

Well begun is half done.
– Aristotle

When we discuss with colleagues our motivation and experience in teaching Puzzle-based Learning, a question that quickly follows from those interested in exploring this paradigm further is: *How can I do this in my university?* Given our engagement with teaching Puzzle-based Learning in a range of settings and to a range of audiences, in this chapter we discuss how an instructor could start teaching Puzzle-based Learning and also how to initiate students to such course.

2.1 The Instructor

At our respective institutions, a course on Puzzle-based Learning was initially targeted at freshman level. The objective was to lay a foundation in domain-independent reasoning that could be used in future courses. Since then, Puzzle-based Learning has worked its way up, down, and outside our curriculum. We have included Puzzle-based Learning themes in other undergraduate courses (e.g., System Development, Intelligent Decision Support Systems) and graduate courses (e.g., Heuristic Problem-Solving, Big Data Analytics). We have also used Puzzle-based Learning in outreach programs in high school, middle school, and even elementary (3rd grade) school. In addition we have offered industry workshops and continuing education courses. As our experience with teaching Puzzle-based Learning improved, we realized that there was also a broad demand for such pedagogy and the theme could be molded to fit the needs of a wide range of audiences. Based on our experience we feel that a new instructor has a number of choices to explore the teaching of Puzzle-based Learning.

Having said this, we would recommend initiating a teaching experience in Puzzle-based Learning in a limited setting such as an outreach effort or as a teaching tactic in another course. Next, we would recommend that a new instructor offer a course on Puzzle-based Learning as an elective so that those in the course are

self-selected and are truly interested in the material. (In one of our institutions, Puzzle-based Learning is a required course for all engineers. This has led to challenges in motivation and assessment. We discuss this further in Chap. 4.)

In addition to courses that exclusively focus on Puzzle-based Learning, puzzles can be added to other courses for a number of reasons. They can be added to provide a diversion that has an educational aspect related to the current course. They can be placed in a difficult course to provide respite. Conversely, very challenging puzzles can be put into a simpler course in order to keep students from becoming bored once they have met all of the existing challenges! However, as we discussed in the motivation, it is the linkage between the puzzle-solving process and its position as a stepping stone from domain-free problem-solving to highly contextualized Project-based Learning activities. In future chapters we discuss puzzles that can be used to emphasize a domain-specific concept, e.g., the value of iteration in software development.

In addition to the obvious requirement of an innate curiosity in puzzles, we recommend an additional characteristic for any instructor of Puzzle-based Learning: *resilience*. In just about all other courses that we authors (and other instructors) teach, we are the domain expert. The skill and knowledge gap between instructor and student is tangible. But, as discussed in Chap. 1, solving puzzles does not require any specific domain knowledge (which is how we differentiate a puzzle from a problem), only reasoning skills. Hence it is not uncommon for students of a Puzzle-based Learning class to solve a novel puzzle before the instructor.¹ Pedagogically this is fine as the goal of any puzzle-solving effort is the reasoning and not the final solution. Hence, as an instructor of a Puzzle-based Learning class, one needs to be comfortable being stumped and using such instances as an opportunity to examine in more detail an incomplete reasoning process.

2.2 Motivating Students

One of the challenges in any course is encouraging, developing, and maintaining student interest and engagement. A bored student is unlikely to take part in activities and is also more demanding in terms of what a given course or class can do for them. This can be a particular problem in a Puzzle-based Learning course as it can be more difficult for students to see how solving puzzles is going to be of help to them in future studies. While students may undertake dull and repetitive activities, such as memorizing mathematical tables or complicated formulas, because it will “be on the test,” they may not be willing to take the steps required to get the most from a Puzzle-based Learning course.

