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Assessing Final-Year Practical Work Through Group Projects

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Abstract

The final year project is a valuable research experience for undergraduates and can be one of the most rewarding aspects of their degree course. With increasing student numbers it is becoming more difficult to supervise students effectively, as truly independent enquiry-based working requires significant supervision, time and resource. To address this, the Department of Chemistry at the University of Reading has recently explored the use of group projects for final year practical work. Students work in teams of 3 to 5 and are presented with a research problem to investigate. These are genuine problems where the answer is unknown and the work open-ended. The students must work together to investigate the problem, dividing the work and sharing results in a manner that more closely resembles project working outside of academia. The students' output is assessed through a variety of means including a group presentation and report. The projects were successful, with all students completing the work to a satisfactory level and developing strong team-working skills. This paper will outline

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some of the issues faced in the first year of delivery, and the steps taken to alleviate them.

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Background

Chemistry is a practical subject and a large element of an undergraduate chemistry course is the practical work. Such is the importance of practical work, the Royal Society of Chemistry (RSC) states that it is an essential component of a degree programme, and for accreditation a minimum number of practical hours must be included (RSC accreditation, 2014). A further element of an accredited degree is investigative work, which should contribute at least 25% of the final-year workload. This investigative work is usually accomplished by a laboratory-based research project. At the University of Reading, the timetabled allocation for laboratory work for the Chemistry BSc project is 2 days per week in the Autumn term, amounting to approximately 180 hours (40 credits).

Within our undergraduate chemistry programmes we have embedded an inquiry-based approach to laboratory work starting in Year 1 and culminating with the open-ended research project in the final year. There is an extensive body of literature on the value of inquiry-based learning in the laboratory, and an excellent review is given by Smith (2012). However, it has been shown that the practical work itself needs to be placed in context and should be carefully considered to allow students to see science that stimulates and challenges them (Reid & Shah, 2007). More recently Szalay and Tóth (2016) outlined some of the advantages and limitations of an inquiry-based approach to laboratory work, showing that many students benefit from it and recommending that it should be used more widely where possible. Much of the support for an inquiry-based approach to learning derives from the theory of constructivism which states that ‘learning occurs when the student utilizes higher order thinking skills by connecting new knowledge to prior knowledge’. (Bodner 1986; Fay 2007). The degree to which the standard chemistry laboratory exercise stimulates scientific inquiry and deep learning has been debated for many years and it is our belief that inquiry-driven deductive laboratory work not only deepens students' understanding, but also underpins the development of many transferable academic and professional skills.

Although enquiry-driven open-ended practical work is a valuable addition to a degree programme, managing the transition from a second year practical class, with a finite degree of student independence but in a semi-controlled environment, to truly independent enquiry-based working requires significant supervision, time and resource, especially in the climate of increasing student numbers. Our move towards open-ended group projects was driven by the desire to provide students with vital skills required for the workplace, where graduates are generally required to work efficiently and effectively as part of a team. Peer-assisted learning, or, more specifically, reciprocal peer learning, where students act as both teachers and learners (Allen & Boraks, 1978) has been shown to be an excellent teaching tool because it provides a safe, supportive learning environment, encourages students to express their thoughts and ideas, can be a valuable way to improve student achievement, and can contribute to life-long learning (Blumenfeld, Marx, Soloway & Krajcik, 1996; Tien, Roth & Kampmeier, 2002; Lyle & Robinson, 2003; Towns, Kreke & Fields, 2000). There have been studies into group work at UK higher education institutions that suggest students prefer group assignments to individual assignments and can achieve more by working in a group (Bentley & Warwick, 2013). Our intentions were to capitalize on this by providing students with the opportunity to experience an investigative group project wherein each team member could independently explore a different aspect of a larger problem and then combine the results to obtain more significant results.

