2011

Integrating Formative Feedback into Individual and Group Assessments in a First Year Organic Chemistry Module

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INTERGRATING FORMATIVE FEEDBACK INTO INDIVIDUAL AND GROUP ASSESSMENTS IN A FIRST YEAR ORGANIC CHEMISTRY MODULE.

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Abstract

It is common for science undergraduates, particularly first year students, to remark that they do not receive appropriate support in their transition from second level to third level education; particularly in effective scientific laboratory report writing, new subject area preparedness and technical 'know-how' [1]. This is compounded by the insufficient, or inappropriate, feedback offered to students in these problem areas. The pedagogical emphasis often focuses on quantity rather than quality; both in report writing and content delivered. This publication describes an assessment methodology redesign to, firstly, incorporate on-line formative feedback and; secondly, to introduce one-to-one and one-to-group lab report feedback in a first year organic chemistry module to specifically target the problem areas aforementioned.

Keywords: Feedback, scientific report writing, blended learning, group work, laboratory preparation.

1 INTRODUCTION

Undergraduate laboratory teaching emphasises a number of key proficiencies, including; technical, manipulative, observational, analytical and discursive skills [2]. This skill set can be particularly daunting for first year undergraduate students, who may have had little exposure to lab work at second level. The provision of appropriate resources to prepare the students before lab sessions can improve the students learning and reduce the learning load during the lab session. Johnstone [3] reported that undergraduate students are often overloaded in the laboratory; they are under time constraints to complete the required technical and manipulative aspects of the laboratory within the allocated time. This results in students having little '*brain space*' to process the new; and often time, complex, information associated with the lab. Students blindly follow the instructions and seldom interpret the observations, or the results, made during the experiment. Insufficient preparedness often results in poor lab performance and subsequent difficulty with report writing. Additionally, little laboratory time is typically afforded to improving students' communication skills; academics are often constrained by time and the requirement to complete the syllabus. Key communication skills, such as report organization, argument development, referencing, critiquing and revising should be developed to guide the student during scientific report writing [4]. Furthermore, timely, formative feedback on completed assessments is central to the students' development; simultaneously promoting critical self-analysis and learning [5].

In this publication a redesigned assessment strategy has been implemented for a first year basic lab skills module to specifically target the problem areas aforementioned over the course of an academic year. To support this approach the module content, both lecture and laboratory, was redesigned to better align to each other and also to help the student to '*construct'* their own learning; however, the focus of this publication is the module assessment redesign. This redesign placed a higher emphasis on continual assessment of lab preparedness, improved the students report writing skills through a reduced number of reports accompanied by formative, constructive feedback and focussed on the correct laboratory technique within the laboratory environment. To prepare the students for their laboratory sessions each student was given the complete laboratory manual at the start of each semester. The manual linked to additional resources, including lab instructional videos which were produced in-house, and available through *Webcourses,* the institutes' virtual learning environment. The students were also required to complete short, graded multiple choice quizzes targeting the important theory behind the upcoming laboratory. The MCQ was automatically graded and provided instant feedback to the student on each question. To support the development of their communication skills, the students initially reported individually on short distinct sections of a typical scientific report and received one-to-one feedback. Following on from this, students worked in small groups to produce four group reports over the course of a twelve week semester. Each report was graded by the lecturer

and one-to-group feedback was given. The students also anonymously peer assessed (APA) each others contribution to the group report. The students did not see individual anonymous peer scores; however, they were given the average peer assessment score and this was used to calculate the peer assigned contribution to the overall report mark. The peer contribution was worth 25% of the total report mark. Upon completion of the APA process, the lecturer facilitated a discussion which was used to suggest improvements for future reports. To align learning outcomes and the assessment of lab skills the students practical, problem solving and report writing skills were assessed by an end of year laboratory-based exam which incorporated both technical and communication components.
During pedagogical evaluation students commented that their understanding of the course content improved over the study; citing that the formative feedback, both on-line and face-to-face, and assessment strategy redesign proved critical for their engagement and motivation. The role of one-to-one and one-to-group feedback was also noted as crucial to student learning and subsequent development of key skills such as scientific report writing. However, formal and informal module evaluation has highlighted areas which require improvement, and many of the students' suggestions will be used to progress this module in the future.

