

## Chemistry Solutions

### *Introducing Gamification and Working Towards Professionalism*

#### Introduction

The current drives to research-based education are well summarised by Brew<sup>1</sup>

*“For the students who are the professionals of the future, developing the ability to investigate problems, make judgments on the basis of sound evidence, take decisions on a rational basis, and understand what they are doing and why is vital. Research and inquiry is not just for those who choose to pursue an academic career. It is central to professional life in the twenty-first century.”*

Teachers of science recognise in this, a validation of the importance of delivery of the scientific method. It also reiterates the initial goal of a university education in the sciences to supply the professionals of the future — educated people, able to function as professional scientists and to create knowledge. In modern times, expansion of the student base, accompanied by sectoral shifts from manufacture to services, has resulted in a minority of science graduates continuing to work in science or research. The motivations of students have changed in response, from ones based on intrinsic desires to learn about a topic that is of great interest to them, to an extrinsically motivated and points-based ambition to succeed in summative assessment of modularised courses. The primary quest for many students is commonly the attainment of degree grade, squeezing the acquisition of knowledge and skills into the position of a minor goal.

In considering the educational journey of our students, it is useful to relate their developments towards being the professionals of the twenty-first century that are championed by Brew. We find that reference point of being a professional scientist can help greatly in aiding us to design and focus our activities, and reinvigorate our feedback structures and assessments. For emphasis, we employ a contrived distinction between **feed-back** and **feed-forward** based on feed-forward being part of an ongoing process of immediate skills reuse and development, while feed-back is a commentary on mistakes or suggestions of improvements for deferred application.

The goal of this brief text is to explore how the role of a professional scientist can be applied to provide perspectives on the different levels of student ability, and how they resonate with gamification constructs which can be embedded within our learning activities. The laboratory-based education that

- 
- <sup>1</sup> Brew, A. (2007) Research and teaching from the students' perspective. In: *International policies and practices for academic enquiry: An international colloquium*: Marwell: Winchester, UK.

characterises many of the sciences also provides a useful architecture within which we can engineer and manage closely how this is done. The techniques introduced are able to support student learning and develop an intrinsic motivation that can assist in improving student engagement. They work directly aims to meet the psychological and educational needs of students, and as a consequence also have the potential to improve the levels of satisfaction expressed within the assessment and feedback components of the National Student Survey (NSS).

### **Gamification in teaching laboratories — Engineering motivation**

Modern education is just starting on a journey to understand how motivation can be enhanced by the application of techniques originally developed for computer games. The massive success of games such as *FarmVille* and *MineCraft* relies on enticing and retaining high levels of user motivation - millions of users chose to spend many hours within these virtual realms and to exchange real money for game objects or opportunities. They chose to because they want to - the games have tools that tap into the psychological needs and desires of the player. The success of the games is testament to the power of the tools they use. These game-based motivators are most clearly seen in the Massive Open Online Courses (MOOCs), such as the *Kahn Academy*, where they are used to reduce the drop-off in student engagement.

The field of gamification has developed rapidly since its large-scale entry into software engineering in 2010 and much of Higher Education is behind on its practice. Techniques such as points, badges and leader boards, check boxes, rewards, badges and leaderboards are common and strongly evangelised. They are simple to apply but we argue that they operate at the wrong level. They are extrinsic motivators that trigger drives based on attainment or possession, and reinforce the points-based ambition that we want to move away from. The key characteristic of modern gamification, and the great potential for it to support our students in Higher Education, is the incorporation of devices that support intrinsic motivation. Working to encourage intrinsic motivation is extremely important as over-emphasis of extrinsic motivators can lead to the subsumption of intrinsic drives — subsequent removal of the extrinsic motivators often causes the motivation to collapse to a level that is below that when the extrinsic motivators were first applied. For this reason, the author proposes that the effective movement from feedback and summative assessment to feedforward and strengthening of professional skills must be supported by a structure where extrinsic motivation, embodied by the ownership of grades, is counterbalanced by intrinsic motivations aimed at encouraging students to operate at the required level. We cannot negate the extrinsic motivations, and indeed they can operate as effective drives, but we can utilise them in a more constructive manner. The challenge in Higher Education is to engineer motivationally balanced learning activities and structures.

Teaching laboratories are rich with opportunities that can be used to develop motivation and help students on their journey to becoming professionals through gamification, and some examples of intrinsic motivations are given below:

- 
- **To perform experiments that they design.** A natural strength of experimental work is the ability to be creative, to come up with a hypothesis that will be tested, to interpret results, and to make deductions. This is tremendously empowering and motivating. While a free rein is rarely possible in a teaching laboratory due to resources and safety, choices and options can be constructed into experiments at levels that match the knowledge and skills of the students. Indeed, well constructed rules of limited resources and possibilities can combine with problems that may be solved in a variety of ways, to fuel creativity by empowering students to make decisions and to **become co-creators**. In turn, this encourages intrinsic motivation. They also receive the powerful **immediate feedback** from the experiment itself, rather than from a person, of whether their decision was good and led to success.
- **To work in subjects relevant to the real world.** Structures where students collect samples from the real world, and perhaps also connect with societal issues, **help them to connect with meaning** and is intrinsic motivation. It would also be likely that these experiments would involve student choice and gain a degree of unpredictability that would also increase motivation.
- **Give a measured level of instruction.** An important aspect of motivation is allowing students to have the space to think about a course of action, and to call on their own experience and skills. For example, the final experiment of a lab course could directly build upon aspects of the experiments that the students have already covered and the level of instruction reduced to encourage deep reflection of these past activities. This structure builds intrinsic motivation as the students **see the connections in what they do**. It also engenders senses of ownership (extrinsic) and co-creation (intrinsic).
- **Leverage peers.** Many laboratory experiments involve group activities, but the analysis and write-ups are to be done separately by the students. Changing to a feedforward structure where activities and initial milestones are formative allows the write-ups and analysis to become group-based. Scheduling regular write-up sessions helps **encourage peer support structures** and strengthen intrinsic motivation through social influence, such as friendship and demonstration of prowess. The social aspects of these sessions would also allow students to learn about different viewpoints and backgrounds, potentially aiding the student transition to university as well as strengthening their motivation for undertaking the practicals.
- **Orchestrated failure.** Effective growth requires students to become comfortable with failure, gain the confidence that they will succeed, and understand that they will be supported. This can be incorporated into

