Crime Scene Investigation In A Lab: A Problem Solving Approach To Undergraduate Chemistry Practicals*

Orla Fenelon†

Carmel Breslin†
‡

†Department of Chemistry, National University of Ireland Maynooth, Maynooth, Kildare, Ireland
‡

Abstract

With an ever demanding job market and industry complaints of grade inflation in the university sector, our graduates need more than just good grades to obtain successful employment. They need to be able to demonstrate a wide variety of skills such as problem solving, team work and the ability to work on their own initiative. This paper discusses a new type of chemistry practical that tries to incorporate all of these skills into an engaging undergraduate laboratory entitled "Mystery Death on a River".

Chemistry undergraduate labs at present often follow the cookbook recipe approach where students follow a distinct recipe with help from a demonstrator. While these types of laboratories provide the students with valuable skills, they inhibit the student's ability to understand or provide insight into what they are actually doing throughout the practical (Beussman 2007). This paper discusses the advantages of a 'Mystery Death' laboratory where the students work in groups to solve the mystery with little help from demonstrators. The students are presented with a scenario of a death and are asked to work together to design and carryout the experiments necessary for solving the mystery death. They are provided with glassware, chemicals and instruments to carry out the experiments and must finish the day's work with a presentation of their findings.

This study provides an interesting insight into group work, student's skills in the laboratory, problem solving and engaging students within a relaxed laboratory environment.

Keywords: Mystery, Undergraduate, Chemistry, Practical, Problem Solving, Instrument.

* Research Articles. URL: http://ojs.aishe.org/index.php/aishe-j/article/view/00071

1. Introduction

Practical laboratory chemistry plays a very important role in the teaching of undergraduate chemistry. The laboratory is a place where “organized opportunities can be provided for students to appreciate and practice a range of skills and techniques that someone graduating from a course would be expected to have acquired” Cannon and Newble, 2000. It is vital that we as teachers provide our students with these skills.

Traditionally, our chemistry students undertake practicals in a cookbook-style approach. This type of lab typically involves the student carrying out an experiment according to the directions in their laboratory manual. They are instructed by a demonstrator and/or lab co-ordinator and finish the lab with a set of results. The lab is assessed by means of a lab report that is written according to instructions in the laboratory manual.

So what exactly is the problem with these traditional labs? What we have noticed is that as the students progress through their undergraduate years, they have lost the ability to think for themselves. Their minds are trained to follow the 'recipe' in the book and they find it difficult to apply what they have learnt should they be presented with a problem outside of the traditional cookbook. In essence, the students lack problem-solving skills. The lack of problem-solving skills poses a problem when students are seeking employment. Potential employers need people who can act on their own initiative and be able to solve potential problems should they arise. Race, 2007 wrote that practical work in science is very important as very often employers will say that while “students have a good knowledge base, they lack practical skills”. This paper investigates whether a problem-solving mystery lab increases the students skill set in the engaging setting of a 'Mystery Death Scenario'. Reid and Shas, 2007 described their aims for work in the laboratory and it is very similar to our aspirations.

They wrote of making the experiment real for the students, giving the students an opportunity for hands on experience, developing skills of observation and interpretation, team working and presentation skills. It is hoped that the design of the Mystery Death lab will increase the students skill set through giving the students a chance to operate instruments that they have not spent much time on, allowing them to develop problem solving skills, providing them with an opportunity to apply their knowledge in a real life application and hopefully provide them with an enjoyable and educational experience.

1.1 Educational Background

The lab was designed for 2nd year chemistry students, all of whom had completed a series of physical/analytical chemistry lab practicals. Within these practicals, the students worked on numerous scientific instruments following a series of instructions as laid out in their laboratory manual. They also had assigned demonstrators to help them with their work. In these labs, the students were shown how to use scientific instruments such as an HPLC (High Performance Liquid Chromatography), UV-Visible Spectrometer, AA (Atomic Absorption) Spectrometer, Conductivity and pH meters. The instruments were used to demonstrate the theory behind these techniques and results were recorded and presented in their reports using graphs from Microsoft Excel. The 'mystery death lab' was therefore designed with the intention of reinforcing the knowledge the students already possessed but in a case study format with little help from the lab co-ordinators. The practicals from the physical chemistry labs were simply modified to fit into a mystery death scenario. This action ensured that the students had the knowledge to solve the mystery but gave them the opportunity to think for themselves and apply what they had learnt to a real-life scenario. This lab was carried out on a voluntary basis during study week and no marks were assigned to the students. The lab took place over one single day.

