Students' Attitudes & Motivation during A-level Chemistry Practical Work (exploring and addressing the needs to enhance the students' laboratory experience)

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Abstract

This study investigates students' attitudes and motivation during their practical work which forms an integral part of their A-level chemistry curriculum. It analyses the factors which determine the student's engagement in learning chemistry through laboratory activities and explores students' expectations to enhance their laboratory experience at this level of education.

The research involved the design and administration of an anonymous survey to a cohort of students studying A-level chemistry in 6 different Maltese post-secondary educational institutions. The respondents represented a good cross-section of students currently preparing for the A-level chemistry exam in Malta and Gozo.

Analysis of the survey confirmed evidence from literature sources suggesting that students in general found their laboratory experience as strongly motivating. Students' attitudes were found to be positively influenced by factors such as teacher support, well-equipped laboratories and the chance to work more regularly and independently in the laboratory. On the other hand, students expressed concern on having to deal with repetitive tasks, a vast syllabus, examination-related pressures and an unfair method of assessment. They suggested that the laboratory programme needs to be revamped to address their concerns by consolidating the link between theory and practice, allowing more space for teacher-student interaction and student collaboration, and revising the assessment criteria for the practical exam.

Findings of this study confirm that Maltese sixth form students share similar attitudes and motivations to their counterparts in other parts of the world.

Educators and other stakeholders are therefore urged to heed students' voices and considerations prior to deciding about any changes in policy-making and curriculum development aimed at enhancing the student's learning experience in the subject.

Keywords: *A-level Chemistry, Chemistry Laboratory, Chemistry Practical Work, Student Laboratory Experience.*

Introduction

Maltese students studying chemistry at an advanced level usually prepare for the local MATSEC examination, although they may opt to sit for an equivalent A-level exam set by foreign boards. The local A-level chemistry exam has 3 components, 2 written papers covering the bulk of the theory and an open-book practical paper which tests a number of students' skills and knowledge in a laboratory setting. The practical exam carries a weighting of 20% of the final score and although not being considered as failing, it plays a determining factor in the overall performance and ultimate grade attained by the candidate.

My rather long first-hand experience of working in a teaching chemistry laboratory shows that students manifest mixed feelings and are somewhat critical about their participation in chemistry practical sessions. Their attitudes and motivation may not always be conducive to exploiting in full the different learning opportunities that a laboratory provides to chemistry students at post-16.

Brief Literature Review

Research suggests that students' perceptions and behaviours in the school laboratory depend on a number of factors including teachers' expectations, methods of assessment and resources available (Hoftein et al., 2005).

Separate studies carried out with Canadian and Australian students found that half of them perceived it as a way of 'doing science' while the other half considered it as mostly focussed on 'learning science'. The studies found a number of students who were primarily concerned with completing tasks, getting correct results and completing the report, rather than thinking about the purpose of the laboratory activity itself (Hodson, 2005).

Another study in Israel found that an inquiry-type laboratory experience which was more 'student-oriented' than other traditional settings, proved to be highly stimulating for participating students. The reasons given by students involved in this study included the opportunity provided to develop scientific skills and be in control of their own learning, standing a better chance to learn through mistakes, sharing ideas and cooperating with other students, having the teacher's support and encouragement and enjoying a challenging laboratory learning experience (Hofstein et al., 2005).

Extensive literature in the area of science education, points to the fact that the school laboratory plays a crucial role in the shaping and improvement of students' attitudes and motivation to learn science (Hofstein & Manlok-Naaman, 2011).

Research Question

Although much has been written on the educators' views on practical work in the teaching of science, it would be interesting to ask students, with at least a four-year background of chemistry, to give their views on their expectations and motivations during their A-level chemistry practical experience.

Hence, the overarching research question of this study is rather simple and straightforward.

"Does practical work motivate students to learn chemistry at A-level?"

In order to answer this question, the researcher seeks to address also a number of related sub-questions:

- What are the main aspects which motivate students during their chemistry practical sessions?
- What are the students' concerns of the current laboratory programme provided by their school / college?
- What can be done to improve their learning experience in the lab and make it more appealing and relevant to students studying the subject at A-level?

Methodology

The method chosen to collect data was a self-administered questionnaire converted to an anonymous educational survey. This method was preferred in order to avoid any intervention from the teacher-researcher which could inevitably lead to interviewer bias and contribute significantly to the total survey error. This method also secures privacy and anonymity from each respondent (Je Jong, 2016).

