1. Cover page

Title : **Formative Assessment: improving students' experience in the teaching labs**

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2. Abstract or summary

Abstract

Formative assessment is recognised as one of the most effective ways to help and promote students' learning. Students consider laboratory learning to be challenging, though sometimes it is not appreciated and not recognised as a valuable source of learning new skills and theory in the physical sciences. In our Advanced Organic Laboratory students were marked at the end of the course and the only feedback they received was summative. In pursuit of high marks students often did not enjoy the labs and although they worked hard they struggled to obtain good scores. In our study a formative experiment was introduced to the Advanced Organic Laboratory followed by formative feedback. We monitored the study through focus groups and surveys over three years. The students welcomed formative practical and feedback because it enhanced their knowledge and laboratory skills and helped them to enjoy their practical work in the chemistry lab.

3. Main Body

Introduction

The value of formative assessment

Formative assessment is one of the most constructive and useful ways to teach students (Nichol and Macfarlane-Dick, 2004; Yorke, 2003; Irons, 2007). There is a broad consensus on the effectiveness of formative feedback. Juwah et al. (2004) wrote that "even when corrective guidance about how to improve is given, students often do not fully understand it or know how to turn it into action". Students could potentially be more focused on marks and as a result could ignore qualitative feedback that is more constructive and beneficial for their future development (Gedye 2010).

If formative feedback is to be effective it should help students to become more efficient with their assignment and show them how to improve their work and affect their future performance (Nicol and Macfarlane-Dick 2004, Laight et al. 2010). It should be given shortly after submission of their work and be relevant to it (Bruner 1970). There also should be an understanding between students and their tutors. Students ought to see the purpose of the course and understand the feedback they are receiving in order to engage with it (Wenger 2008). They have to realise that formative feedback is used to help them improve their work and knowledge not to criticise them. When there is trust between students and tutors, students are more confident and happier to value and apply the formative feedback that is given to them (Laight et al. 2010).

The value of laboratory work

Laboratory work has been recognised as an essential and fundamental part of chemistry education. Through laboratory classes students can develop a broad range of skills that can be used in different disciplines not only in Chemistry, for example, organisational, communicative, investigative, critical thinking, problem solving, analysis and synthesis. They develop their understanding of the nature of science and their attitudes such as curiosity, interest, risk taking, objectivity, precision, confidence, responsibility, consensus, collaboration and appreciating the value of science, and many others (Travers 1973).

Practical training also aims to develop students' skills necessary for more advanced study and research. This is why the laboratory should be a place that stimulates students and teaches them how to analyse and reflect on the problems they encounter and a place where they can apply taught theories and test them. During their learning process students need guidance to understand and interpret their results. This is why demonstrators and tutors' feedback is so important.

Data Collection

Students' feedback was collected through online surveys and in the focus groups. During focus groups, students were asked open-ended questions about their work and experience in their lab. They were also encouraged to comment and provide feedback on how to improve their learning experience in the lab. We used a mixture of questions on the online survey including free-text questions analysed using Thomas (2006)

approach and also some tick box questions using Likert (1932) and Osgood et al. (1957) formats.

A total of 121 chemistry students completed the survey: 40 in the first year of data collection, 36 in the second and 45 in the third year. There were 181 students in total participating in the focus groups: 50 in the first year, 60 in the second and 71 in the third year of data collection.

Previous system

The previous system was in place for two consecutive years. Students had to complete four experiments and collect all the necessary data for their final products (melting and boiling points, Nuclear Magnetic Resonance (NMR), Infrared spectroscopy (IR) and Mass spectra (MS)). At the end of the course they had to submit their write-up following the Royal Society of Chemistry (RSC) journal format. The results and written feedback were returned to them within four weeks after submitting their scripts. Guidelines about experiments and presentation of their results were provided in the lab manual. Students were encouraged and prompted to ask questions about their lab work and results during the lab classes.

After the return of scripts including feedback only 26 % of students collected and checked the written comments. Over 80 % of students did not look at their returned scripts again. The majority of students were satisfied with confirming their marks on the online system. Amongst the 26 % that analysed their scripts and read the provided feedback the largest number included students unhappy with their mark who wanted to find out why their mark was lower than they estimated.

Although written instructions for the experiments and final write-up were provided students found them difficult to understand and follow. Students' feedback was used to rewrite the instructions but there was still large number of students who did not make the most of the instructions. Also the understanding of the experiments was not satisfactory. Students had a tendency just to follow the written instructions instead of trying to understand the underlying chemistry in their experiments.

Students viewed this system as a closed module and rarely realised that the material taught during the lab classes may and should be used as a base for their future learning. Those who checked their scripts did not understand the marking system and were frustrated with their performance.