1.2 Background to Experiment

The experimental design was inspired from Beussmans (2007) 'Mysterious Death HPLC Lab Experiment' with the crime scene investigation aspect hoping to capture the students' interest. 14 students were presented with a hypothetical case study of a death which occurred on a river in a city. The male (50 years old, 6'2") was collecting water samples on the river on a particular day. Later that same day, he was found dead in the river. On discovery of his body, the police recovered the water samples he had already collected, which gave them a clue as to what section along the river the man had died in. It was initially thought that the man died accidentally from drowning, however with further examination it became clear that the man was actually killed by a drug overdose. After being presented with the scientific data, the students were expected to work together and try to discover which drug killed the man and where along the river he died. The students were told that the man was taking two types of medication, one containing potassium iodide and the other containing caffeine. The students were also presented with the chemical characteristics of the river, see Table 1, which was divided into Upstream, Middle and Downstream. At the start of the day, the students were handed samples from the river which they then analysed by whatever technique they deemed appropriate to work out the chemical characteristic of that sample. They then compared their results to the table of known compositions to decide which part of the river the man died in. They also analysed one of the samples for the presence of the two drugs.

Table 1: Known chemical characteristics of the river.

Measurement	Upstream	Middle Stream	Down Stream
Conductivity (mS cm^{-1}) @ 25ºC	7.7 – 9.5	6.0 – 7.7	6.0 – 7.7
pH Measurement	7.0 – 9.0	4.0 – 6.5	4.5 – 7.0
Iron Content (mg/100 g)	16 – 24	8 – 16	0 – 8
Ca^{2+} (ppm)	30 – 40	15 – 30	10 – 25

1.3 Objectives for the Student

The students were expected to split into two groups and assign the roles to people within the group. The roles consisted of Group Manager, Chemists, Software Specialists and Instrumentation Specialists. Once the roles were assigned, the group designed the experiments necessary to obtain scientific results to back up their final conclusions. They had to ensure that the laboratory experiments, the analysis of the data and the preparation of a presentation on MS PowerPoint could be carried out within the day.

On carrying out their objectives, the students had to follow a series of rules/guidelines as follows.

- Only the group manager can communicate with the lab co-ordinator throughout the process.
- The group must work together to solve the mystery.
- The students must design and gather all of the necessary glassware/chemicals they need from the lab.
- The 'Instrument Specialists" will be assisted by a technician/demonstrator with the running of the large instruments, e.g., High Performance Liquid Chromatography (HPLC) and Atomic Absorption (AA) Spectrometry. This assistance would only be technical, they would not receive information on the background of the instruments. They would need to know this themselves.

- Each group must only use any instrument once e.g.: if they decide to use the UV- Vis spectrometer to determine which drug killed the man, they must use a different instrument to work out the calcium concentration, etc.
- Each group must report a result for each of the measurements that characterises the river, i.e., just reporting the pH value alone will not suffice.

2. Procedure

2.1 Preparation of 'collected river water samples' to give to the students for analyses.

Prior to the start of the lab, the lab co-ordinator prepared the mystery samples for the students to use. These samples correspond to the samples the man collected prior to his death.

2.1.1 pH and conductivity analysis

The sample for pH and conductivity was prepared using deionised water and the pH and conductivity were adjusted using phosphoric acid. The resulting solution gave a pH of 5.41 and a conductivity of 7.35 mS @ 25 oC, indicating that the man either died in the middle or downstream of the river. It was hoped that the students would use a conductivity meter and a pH meter to analyse these solutions. A water bath was also provided.

2.1.2 Calcium analysis

Using calcium chloride (CaCl2) as a standard, a 20 ppm solution was prepared for calcium analysis. Once analysed, this solution would again indicate the man either died in the middle/downstream of the river. To obtain this result, the students need to use the Atomic Absorption (AA) Spectrometer. They are expected to prepare calcium standards using CaCl2 as their standard chemical, set up the instrument, obtain a calibration curve and analyse the pre-prepared 'mystery sample' to obtain the result of 20 ppm.

2.1.3 Iron Analysis

This sample was prepared using a vitamin tablet containing iron and complexing it with o-phenanthroline and hydroquinone resulting in a red/orange solution. Iron standards were prepared using ammonium iron sulphate and used to create a calibration curve. The solutions were analysed using UV-Vis Spectrometry. The final solution contained 11.5 mg/100 ml of iron. This indicated the man died in the middle of the stream.

The students were expected to make up iron calibration standards and use UV-Vis spectrometry to determine the concentration of the iron.

2.1.4 Drug Analysis

A sample of deionised water was spiked with a concentration of potassium iodide suggesting the man died of a potassium iodide overdose. It was hoped the students would use the High Performance Liquid Chromatography (HPLC) for the drug analysis. They were expected to prepare a mobile phase of methanol:water and set up the instrument to run known samples of caffeine and potassium iodide. Through comparison of the retention times, it would then be possible to determine which drug the man died from.