The survey was designed to gather substantial data from chemistry students, to give an insight to the researcher on the participants' views on various aspects of their experience in both secondary and post-secondary school laboratories. It was intended to be completed within 20 minutes.

The survey was created in a student-friendly way using Microsoft Forms software and was disseminated online, so that potential participants could easily access it directly and complete it anywhere at their own leisure, over summer holidays, even using their own hand-held gadgets.

The survey, which was only eligible to post-16 students studying A-level chemistry was divided into 3 sections:

- **Section A** involved questions seeking background information about the participants;

- **Section B** included questions regarding the students' experience in the secondary school laboratory;

- **Section C** asked students to reflect on their experience (partial or complete) in the A-level chemistry lab. It included questions on activities carried out in the lab and provided a space where respondents could voice their opinion on how to make chemistry practicals more appealing and a more effective learning experience to all students concerned.

The survey consisted of a set of 51 items, including multiple choice questions, Likert-scale responses, and a number of open-ended questions. The survey was validated by academic peers and trialled online prior to being sent for approval, authorisation and dissemination. The study was fully endorsed by the University Research Ethics Committee, and by the relevant educational authorities, schools and colleges who accepted to participate in this research investigation.

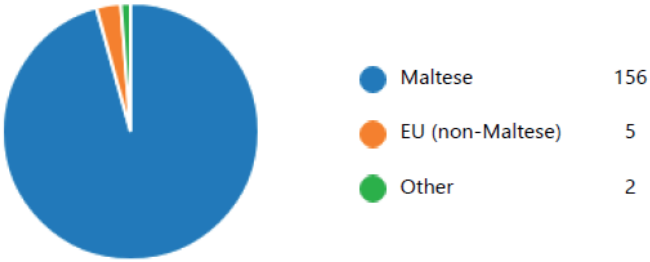
The survey weblink was eventually distributed by the colleges to their A-level chemistry students through an e-mail which included also an information letter by the researcher to all participants. All data was collected over a 20-day period, from 19th July to 7th August 2019.

Context and Participants

There were six local post-secondary institutions who accepted to participate in the study. These consisted in 3 state and 3 non-state sixth forms, 5 based in Malta and 1 in Gozo. These sixth forms represented the bulk of chemistry students (771) who were studying A-level chemistry during academic year 2018-19. In fact, this number compares well with the total number of candidates who sat for A-level chemistry in the last 2 main sessions which amounted to 888 (MATSEC, 2018; 2019).

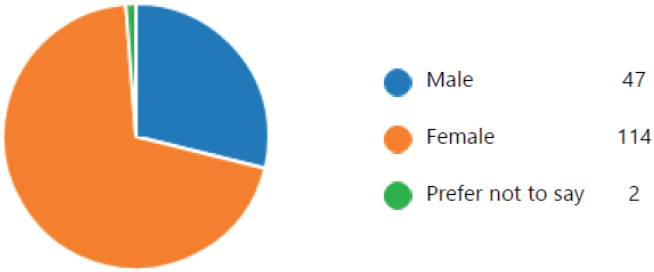
The total number of survey respondents by 7th August was 163, representing a reasonable response rate of 21%. The majority of respondents (96%) were Maltese with the rest being partly from EU countries (3%) and partly from non-EU regions (1%), as shown in figure 1.

Figure 1: Nationality of Participants (N=163)



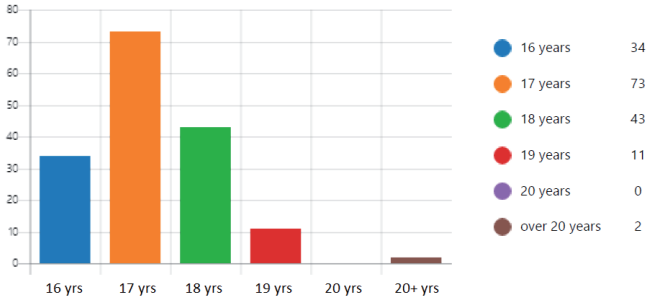
The male to female ratio of participants was approximately 3:7 (or 29% males, 70% females) as shown in figure 2.

Figure 2: Gender of Participants (N=163)



Respondents were predominantly within the 16-18 years age bracket (92%) at the time of the survey with the rest (8%) claiming to be over 18 years of age (refer to figure 3).