2 METHODOLOGICAL OVERVIEW.

The student group were selected based on their participation in suitable modules lectured at Dublin Institute of Technology, School of Food Science and Environmental Health; Laboratory Techniques and Computer Applications, DIT Module Code: TFCH1007 and Foundation Organic Chemistry, DIT Module Code: TFCH1003. These modules aim to provide the student with the basic skills required to function safely and efficiently in a laboratory environment, with an emphasis on organic chemistry. These were suitable modules as there are no pre-requisites; all students are assumed to have little or no experience in a laboratory environment or in correct scholarly, scientific reporting. The duration of each weekly lab session was two hours, and student numbers ranged from twenty-six to thirty-two students per session. The lecturer, demonstrator and lab technician were present for all sessions. Each lab was designed to be relevant to student, link to common techniques carried out in science and to align with the corresponding lecture content.

3.1.1 Preparation of on-line multiple choice quizzes.

The on-line quizzes, and associated feedback, were prepared and run through the institutes' virtual learning environment, *Webcourses*. MCQs were designed in-line with best practice [6]. The multiple choice quizzes were run as ten short, four-option questions. Each quiz was open book, single attempt only and one hour in duration. Formative feedback and the assessment grade were instantly provided upon completion of the quiz. The feedback included highlighting both the correct answer, the response chosen by the student and suggested reasons as to why the student may have chosen the wrong answer. The students had a one week window to complete each quiz before the associated lab session.

3.1.2 Preparation of in-house instructional videos.

Instructional videos were prepared in-house with the support of the Telematic Facility, DIT. Recording took place in the undergraduate teaching labs, utilising the same apparatus and instrumentation to aid familiarisation. Editing and voice-over recording took place at the Telematic Facility, DIT. The instructional videos, typically five to seven minutes in length, were hosted by HEAnet (www.heanet.ie). The students streamed the videos through the institutes' virtual learning environment.

3.1.3 Provision of one-to-one and one-to-group feedback.

Initial one-to-one feedback sessions took place at the student's lab bench to help the student feel more relaxed. Subsequent one-to-group feedback sessions took place at the top bench of the laboratory to allow all members of the group interact and participate in the discussion forum. Feedback was always constructive and the academic facilitated discussion forum varied between the '*Sandwich Approach*' for basic feedback and the '*Socratic Approach*' for a more in-depth critique [7].

3.1.4 Pedagogical evaluation.

Pedagogical evaluation took the form of an anonymous multiple choice questionnaire (n=100), an independent academic facilitated discussion forum (n=15) and an anonymous evaluation sheet (n=60).

4 RESULTS

Table One: Summary of the results from anonymous multiple choice questionnaire. The questionnaire was divided into five distinct categories and was answered by one hundred participants. Participant responses were anonymously collected by use of personal voting devices.

