Engaging Learning And Addressing Over-assessment In The Science Laboratory: Solving A Pervasive Problem. *

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Abstract

This small-scale, mixed-method research study aimed at improving the learning experience for students in laboratory practical sessions. A sub-group of undergraduate Science students performed the Biochemistry practical component using a range of innovative integrated approaches over one semester, including a reduction in the number of laboratory reports performed and the introduction of a suite of in-class formative assessments. Group-work and self-assessment activities were combined with a distinctive incremental grading system designed to encourage feedback uptake. The outcomes of the intervention were assessed using data collected by two mixed-method approaches in an ethically approved manner: an online questionnaire and comparative focus groups. Quantitative analysis of grades obtained from laboratory reports over the semester demonstrated improvement in quality via uptake of feedback. Qualitative data obtained from the questionnaire/focus groups were thematically analysed and triangulated. Results showed the students engaged with, and implemented feedback, developed self-assessment reflections on their work prior to submission and improved the quality of their laboratory reports and theoretical understanding throughout this intervention. This study recommends implementing the feedback approach, incremental marking system and the self-assessment forms in teaching curricula. Together, they encourage the development of lifelong skills, such as self-reflection and an always-improving attitude in students.

Keywords: Assessment; undergraduate; incremental marking; feedback; self-assessment; learning experience; biochemistry; laboratory; practical; student centred learning.

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1. Introduction

The goal of the scholarship of teaching and learning (SOTL) requires those in a teaching capacity to research and focus on the *quality* of their students' learning and understanding while *encouraging* learning focused conceptions of teaching (Boyer, 1990, 1997; Light & Cox, 2009).

This study's aim was to implement and evaluate changes in the delivery and assessment of the standard laboratory system. Students were previously producing a laboratory report per weekly practical session, amounting to ten lab reports per module. Across all modules over a 3- or 4-year degree, the number of lab reports submitted rose into the hundreds, with each educator often examining the same skill sets (Hughes, 2004). Leach and Paulsen (1999) argue the link between instructional activities and learning in the laboratory needs attention (echoed by Psillos & Niedderer, 2002). Concerns exist regarding the method of laboratory assessment (*i.e.* writing summative laboratory reports for every practical session with little or no guidance, training, feedback sessions, formative assessments or group interaction exercises) (Pickford & Brown, 2006; Hunt et al., 2012). There has to be a connection made by the student that laboratory sessions are not simply a set of protocols to be followed, but are present to facilitate understanding of practical theories.

This article describes a short-term mixed-method study performed over one semester of the Biochemistry module (the study was piloted 12 months earlier to facilitate its design with the evaluation of the main study presented here). It was performed with a sub-group of 16 second-year undergraduate students studying a B.Sc in Pharmaceutical Science. Students attended weekly 3-hour laboratory sessions with their work assessed by a lecturer. An incremental marking system, combined with individual feedback sheets and self-assessment forms and a newly designed interactive laboratory manual, was implemented and evaluated. A second year class was selected, as the students will have adjusted to college life and assessment styles

(Fee et al., 2009). A small-scale sub-group was chosen to allow close observation of the formative skill set tests and feedback implementation. Online questionnaires and comparative focus groups were carried out to gather feedback and evaluate the intervention. The goal of this research was to develop self-learning, always-improving instincts in practically minded and formative-assessment driven students.

1.1 Research Aims

This intervention focused on addressing four research questions (See **Table 1**). With this approach in an action-research based study, the aim was to derive recommendations for curriculum design of practical sessions, enhancing the SOTL.

(1)	Would modifying the manner in which practical laboratory sessions are conducted and assessed improve the student learning experience?
(2)	Could the assessment/feedback process be improved so that all parties can engage in a feedback-feed-forward dialogue to generate improvement?
(3)	Would the introduction of an incremental marking system stimulate an always improving, self-learning trait in students?
(4)	Would reducing the number of lab reports required, in combination with the introduction of formative assessments and peer-assessment oriented approaches, facilitate understanding of a topic and students' practical skills?

Table 1: *The four research focused questions of the study.*

1.2 Literature Review

For an educational system to function effectively and efficiently, each aspect of the network involved must be constructively aligned for both short- and long-term learning (Biggs, 2003; Boud & Falchikov, 2006). Educators need to assist students in meeting learning outcomes through setting appropriate assessment tasks that support learning (Brown & Knight, 1994; Miller et al., 1998; Palomba and Banta 1999; Heywood, 2000; Fry et al, 2009).

‘Assessment is at the heart of the student experience’, wrote Sally Brown and Peter Knight (1994). Assessment represents one of the most controversial aspects of teaching, while also being an emotionally sensitive aspect (Fry et al, 2009; Light & Cox, 2009). The form assessment takes has been shown to influence the way that students view the learning process, determine their learning style, nurture motivation and build self-confidence (Black & Wiliam, 1998; Miller et al., 1998; Prades and Rodriguez Espinar, 2010). The overall student experience has been shown to be more positive in modules where assessment for learning approaches are used, with a deeper approach to learning being adopted (McDowell et al., 2011). Nicol and Macfarlane-Dick (2006) discuss how formative assessment promotes students to become self-regulated through empowerment, agreeing with the works of Boud (2000) and Boud & Falchikov (2006), who describe the requirement of these skills for life after college. If assessment can be approached in the ‘correct’ way, initially by the educator in its design and subsequently by the students involved, both parties can embrace the presence of the formative assessments allowing the students to become encouraged and more motivated (Barnett, 2007). This can empower a student and focus their attention on continuous improvement and self-assessment skill development.