However, although it is well documented that group work can be an effective way to engage students and can allow for more complex tasks, the final assessment of such work can be problematic (Gibbs, 2009). In addition it has been shown that using existing assessment practices can undermine the original goals of peer learning and actually leads to students rejecting working cooperatively (Boud, Cohen & Sampson, 1999). The nature of the assessment used was of particular importance in this case because the final year project contributes 40 credits (one third) to students' final year results. With this in mind, an assessment scheme was devised such that overall the assessment included a written report containing both individual and group contributions (50%), a team presentation (25%), and individual laboratory skills (laboratory notes book/journal, team-working practice) (25%). There was also an element of peer review, allowing students to assess each others' performance.

Group Projects

Prior to the start of term students were asked to select their two preferred areas for investigation (inorganic, organic, physical and analytical) and were divided into teams of between 3 to 5 students, according to their preferences. Students were not arranged according to academic ability, and where more than one type of group project was possible students were allowed to choose their own groups.

In the first year of operation students were tasked with undertaking two projects in the Autumn term, potentially in two different teams, with each project lasting five weeks. The first project was mainly a formative exercise and was in the students' second-choice of research area. The second project was in the students' first-choice of research area. The rationale behind this was that students would be able to undertake their first project without the pressure of assessment, and would be able to make mistakes that would not adversely affect their final grade. Following the first project students presented their work to both academic staff and their peers and received formative feedback. It was intended that this feedback would feed forward into the next project that students completed.

The projects themselves were in a broad array of areas, and a description of each was written such that they fitted into one of the traditional areas of chemistry (inorganic, organic, physical and analytical), although this was not always possible. Determining tasks that would be suitable for group projects was one of the hardest aspects of the whole exercise. Some preliminary work, made possible by a small University-funded grant, was carried out by two Year 4 students over the summer prior to the first iteration of group projects. The students investigated the viability of the different project ideas and prepared some starter guidance for students in each of the topics. Reports in the Journal of Chemical Education provided a rich source of ideas for potential group projects, and with a little thought, the published procedures were adapted for our use.

The projects selected were:

- Organic: determining the main components of lavender oil
- Organic: C-H activation/functionalisation using Co and Fe (Roane & Daigulis, 2016)
- Inorganic: Investigating various novel ligands and their position in the spectrochemical series (King, 1971).
- Physical: Design and construction of a UV spectrometer (Bougot-Robin, Paget, Atkins,& Edel, 2016)
- Analytical: Investigation into the Finkelstein reaction using ^{1}H NMR (Mobley, 2015)