Section	Question	% Agree	% Disagree
MCQ	I felt the on-line pre-lab quizzes were user friendly.	94	6
	I had enough time to comfortably complete all questions.	91	9
	I felt the better prepared for the lab after completing MCQ.	77	23
	I felt the feedback at the end of each quiz was helpful.	91	9
	Feedback improved my understanding even if I got the answer wrong.	90	10
Preparation	I felt the labs were clearly explained in the lab manual.	89	11
	I felt the examples helped me to understand the calculations.	74	27
	I prefer to prepare for the laboratory by reading the manual.	53	47
	I felt the lab videos helped me to prepare for the laboratory.	76	24
Lab Work	I feel more familiar with the lab equipment and techniques.	96	4
	I feel more confident recording data during an experiment.	92	8
	I feel more confident carrying out calculations with my data.	65	35
	I can see the relevance of the techniques covered in this module.	91	9
	I felt the topics linked to the content covered in lectures.	83	17
	I felt that working in groups got easier as the semester progressed.	71	29
	I preferred to work in groups in the lab.	53	47
Reports	I feel that fewer reports allowed me to focus on my writing.	92	8
	I preferred to work in groups to write the lab report.	53	47
	It was helpful to have other group members to call on during lab/report	86	14
	The division of lecturer and peer allocated marks was fair.	66	34
	My lab reports improved over the semester.	82	18
	I feel that I could now produce a good quality scientific report.	79	21
Feedback	The feedback was timely, constructive and helped me.	96	4
	I took on board the feedback and tried to apply it.	96	4
	The feedback helped me in writing reports for other modules.	84	16
	I was more engaged and motivated by the alternative assessment strategy of reduced number of reports combined with pre-lab MCQs and end of semester lab skills exam.	81	19

5 DISCUSSION

5.1 Overview

The reasons behind the module re-design are several-fold; however the common theme is to improve the learning student experience. This is evidenced through better organisation (e.g. constructed scaffolding of the content), improved assessment feedback (e.g. formative feedback on MCQs and lab reports), aligned content (e.g. linking lecture content to the subsequent lab session and on to associated assessments), blended learning (e.g. use of virtual learning environment based MCQs) and use of engaging technologies (e.g. content delivery through multiple types of media). The literature supports these ideas.

Angeli & Valanides [8] noted that there are five different types of scaffolding science education. Including; (a) scaffolding conceptual understanding in science, (b) scaffolding general critical thinking skills, (c) scaffolding science-specific processes, (d) scaffolding general habits of mind in science, and (e) scaffolding the application of criteria or standards in science. The aim of the reworked module was to incorporate these concepts into the constructed scaffold, thus allowing the students to see and make connections between individual components of both the lecture course and also the associated laboratory. One of the key aims of this re-organised approach is to activate the students prior knowledge by linking new (previously unencountered knowledge) to the old, prior knowledge, which could be easily achieved by suitably scaffolded content [9].

Higgins and co-workers [10] noted the positive impact correct assessment feedback had on students in higher education. They described how feedback was essential to encourage '*deep*' learning within a student cohort. However; the quality, quantity and language of the comments were all deciding factors when it came to student feedback usage. It was noted that the modern student in higher education is highly motivated and will actively seek feedback as a means to improve their understanding of the content and help them to engage with their subject in a '*deep*' way. Wood [11] describes eloquently the symbiotic relationship that should evolve from timely and correct feedback: '*the teacher/tester and student collaborate actively to produce a best performance*'. Ultimately, this is another outcome of the re-worked module.

Ramsden [12] noted "*from* [the] *students' point of view, assessment always defines the actual curriculum*", and in many ways this is true. However, with correct alignment of the curriculum to the assessment, and not the other way around, the student will be encouraged not to solely see the assessment as the outcome of the module. An important aim of assessment is to "*engage students in intellectually challenging tasks that are realistic and relevant in the context of a discipline*" [13] and as such both the experiments (e.g. production of biodiesel) and the assessment strategy (scientific report writing, both individual and group) were relevant to everyday life as a scientist. Development of these technical and transferable skills and subsequent aligned assessment uncovers the students true understanding of the module and achievement of the learning outcomes. Assessments must be designed to align to the learning outcomes and not just a memory game for students [14].

Students are becoming ever more aware and comfortable with technology [15]. It is part of their everyday life, and as such, integration of technology into the laboratory is a *'fait accompli'.* Students demand the most interesting and up-to-date technology as part of their learning [16]. Research has proven that an engaged student will absorb and understand more, with blended learning (in which technology is seamlessly integrated into the laboratory) a key method of student engagement [17].