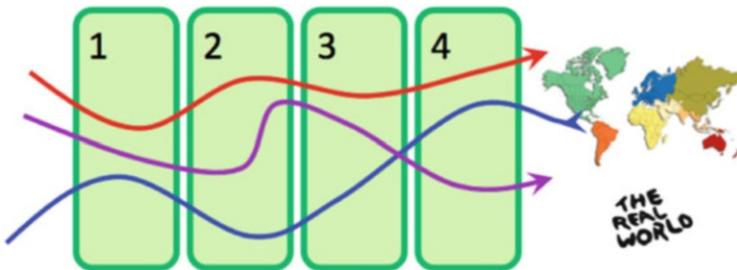
As we will discuss in more detail, students need to think that what they are doing is useful now and be motivated to try and must also see some value in the future, if they are going to have the highest motivation to take part. Given that Puzzle-based

¹ We discuss one common instance of this in Sect. 4.2 under the theme of “puzzle of the day.”

Learning sometimes requires students to step outside of their comfort zone and risk being incorrect in public, we need as much motivation as possible for the students to take part. Given that Puzzle-based Learning is a highly thoughtful exercise, it's not enough to force students to participate or to try to control their behavior with marks; we have to provide the right environment and approach to help students to realize that this is worth doing.

However, communicating this to students requires us to know who the students are and what matters to them, and this is specific to the class, the educational level, the teacher, the country, etc. – so many variables that we can't list them all here. It is fair to say that many students, through years of training, often regard courses of study in terms of what can be achieved and, all too often, in terms of how easy it will be to achieve a passing or excellent grade. Thus, any argument that depends upon “you should solve puzzles because it's good for you” is unlikely to make much progress. A number of companies have employed puzzles as part of their job assessment strategy, so any industry speaker you can find to support the utility of this in job interviews will be valuable.

An approach we have used to motivate Puzzle-based Learning to our students is discussing the “big picture” in their education. Consider the below diagram depicting paths through four years of undergraduate education:



Undergraduate education is expected to be a transformational experience. At the end of their UG experience (hopefully, all), students emerge into the so-called real world. Some continue onto graduate school, many enter into the work force, few start their own businesses, etc.

As an instructor, an intriguing question to propose to your class is: *What are the characteristics of the real world?* How would you describe the real world? What adjectives might you use? We've done this as an in-class exercise in a number of formats (poll each member of the class, group exercise on the board, etc.) ultimately resulting in a pooled collection of thoughts. Typical responses have ranged from scary and unforgiving to colorful, fun, and exciting.

After discussing these responses, a follow-up question is: *What skills do you need to succeed in the real world you've just now described?* Responses often include problem-solving, critical thinking, perseverance, resilience, etc. Typically one will be able to cluster these skills into two groups – soft and hard skills.

Over the years, a number of researchers have investigated similar questions. Under the direction of Cynthia Atman at the Center for the Advancement of Engineering Education (CAEE),² a longitudinal study of important design activities was conducted among undergraduate engineering students. For the following 23 design activities, which do you view as the six most important?

Abstracting	Generating alternatives	Making trade-offs	Synthesizing
Brainstorming	Goal setting	Modeling	Testing
Building	Identifying constraints	Planning	Understanding the problem
Communicating	Imagining	Prototyping	Using creativity
Decomposing	Iterating	Seeking information	Visualizing
Evaluating	Making decisions	Sketching	

While there are variations from 1st year to 4th year (e.g., the value of *iterating* was perceived to be higher in 4th year than 1st), four of the top five skills are consistent across the years and also match top five skills suggested by practicing experts: *understanding the problem*, *communicating*, *identifying constraints*, *brainstorming*. Experts also had *seeking information* in their top five, while seniors had *making decisions*. As discussed in Chap. 1, we believe Puzzle-based Learning provides an opportunity to explore and practice some of these skills.

One thing should be established early on. The course is about getting into good mental shape – not getting the answer. Having the answer does not build the brain; thinking builds the brain. To explain this to the student, you can make an analogy between a physical workout and a mental workout. Spending two solid hours thinking about a problem and not getting the answer is OK. It’s analogous to leaving your house and jogging a three-mile loop. In both cases you didn’t get anywhere, but that’s not the point. The point is to develop strength and stamina. Puzzles can develop mental strength and stamina, while jogging develops physical strength and stamina.