Dochy et al. (1999) describe that to meet the goals of education, including a plethora of methods aimed at developing specific competencies is essential. These aim to develop meta-cognitive skills such as self-reflection and self-evaluation, producing highly-knowledgeable individuals who also acquire problem-solving skills and critical thinking skills in addition to internal motivation and self-efficacy, all of which are lifelong skills (Boud, 1989; Black and Wiliam, 1998; Taras, 2001). Stefani (1994) describes the ability of students being able to assess/evaluate their work in ways that are applicable to their future professions as invaluable. Designing self-assessment strategies and thereby encouraging students to reflect on their own work and evaluate their effort, feelings and accomplishments will develop self-regulated students with improved problem-solving skills (Kraayenoord and Paris, 1997; Orsmond et al., 1997; Dochy et al., 1999).

For any assessment performed, high quality, effective feedback (and feed-forward (Bjorkman, 1972)) represents a critical, yet often under-weighted component (Black & Wiliam, 1998; Price et al, 2010). Ideal feedback needs to provide supportive and constructive comments on what has been submitted and also what can be done to enhance performance, allowing students to actively construct their own information and skills (Boud & Falchikov, 2006; Nicol and Macfarlane-Dick, 2006; Brown, 2007; Sadler, 2010). This forward-moving approach helps stimulate motivation, yet also creates the 'always improving', action-research mind-set while promoting an experiential basis for reflection and self-assessment (Boud & Falchikov, 2006; Nicol and Macfarlane-Dick, 2006; Quinton and Smallbone, 2010). However, for many students, feedback can often have little or no impact (Gibbs & Simpson, 2004; Sadler, 2010). A common theme in the literature is how lecturers can stimulate students to register, reflect on and implement this feedback rather than just have them solely look for a grade in a corrected piece of work (Wotjas, 1998; Chanock, 2000). From an educator point of view, the more immediate and focused the feedback is, the stronger the response on the learning (Kvale, 2007; Hunt et al., 2012).

In the context of the constructivist theory of learning, feedback is part of the scaffolding the lecturer provides to enable students to learn (Orsmond et al., 2005). Carnell (2007) presented the theoretical concept of co-constructivism in which she expanded on the original constructivism theory revolving around the introduction of dialogue where collaboration in co-constructing knowledge, encourages effective learning (Carnell and Lodge, 2002; Watkins et al., 2002). Using Carnell's dialogue idea in addition to using what students already know as a base, we can design lab assessment criteria allowing the student to progress not just with an analytical way of thinking, but also how their knowledge can be applied in various situations

(Doran et al., 2002). Price and colleagues (2010) concur with Carnell, stating that educators should treat feedback as a long-term dialogic process with all parties engaged.

The laboratory represents a significant place of learning. Students encounter group work, skill tests, academic writing, peer learning in addition to summative and formative assessments (Pickford and Brown, 2006). During practical sessions, students have to master experimental theory and acquire laboratory skills (Prades and Rodriguez Espinar, 2010). Brown and colleagues (1997) comment on the work of Yager, Engen and Snider (1969), where they showed that "technical skills require practice but intellectual skills may be learnt as well in discussion settings as in the laboratory". Brown also states "if students are to experience the processes of scientific enquiry, course planners must design special learning activities. Laboratory cookbooks are not effective". The laboratory also promotes a peer-assisted learning environment (Falchikov, 2007). Falchikov (2007) describes how peer involvement encourages learning and develops assessment skills to last a lifetime, while Brindley and Scoffield (1998) showed that students, who obtained opportunities to compare and discuss, developed a greater understanding of the topic and became more personally motivated. Recently, Hunt et al. (2012) published a study in the field of practical laboratory education whereby they initiated assessment of students' active participation and learning to foster deep learning and they state that a future challenge is to "design all dimensions of learning" in the laboratory. To facilitate this, a considerable part of any learning and teaching approach depends on the suitability of its actual design – both in its delivery format and assessment methods used (Prades and Rodriguez Espinar, 2010). Hunt et al. (2012) cite a quotation from Bamber et al. (2009): "changing only an element at one level may have limited, local and provisional success… because the rest of the system is not touched and established patterns prevail over the single change". This statement supports the rationale for implementing a full overhaul of the system, such as that described in this article. For all readers, aspects of the learning and teaching processes presented would also be transferable to a classroom environment to facilitate learning and other skill development, e.g. improved feedback uptake.

1. 2. Methodology

A common strategy of institutions is to ensure students experience '*holistic learning environments'* containing a varied mix of assessments, capable of engraining life-long learning skills. The conduct and assessment of practical sessions is critical to meeting this milestone. To achieve this goal, the objectives and aims of this study were to:

* reduce over-assessment in science labs
* improve students' technical abilities
* enhance students' learning experience in practical sessions
* instil a mentality of self-learning and always-improving
* improve grades achieved in laboratory reports
* improve feedback uptake
* advance group and teamwork

Table 2*: An overview of the study aims*

Targeting these objectives, the delivery format and assessment method for the laboratory practical sessions were modified. **Table 3** presents an overview of the changes implemented. The new design encapsulated strategies aimed at improving the students' learning experience in the practical sessions, with each centred on developing the SOTL.

