Challenging The Lecturer: Learning From The Teacher's Mistakes

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ABSTRACT

Teaching science and engineering involves students being asked to solve problems. The two most common approaches are complementary. Firstly, traditional lecturing initially presents the fundamental material that the students need to solve the chosen problem; then students learn about applying this knowledge through problem interaction. Secondly, problem-based learning (PBL) initially engages the students in solving the chosen problem; then the students – often through the guidance of the lecturer – discover the fundamental material "themselves". In both approaches, lecturers must identify learning objectives, and ensure that the problem both facilitates students in meeting these objectives and helps to identify which objectives have not been met by particular students.

We have observed that students also learn by watching others trying to solve problems. For example, with traditional lectures the lecturer often presents a solution to a classic problem in a manner that simulates, quite artificially, the way in which the problem can be solved. The advantage of this is that the lecturer has complete control over the material being presented. The disadvantage is that the students do not observe a real problem-solving process. In contrast, students watching other students problem solving (during PBL) offers the advantage of them observing a real problem-solving process. However, the lecturer has less control over them meeting their learning objectives.

We report on a third (middle) way: the students formulate the problem to be solved and then observe the lecturer trying to solve it. The lecturer guides the student in problem creation and selection, and so ensures that the problem is suitable for meeting the learning objectives. Our experience shows that students learn more from watching the lecturer struggling (and often failing) to solve the chosen problem than from observing the lecturer presenting an obvious solution.

Lecturers must be encouraged to exploit rather than hide their fallibility.

KEYWORDS: Problem-Based Learning, Science, Engineering, Student-Teacher Interaction

1 The Whole Art of Teaching

The whole art of teaching is only the art of awakening the natural curiosity of young minds for the purpose of satisfying it afterwards.	*L'art entier de l'enseignement est seulement l'art de réveiller la curiosité normale de jeunes esprits afin de la satisfaire après.*

Anatole France (1844—1924)

As a scientist, I wish that that I had a better understanding of teaching and learning. However, after years of self-analysis, it is clear to me that teaching is an artistic discipline; albeit one which can be studied using scientific methods. Every year, and for every module/class that I teach, I look back in amazement as I evaluate (or more precisely, try to evaluate) the success, or failure, of the teaching activities that I have undertaken. In the worst cases:

- Actvities that worked well in previous years fail completely in a following year.
- The predicted success of new activities does not materialise.
- Refinements to existing activities magnify the problems that they were introduced to address rather than alleviating them.

This appears to paint a rather depressing picture. One may ask why bother going to all this effort to rework old activities and to replace old activities with new. The only answer that I can offer is that I believe that all this extra work is the best way to keep ones "teaching fitness". Without teaching fitness, I find it difficult to address the four main problems that I have in my day to day life as an educator:

- The majority of my students are poorly motivated.
- My students have a wide range of abilities.
- The questions I (have to) ask do not have clear, concise, easy-to-evaluate answers.
- Presenting the answers to questions does not necessarily benefit students as the answers misrepresent the complexity of the solution space.

These problems are not unique to my discipline (computer science and software engineering). However, there is general consensus – amongst my teaching colleagues around the world - that these issues are growing in importance **[Nwana 1997, Mann et al. 2008]**. In the following, each of these problems is addressed in more detail. I argue that a range of activities are required to address the problems (individually and collectively). The technique of "learning from the teacher's mistakes" (LFTTM) - the subject of this paper - is one such activity.

1.1 Motivation

Motivation is one of the most important ingredients for success in any discipline. An unmotivated student will most likely fail to achieve a level of learning appropriate to their natural ability. Recent research **[Ryan & Deci, 2000]** demonstrates that motivation varies by degree and by type. Different types of educational motivation can be classified according to the reasons or goals behind the activities of learning. One can also distinguish between intrinsic and extrinsic motivation **[Glynn et al. 2005]:** intrinsic motivation arises because a particular task is interesting or enjoyable, and extrinsic motivation arises because a particular task leads to a desirable outcome. It is generally accepted that intrinsically motivated students do not require additional incentives (extrinsic motivation) in order for them to want to learn. However, extrinsic motivation is less clear-cut. In the worst cases, students do not want to learn, they wish only to pass their exams.