The first week of the course should be devoted to convincing the students that Puzzle-based Learning will help make them successful as adults. A Puzzle-based Learning course provides the opportunity for the student to increase the number of neurons in their brain and the connections between them as well. A Puzzle-based Learning course is a workout for the brain. The way to become a good problem-solver is to solve problems – hard ones.

The specific answer to *Why Solve Puzzles?* will vary by student, and by assessment scheme to an extent, but some useful guidelines are as follows:

- Draw on any industrial or practical applications of puzzle-solving, in terms of concrete skills.
- Conduct exercises to show students how simple puzzling can help them to think.
- Reinforce that it’s a way of looking things from another angle.

² <http://www.engr.washington.edu/caee/>

Puzzles are, in the main, domain-free challenges that require very little formal progress in other areas of study to be enjoyable and exacting while still approachable. Puzzles help to get students thinking about the kind of problems that they will face outside of the educational experience: problems where no one gave them a chapter to read and a set of questions that derive from that chapter.

A well-constructed puzzle course will help students to realize that they are capable of much more than they think, help them to frame problems in a useful way, and remind them of ways to deal with the kind of situations they will encounter later on in life. In later chapters on effective teaching approaches and problem-solving strategies, we go into a lot of detail about how to make an environment suitable for the kind of student community that will enjoy solving puzzles, but this assumes that you've got them in the door in the first place!

Some of the most effective Puzzle-based Learning environments, regardless of whether at school or college, have a strong element of play and participation to them and starting on a playful note will set the tone for the rest of your time with students. Can you invite students with a puzzle? Can you put up puzzles outside of class or around your school or college so that you start community formation before the first student has entered your classroom? We already know that students will invest large amounts of effort into certain types of games, often for little real reward, if there is enough motivation, so try to tap into that "game" effort early as locating a few students who are keen will help you to form a more solid environment.

A Puzzle-based Learning course can be enjoyable, but very few of the puzzles will remain enjoyable if they immediately segue into arduous or complex mathematical proofs, especially for younger students. Rather than consider Puzzle-based Learning a gateway to a particular concept, it's better to plan for it as a parallel development of thinking skills, so that traditional content and Puzzle-based Learning content are linked thematically rather than sequentially. Many of the probability puzzles will help students think about probability, but there is no great benefit to setting 10 puzzles and then moving into a detailed discussion of the Z test.³

When explaining to the students why the course is valuable, be genuine. Tap into your personal experiences. There is bound to be a reason that you have chosen, or been asked, to conduct a Puzzle-based Learning course, based on what is believed to best for your students. Use that to communicate to the students why they should be interested.

2.3 Hosting a Puzzle Contest

Puzzle-based Learning is a course that increases in effectiveness as more people get involved – a course that relies upon one teacher to keep moving students forward will quickly become arduous for the teacher and unrewarding for the students.

³ http://en.wikipedia.org/wiki/Z_test

When a puzzle-based approach is working, students will actively seek out new challenges and look for like-minded people to work with, and, in many cases, they will look for new people to stump with interesting and challenging puzzles!

One way to create an awareness of and to develop interest in Puzzle-based Learning is to host a puzzle contest. The simple reason is that puzzle contests are fun! Both the participants enjoy solving puzzles under contest conditions and the organizers enjoy assembling puzzles to stump their peers. We have organized puzzle contests in a variety of settings: as part of the activities of a puzzle club, a component of an outreach effort, and a capstone experience for students in a class on Puzzle-based Learning. The following are some factors and suggestions we have for conducting a successful contest. Naturally the format and content of any contest will have to be tailored based on the target audience, objective of the contest, duration, and background of the organizers.

As with any public event, many issues need to be considered:

Publicity One needs to consider three parts: (1) before, (2) during, (3) and after the event. Unless the contest is being held as part of an outreach event where it is known beforehand (approximately) how many people will attend, promoting the contest is crucial for a good turnout. Social media, the school newspaper, eye-catching creative posters across campus, and a general e-mail to the faculty to announce in their classes are all great ways of getting the word out. The “buddy system” is also effective – if each organizer were to bring 3 friends, one can augment the audience. Media coverage of the event itself (audience solving puzzles, winners, organizers) is critical for sustaining the effort. Be sure to contact the local news station, the school photographer, and other faculty members.

