

FIVE LEVELS OF TEACHING - FIVE METHODS OF TEACHING

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Abstract

In this work the author, a physics teacher in high-school and an engineering lecturer in college with more than 20 years of experience, compares teaching five levels of students: high-school freshmen that still do not know whether to choose physics as a path, 2nd year high-school students that chose to study physics but are still only examined within the school, 3rd year high-school students studying for their matriculation external examination, 1st year college students studying a basic course in electrical engineering and 4th year college students taking a course with their chosen specialization. The students are at very different stages in their lives and require different teaching methods, such as flipped classrooms, project-based learning (PBL), predict-observe-explain (POE), talk-based-learning (TBL) and productive failure. The author compares the different methods and examines which methods might be more appropriate for which group of students. After trying several methods, the following assumptions rose: the high-school freshmen seemed to lose interest quite rapidly unless the material was explained via experiments and simulations, therefore predict-observe-explain seems to be the best method to give them motivation to study. 2nd year pupils reacted best to discussions from which the laws of physics arose; thus talk-based-learning was best for them. 3rd year pupils had to study an enormous amount of material, so the best way was to let them go over the theory at home and then practice and practice at school, thus applying the flipped classroom approach. 1st year college students, to my experience, are best taught by letting them make mistakes and then harnessing these mistakes to explain the correct method to solve a problem, thus using productive failure. Finally, 4th year students usually need a large project that incorporates all the course syllabus to keep them at full focus, thus project-based learning is usually the best option.

Keywords: *Flipped classrooms, project-based learning, predict-observe-explain, talk-based-learning, productive failure.*

1. Introduction

In this work, five stages in a student's life were chosen, three as teenagers in high school and two as an undergraduate engineering student. The research compares the different populations and examines how different teaching methods might or might not fit the different students and from which teaching method the students benefit more. The research took over several years; in some cases, an entire course was taught in a specific method while in other cases different methods were put to the test during the same semester. In the following paragraph we introduce the five groups, the material taught and the expectations from the students. In the following paragraph we discuss five teaching methods, explain the logic behind them and discuss their pros and cons. Later we analyze the results of teaching in each method for the different groups. Finally, we conclude what method seems to fit what group.

2. Different teaching and learning stages

The five groups that were taught and examined are as follows: first, 14–15-year-old children in the 9th grade that were picked to study physics as a part of a "Scientific and technological reserve" plan of the Ministry of Education. They study mechanical and thermal energies and basic electricity. Second, 15-16-year-old children in the 10th grade in either robotics or cyber classes that study optics and basic kinematics. Third, a group of 16-17-year-old children in the 11th grade that are studying for their matriculation exam in mechanics. The fourth group are undergraduate college students (generally aged 20-25) studying for a degree in engineering (electrical, mechanical or software engineering) that are taking a first-year course in electronics. Finally, the fifth group are undergraduate college students that are taking

a fourth-year course in electro-optics (within electrical engineering). The groups differ in ages, mental abilities, learning load and material complexity, and obviously must be addressed differently.

3. Different methods of teaching

Before we address the different methods, we point out the old school approach, frontal teaching in class with a whiteboard and markers, and occasionally a short video clip or computer simulation. In the classic teaching method, many students get bored after a short while and it is difficult to keep them alert for more than 15-20 minutes in a row. Another problem is applying most of the practice in home assignments. Nowadays, with increasing AI abilities many students let the AI tools solve the home assignments for them, and the teachers spend more time checking if the assignment was actually done by the students rather than focusing on the quality of the work. Below are the chosen teaching methods that try to solve some of these problems.

3.1. Flipped classroom

In the Flipped classroom approach (Bergmann and Sams, 2012), the home assignment is usually to read the theory before class and the time spent together in class is mostly used for practice. This can solve the problem of using AI tools as most practice is in class, without the use of external aid. Solving problems in class is also more interesting for the students than copying text from the whiteboard. The success of this approach depends on the willingness of the students to read theory in advance and their ability to solve problems in a noisy class environment. This tool was originally developed for high school students, but it is now commonly used in the academy (Kerr, 2015).

3.2. Project-Based learning

Project-based learning (PBL) is an educational approach in which students learn through real, meaningful, multi-stage projects, rather than through lectures or short exercises. It is a method that brings learning to real life and encourages inquiry, creativity, and responsibility. In PBL we start with the challenge of solving a real problem, the students have to collect data and analyze it by themselves, this leads to a product such as a model, an application, a presentation or a video. It develops teamwork abilities and the students have to present their final product to an audience, thus adding a sense of significance to the project (Santana and De Deus Lopes, 2024, Mills and Treagust, 2003). The drawback is that students might be mistaken to think all projects are to be addressed the same way.

3.3. Predict-Observe-Explain

Predict-Observe-Explain (POE) is a three-stage learning approach in which students: predict what they think will happen in a given situation (and explain the reasons for this prediction), observe the actual outcome through a demonstration, experiment or video, and explain why their prediction matched or differed from what they observed. POE is widely used in science because it encourages active thinking, reflection, and conceptual change (Sajidan, Akhyar and Rochsantiningsih, 2014).

3.4. Talk-Based-Learning

Talk-Based Learning (TBL), sometimes called Dialogic Teaching, is an approach that uses structured classroom dialogue as the main driver of learning. Instead of the teacher delivering information and students passively listening, students learn through conversation—asking questions, reasoning aloud, debating ideas, and building understanding together (Barnes 1976 and Alexander 2020). The involvement of the students is extremely importance in this approach, if satisfying results are expected.