Example of a project: designing and building a spectrometer

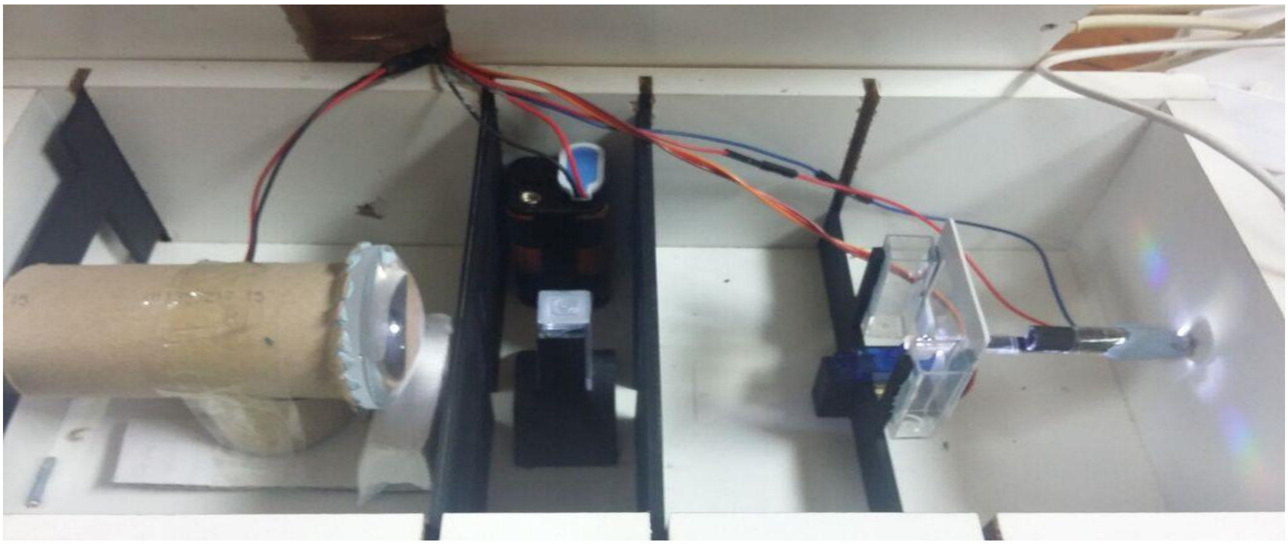
For the Physical Chemistry group project the students were set the general task of designing and building a spectrometer, powered by a low-cost Raspberry Pi computer. This broad and flexible remit gave them considerable scope to shape the project and the direction it took. They were provided with the Raspberry Pi computer (which had no relevant software installed), basic optical and electronic components (a light sensor, a white LED, an analog-digital convertor, diffraction grating, cuvette cells to hold samples, breadboards, jump lead connector cables), and a “Getting Started with Raspberry Pi” manual (Raspberry Pi, 2017; Richardson & Wallace, 2012). The member of staff running the project agreed to 3D print components from *.stl files provided by the students if required, but the students were encouraged to be imaginative in thinking of other building materials (cardboard, cloth, plastic bottles etc).

Students had to take responsibility for searching online or in the library for their own resources in order to be able to code in Python, run a Raspberry Pi, read voltages, and switch on an LED. They also had to find their own designs for their spectrometer, and suitable chemical systems with which to test it. For this they were encouraged to undertake literature searches within suggested journals, for example the Journal of Chemical Education, and were provided with a few key references to similar tasks such as the Lego Spectrometer (Raspberry Pi, 2017b; Wang, Rodríguez Núñez, Maxwell & Algar, 2016; Asheim, Kvittingen, Kvittingen & Verley, 2014; Martin, 1990)

The students were clearly motivated by the creative freedom and input the project allowed them. For example, the supervisor had originally envisaged a spectrometer operating at a fixed angle (wavelength), which could perhaps be varied manually, as in literature examples (Bougot-Robin, Paget, Atkins,& Edel, 2016; Albert, Todt & Davis, 2012). However, one group felt that it would be better to have an automated design, with the angle selected by moving a motor. They explained this to the supervisor who ordered a low-cost servo motor for the project, which the students learned to control with the Raspberry Pi and incorporated into their spectrometer. This aspect added a more exciting dynamic quality to the project because the supervisor needed to stay one step ahead of the students; in this case, researching in real time which motor technology is feasible in terms of cost and coding simplicity. The motor was ordered from Amazon, with next day delivery specified, to ensure that it minimized any delay in the students' project progress.

During the investigation, students were encouraged to break down the overall project plan into individual tasks with measurable outcomes. For example: “Student A will demonstrate that it is possible to programme the Raspberry Pi to read light sensor values via the analog-digital convertor; Student B will code the Raspberry Pi to move the motor to different requested input angles; Student C will find a suitable dye and concentration range that gives a linear absorbance at a certain wavelength using a commercial spectrometer”. Further tests then built up the complexity of the project, for example investigating the linear response of Student C's dye using Student A's light sensor at a fixed wavelength by manually setting the diffraction angle. The final spectrometer design is shown Figure 1.

Figure 1. UV spectrometer built in 2015/16.



Discussion

The first iteration of group projects (2015/16) provided us with a great deal of information about how to run such projects in subsequent years. Student evaluation of the projects was carried out by questionnaire at two points during the projects and these were triangulated by small discussion groups. Students attending the discussion groups were from a range of academic abilities, and were students who had fully engaged with the projects. For the most part the students we consulted enjoyed the practical aspect of the project but were less happy with the assessments used, primarily the group report (*vide infra*).