Modification	Description
Lab reports	The number of lab reports was reduced from ten to four.
Formative assessments	The introduction of short answer questions, sketch diagrams, multiple-choice questions, graph exercises etc. into the lab manual assisted in developing learning and understanding in the session itself.
Self-assessment checklists	Building self-assessment checklists into the lab manual allowed students to self-assess their work prior to submission.
Self-assessment grading	Requesting students to assess and grade their own work allowed them to consider their work in a more holistic manner. This facilitated the development of a self-reflective approach to their work.
Peer assessment	Exercises were introduced that were assessed by a student's lab partner.
Training & Exemplars	Training on writing laboratory reports was provided in an open forum, in addition to display of an exemplar.
Feedback sheets	Individual, sectioned and personalised feedback sheets were promptly generated and returned to the students. Feedback-review time periods were built into laboratory sessions.
Guidelines /Training	A training exercise focused on structuring a discussion and writing in the correct tense for lab reports was included.
Practical tests	Skill set tests on topics such as pipetting, data analysis, graphing and tabulating data and result interpretation were introduced.
Group work/ exercises	Implemented classroom assessment techniques that assisted in developing peer-to-peer group work. For example, the introduction of think/pair/share exercises assisted in stimulating student dialogue on topics.
Team submission	A lab group submitted a report together, rather than individually for one lab session. Each team had to plan, delegate tasks, work to deadlines in addition to proof read and self-assess ahead of submission (see Hughes, 2004).
Submission timeframe	Students were provided with a week to generate a formal lab report when required. This was increased from two days with the rationale that it facilitated the structuring, production and self-assessment of the report prior to submission.
Interactive exercises	For example, splitting the students into groups of 6, and asking them to generate 5 multiple-choice questions from the laboratory manual was one task used for them to process and synthesise information. By exchanging the questions generated by each group with another, learning was evident in an enjoyable 'table-quiz' type exercise.
Incremental marking system	With each successive laboratory report being worth more than the previous one, this aimed to develop the mind-set of the students towards improvement in subsequent assignments via impactful feedback uptake and synthesis.

***Table 3**: An overview of the modifications made to the format and assessment process in the presented intervention. A brief description of each modification is presented.*

Please note, a key background aspect to the intervention, is the development of a policy to deal with absenteeism. What occurs if a student is genuinely sick on a lab report week? In this study, and in this case, the student would be asked to submit a report of a previous lab. Over the term, every student will submit 4 pieces of work for assessment and feedback. Institute penalties are applied if leave is uncertified.

2.1 Data collection and analysis methods

To address the objectives of this mixed-method study, three avenues of data collection for analysis were used (lab report grading averages (each aspect of a report was assessed (i.e. introduction, materials & methods, results, discussion, conclusion and presentation to generate a grade as per **Supplemental material 1**), online questionnaire data and focus group transcripts). These 'best fit' evaluation approaches were carefully selected and piloted to ensure validity and reliability.

Ethical approval was obtained prior to study commencement. The second year pharmaceutical science group of 16 undergraduate students was invited to an information session on the study. Each student was provided with study information leaflets, an overview of the evaluation methods (i.e. online questionnaire, focus groups) and study participation forms. Participation was voluntary and students had the right to withdraw at any stage. It was stated all data would remain anonymous and participation/withdrawal would have no influence on grades.

The previously piloted online questionnaire was structured with a combination of ten open-ended, rating, dichotomous and multiple-choice questions (as recommended by Adams and Cox, 2008; Cohen et al., 2011) (**Supplemental material 2**). A non-probability convenience sampling method was applied for the online questionnaire (Cohen et al., 2011). All data was transferred to, and stored in a password-protected Microsoft Excel spreadsheet for analysis.

To obtain data to triangulate with the questionnaire responses, focus groups were employed (Merton et al. 1990; Kitzinger 1996; Morgan 1996; Puchta & Potter 2004; Wilkinson, 2004). Two, pre-piloted, one-hour comparative focus groups were performed in accordance with Krueger's (2002) recommendations, allowing triangulation between group responses. A non-probability volunteer sample selection of 5-6 learners was selected to participate in each focus group (Cohen et al., 2011). One focus group contained 6 students, with 5 in the other. The researcher/moderator and a co-moderator were present to record handwritten notes to avoid bias from any one group/individual (Millward 1995; Lunt and Livingstone, 1996). Audio/video recordings of the focus group were not performed, as there have been reports of them being off-putting, potentially affecting responses to questions (Polgar & Thomas, 1995; Adams & Cox 2008). The focus group approach was semi-structured (organised around a set of predetermined open-ended questions, with other questions/clarifications/elaborations emerging during the dialogue (DiCicco-Bloom & Crabtree, 2006) (**Supplemental material 3**)). Hand-written transcripts from both moderators were transcribed to a password protected Microsoft Excel spreadsheet with each comment/statement open-coded (Cohen et al., 2011) based on a thematic area (using a colour coding system). The analysis method presented by Brenner and colleagues (1985) was then followed – *i.e.*, after categorising the data, it was reflected on, synthesised and then condensed with key statements/findings excised and interpreted. A cross-comparison of statements coming from each focus group was performed. Once the final focus group findings were interpreted, they were triangulated with the online questionnaire results increasing reliability and validity (Cohen et al., 2011). The data analysis procedure was reviewed by one of the co-authors. Final findings and focus group transcripts were circulated to all study participants.

3. Results & Discussion

This intervention implemented an innovative laboratory format and assessment process (**Table 3**). Sixteen students participated in the practical sessions, with 12 taking part in the online questionnaire, and 11 in the focus group sessions.

3.1 Reduction in the number of lab reports

Students reacted positively to reducing the number of lab reports from 10 to 4. Eleven students (91.7%) stated they would prefer not to revert to a system of one lab report per week. One student commented that it

"…*takes too long to do one every week and is then rushed" and that "If there was a lab every week there would be an overload and not enough time would be put in to them."*

Another stated that having a lab report per week could impact on quality:

"…*because of the volume of work it would be difficult maintaining the quality".*

In the focus group, students commented that the reduction provided them with more time for other studies and assignments and they enjoyed the idea of being able to "*focus*" on the lab reports. The students felt the reduction did not impact upon their learning and understanding of theory and skill development, citing the incorporation of formative exercises in the lab manual helpful in assisting understanding. Ten of the questionnaire respondents (83.3%) stated they learned more in the lab sessions from performing them using this intervention:

"*I believe a lab write-up every week would not only waste valuable study time but lead to students not enjoying the laboratory sessions. I personally found myself learning a lot more because I was enjoying the laboratory practicals and not constantly fretting about what I was going to write in the reports."*