In previous research, I have been involved in studies with respect to different techniques to improve motivation. Examples include: using games **[Gibson 2003]**, introducing student competitions **[O'Kelly & Gibson 2006]**, or increasing the amount of self and continual assessment **[Traynor & Gibson 2005].** These approaches have improved student motivation within a particular module/class but have negligible impact on students' motivation within the (computing) discipline as a whole. Previous research **[Deci et al. 2001]** has observed that such efforts may reduce intrinsic motivation because students feel that their behaviour is being restricted or manipulated.

Experience shows that students are much more motivated to learn about computing when they observe their lecturer struggling to address problems that they have not prepared in advance. Rather than losing motivation because they believe that they will never be as good as the lecturer, they are encouraged to see that the lecturer makes mistakes, just like them.

1.2 Diverse Range of Student Abilities and Backgrounds

This problem was first identified more than a decade ago **[Tucker et al. 1996]**:

> *Because students come to CS&E with a wide range of learning styles and backgrounds, faculty should look for opportunities to develop teaching methods, lab materials, and technologies that appeal to as broad a collection of students as possible. ... CS&E educators have been slow to take advantage of new methods in teaching, and many of our current methods are not ideally suited to encouraging across-the-board new student interest in the field.*

The LFTTM approach improves interaction between the lecturer and the students. Students of all abilities and backgrounds are able to participate and the role of the lecturer is to encourage participation by making each student feel as if they have made a positive contribution.

More recently, the impact of diversification has led to proposals that computer science education needs to be re-focussed on innovation **[Denning & McGettrick 2005]**:

> *The first challenge is to embed the foundational practices of innovation into the curriculum, so that students learn innovation by doing, without necessarily being aware they are engaged with systematic processes. The intention is that innovation should become an essential aspect of their attitude of mind. Seeking opportunities for innovation can become a way of life for students, ingrained from the very start. We would aim to instill a habit of innovation.*

The LFTTM approach encourages innovation in the students. They are no longer passive with respect to the material being presented: they are actively involved in defining the problems to be solved. Further, their innovation is no longer dulled through the presentation of well-established solutions to traditional problems: they are free to propose their own solutions.

1.3 Complex Solution Space

The problems faced by computer scientists and software engineers are open and complex. There is rarely a unique acceptable solution. In general, there are an infinite number of solutions which can be grouped into a large number of equivalence classes. Each class of solution can be judged on its own merits: whether one solution (class) is better than another depends on the context in which the solutions are being proposed. This context is defined by a solution space of a large number of inter-related variables/criteria. Evaluating solutions is a non-trivial task that requires expertise. Each solution can be viewed as a compromise position within the complex solution space. This problem is particularly evident when students are required to design solutions to problems **[Gibson et al. 2008].**

The LFTTM approach helps the students to better understand the complexity of the solution space. Typically, they will observe the lecturer moving around the solution space, making large leaps between possible solutions during the initial stages of understanding the problem and finishing with small adjustments as the students better specify the evaluation criteria by which the lecturer has to tune his solution.

1.4 It's Easy Once You Know How

Analysis of student feedback over a large number of years of teaching has identified the most common shared sentiment as being: "it's easy once you know how", or "once you see the solution it's obvious", or "I would never have found that myself but I'm sure that your solution is correct", or "I'm really stupid not to have found that", etc …

Unfortunately, most problems that are presented to students are selected because the lecturer wants them to learn (about) particular solutions that are well-documented. Pressures on students (and lecturers) lead to them following the path of least resistance when learning about such things: they focus on analysing the classic solutions. A student rarely has the motivation (or opportunity) to try to solve these problems themselves: a good example in computing is the problem of sorting a collection of things.

Furthermore, lecturers present solutions to problems with which they are very familiar. Traditional lectures generally do not encourage the lecturer to work outside their comfort zone. Thus students never get to see anything other than the "simple solutions". In reality the process by which these simple solutions have been developed is much more complex than could be imagined through examination of the solution in isolation.

The LFTTM approach overcomes this problem. The lecturer is, in general, working with problems that they have not seen before. The lecturer's role is to allow students freedom in proposing problems and variations, and then to select a problem that is just outside their comfort zone. In other words, they select a problem which they think they will be able to solve even though they do not yet have a specific solution.