The discussions with students about their work and results during the lab classes were difficult for staff (Senior Demonstrators). Senior Demonstrators were busy overlooking the experiments and the safety in the lab and found it challenging to spend enough time with each student to provide feedback about their lab performance and data they were collecting

New system

In the new system we have introduced, students are required to do a formative experiment, collect the data and present it in the compulsory format before they proceed to the longer summative project. They receive verbal and written formative feedback on their formative experiment within a week after submission of their write-ups. Written

feedback for the summative experiment is provided after four weeks from submission of their scripts.

The formative experiment is a two step reaction. Students have to use a product from the first step to proceed to the second. They need to characterise the products using melting and boiling pints, NMR, IR, and MS spectroscopy. All the collected data has to be presented in RSC journal format. Students are given formative feedback on their experiment and write-ups in one-to-one interviews with a demonstrator. Interviews are arranged during the lab classes.

Results

In the first year of introducing the formative experiment and feedback, 35 % of students used the given feedback and later applied it successfully for their summative assessment. The low figure was the result of insufficient understanding of the applications and benefits of the formative feedback and their failing to employ it in the consequent summative assessment.

During the focus groups students suggested that they would like to hear more information on how the formative feedback works and how it can help them with their future assignments. In year two the benefits of formative feedback were explained during the introductory lecture and later during the lab briefings that are held on the first day of the lab session before the students start their experiments. It was emphasised that the formative experiment and feedback should be used to support their understanding of chemistry and help them improve their lab, presentation and written skills. That year the awareness improved and over 58 % students understood how to use it and what is it for.

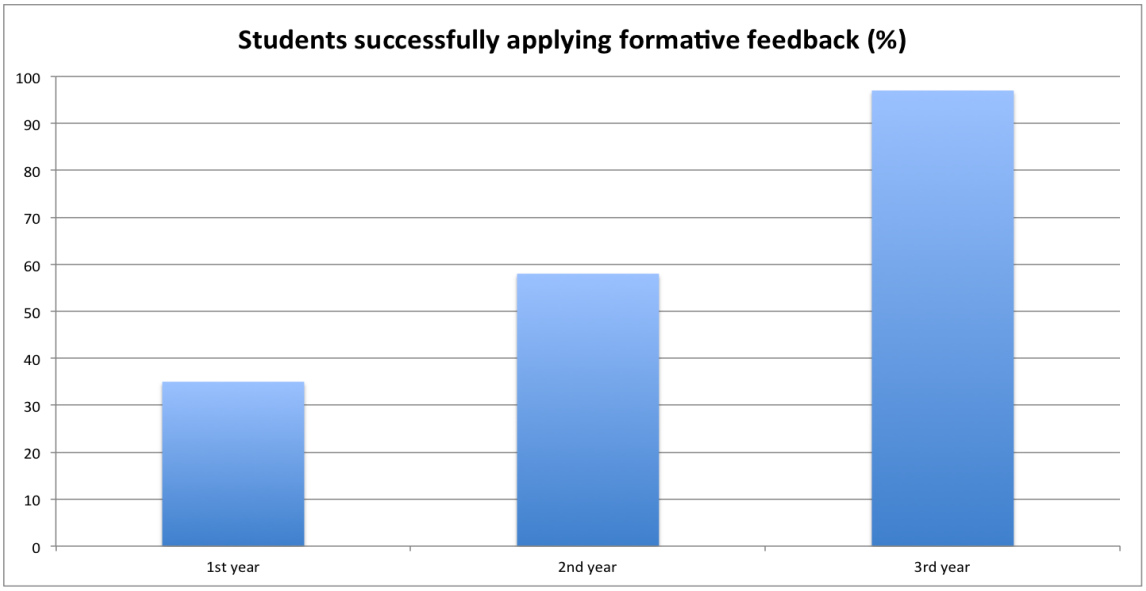

Figure 1 Graph comparing number of students successfully applying formative feedback over the three year period

The following is a selection of quotes from students that we received about the formative assessment:

It was good to have formative feedback. It helped me to understand what I was doing. Organic Chemistry wasn't a black magic anymore.

I really enjoyed having formative feedback. It is good to have your own time with the demonstrator when you can ask all these questions and get advice without worrying that you will be marked down.

Formative experiment works for me. It helps me to warm up and find out what is expected from me. And having feedback was great. It was so easy to do the final write-up later.

I wasn't sure about the formative experiment at the beginning. It took me time that I would rather spend on the project. But now I can see the point. It prepared me for my project. For the first time I actually understood what I was doing in the lab. I liked the discussion with the demonstrator too. My results were not very good and she helped me to see what I was doing wrong and how to improve them in the summative project.

However there was still a significant number who made mistakes and did not use the given feedback effectively. In year three two students who did the labs the previous year were invited to the introductory lecture to explain the uses of formative feedback and to motivate their junior colleagues.