3.2 Incremental Marking System

The intervention introduced an incremental marking system for the four lab reports, which were worth 4%, 7%, 9% and 10% respectively (totalling the 30% practical component of the module). The system was introduced in an attempt to stimulate the generation of an always-improving attitude and mind-set in the students. However, for the system to work, it was critical that prompt, individual, sectioned feedback sheets be provided (Kvale, 2007; Hunt et al., 2012). It was hoped that the incremental marking system would stimulate feedback uptake. Students realised this from performing the intervention:

"*Incremental marking scheme combined with the feedback process gave students a chance to improve as they could see where they needed to improve."*

"*Feedback helps you improve over the term."*

From the questionnaire, 8.3/10 was the average score provided for the incremental marking system while all twelve of the respondents (100%) were satisfied with its implementation. There was a slight reservation from one student with regard to the higher weighted lab reports, who stated that they

"*felt that there was more pressure to try and achieve a better result."*

Other students in the questionnaire repeated the increased pressure and time required for the last two lab reports, but still agreed that it was a good concept. Both focus group discussions concluded that the system actually reduced pressure on students as they have a low weighted report initially allowing them to adapt to the lecturer's requirements without any costly penalties at that point.

Overall, the incremental system was seen as a positive intervention that "*improved quality*", allowing students to "*adapt*" to what is required. There was general agreement that it "*encourages you to do your best, keep improving*" through developing a "*new mind-set*", when subsequent reports are worth more, you "*work harder*" and "*right your wrongs*" through uptake of feedback. The groups commented how various lecturers/modules can have different requirements with regards to lab report structure/content and that this approach assisted them in adapting to requirements.

"*The first write-up/report is experimental. You have to make your own mistakes to learn from it. Build on them.*"

Eleven respondents (91.7%) felt they improved their performance in writing lab reports and learned how to implement feedback. **Figure 1** shows the improvement of the class average mark for the lab reports over the semester.

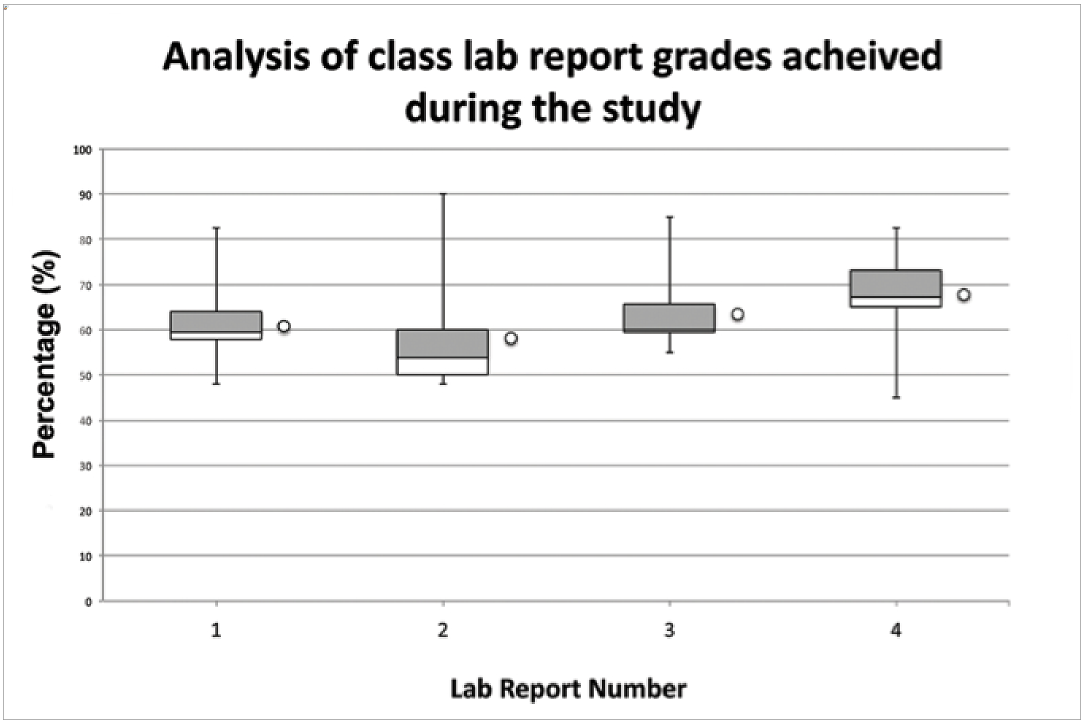

Figure 1: A box plot showing the analysis of the class' lab reports over the four submissions during the intervention. *The medians for each lab report are as follows: [1] 59.5%, [2] 53.75%, [3] 60% and [4] 67.25%. The mean values ([1] 60.7%, [2] 58.2%, [3] 63.4%, [4] 67.7%) are also displayed (white circles). Please note the Irish grading system for a B.Sc degree used is as follows: Distinction: > 70%; Merit, Grade 1: 60% - 69%; Merit, Grade 2: 50% - 59%; Pass: 40% - 49%; Fail: 0%-39%.*

Students progressed from a mean/median of 60.7% / 59.5% in the first report to 67.7% / 67.25% in the final report. There is a slight decrease in the mean/median for the second lab report (58.2% / 53.75%), possibly explained due to the team report that was performed just prior to, and during, a reading week - students stated afterwards, they would prefer this to occur completely during normal term time. From this point on, the final two lab reports improved further (with mean/median values being 63.4% / 60% and 67.7% / 67.25% respectively). Interestingly, the pilot of the intervention indicated a similar trend, even with a slight decrease for the second report. Therefore, one must consider that students may require time to adapt to the system, and in particular realise the role of the feedback/its uptake (Price et al., 2010; Boud & Falchikov, 2006; Nicol & MacFarlane Dick, 2006; Brown, 2007). This requirement may stem from previous educational experiences and potential unfamiliarity with the feedback uptake concept (Fee et al., 2009).