One outcome of the evaluations was that students would have preferred a single large project rather than two shorter ones. They felt that five weeks was the minimum amount of time they needed to acclimatize to the project as they were just beginning to understand the concepts and to contribute something useful. Students said that having to finish the first project and switch to another one at this time actually had a negative impact, and students felt they were regressing rather than progressing.

Students were also clear that a strong academic lead for each project was crucial because the academic provided a key role in the motivating the students, organizing the team and driving the work forward. Where there was less academic input, and the lead staff member had a more hands-off approach, a lack of student engagement was sometimes observed, which ultimately resulted in less project-work being achieved. The students concluded that weekly meetings with their academic supervisor were essential to ensure that all students contributed to the project, which was sometimes an issue. The students suggested that it would be beneficial for the team to set milestones (either weekly or half-termly, the exact frequency depended upon the project) because having meeting targets provided excellent external motivation. Staff noticed that it made a large difference to student engagement and motivation if students achieved a positive result in the first few weeks of the project, which was also taken into account in the second iteration of the projects.

Students stated that a lack of engagement among team members was a major issue, which was more pronounced when writing the group report. The report grading was split such that 60% of marks were for individual contributions and 40% was a group mark, therefore the cohesion of the team had a large impact on the individual students' final grade and, potentially, a student's overall degree classification. The group aspects were the abstract, introduction, discussion, conclusions/future work, references and figures/diagrams. The individual aspects were experimental/methodology, use of English and individual diagrams/figures. Both staff and students found that the assessment led to division among the groups because students worked to different timescales, had differing ideas of what was appropriate/acceptable for a report, and contributed varying amounts. In addition, if a student was granted an extension, or a student had to resubmit the report in Summer because they failed their examinations, the group report added an extra layer of complexity to the reassessment. From a staff perspective it was difficult to accurately assess students' individual contributions to the report, even though the mark scheme had designated individual aspects, and because of this the reports took a lot more time to mark than they had in previous years when students completed individual projects and wrote individual reports. Although students were asked to peer evaluate each other's contributions by completion of an online form, the issue of non-engagement was not fully addressed and we actually observed that students were reticent to give each other a poor peer assessment because they wanted to avoid confrontation. This made mediating any group disagreements difficult.

One possible reason for students' dissatisfaction with the group report is that they were uncomfortable about submitting a group assignment that that held such a high proportion of credit in the final year. Although our undergraduates regularly complete group-based presentations and have had experience of writing group-reports in earlier modules, when confronted with such a critical assessment they can become anxious, disorientated and suspicious of the fairness of the assessment system (Gibbs & Dunbar-Goddet, 2007). This may have contributed to some of the issues that we encountered and is difficult to address without creating more heavily-weighted group reports earlier in our undergraduate programme.

The report here is based on a single iteration of the group-project delivery and, as such, it is important that we respond to student feedback and evaluations, but it is not appropriate to lay too much weight on final marks as these naturally vary year-on-year. In the following year, students will be given one ten-week project rather than two five-week projects to address their comments about project length. To resolve problems posed by the group report it is proposed that individual reports will be required, which will be accompanied by a group abstract and a short group discussion describing the goals of the project and what students actually achieved. This will be worth a maximum of 5% of the overall marks to avoid difficulties encountered previously. We recognize that the findings presented here are purely qualitative and a larger more in-depth study will be undertaken, which will include formal student feedback questionnaires. Further results, observations and recommendations will be reported in due course.

Conclusion

In summary, despite the problems with the group report as the main assessment, our initial experience of using group projects as a means for carrying out practical work and collecting data for final year BSc students was successful, with students collecting enough data between them to write a meaningful report with conclusions. The students in the discussion groups reported that they enjoyed the freedom of the open-ended work and the larger pool of ideas provided by working collectively as part of a team.

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