experiments with relative ease. Situations where aspects of an experiment fail can be contrived and matched by learning goals centred on the discussion of the reasons behind the failure and an appropriate response, rather than the gaining of a 'correct' answer. These events teach about consequences and need to be matched by frameworks that provide the students with support and guidance. Allowing safe failure is potentially a powerful tool in the **movement away from extrinsic motivation** based on the possession of grades.

As said earlier, extrinsic motivators also have a place in a balanced motivational structure. Bringing several into play can help weaken the predominance of grade ownership and so round the student drives and experience. Some examples relevant teaching laboratories are given below:

- **Completing stages quickly and leaving early.** The speed with which a student accomplishes the required work is effectively a **leaderboard** and acts as an extrinsic motivator. Importantly, it shows accessible outcomes — students are able to complete stages quickly and to finish early. Care must be taken to prevent those that fall behind from becoming demotivated. Additional coaching from the (senior) demonstrator can be effective in turning a potential demoralising situation into one where the student feels supported and a sense of achievement.
- **Increasing the challenge - levelling up.** Making laboratory experiments harder and more completed increases the **sense of accomplishment**, an **extrinsic motivator**. This often occurs in large steps, such as in going from year 1 to year 2, which students can find strongly demoralising. A better scenario is to engineer an increase in performance that is accessible but still challenging, such as by raising the workload by 20% once a particular skill set (level) has been attained. Experiments that are done in different orders by different groups could have additional activities if they build upon practicals that are already been completed.
- **Making it personal.** As introduced above, the act of selecting directions within an experiment can create the sense of co-creation. It also imparts **ownership**, an extrinsic motivator. Care must be taken to avoid possible negative consequences from scarcity and the student not getting what is desired.

E-learning tools are able to play many roles in supporting these structures and enabling learning analytics to be created, though it must be recognised that a tension can exist between the ideal of supplementing intrinsic drives and the more easily programmed extrinsic motivators based on accomplishment and ownership that characterised early gamification examples, such as completion boxes, rewards, badges, and leaderboards.

**Towards professionalism and an end to feedback?**

The movement from feedback to feedforward occurs naturally within the working environment of an early-career professional where coaching structures are used to support the development of skills and abilities — employees are shown where they have made mistakes or underperformed and how they can improve. This behaviour lies in the best interest of the employer as it is focussed on the rapid improvement of an employee's performance. In education terms, this can be classed as a feedforward mechanism where the goal is to help improve abilities and knowledge for the next activity. The coaching structure is key to this process as it intrinsically allows failure to occur, to become accepted as part of the role, and for employees to start building a network that provides them with the help and support that they need. It also makes clear the level of performance that they are expected to operate at.

In many UK chemistry degree programmes, this structure is most effectively mirrored by the final year research project, the pinnacle of any research-based learning programme. For undergraduate students to operate effectively, they need to report frequently on progress and problems, and to receive guidance on how they should proceed. The primary coaching role may be held by an academic or another member of the group. It is expected that experiments will not always work and that there will be problems that the student will need to overcome by the application of rational analysis and hypotheses. Experience quickly allows the coach to define the student's performance with respect to the norms of the research group and this understanding can be swiftly passed on to the student during informal conversations. Again, the drive of this feedforward discussion is improvement of the student's performance and, ideally, increases in their confidence, self-motivation and productivity.

It is interesting to consider how effectively this coaching structure can be translated to earlier on in a degree. In UCL's own chemistry laboratories it most effectively begins in the 3<sup>rd</sup> year practical modules that aid students make the transition from teaching-labs to working in the research environment. A baseline practical module, where students gain the lab skills necessary to complete the more specialised experiments, is used to support synthetic organic and inorganic chemistry. Importantly, no feedback is made on the milestone submissions from the students. Instead, feedforward is provided within a coaching structure of one-to-one discussions with academic staff. This is timely as it helps students improve their performance in the following practical. The milestones are assessed by comparison against the standard of a professional, which reinforces the role of extrinsic expectations and the level that the students should aim to meet. The face-to-face nature humanises the processes and strengthens the effectiveness of the coaching.

Moving to the earlier years, conventional laboratory write-up and feedback types still dominate, as vestiges of the rule of summative assessment. Possible feedforward coaching structures are being introduced. The importance of the face-to-face contact pushes this effectively towards the

postgraduate demonstrators. They are able to translate guidelines and operational standards for the students in their charge, imprint expectations, and provide the frequent feedforward that best helps correct mistakes, and build skills and confidence. Professionalism can be reinforced by replacing classical and highly directed laboratory write-ups with the report style write-ups of a practicing chemist. A coaching discussion with the demonstrator or a senior academic again allows the identification of problems and actions that would improve them. Summative assessment can then be based on the quality of the student's milestones or their ability to work with the information that they have themselves generated and collated.

As well as helping restructure feedback, working with a framework of professionalism can also make clear the connection between the learning activity and what it is to be a professional. Its perspective traverses the potential division between being a student within Higher Education and the application of its knowledge and skills within employment, while also connecting with an intrinsic motivation to find meaning in what we do.