In summary, the system empowers the student to "*build on*" any mistakes, helping them become more self-regulated learners (Nicol and Macfarlane-Dick, 2006). All of the focus group participants recommended that this grading approach be retained.

1.1 3.3 Feedback Uptake

While a good concept, the incremental marking system would be ineffective without constructive feedback on how to improve. Price and colleagues (2010) stated students who did not recognise the feed-forward function of feedback were only taking a short-term view in its application. Nicol & MacFarlane-Dick (2006) and Boud & Falchikov (2006), would prefer this to be reversed, through the development of a long-term, self-regulating learner approach. Hence, it was essential that the role/function of feedback, were both understood by the lecturer and the students (Gibbs and Simpson, 2004). Sadler (1998) identified that students may have to be educated how to use feedback to develop metacognitive control, hence a session on the role of feedback was performed at an early stage.

In this study, each student was provided with a completed individual feedback sheet per lab report submitted (**Supplemental material 4**). As recommended by Orsmond et al., (2002), feedback review time-slots were built into laboratory sessions allowing students to ensure they understood the feedback, cross-checked it against their report and requested clarification during the session, *i.e.* improving the co-constructive dialogue promoted by Carnell (2007). The utilisation of educators' feedback by the students can enhance motivation and learning, encourage reflection and clarify understanding (Orsmond et al., 2005). Empowering the students with feedback is essential for the process of feed-forward improvement and comments from the students who undertook this intervention supports this:

- "*You can't improve without feedback*"
- "*Feedback worked as it helped you get better marks*"
- "*Improve as you go*"
- "*Feedback lets you correct your work*"
- "*You knew exactly where you went wrong and how to fix it*"

From the educator's point of view, generating the feedback was time-consuming (echoed in Hughes, 2004; Pickford and Brown, 2006). The researcher was very conscious feedback often solely points out errors, without any praise being provided for aspects of the work done correctly or beyond expectations (a sentiment presented in Brown, 2004). A strong effort was made to ensure positive aspects were highlighted and encouraging remarks written. The researcher felt this improved the dialogue and acceptance of feedback.

"*This really helped me as you had paragraphs of feedback, so you knew exactly where you were going wrong and were also told what was done well, which I really liked.*"

"*The feedback sheets gave me the information I needed to improve my mark with every submission. Prior to completing my reports, I referred to the feedback sheets of previous submissions. This ensured that I would not repeat the same mistakes.*"

"*I felt like the difference in the quality of my first submission and my last submission was huge because of it (feedback).*"

In general, the researcher noted the students were implementing feedback suggestions and not making the same errors a second time.

3.4 Interactive Lab Manual Exercises

Contributing to the intervention's success in the students' eyes was the newly designed interactive laboratory manual format, as it received a 9.5/10 score on the questionnaire. The scientific protocols were present in the original lab manual along with a thorough theoretical background (please note this was already in place from another lecturer). This intervention added:

- extra formative assessment exercises
- skill tests
- group exercises performed in the lab
- a lecturer sign-off sheet per lab session

One student stated that the "*lab exercises helped me understand the experiments more*", while others commented that performing the exercises/questions in the lab, versus at home, was critical in developing understanding – all of the students agreed with this in the questionnaire responses. The focus group discussions stated the interactive nature of the lab manual helped facilitate retention of information, reinforce theory and provide clarity to students when they left the laboratory while performing and discussing the answers as a group was regarded a key aspect. Each of these were noted to help with the module exam at the end of the course as the intervention stimulated a "*deeper learning*" process. This echoes the findings of McDowell et al. (2011) who found that assessment for learning approaches developed a deeper approach to learning. Students noted the practical tests (e.g. a pipette test, graph drawing test) were valuable training while the lecturer sign-off following each lab session "*makes you do it*".

Peer-learning/assessment has been shown to contribute to the development of self-assessment skills, so this was used regularly (Nicol and Milligan, 2006; Segers and Dochy, 2001). Within the current study, students commented on how they appreciated working in groups, hearing "*different viewpoints*", stating that peer-learning was of benefit as:

- "*colleagues explaining in their own words was effective*"
- "*learn off each other", "explaining to each other*"
- "*easy to understand*"
- "*I didn't feel pressure*"

This concurs with Brindley and Scoffield's (1998) finding that students become more motivated and develop increased understanding through discussion opportunities. To stimulate group interaction further, a team lab report was included (recommended by Hughes (2004)). A student with their lab partner had to brainstorm, plan, set deadlines, produce, peer- and self-assess, before submitting their report. It was introduced just before the institute's reading week so students would have more time to perform the activities and engage in face to face meetings initially, and subsequent e mail/phone communication. The majority of students found the team project "*useful*", advising it be retained in future years, but that it occurs during term time to maximise the face-to-face contact. It did help them realise:

"*You have to learn how to work in a group".*

1.2 3.5 Self-Assessment Skill Development

The self-assessment aspect of the intervention provided the most unexpected results (Boud, 1989; Dochy et al., 1999; Taras, 2001; Nicol & Macfarlane-Dick, 2006). Accompanying each lab report, the students submitted a self-assessment checklist (see **Supplemental material 5**). Sadler (2010) states we have to shift the focus away from informing students about the quality of their work and instead get them to realise and understand the reasons for quality and their ability to develop personal capability. Overall, the self-assessment checklist received 8.1/10 in the questionnaire responses, as "*it ensures you have all parts of the lab write-up completed and no parts missing*" and "*gave me a clear concise layout for the lab write-ups*". However, the self-assessment aspect proved to be "*difficult*" for the students (echoed in Stefani, 1994). One student stated they "*didn't like judging themselves but can see the benefit of it*" with another commenting that it was "*difficult to assess my own work*" and that they "*want to be told where I am going wrong*".