5.1.1 Laboratory Preparation; Lab Manual, MCQs and Instructional Videos.

The main purpose of the on-line multiple choice quizzes was to prepare the students for the up coming laboratory session. Content of the quizzes included safety issues, lab theory, lab technique and simple calculations. The students participated fully with the on-line quizzes (100% completed at least 8 out of the 10 quizzes; students were not required to participate in quizzes which they were absent from the lab due to personal reasons, e.g. sick, medical appointments etc.). The vast majority of the students, 94% and 91% respectively, felt the quizzes were user friendly and gave them enough time to complete. Seventy-seven percent of those surveyed felt better prepared for the upcoming laboratory after completing the quiz; however almost twenty-three percent felt that they were not better prepared for the lab after completing the quiz. Those that felt better prepared for the lab noted that they felt more familiarised with the lab (equipment, concepts, aims etc) after competing the MCQ and this helped remove anxiety from coming into the lab, one student commented "*The MCQ informs you of what's going on in the lab, that's the main goal*", during the evaluation forum.

Student opinion from the evaluation forum gave further insight into the possible reason behind why almost one quarter of students, after engaging with the lab manual and quiz, did not feel better prepared for the lab. The main problem evidenced was scientific calculations; the general student consensus being "*we feel like we were thrown in at the deep end*". The sample calculations available to the students in the lab manual were not sufficient for the students and some student suggestions included: *"Allocate more time when there are calculations involved"* and *"Do* [the MCQ] *before the lab, then do it after the lab to see can you improve* [your score]*"* or *"Do an MCQ before the lab with no calculations, then do one after with calculations"*. However the students did see the benefit of the calculations as part of the MCQ, but their timing would be better following the laboratory, stating "*I do think that the calculations are good, because once you do them in class it would give you time to recap on them to understand them when you are on your own doing them*". Indeed, after the lab the students understood the calculations: "*I did badly in that MCQ, but I understand* [the calculations] *now*".

Students felt motivated to complete the up coming lab after completing the quiz and it encouraged the students to read the manual before going into the lab:: "*Sometimes when you read it* [the lab manual]*, its just words on a page, but when it's in a question you have to think about it*". Indeed, if there was no MCQ associated with the lab manual the students "*would have just skimmed over the lab manual*" as with other lab based modules. Students noted that the alternative assessment strategy was a viable substitute for the traditional one report per lab module currently pursued within in many other lab based modules: "*For every other lab we would have to do a report, this [the MCQ] was an easier way...it only took an hour, but you were still preparing yourself for the lab*". Additionally, Students commented: "*This* [assessment strategy] *gave you a break, where you could actually enjoy the lab, because you have done the MCQ, you've done the work...when you had to do a report, you could spend longer on it*". One student noted that "*its sounds like we are lazy, but its actually not!*" and that fewer reports would mean that "*the lecturers would have more time to go through* [the lab report] *with you*". Following on this feedback theme, ninety percent of those polled stated that the feedback was helpful even if they got the question wrong. This aligns with the work of Butler & Roediger [18] who noted the importance of MCQ feedback, both immediate and delayed; citing the positive effect feedback has for information retention and misunderstanding correction. Furthermore, in this study students could download their individual feedback for analysis and discussion promoting deeper understanding and improved retention [18].

Students engaged more with the in-house produced laboratory videos than with the lab manual as a method of preparation for the upcoming lab session (76% compared to 53%). Incorporation of instructional videos and virtual learning environments as pre-laboratory exercises has the potential to standardize techniques and to promote successful experimental outcomes [19]. Virtual labs are also a cost-effective method to allow students to become familiar with key techniques in a time efficient manner [20]. However, VLE based laboratories should not replace face-to-face laboratories. Interactivity and feedback are crucial influences in the laboratory learning experience, and as such, VLEs can act as a superb learning resource but should not replace the traditional "*wet bench*" laboratory [21].