2.2 Division of groups and assigning of roles.

At the start of the lab, the students were presented with a hand out of the case study scenario. They were asked to split into two groups and assign themselves roles. The group manager was the overall leader of the group. It was up to this person to assign suitable roles to the members of the group. In addition, the group manager was the only person responsible for communicating progress to the lab co-ordinators. The chemists helped in the design of the experiments and carried out the necessary lab work.

They prepared all of the solutions and explained their dilution and calculations to the rest of the group. The chemists were also in charge of the health and safety issues, disposal of the necessary waste and had to ensure the lab was left clean. The instrumentation specialists ran the samples on the instruments. They had to show familiarity with the background of the instrument and be able to explain the techniques to other members of the group. They also helped with the initial design of the experiments. The instrument specialist was able to receive help from the lab co-ordinators with the running of the instrument.

The software specialist was responsible for the collection of the results and preparation of a presentation of their findings using MS PowerPoint. The 15 minute presentation included a summary of group dynamics, experimental design, reasons for using each instrument/technique, procedures, results, conclusions, possible errors and of course the solution to the mystery. The lab co-ordinators organised the mystery experiment, provided advice to the students, helped them with the technical side of the instruments and encouraged them to think about the problems and ask questions.

2.3 Design of experiments

The students were expected to design the experiments with little or no help from the lab co-ordinator. However, once they had decided on the experiments, the group manager checked the groups design with the lab co-ordinator indicating why they had chosen that technique. The students had access to their laboratory manual and other reading material but decided for themselves which technique was best suited to obtaining the necessary data.

2.4 Glassware and Chemicals

All of the lab glassware and chemicals were placed on a single bench in the lab. The students were also provided with pH meters, conductivity meters, reading material, lamps for the atomic absorption spectrometer and instruction manuals for the pH and conductivity meters.

2.5 Analysis of solutions

Once the students had their experiments designed, the lab co-ordinators assisted students in the use of the larger instruments as the students have minimal experience in using instruments such as the Atomic Absorption (AA) Spectrometer and the HPLC. They were also advised on health and safety matters and the disposal of chemicals.

2.6 Presentation of data

On completion of the laboratory work the students designed a PowerPoint presentation detailing their scientific approach, the techniques chosen and their final conclusions as to the nature of the drug and the section along the river where the man died. Two members of the team were nominated to present these findings. The group who solved the mystery and delivered the best overall presentation was awarded a small prize.

2.7 Feedback from Students and Co-ordinators

On completion of the lab, the students were given a questionnaire to complete for feedback on the experiment. In total we received 14 feedback questionnaires. As lab co-ordinators, we also made our own observations throughout the day.

3. Results And Discussion Of Feedback Questionnaire

3.1 Group Interaction and Division of Roles

From our observation, the students quickly divided themselves into 2 groups and had no problem in assigning roles to the members of their respective teams. All of the students confirmed this observation in the questionnaire.

Most students took on the role of the Chemist within the group and overall 8 students were Chemists, 2 were Instrumentation specialists, 2 were Leaders and 2 were Software Specialists. Observing the different groups, it was evident that students did mix roles to some degree throughout the day. This was to be expected as the group sizes were small (7 students in each). In order to complete the tasks, it was necessary to have a crossover of roles. Group interaction was very positive with 12 out of 14 students answering yes to 'Did everybody contribute equally to the work within the group?' Only 1 student answered 'No' to this and 1 had no answer. It was clear to see that work completed was very much a team effort. The fact that the students were not given any help with the design of the experiments encouraged this team attitude as they were left to 'fend for themselves' or sit blankly while the other team solved the mystery.

3.2 Problem solving

One of the aims of the day was to enhance the problem solving skills of the students and encourage them to apply the knowledge they had learnt and possessed. From the 14 students, 12 said they did understand what was expected of them on first reading the mystery death scenario. The other 2 students understood what was expected after re-reading it. Once the students understood what was expected of them, they needed to design the appropriate experiments to solve the mystery.

The students were questioned if they thought that it was difficult to come up with the experiments to approach the problems. Their answers can be seen in Table 2 below.

Table 2: Answers to the question 'Was it difficult to come up with the experiments to approach the problems?'

Student Answer	No of Student
No	6
No - but it took some thought	4
It wasn't difficult or easy - OK	1
Yes, it was difficult	3

From Table 2 it is evident that the difficulty level of the experiment is about right to encourage independent thinking for the students. This was further confirmed by the class of students when they were questioned if they thought the difficulty level of the 'Mystery Death' day was 'A little Hard', 'Too Easy' or 'Just Right'. 9 out of 14 students said the difficulty level was 'Just right', 3 students thought it was 'A Little Hard' and 2 students thought it was 'Easy'.