2 Unless I Am Mistaken

Il ne suffit pas de dire:
Je me suis trompé;
il faut dire comment on s'est trompé.
Claude Bernard (1813 – 1878)

A life spent making mistakes is not only more honorable, but more useful than a life spent doing nothing.
George Bernard Shaw (1856 - 1950)

This section reviews the three main ingredients that gave rise to TFTTM: learning from mistakes, problem based learning and traditional lectures.

2.1 Learning From Mistakes

It is generally accepted that students' learn from their own mistakes. Through our own research into how students learn whilst working in teams, it is clear that students also learn from observing the mistakes of their team-mates. This phenomenon has been reported in very young children **[Want & Harris 2001]**:

> *…[they] benefit from observing an incorrect action when it can be contrasted with a correct action…*

Our students make many mistakes (as individuals and in teams). This can have a very negative impact on motivation. We do not wish students to stop learning from mistakes, but we also do not wish them to become demoralised. The TFTTM approach permits the students to learn from the teacher's mistakes without additional risk of the students losing motivation.

2.2 Problem Based Learning

The TFTTM approach is a type of Problem Based Learning (PBL). While there is no universal definition of PBL, the following definitions from the last 3 decades capture its essence:

- "the learning which results from the process of working towards the understanding of, or resolution of, a problem. The problem is encountered first in the learning process". **[Barrows & Tamblyn 1980]**
- "an approach to learning that uses a problem to drive the learning rather than a lecture with subject matter which is taught." **[Woods 1996]**
- "focused, experiential learning (minds-on, hands-on) organised around the investigation and resolution of messy, real-world problems." **[Torp & Sage 2002]**

The problem is the driving force behind the learning. The novelty in TFTTM is the role reversal: the lecturer is central to the problem solving and the students are central to the problem setting. The students learn mainly from observation and feedback into problem setting and solution evaluation.

The success of TFTTM is dependent on the quality of the problems being addressed **[Duch 2001]**:

1. Effective problems should engage the students' interest and motivate them to probe for deeper understanding.
2. PBL problems should be designed with multiple stages.

3. The problems should be complex enough that cooperation within a group will be necessary in order for them to effectively work towards a solution.
4. The problem should be open-ended.
5. The content objectives of the course should be incorporated into the problems.

It is the role of the lecturer to guide the students in formulating a problem that meets these five quality criteria.

2.3 Lectures

It is very difficult to teach all material using only PBL. I revert to traditional lecturing when a problem has not been successful in helping students to meet specific learning objectives, or where I have yet to find a problem that has been able to do so. PBL quite often leads, in my experience, to weaker team members being dominated by stronger team members, resulting in the weaker students being less involved and losing motivation. Further, the freedom offered to students in PBL can lead to a chaotic/unstructured learning environment with the lecturer being detached from the process.

Lecturing can help to overcome these problems. However, balancing the PBL approach with traditional lectures is very difficult, and it is a skill that I feel that I have never mastered. TFTTM was introduced as a compromise approach that combines lecturing and PBL in a manner which I find much easier to control.

2.4 Putting These Together

When I first started the interactive lecturing I was hoping that an appropriate name for the technique would be "learning from observing the teacher's problem solving". However, after a number of interactive lectures it was clear to me (and to the students) that the best lectures were those in which I struggled to solve a problem, making many mistakes throughout the lecture. The worst lectures were those in which I solved the problem directly: the students felt as if they were "cheated" into participating in a more traditional lecture where I had already prepared a solution in advance. Consequently, the interactive lectures became known as LFTTM.

3 On "Creating An Engaging Learning Environment"

The golden opportunity you are seeking is in yourself. It is not in your environment; it is not in luck or chance, or the help of others;

I've come to the frightening conclusion that I am the decisive element in the classroom… As a teacher, I possess a tremendous power … I can be *it is in yourself alone.* *a tool of torture or an instrument of inspiration.*

Orison Swett Marden (1850 - 1924) **Haim G. Ginott (1922-1973)**

The citations from Marden and Ginott capture the confusing essence of teaching: I agree with both whilst acknowledging their inconsistency. Teaching is like parenting – the students need to learn to take responsibility for their own actions, yet the teacher is responsible for them learning this. There is a clear joint responsibility, and TFTTM more explicitly captures the essence of co-operation (between teachers and students) that is required for successful learning.

An engaging learning environment is critical to successful teaching. The teacher is the most important component of a learning environment. TFTTM is an approach which engages both the teacher and the students.

APPENDIX A: BIBLIOGRAPHY

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