spend some time describing IBL to my students. I explain the specific methods I will be using in the class and give the rationale behind the IBL approach. I also distribute a handout going over the same information and strongly recommend that students read the handout before the next class and come back to it as needed throughout the semester.

I also assign my students a self-evaluation, to be turned in at the start of the second class session. I ask my students to write a couple of paragraphs about themselves as mathematicians, including their strengths, weaknesses, and potential areas of improvement. This not only helps to activate their metacognition, but also sets the stage for the end of the semester when they will be asked to write another self-evaluation reflecting on their own growth as a mathematician during the course.

Tip #2: Reiterate Throughout the Course (But Especially at the Beginning) Students, like all of us, need to hear something many times before it truly sinks in. One of my goals during the first couple of weeks of classes is to remind my students several times per class of the intentionality of the class structure and the philosophy behind an IBL approach to class. For example, when the students are struggling to make progress and starting to feel frustrated, I might say, "I know that this is hard, and you might feel like it is pointless, but this struggle is actually part of the learning process. Don't give up now!" When they have finally figured something out together, they'll hear, "Great job! You figured that out without my help, and you should be very proud! If I had just told you the answer, you wouldn't feel the same sense of accomplishment, and you wouldn't understand it as thoroughly as you do now." Here are some other examples of phrases that you'll hear in my IBL classroom:

- Learning math is a process, and not knowing the answer is part of the process.
- This is what mathematicians do! You're becoming a better mathematician right now![4]
- I could write this on the board, or I could have you guys figure it out. I think you'll learn better if you figure it out for yourselves.
- This is exciting! You're figuring out all of this without me needing to tell you!
- That's a great question! I'll write it on the board so you can all think through it and find the answer together.
- You've really learned the right kind of question to ask!

In keeping with the theme of inquiry, I ask them questions like this:

- Do you see how this is helping you learn?
- Do you feel like you understand this better than if I had told you the answer?
- Do you understand why I wanted you to figure this out for yourself?

These sorts of encouragements and questions, while more frequent at the beginning of the course, never really go away. Students need to be reminded throughout that there is indeed "a method to the madness." Sometimes I start to feel like a broken record, but my students appreciate hearing it again and again.

Tip #3: Homework Counts Too As I mentioned above, I extend the IBL mentality to the students' work outside of class by assigning problem sets that go beyond what we have covered in class, requiring them to learn something new on their own. What I have found is that if students are not told *how* this relates to the IBL approach, they assume it is accidental (or worse, that I am just being a mean professor). I still assign the same types of problems, but now I tell them about my rationale way back at the beginning of the semester and call attention to it again with each new assignment. I indicate which specific problems will require them to go beyond where we have gone in class. I point out that I am not asking them to follow a process that is any

[4]I like to use this one when they're stuck, since they don't think of being stuck as *doing* mathematics.

different or more difficult than what they do in class, and as such, they can expect to struggle, but then ultimately to figure it out. Finally, as small groups are frequently utilized in class, I remind them of the benefits of working with classmates, and I encourage them to come to my office hours for additional help.

Tip #4: Ask Them About Their Learning This one sounds a little silly at first. After all, teachers commonly ask students about their learning, and I certainly asked plenty of learning-related questions during that first semester of abstract algebra. But the kind of question I have since added to my repertoire goes beyond the usual "do you understand? Do you need more time? Any questions?" and asks students to delve more deeply into metacognition and reflect on their learning process. I typically start asking these questions about halfway through the course in order to give them enough time to start seeing signs of their own progress. Here are some examples of the types of questions I ask:

- Have you noticed that when I ask a question, you get right to work, whereas at the beginning of the semester you had trouble getting started?
- Can you see how your proofs have improved?
- Do you see any benefits to spending more time and going deeper into the material rather than trying to cover a lot of content?
- Do you think that you learn better by copying information from the board or by working through questions with your classmates?

This "asking" technique culminates at the end of the semester, when I assign a second self-evaluation. Once again, I ask them to think about their strengths, weaknesses, and areas of potential improvement, but this time with a focus on how this course has helped to bring about change. It is good for my students to take some time to put in writing how they have grown throughout the semester, and as their teacher, I love seeing them recognize specific ways that my course has helped them develop as mathematicians.

Tip #5: Don't Stop I mentioned this one before, and yet it seems fitting to say it again. After all, the point here is that even when I feel like I've said it all before, continually encouraging and reminding students that they're making progress, students are ready for more! I have come to believe that part of my job as a teacher is providing my students with a narrative of their experience in my course. Working hard can be either discouraging or invigorating for my students, depending on how I frame it, so I do my best to frame it in the most positive way possible, and I keep doing that right up until the end of the course.

5 Survey Says . . .

As of this writing, I have taught my IBL abstract algebra class five times since that first disastrous semester. Consider the following results from student evaluations and decide for yourself whether or not my tweaks have made a difference in

my students' attitudes toward the class. Since the first semester, the numerical ratings for "Excellent Teacher" and "Excellent Course" on student evaluations have consistently been around the 70th percentile (compared to well below the 10th percentile the first time I taught it), and representative student comments now include:

> I really liked how we worked together on problems and coming up with answers versus it being just a lecture where we take notes.
>
> I really appreciated the style of this course. I like getting to work individually, in groups, and as the whole class on problems. This way, we learned the definitions and theorems deeply rather than just memorizing.
>
> I enjoyed trying to first discover things on my own and then working in groups and finally discussing it as a class.
>
> What I liked best about the course was the requirement/expectation that we prove everything to ourselves rather than simply memorize results.
>
> My favorite part of the course was that instead of telling us important concepts, [the instructor] pointed us in the right direction and we discovered them for ourselves.

6 In Conclusion

My purpose in sharing about my experience is to help other mathematics teachers who find themselves struggling with student attitudes in their IBL classes. Please use what is helpful and ignore whatever is not. If you are interested in learning more about teaching an IBL abstract algebra course, I enthusiastically recommend the IOAA curriculum [3], which you can read more about on the American Mathematical Society's Math Education blog [1].

References

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