That year all the students followed the required format for the written work and very few (3 %) lost marks on presentation of their experimental data. The understanding of their experiment also improved. Students were more focused and interested in the experiments they were performing. They were eager to discuss with the demonstrators the potential mistakes and difficulties that they could encounter during the process of synthesis. They were also more careful with their work and that helped them avoid or minimise the potential mistakes.

During the sessions where formative feedback was provided students were encouraged to read a number of scientific articles. Recommended papers were related to their experiments and selected to support and expand their practical and theoretical knowledge as well as to arouse their interest in experimental Chemistry. Discussions with students (general lab interactions, interviews, focus groups) confirmed that students not only read the proposed papers but also looked up additional related articles investigating and analysing their results. Teaching Assistants (Junior Demonstrators) were trained and requested to give formative feedback to students on a daily basis during the lab classes on their experimental achievements and understanding of the experiments.

Conclusions

Students were very supportive towards the formative experiment and feedback knowing that these can help them with the summative project.

Before the introduction of the formative assessment students rarely looked up the written feedback from their summative assessment. After introducing the formative experiment and feedback students' interest increased from 30 % in the first year to 83 % in the third year of introduction of the formative experiment. When asked question why they checked comments on their summative assessment all responded that they wanted to see what they did right and wrong compared with the formative assignment and see what affected their mark.

We found that the introduction of formative experiment and formative feedback helped students with their understanding of the lab experiments and improved their practical, written and verbal skills. They are more aware of the importance of purification and yield in their experiments. The collection of the data and its presentation also became clearer. The new structure of the lab made them realise that knowledge and understanding of the experiment and the Chemistry behind it helps them avoid mistakes and ruining the experiment. They are keener to look for more information on the experiments in the scientific journals. Those who understand the chemistry of their experiment are more confident and eager to discuss synthetic procedures and potential issues. They usually score higher marks in the summative projects that follow the formative experiment.

We also found that formative feedback is more effective if its objectives and benefits are explained clearly at the beginning of the course.

Furthermore it was discovered that students are more prone to accept and follow the advice received from their peer than from a member of academic staff and they are easier to be motivated by their colleagues than by academics

The Senior Demonstrators found the new changes constructive. The interview system helped them to get to know the students better and build trust between them and staff. When students feel more relaxed and their confidence improves it is easier for academic staff to find out about their progress in the lab and support them during their work.

5. References

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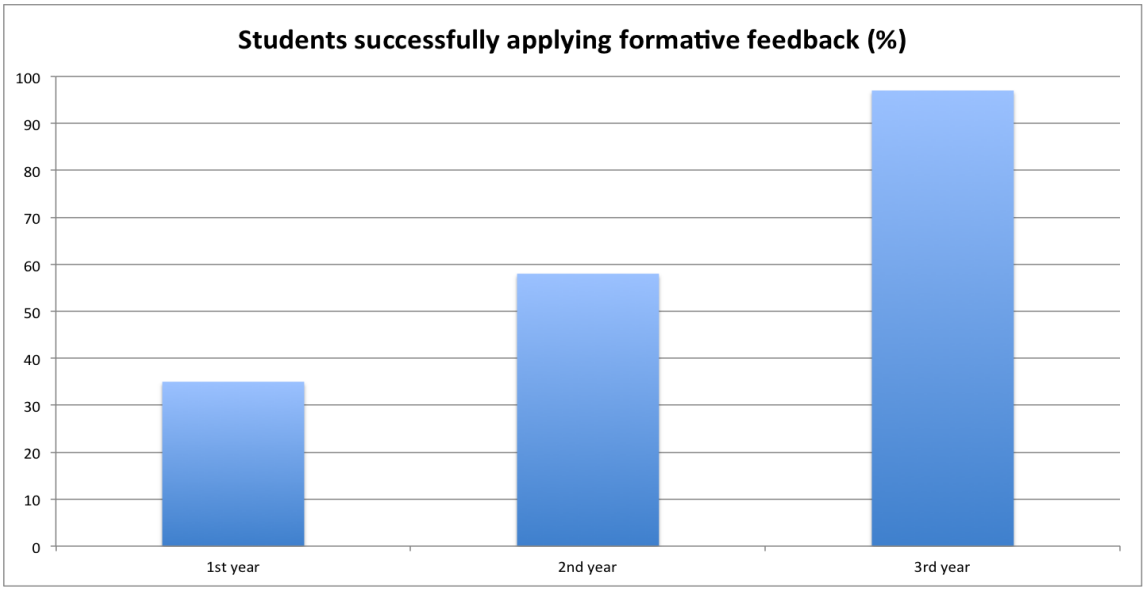
Figure



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