3.3 Positive and Negatives

There was a large range of answers for the positives for the experiments from enhancing problem solving skills, working in a group setting, having a sense of ownership of the experiment to learning new chemistry skills and 7 students said that they liked the fact they could 'apply their knowledge in a real-life situation' The most common negative was 'Time Constraints'. This indicates that perhaps the students would need longer time to complete the mystery or else we could have larger groups to complete the work. It was originally planned to have 2 groups of 10 but only 14 students turned up on the day. Only 3 students gave different negatives other than time constraints. These were 'More segregation of groups', 'More direction at start of experiment' and 'Presentation of results'. The 'presentation of results' comment was in relation to a power point presentation they were asked to prepare at the end of the day.

Another big positive was when students were asked if they enjoyed the experiment, 13 answered yes and 1 made no comment.

3.4 New Skills Learnt

One of the primary objectives of this lab was to increase the skills set of our students. The students were asked 'What new skills have you learnt today?' Student responses were categorised into skill categories seen in Table 2 below.

Table 3: New skills learnt by students.

Skill Categories	Number of Students
Team Skills	3
Thinking & Reasoning	4
Instruments/Computers	5
Calculations/Accuracy in preparing samples	5
Analysis and Interpretation	2
Problem Solving	3
No Answer	2

It is clear from Table 3 that the students learnt a variety of skills throughout the course of this lab. This is a very positive result as one of the main aims of the experiment was to increase the skill set of the students.

Instruments/Computer featured as one of the most frequent student responses. Students get limited exposure to scientific instruments as part of their main undergraduate labs due to large numbers in 2nd year and limited resources to provide more teaching equipment. This lab clearly provides the students with more experience in using these instruments and prepares them for working within a scientific laboratory. The other skill that featured high in Table 3 was Calculations/Accuracy in preparing samples. One of the observations that we, as lab co-ordinators, made on the day was that the students experienced difficulty with calculations and accuracy in preparing samples for lab work. Feedback from the students indicated that they found scientific calculations difficult and they would like more help with this during their coursework. This highlights the need for us, as educators, to think about how to improve the mathematical ability of the students throughout their course work.

3.5 Solution to the Mystery

Both groups accurately identified the location of the man's death and the drugs that were found in his body. If, when talking to the tutors, the groups suggested the use of incorrect equipment for their analysis, they were guided to re-think their choice of analysis. This ensured that groups would be able to complete the mystery in the allocated time.

4. Conclusions And Future Work

4.1 Learning Outcomes

It was clear from the questionnaire and the presentation that the students produced at the end of the day that they found the experience very enjoyable and they learnt a lot from it. The learning outcomes achieved in the days work are listed below.

- Opportunity to use scientific equipment
- Sense of ownership over designing experiments
- Enjoyed working as part of a group
- Achieved a greater knowledge of Chemistry
- Enhanced problem solving abilities
- Had an opportunity to apply knowledge to real life application
- Enjoyed the challenge of the mystery scenario.

4.2 Enjoyment of experience

When asked if they prefer this type of lab to the ones they have already completed this year, 13 of the students answered yes with 1 student giving no answer. They also thought that it should be included into the main curriculum but time constraints would need to be considered. As lab co-ordinators, it was a very enjoyable and rewarding day of teaching. The students seemed more relaxed and it was very easy to interact with them.

4.3 Possibility of integrating this lab into future experiments

It is important however to remember that this work was done on a voluntary basis with no assessment. It is hoped to run this lab again in the next academic year with a similar number of students again on a voluntary basis. It would be very beneficial to the students to introduce this lab into the main curriculum and to have it assessed as part of their module mark, however, this is not possible at the moment due limited amounts of instrumentation and large students numbers. It may be possible to simplify the experiment so more groups of students could take part. Perhaps we could change the data so they wouldn't need to use all of the instruments to solve the mystery. It is something that will be considered for future years.

5. References

Beussman, Douglas. J (2007). "The Mysterious Death: An HPLC Lab Experiment," Journal of Chemical Education, 84(11) 1809-1812.

Newble, D. and Cannon, R. (1989). Teaching practical and laboratory classes. Chapter 4 (p 57-69) in A Handbook for Teachers in Universities and Colleges: A Guide to Improving Teaching Methods.

Race, P. and Brown, S. (2004). 500 Tips for Tutors (2nd edition). London, Routledge Falmer.

Reid, N. and Shah I (2007). "The role of laboratory work in university chemistry," Chemistry Education Research and Practice, 8 (2), 172 -185.