Sponsors and Prizes Our experience has been that students like to compete for the fun of it and also for bragging rights. Prizes certainly help. Local companies, campus recruiters, and bookstores are often supportive of such student-organized events. As with all campus events, food is almost a must and is a great way to retain and engage the audience while the winners are being determined. Local restaurants can be explored to support this component of the contest.

Logistics A primary decision to be made early on is indoor vs. outdoor, as the puzzles that can be used will depend on the venue. The main criterion is to have sufficient space for the participants to work. As with all campus events, the day and time of the event can determine attendance. Whereas a puzzle contest as part of an outreach event could be longer, given the tight schedule of college students, an event of at most 2 hours is effective. This duration would support 5–7 puzzle sets to be solved in 10–15 minutes.

Contest Structure An effective way to run a contest and to keep *all* participants engaged till the end is *not* to have a knock-out style contest. We have found the following to work well:

1. To add a social component, teams of two people participate. The ability to mutually discuss a puzzle increases the engagement factor.

2. The contest is conducted with multiple rounds of puzzle sets. Each puzzle consists of a pair of puzzles. Puzzles vary in difficulty from easy, medium, and hard and have different point values (e.g., 3, 5, 8).
3. While all teams work on the same puzzle set at the same time, the constituency of the puzzle sets will vary (e.g., easy to medium, medium to hard, etc.). Contestants are made aware of the point value of each puzzle.
4. Each puzzle set has a fixed time limit (e.g., 10 minutes). Once a publically viewable countdown timer starts (many are available on the web), the teams can start working on the puzzles. When a team is ready to submit their answers (written on the puzzle sheet itself), the time taken (or left) is also noted to determine tiebreakers. In order to ensure that all teams proceed in lockstep, if a team finishes before the allotted time, they will need to wait till the time for that puzzle set runs out.
5. After the predetermined number of puzzle sets, the winner is determined by a combination of their points and time taken. Given the nature of the contest, assessment of team's answers will need to be binary – full points or 0. Unlike in classroom assignments, puzzle contests do not support the ability to give partial credit.

Running the Contest Depending on the size of the event, you will need many assistants. Some of the tasks involved for which you will need 2–3 people each are (a) registration of the participants and teams, (b) entering scores and times for each puzzle set, (c) handing out and collecting puzzle sets, and (d) grading the contestant answers.

Pre and Post Puzzle Set As people register for the contest and await the start, it is fun to handout a sheet of sample puzzles for the contestants to ponder. Some pre-contest puzzles we have used are given below (answers are left to the reader). Once the contest is over and the winners are being determined, as the contestants mingle over food, it is fun to display a visual puzzle (say, projected on a screen) for them to consider.

Puzzle 1 The proprietor of a rural farmer's market would like to be able to weigh out any integer amount of grain from 1 to 40 pounds in only one weighing using a two-pan balance. What is the minimum number of weights that will accomplish this and what are their weights?

Puzzle 2 You have the misfortune to own an unreliable clock. This one gains exactly 12 minutes every hour. It is now showing 10 pm and you know that it was correct at midnight, when you set it. The clock stopped four hours ago, what is the correct time now?

Puzzle 3 A pie was stolen from Bakery Square by one of five suspects. Each suspect gave a statement:

Dave: It wasn't Jen. It was Eric.

Eric: It wasn't John. It wasn't Jen.

John: It was Jen. It wasn't Dave.

Meghan: It was John. It was Eric.

Jen: It was Meghan. It wasn't Dave.

The police identified each suspect told exactly one lie. Who stole the pie?

Puzzle 4 Below, 10 countries have been broken into chunks of letters. These chunks have been mixed up, no chunk is used twice, and all chunks are used. Can you determine what the 10 countries are?

EZU ITZ ZIL ELA BRA GI IA FI
PAN MBA BEL AND BER ZI NL BO
CAM VEN DIA AND UM SW
BWE MEX ERL ICO JA LI



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