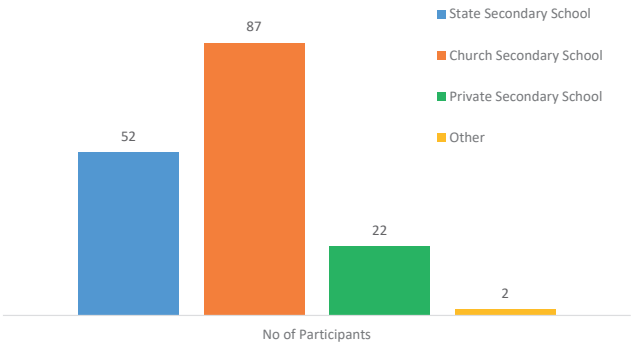
Figure 3: Age of Participants (N=163)



Participants represented a good cross-section of the Maltese society as they resided in 43 different areas, 39 localities in Malta and 4 in Gozo.

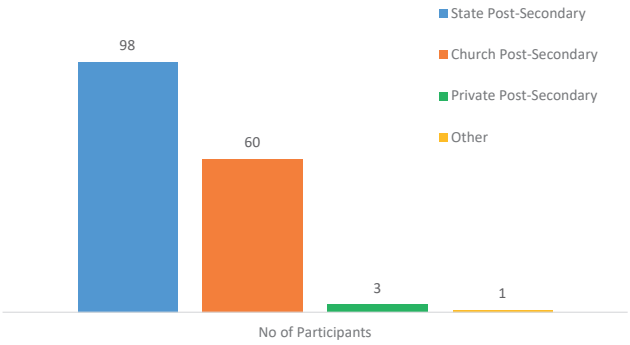
More than half of the chemistry survey participants (54%) received their secondary education in a Church school, with about one third (32%) having attended state secondary school and the rest (14%) having received similar education in an independent school (refer to figure 4 hereunder).

Figure 4: Secondary Schools attended by Participants (N=163)



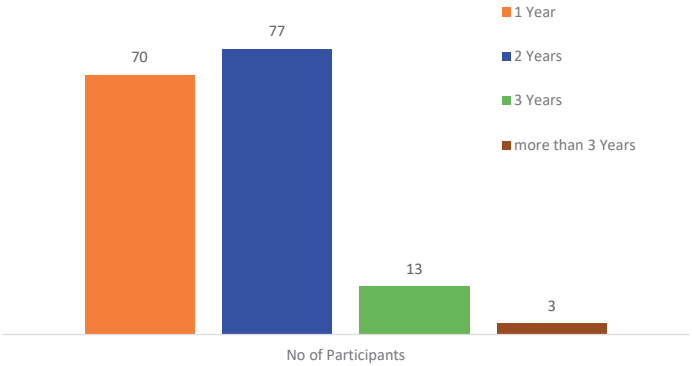
On the other hand, the number of participants who attended state sixth forms (61%) was significantly higher those following same education in Church sixth forms (37%), with the remaining participants (2%) originating from an independent sixth form college, as illustrated in figure 5.

Figure 5: Sixth Forms attended by Participants (N=163)



Almost half of the respondents (47%) had completed their 2 years of A-level chemistry studies at the time of the survey. This was only slightly higher than number of participants who were still half way through their course (43%). There was also a minority of students (10%) who extended their A-level chemistry studies beyond 2 years. This means that the survey responses represented a good mix of participants representing students at the end of their first and second years of their course of studies, as shown in figure 6.

Figure 6: Time Spent Studying A-level Chemistry (N=163)



Virtually all participants studied Biology (95%) as their second A-level subject, with Physics being the next most popular choice (4%), followed by Pure Maths.

Respondents were almost equally divided on their intentions to continue studying chemistry, 51% agreeing and 49% disagreeing. The main reasons why some participants wished to continue studying chemistry at tertiary level included:

- pursuing a career in medicine (chemistry being a pre-requisite for the course);
- following other courses requiring chemistry;
- pursuing a chemistry-related career.

Participants who were inclined to stop studying chemistry cited various reasons such as:

- interest in other courses which do not require chemistry;
- the subject was too hard and vast;
- interest to follow careers unrelated to chemistry;
- decreasing interest in chemistry;
- stronger interest in biology and other subjects;
- lack of career opportunities related to chemistry.

When asked about their immediate future plans upon finishing post-secondary education, the majority of participants (92%) expressed their interest in furthering their studies at the University of Malta, others (6%) showed preference in joining a different educational institution, while very few (2%) opted to take a gap year.