5.1.2 Module Content and Skills Development.

The student responses (***Table* one**) were very clear that the content of the module, and the skills they learnt, were appropriate to their course. For example, 91% of those surveyed could see the relevance of the techniques they learnt in this module to other modules in their course. Furthermore, 96% and 92% respectively felt more confident in the application of the skills learnt and collection data during a typical lab. Here the critical technical skills are highlighted (e.g. instrument calibration and usage), in conjunction with transferable skills such as data recording and observation. However students note the difficulties in calculation and analysis of laboratory data as continued problem area. Only sixty-five percent of students felt more confident in carrying out calculations on collected laboratory data after completing the redesigned module. This is in direct comparison to the confidence levels of students (96% and 91%) using the instrumentation and collecting the data in a typical lab. It appears the students are confident in using the instruments and collecting data, but struggle with the analysis of this data and subsequent higher order thinking skill of evaluation. The basis of this problem may be other areas of the students learning, typically the areas of maths and logic. In the discussion forum a student noted: “*I struggle with maths...so when you are given calculations....and you haven’t studied them before I found that very difficult*”. Basic mathematical skills and previous exposure to scientific courses are documented as some of the main reasons why students struggle with calculations in science courses [22], and in particular more challenging problem based learning style laboratories [23]. Although worked examples of the calculations encountered in the laboratory are cited in the students’ lab manual; it again appears that this is the problem area for students. Eighty-nine percent of those surveyed noted that the lab manual clearly explained the lab; however, the satisfaction rating for the helpfulness of the example calculations in the lab manual was only seventy-four percent. Again, it is clear that the technicality of the lab technique (and instrumentation) is not a problem for the student cohort; the manipulation of the data and subsequent analysis is. An alternative ‘*calculations-only*’ tutorial class may address these issues, as would alignment of the current maths syllabus to the laboratory curriculum. In this way the students could see how the data generated in the lab could be incorporated into the lecture hall (e.g. during explanation of statistical terms such as averages, medians, standard deviations etc.).

The current aligned nature of the module (lectures aligned to labs and subsequently the real world connection) was observed by eighty three percent of the students. Students commented that “*the lab work helped me to understand the lectures and visa versa*” and “*I could see the application of some of the labs in the real world*”. Students worked individually for one semester and in small groups (four or less) for the second semester. The students are comfortable working in either environment (fifty-three percent satisfied to work in groups, compared to forty-seven percent preferring individual work), although initially group work was resisted by the students; “*we did not know what to do, we had never worked in groups this size before...we were out of our comfort zone*”. However, over the course of the semester the students settled into group work (seventy one percent felt the lab work in groups became easier with time). The anonymous evaluation highlighted the division of the lab work as a potential problem, one student noted: “*I was bored sometimes because my part of the experiment was not interesting or challenging”*. The fair division of lab duties is crucial for engaging and motivating all members of the group. Students appreciated the importance of group work, noting that “*we will be working in groups after college, so it’s important we learn how to deal with it now*”. Learning is enhanced through socially supported interactions such as group work which align to the environments in which most practicing scientists work. The provision of a safe environment in which students can develop the skills of discussion and peer observation can be very beneficial to the overall learning experience for all involved [24].

5.1.3 Report Writing.

It is common for undergraduates, particularly first year students, to remark that they do not receive appropriate instruction on how to write an effective scientific laboratory report [1]. This is compounded by the insufficient, or inappropriate, feedback offered to students permitting improvement in their next submission. Typically each lab completed requires a report; this weekly report submission places an emphasis on submission at any cost, consequently a trend of quantity rather than quality is observed. In this module redesign the number of reports was reduced from twelve to four per semester. With fewerreports, short weekly MCQs could be incorporated (see section 4.1.1) and also an end of year laboratory skills exam. Overall the module scores improved modestly (5% for semester one and 9% for semester two) compared to the previous year before module redesign. This compares well with Shibley and Zimmaro [25] who noted minimal grade difference when comparing individual versus group report scores during an identical introductory chemistry laboratory module. However, the benefits of group work include improved perception of the subject area and preparedness for future group work activities [25]. Although the students are comfortable writing reports in both individual and group environments (47% and 53% preference respectively), the benefit of peer involvement (86% perceived benefit of working with peers) almost matched the confidence of the student in producing a good quality scientific report (79%). This links to the discussion forum where students mentioned the lecturer facilitated feedback session as important as “*you could see what other group members had done well in the report*” and “*I learnt what I had to do to improve my section of report from discussing reports written by my groupmates*”.