3.5. Productive failure

Productive Failure is a research-based learning approach developed primarily by Manu Kapur, and it has become one of the most influential ideas in contemporary learning (Kapur 2008, Kapur 2010, Safadi 2022). In productive failure students attempt to solve a complex problem before receiving instruction, struggle, generate ideas, and often fail to produce a correct solution and receive targeted instruction afterward, which helps them reorganize and deepen their understanding. The goal in this approach is of course not the failure but rather the struggle.

4. Discussion

Beginning with the 9th graders, flipped classroom seemed to be a total failure at first, as most students did not read the material in advance. Understanding that, they were given motivation to read the theoretical material before class by telling them that a short quiz will be given in the next class. This way class itself could be fully used for practice, yet students still seemed to be bored. PBL was quite nice on a small scale as they were given assignments to demonstrate some of the laws of physics in their home environment. But real projects are too complex for this age. In POE I'd show them a short clip or simulation and stop just before we see the outcome. Then the students would guess what is expected and I'd write on the whiteboard all the answers. Next, the clip/ simulation continued and the students saw the correct answer. This was followed by a discussion explaining why the other answers were wrong. TBL was less productive since talking about physical issues rarely led to an understanding of the actual laws. Finally, productive failure was used when I asked about energy matters before they learned about them. Some students knew the answers from prior knowledge but most of the students did not bother to guess what the answer would be and preferred to wait for my explanation.

Continuing with the 10th graders, again only a quiz at the next meeting persuaded the students to read the theory before class but many of them did not understand the theory completely despite many examples given in class. PBL was less appropriate for these students as building an optical setup can be done only in a fully supervised laboratory. Short projects on kinetics were given from the site of the Ministry of Education, as the site includes demonstrations and instruction on how to conduct mini projects. Due to the relative simplicity of the material POE was only effective when physical terms differed from everyday terms, such as average velocity of an object completing a track and returning to its initial position (it equals zero because there's no displacement). TBL was especially effective after a mathematical example; to explain the meaning of the results we got in a wider frame. Productive failure was less appropriate for these students as they either understood enough to say the right answer, or they kept silent and did not want to make a mistake (probably age related).

With the 11th graders, the motivation to read theory before class was larger as they are studying for their matriculation exams, thus it was easier to give them tasks read or solve before class, making the flipped classroom much more appropriate for them with comparison to the lower grades. PBL was very successful for these students as it involved full laboratory experiments. Although all the students performed the preliminary work, lab work and post-lab analysis on the same subjects it was as if each performed his/her own mini project. Students had less patience for POE as they were focused not only on their physics final exams but also on final exams in other high school subjects. Just like for the 10th graders, TBL was especially effective after a mathematical example; to explain the meaning of the results we got. Productive failure was used in this class at the beginning of every new subject (Kinematics, Vectors, Dynamics, Energy, Momentum etc.) followed by an example to contradict each wrong assumption. This approach helped students focus on the correct way to look at a problem, knowing that other views lead to mistakes.

Moving to college students, beginning with 1st year freshmen studying their basic introduction to electronics course. Students were disappointed with the flipped classroom approach. Many of them felt that they pay good money to go to college, and they expect the lecturer to teach them everything and not tell them to study some of the material by themselves at home. Year after year the students expected the teacher to give them all the theory in class so finally this approach was abandoned. The lack of knowledge in engineering-based programming didn't allow any PBL in these classes as they were just taking their first steps in the academy and had no bag of tools for a real project. The course was very theoretical, and more practical hours were used for solving problems and not performing experiments, so POE was less fit for this type of course. TBL, however, was very useful for these students as the thirst to understand beyond the equations was very big and only through conversation, I could fully explain the meaning behind every problem I solved. Productive failure was useful only at the beginning of the course, since at later stages most students knew the right answers and those who did not know the answers - preferred not to talk.

Coming to the final group, 4th year students, just one short step from the finish line, taking a specialty course in electro-optics. These students accepted the flipped classroom approach with open arms as their maturity and experience taught them that there's no reason to waste time in class for proving theorems and lemmas. PBL was also very helpful as some home assignments could be replaced by a mini project. At this stage the final part of a project – presenting the outcome to the other students (and lecturer) and having to answer questions- was more significant as they are expected to do the same in their final academic project. TBL was less used in this class as the students were more focused on passing the course and being one step closer to the end of the degree and less interested in talking about the meaning of the results. Since the course contains many sub-subjects (Optics communication, Lasers, Polarization, Coherence, etc.) each subject began with a productive failure scenario later explained as the time advanced.

5. Conclusions

Over two decades of pedagogical practice, it has become clear that the "perfect" method is a myth; the only constant is the necessity of adaptation. In the above the author shared his own experience with different teaching approaches and different students for the past 20 years. The subjective conclusions from the results indicate that students at the beginning of high school can take advantage from flipped classroom, project-based-learning and predict-observe-explain if correctly motivated. For later classes in high school, talk-based learning became a more efficient method. It seems students are more open to new experiences at the beginning and end of high school and less in the mid-years. As for college students, freshmen are more likely to object to new teaching methods while the more experienced students tend to rely on the lecturer, giving more flexibility to the teaching experience. Some of the core principles for educators might be: Adaptation to Maturity (Methodologies must be calibrated to the learner's developmental stage. While 9th graders require the sensory engagement of POE, 4th-year engineers require the professional agency of PBL and the efficiency of the Flipped Classroom). The Critical Role of Motivation (In non-traditional formats, motivation must be manufactured through strategic incentives, such as quizzes, or real-world project significance to ensure student compliance and engagement). The Balance of Theoretical Depth and Practical Efficiency (Educators must navigate the tension between the "struggle" of Productive Failure and the high-speed requirements of external examinations or professional deadlines). The hallmark of a master educator is the flexibility to recognize that as students grow, their capacity for diverse learning formats increases—provided those formats are strategically aligned with their shifting psychological and professional goals.

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