In the following examples, a number of students identified the benefits of the self-assessment process:

- "*I think it forced students into actually thinking about the quality of the work that's being submitted one last time and even encourages students to improve as they're judging their own work.*"
- Self-assessment required time to "*reflect on the work; definitely keep it.*"
- "*It helped a lot with lab submissions as it made me check my report more thoroughly.*"

Kraayenoord and Paris (1997), Orsmond et al., (1997) and Dochy et al., (1999) all indicate that self-reflecting students develop into self-regulated learners with better problem-solving skills. The development of self-reflection through a self-assessment process was one of the key goals of the study (Stefani, 1994; Dochy et al., 1999; Boud, 2001). The students stated the self-assessment process with the lab reports "*made you back-track*", "*look at it again*", giving you "*a feeling of you can do more*" or making you ask "*could it be done better?",* demonstrating self-reflection.

An unexpected finding was the level of emotions self-assessment brings into play. One student stated in the focus group that the "*self assessment made me feel guilty*" regarding their level of work, causing him/her to state they "*wrote down excuses*" in the self-assessment form. The same student stated the process "*made me feel I wasn't ready to submit*" and that "*maybe I should try and do it again*". In general, other focus group members echoed this perspective. Other responses included that students felt they "*had to be modest*" with their self-assessment and that they were "*very reserved with the 'well achieved'*" option, with one commenting that self-assessment had a major impact: "*I had to think*". Stefani (1994) identified in almost 100% of students engaged in self-assessment activities, they considered it made them think more. Reflection on effort and work induces the mind to evaluate and this stimulates ways to thinking of how to improve. A very different emotion identified in one student regarding self-assessment was that of fear – the student "*felt that the self-assessment marking might sway the mind of the corrector and that they'll agree my work is bad*". The same emotion and reason has been reported previously (Lew et al., 2010). This aspect of the intervention highlights the requirement for an open dialogue between lecturer and students on self-assessment (as recommended by Carnell (2007) with regards to feedback).

Finally, one student utilised the self-assessment form as an "*opportunity to explain where you were struggling, ask for help*". For a student to identify where they are having difficulty, they must be reflecting on their efforts to identify these weaknesses. The fact that the self-assessment resulted in an emotional response, demonstrates the students were actively reflecting on their work and evaluating their efforts – an invaluable ability (Stefani, 1994).

A summary of the key findings of this study is presented in **Table 4**.

Key Findings
The use of an incremental marking system in combination with promptly-returned detailed, personalised feedback sheets clarified the role of feedback for students and encouraged its uptake, resulting in higher quality lab reports being submitted. In essence it developed a "*new mind-set*" in the group.
Students appreciated addressing the over-assessment issue with lab reports as it allowed them to produce higher-quality work (vs. overload and less time per report).
Self-assessment forms were very effective in generating reflective lifelong learning skills in students.
Students found grading their own work a difficult process possibly due to unfamiliarity with the concept at this early stage in their careers.
Self-assessment and reflection activities are strongly linked with emotions.
Lab manual based formative assessments improved learning and understanding and increased retention of information.
Group work and peer assessment activities developed key skills in learners (with students preferring face-to-face group work vs. project communication via e mail).
An open dialogue on feedback and self-assessment is essential throughout the intervention.
Performing exercises/activities in the lab is preferred as compared to doing them at home.
Incremental marking system allows students to adapt to lecturer's requirements.

Table 4*: The key findings of the study are presented.*

4. Concluding Remarks & Recommendations

This study presents an intervention whereby the whole process, rather than a single element, has been changed (as recommended by Bamber et al., 2009). The intervention was not only geared towards improving the students' theoretical, practical and writing skills but also lifelong, transferable skills such as self-reflection, feedback uptake, responsibility and problem-solving ability. The study presented the opportunity to develop recommendations for the development and performance of practical sessions. Recommendations were requested of the student group and these can be seen in **Table 5**.

Student Group Recommendations
Continue and maintain intervention in future years (please refer to **Table 3** for intervention changes introduced).
Continue to fill the full 3-hour session with exercises/activities to facilitate learning and understanding.
Include a notebook for students to use in the lab sessions as rough work (rather than hard back copy). Suggestion that this be collected and graded.
Introduce more quizzes to test theoretical knowledge. Idea to have one at the half-way stage so students could track progress.
Allow choice of submission format (the majority would prefer electronic (vs. handwritten) submission of lab reports).
Develop more practical skill set tests and consider introducing grades for them.
Keep the team project and ensure it runs during term time – more face-to-face interaction.

Table 5: *An overview of the recommendations made by the students with regard to improving the intervention.*

Any educator designing a laboratory-based curriculum should certainly consider the options presented by Hughes (2004). For any educators considering aspects of this particular intervention for their own practice, the authors would recommend adopting the incremental marking system in combination with personalised, sectioned feedback sheets and self-assessment forms after observing their success in this study. It is critical for the process that feedback is individual to the student, appropriate, detailed, effective and timely (Ramsden 2003; Knight and Yorke, 2003; Mory, 2004; Poulos and Mahony, 2008; Ferguson, 2011). Equally important is that a dialogue on the role of feedback and self-assessment be established early in the process between the educator and the students - engaging with feedback should be presented as an opportunity for learning, showing students how they may develop further in future work (Knight and Yorke, 2003; Poulos and Mahony, 2008). Despite the limitation of a small sample size, the authors would not anticipate any concerns performing the intervention with larger group numbers.