5.1.4 Feedback.

Feedback was formally given to students on two major areas; the MCQ and scientific reports. Feedback for the MCQ took the form of personalised, on-line comments based on the student responses to the quiz questions. Invariably the students were encouraged within the online feedback and if the student selected the wrong answer, (s)he was given the correct answer and an explanation why their choice was incorrect. The vast majority of students (91% and 90%) felt that the on-line feedback was helpful, and improved their understanding even if they got the answer wrong. Student comments included: *"*[Feedback was] *really good, if you didn't get the question, it explained it...it didn't just say, 'incorrect'...it gave you a reason why you were incorrect*" and "*feedback was really helpful, it was the best part*"

Feedback for lab reports took the form of one-to-one discussions in semester one and one-to-group discussions in semester two. Almost all students (96%) felt that the feedback was beneficial, with 98% of students commenting that one-to-one or small groups were the best way to give feedback. One student commented: "*If I don't get any feedback I don't know if am doing it right or wrong!"* however, "*with feedback you know you are improving, you know you are going in the right direction*". The student further expanded on this point; "*no feedback is not going to help, just getting a mark means nothing*". It is clear that the students appreciate a higher level of reporting is required in third level, but they need guidance and help to achieve this standard. Indeed, the students that took part in the discussion forum were very motivated and were eager to improve their report writing skills, stating that one-to-one feedback was "*very helpful*, [the lecturer] *points out what I need to include in my report, what would improve my report*". Many students were motivated by the feedback and their perceived improvement in their report writing skill: "*you see your marks rise every week...your aiming for 10/10 in your last one* [report]". The students did not find the discussions intimidating, but instead very beneficial as the module drew to an end: *"I thought the last report was the easiest one* [to write]*, you had all your previous reports, all your previous mistakes; I found it the easiest but it was supposed to be the longest! Because you knew what you were doing because of the feedback*."

In semester two lab report feedback took a one-to-group constructivist feedback approach (Askew & Lodge, 2000). In this arrangement the group (typically 4 students) report was initially graded and then discussed, both by the group and also the lecturer, linking previous feedback sessions to the current report and, ultimately, towards future submissions. The group leader was given a copy of the written feedback discussed and (s)he disseminated this to the group after class. This timely formative feedback concept chimes with Epstein and co-workers [26] idea of '*Immediate Feedback Assessment Technique'* (IFAT). Here, the student can use the formative feedback to improve their understanding of the topic and thus improve their next report submission or end of module exam. Ninety-six percent of students noted that they tried to implement the feedback points in subsequent reports and consequently eighty-two percent of students noted that their scores improved over the course of the year. Furthermore, the majority (84%) of students noted that their reports improved in other lab based modules also and eighty-one percent of students felt more engaged by the alternative assessment strategy and module redesign.

6 CONCLUSION

Ultimately the student learning experience was improved by the adaption of the module and the subsequent redesign of the assessment strategy. Students were more engaged and enthusiastic about the subject throughout the clear, concise and well structured module. The learning outcomes were unambiguous and directly aligned to the assessments. The major objectives of preparation and communication were broadly achieved. Based on student evaluation, and overall module scores, the key concepts of lab preparedness, technical skill development and scientific report writing were improved. The role of feedback was noted as crucial to student learning and development. However, within these modules there exists a number of areas for improvement, most notably laboratory-based calculations. Student suggestions, collected during formal and informal module feedback, will be used to improve this topic in the future.

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