The university course which generated most interest among participants was that in medicine and surgery (49%). Other courses that appealed to participants were those related to the pure sciences (12%), pharmacy and pharmaceutical technology (12%), dentistry (6%), applied biomedical science (5%), medical biochemistry (5%) and veterinary medicine (3%). Very few survey participants showed interest in humanities courses (3%) while the rest were still undecided.

The Secondary School Laboratory Experience

The following represents a brief summary of the outcome of the section of the survey dealing with students' experience in their secondary school chemistry laboratory.

The three aspects that participants liked most about their secondary school experience was:

- serving as a bridge between theory and practice;
- giving them the chance to learn by a hands-on approach;
- providing the opportunity to work independently.

The survey showed also that the following were the students' main concerns at this level were:

- enjoying limited laboratory practice;
- problems related with health and safety;
- issues relating with the teaching style.

The majority of participants expressed their overall satisfaction with their secondary school laboratory experience, as shown in figure 7.

Figure 7: Level of Satisfaction with Secondary School Laboratory Experience (N=158)

Participants attributed their positive attitudes to reasons such as:

- the use of well-equipped laboratory facilities;
- clear explanations and professional guidance by the teachers;
- good organisation of practical sessions.

Participants who had a less positive laboratory experience, complained of a number of shortcomings such as:

- inadequate laboratory facilities;
- frequent demonstrations and group work;
- issues related with the method of teaching.

Some argued that experiments were not regular, not always well-organised and below their expectations. Other negative issues mentioned were the rushed syllabus, time limitations and lack of student feedback. Some respondents also declared they never had any formal practical sessions at all at secondary level.

The Sixth Form Laboratory Experience

The survey analysed the students' laboratory experience through a series of questions aimed at eliciting the students' views on several aspects of their practicals, what affected their attitudes and suggestions to increase their overall interest and motivation in lab work.

The survey found that while most students were able to understand written and verbal instructions from the tutor, only about half of them demonstrated full understanding of the theory involved. The analysis showed that one of the main issues in understanding theory / calculations supporting practical sessions was that these might not have been previously covered in class.

Results show that students generally worked in very safe laboratory conditions. In fact, responses showed that:

- an overwhelming majority of students always felt safe working in the lab, and well prepared on risks and hazards linked with the use of equipment and chemical reagents;
- participants were always aware of safety precautions required for every chemical practical session;
- students were also well-informed of methods of disposal of broken glassware and chemical waste.

The survey participants underlined their motivation during chemistry practical sessions and most of them (62%) usually looked forward for the next practical. One of the main student motivations in chemistry practicals remains the A-level exam. In fact, most of the participants thought that the practical sessions were solely meant to train students for exams (42%). Fewer students recognised that there were other motivating factors beyond the exam (28%) while a significant number (31%) were undecided.

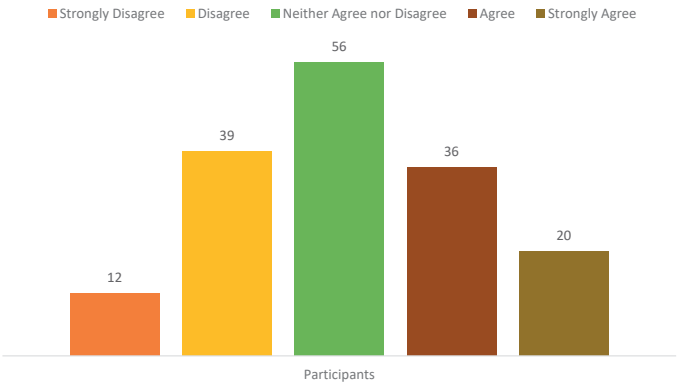
The survey analysed also the aspect of time during the practical and found that:

- three fourths of students managed their time well on a regular basis;
- most students also succeeded to complete writing their laboratory report regularly by the end of the practical;
- students also generally found enough time to clean and re-organise their workstation by the end of each session.

The analysis also showed that participants generally received sufficient attention and support by their tutor during practicals, with more than two thirds (69%) being satisfied with such help.

One interesting finding of this survey was that respondents who felt that the laboratory experience was crucial in learning chemistry was only marginally higher than those who thought otherwise (refer to figure 8).