The inclusion of performance-based assessment or problem-based learning methods would allow students to become more involved, giving them more responsibility for determining the procedure and improving technically (Domin, 1999; Herrington and Nakhlek, 2003; Hunt et al., 2012). These approaches would build on Hunt and colleagues' (2012) recommendation to improve "all dimensions of learning" in the laboratory.

In summary, reducing the number of lab reports, combined with the introduction of formative assessments and peer-assessment oriented approaches, facilitated students' understanding of a topic and development of practical skills. An incremental marking system stimulated an always improving, self-learning trait in students while the self-assessment/feedback process was improved so that all parties involved actively engaged in a feedback-feed-forward dialogue that led to improvement in the quality of laboratory reports. With the laboratory representing a significant place for learning and understanding, it is critical an effective learning framework is present to maximise development of both lifelong learning and practical skills in our future scientists.

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Supplemental Material 1 – Lab grading Rubric

Classification	% Range	Introduction	Methodology	Results	Discussion	Conclusion
Distinction	70-100	Correct aim precedes introduction. Complete and thorough background to topic provided with extensive reading around the topic (i.e. extra information identified and included in correct context). Introduction well structured, with good flow between sections. Suitable diagram(s) included. Flawless spelling and grammar with appropriate Harvard referencing used where appropriate. Written in 3rd person, passive voice.	Link to appropriate lab manual section/pages perfectly represented. A detailed overview of any experimental specificities or deviations presented clearly and accurately. Table presented perfectly if reagent set up was required. No spelling or grammar errors. Written in 3rd person, passive voice.	Introduction to results section clearly presented. Results presented and labelled perfectly. Graphs/tables drawn and labelled correctly. Tables used at every opportunity where appropriate to present data. Calculations clearly explained. Any printed results neatly included in report. Correct units used throughout. Perfect presentation. Written in 3rd person, passive voice.	Summary of experiment performed perfectly. Experimental approach discussed. Results obtained thoroughly discussed in detail. If experimental processes did not yield results, reasons are presented and discussed thoroughly. Link to literature/outside reading presented. Future work, or changes for future repeats of experiment are presented and discussed. No spelling/grammar errors. Written in 3rd person, passive voice.	A succinct and concise conclusion is deduced. The conclusion is accurate from the data obtained. Overall relevance also presented.
Merit 1	60-69	Correct aim precedes the Introduction. Section is structured well with relevant content presented in a logical manner. Major sources referenced and suitable diagram included, however extensive reading around the topic not evident. Minor layout, spelling and grammar errors. Written in 3rd person, passive voice.	Link to appropriate lab manual section/pages perfectly represented. An overview of any experimental specificities or deviations presented. Table presented with minor errors if reagent set up was required. Minor spelling or grammar errors. Written in 3rd person, passive voice.	Introduction to results section clearly presented. Results presented and labelled to a high standard. Minor errors with graphs/tables. Tables used where appropriate to present data. Calculations clearly explained. Any printed results neatly included in report. Minor errors with units. Clear presentation. Minor spelling or grammar errors. Written in 3rd person, passive voice.	Summary of experiment performed to a high level. Experimental approach discussed. Results obtained discussed in detail. If experimental processes did not yield results, reasons are presented and discussed. However no link to literature/outside reading presented. Future work, or changes for future repeats of experiment are presented and discussed. Minor spelling/grammar errors. Harvard referencing used correctly where appropriate. Written in 3rd person, passive voice.	Correct conclusion deduced and presented succinctly. Relevance not mentioned/discussed.
Merit 2	50-59	Correct aim precedes the introduction. Section structure and flow is not very strong. Depth and context of background material can be improved further. Diagram used is omitted/not relevant to text presented. Minor errors in tenses used.	Methodology section linked to correct lab manual/page number. Deviations made to protocol mentioned but with minor errors. Errors in spelling and grammar. No tables presented for reagent make up. Minor errors in tenses used.	Introduction to results section not presented. Results presented and labelled but with omissions or errors. Tables not used at every opportunity where appropriate to present data. Calculations included but not clearly explained. Any printed results are not neatly included in report. Minor errors with deducing results/units. Minor errors in tenses used.	Brief summary of experiment performed. Experimental approach mentioned. Referring to results obtained but not putting them in context or discussing relevance. If experimental processes did not yield results, reasons are not presented or discussed. Future work, or changes for future repeats of experiment are presented briefly. Minor spelling/grammar/tense errors.	Conclusion correctly deduced but not presented in a clear manner.
Pass	40-49	Aim presented but incorrect. Key background points present, but with no depth or true context. No diagram included. No extensive reading evident. No structure/flow to introduction. No external sources mentioned/ referenced. Errors in spelling and grammar. Errors in tenses used.	Methodology section linked to correct lab manual/page number. No mention of deviations made to protocol. Errors in spelling and grammar. No tables presented for reagent make up. Errors in spelling and grammar. Errors in tenses used.	Results included in report but not neatly presented in a very logical way. No use of ruler in tables. Poor quality of presentation of data. Errors in deducing results. Errors in spelling and grammar. Errors in tenses used.	Discussion section very brief but contains some relevant material. Results not discussed correctly/accurately. Minimal structure to discussion section. Errors in spelling and grammar. Errors in tenses used.	Conclusions deduced not entirely correct.
Fail	0-39	Aim presented is not correct or is omitted. Introduction is incomplete/missing key background points, and no diagram is provided. Scientific errors evident in text presented. Many spelling and grammar errors. Written in incorrect tense.	Methodology section missing or incomplete. No reference to appropriate lab manual section/pages. Incorrect/no deviations presented. Many spelling and grammar errors. No tables presented for reagent make up. Written in incorrect tense.	Incorrect/incomplete results presented. Graphs/tables presented with errors. Incorrect units throughout. Many spelling and grammar errors. Written in incorrect tense.	Discussion very incomplete and does not contain any relevant material. Results not discussed correctly/accurately. Poor presentation and logic to flow of text. Many spelling and grammar errors. Written in incorrect tense.	Incorrect conclusion deduced and presented / conclusion omitted.

Supplemental material 2 – Online Questionnaire

1. On a scale of 1 to 10, how would you rate the following aspects of the new laboratory assessment procedures implemented in the Biochemistry laboratory sessions last semester? (1=Poor; 10=excellent)
Please tick the box that applies to you for each topic.

	1	2	3	4	5	6	7	8	9	10
Reducing number of lab write-ups	○	○	○	○	○	○	○	○	○	○
Performing exercises in a lab manual	○	○	○	○	○	○	○	○	○	○
Use of pre-submission check-lists	○	○	○	○	○	○	○	○	○	○
Incremental marking scheme (4%, 7%, 9%, 10%)	○	○	○	○	○	○	○	○	○	○
Feedback process used (individual/personalised sheets)	○	○	○	○	○	○	○	○	○	○
Overall experience of new process	○	○	○	○	○	○	○	○	○	○

2. Reducing the number of laboratory write-ups due per semester (i.e. reduction from 10 to 4 write-ups) is something that I __________________with. Please fill in the blank by ticking one of the following options:

○ Strongly Agree ○ Agree ○ Neither agree nor disagree ○ Disagree ○ Strongly Disagree

3. Do any of the following apply to your experience of using the new laboratory assessment system? Please tick each of the boxes that apply to you. You may pick more than one box.

- ☐ I had more time for lab-write ups
- ☐ I learned more in the lab sessions
- ☐ I had more time for work/life balance as less write-ups were due per term
- ☐ I had more time for study as less write-ups were due per term
- ☐ I enjoyed the lab sessions more
- ☐ I improved my lab write-up performance
- ☐ I learned how implementing feedback can improve my next submission
- ☐ I found the pre-submission checklists helped me before my submission

Other (please specify)

4. Overall, do you feel that performing and completing exercises in the lab manual during the laboratory sessions facilitated your understanding of the topics being covered? Please tick the box that applies to your feeling towards this question.

○ Aided understanding greatly ○ Aided understanding slightly ○ Don't know ○ No major gain in understanding ○ No gain at all in understanding

5. Please comment on the strengths/weaknesses of the new format of the Biochemistry laboratory sessions implemented last semester. Please enter your responses in the text boxes below.

Strengths (what worked well?)

Weaknesses (what didn't work well?)

6. In the box below, please comment on the value of the pre-submission checklists that accompanied your lab write-up submissions in Biochemistry.

7. Are you satisfied with the concept of assessing the lab write-ups using the incremental marking system during semester 1 (i.e. lab write-up 1 worth 4%, lab write-up 2 worth 7%, lab write-up 3 worth 9% and lab write-up 4 worth 10%)? Please choose the option that best describes your level of satisfaction.

- Extremely Satisfied
- Moderately Satisfied
- Neither satisfied nor dissatisfied
- Moderately Dissatisfied
- Extremely Dissatisfied

Please state the most important reasons for your answer

8. Explain how you used the feedback provided (i.e. the feedback sheets, with information per section, provided to you for each submission)? Please enter your response in the text box below.

9. Would you prefer to revert to a lab write-up due for every lab session performed? Please tick the box that applies to your answer to this question.

- Yes
- No

Please state the two most important reasons for the response you have given.

10. Do you have any additional suggestions to improve how these Biochemistry laboratory sessions are performed and assessed? Please enter your response in the text box below.

Supplemental Material 3 – Focus Group Questions

Question 1: Over the term (using this new system in the labs), the class' average mark for Biochemistry lab write-ups increased, why do you think this occurred?

Question 2: How do you feel about the incremental marking scheme used over the term? Did you feel it made you improve as the term progressed?

Question 3: Can you comment on the feedback system used in this project?

Question 4: How do you feel about the structure of the biochemistry lab manual? Interactive Exercises? Improved practical skills? Pipette tests, graphs, exercises? Aided understanding?

Question 5: How did you feel about the self-assessment checklist/form that accompanied your lab submissions?

Question 6: Suppose that you were in charge and could make one change that would make the lab practical program better. What would you do? Something new? Fix/update/change something

Supplemental Material 4 – Feedback Sheet Template

Lab feedback sheet **BIOCHEMISTRY**

Lab Group: B.Sc Pharmaceutical Science

Stage: 2

Lab: : **Lab topic**: **Student:**

Introduction

Materials and Methods

Results

Discussion

Conclusion

Presentation

Comments

Supplemental Material 5 – Self-Assessment Form

Criteria / Component	Well Achieved	Achieved but could be better	Not achieved
Aim/Objectives. Have you clearly stated the aim of the experiment?			
Introduction. Have you provided a thorough background to the technique/principle being tested in the lab session? Have you included a diagram if it can help explain the process?			
Materials & method. Have you referred to the correct section of the manual? Have you provided details on any deviations to the method? Have you included a table if reagent set-up was performed?			
Results: Have you presented the results from the experiments? Are they neatly presented? Have you used a ruler? Are any pieces of paper stuck neatly in to your copy? Are all the aspects labelled correctly? Are units correct?			
Discussion: Have you provided an overview of the principle? Have you talked through the experiment? Have you discussed the results you obtained and shown understanding about what they mean? Were they what you expected? If an experiment did not work, can you explain why? What would you do differently if you were performing the experiment again?			
Conclusion: Have you included a conclusion section? Have you made a conclusion statement on the lab session/experiment? What is the relevance of the conclusion being deduced?			
Have you Proof-read your work?			
Have you written your write-up using the 3rd person, passive voice?			

What are the strengths of this piece of work?

What are the weaknesses in this piece of work?

How could this work be improved?

The grade I feel it deserves is………….(out of 10)