Figure 8: Won't Choose Chemistry without a Laboratory Experience (N=163)



However, survey participants were overwhelmingly satisfied with their laboratory experience, with only a minority of participants (3%) showing contrastingly negative attitudes. Evidence suggests that level of student satisfaction in laboratory practice was considerably higher than in their earlier experience at secondary level, as shown in figure 9.

Figure 9: Level of Satisfaction with Sixth Form Chemistry Laboratory Programme (N=163)

The main reasons given by students to explain their positive attitudes towards the A-level laboratory experience were:

- greater teacher support;
- better laboratory facilities;
- greater sense of ownership and empowerment.

There were several variables which rendered the students' lab experience less satisfactory than their expectations. Negative attitudes originated from factors such as:

- issues related to teaching style;
- the occurrence of repetitive work;
- time constraints.

Analysis showed that the aspects of the A-level laboratory experience which generated most positive attitudes among students included:

- investigating unknown substances (qualitative analysis);
- performing titrations (volumetric analysis);
- applying theory to practice by using always an individual hands-on approach.

Students' attitudes were also influenced positively by the actual visualisation of concepts learnt in theory lessons, discussion of results with classmates, the occasional chance to work in teams, the type of lab report required and the teacher-student interaction.

Titrations and qualitative analysis featured again as the most disliked laboratory activities (in reverse order) for another section of participants, but for different reasons. In fact, the aspects that clearly affected most negatively the students' attitudes towards laboratory work were:

- titrations (volumetric analysis);
- qualitative analysis;
- problems related with time management.

Other tasks and aspects of their A-level laboratory experience which students disliked involved repetition, mathematical calculations, teachers' demonstrations and practicals involving synthesis or analysis of organic unknowns.

Students' Viewpoint to Improve the Laboratory Experience

The survey also gave the chance to the students to have their say on what improvements they would like to see in order to make the laboratory experience more student-friendly and a more effective learning activity.

Reduce Content, Intensity & Repetition

Participants suggested that the syllabus content for the practical component should be reduced to allow more time to think more critically and re-visit parts of the experimental procedures, if necessary.

One common idea was to reduce titrations which involves substantial repetitive techniques. Another idea was to shift emphasis from 'procedure following' to 'problem-solving' tasks.

Participants argued that even the number of unknown substances to be investigated during qualitative analysis can be reduced to a defined set, making it reasonably less difficult and complicated to arrive at correct identifications, whilst limiting also the load of examinable tests in this area of practical work.

Non-examinable Material & Outreach Activities

Students thought also that practical sessions need not be always examination-oriented as this puts extra stress on students in the lab, rendering the sessions less appealing. They suggested the design of practicals to introduce modern concepts and real-life applications of chemistry. Others came up with the idea of setting up outreach activities such as visits to specialised laboratories. They explained how this dimension of practicals would expose students to other laboratory settings, introducing them to new analytical techniques including instrumental analysis.

Stronger Link between Theory and Practice

Survey participants also agreed that it was time to update practicals radically to reinforce the link between theory with laboratory activity. This could be done in a number of ways including better use of demonstrations and visual aids.

They also proposed exposure to a greater variety of experiments and hands-on activities including other techniques encountered in the syllabus. Students also believed that experiments should touch on more areas of the A-level curriculum, enabling theory to be more relevant and easier to understand and remember.

Increased Student-teacher Interaction

Students also wanted an increased teacher involvement during the practical, with greater emphasis on explanation, guidance and individual attention in all tasks including working calculations and writing chemical equations. Whenever tested under examination conditions, students also expected a stronger feedback from the teacher which they consider as crucial in their preparation for the exam.

More Student Collaboration

One finding of the survey pointed towards the benefits gained by students when given the space to cooperate and collaborate with each other during the chemistry practical sessions. Participants felt that exercises which encouraged teamwork would allow them to share their ideas and knowledge, thereby allowing them to learn from each other's experience.

Revise Methods of Assessment

One concern shared by most of the participants was the way volumetric analysis was being assessed during practical exams. They suggested that there should be less emphasis on accuracy and an increased evaluation of other skills employed.

The survey also showed that some students preferred to have practical examination replaced in part or completely by coursework which would reflect the student's participation and aptitude throughout the entire two-year laboratory experience. They thought that this system would provide a fairer way of judging their skills and knowledge, based on continuous formative assessment.

Improve the Laboratory Environment

Some participants felt that their experience could be enhanced further if their school laboratory facilities were modernised and upgraded accordingly. Participants thought also that working in small groups in well-equipped labs would be more conducive to a less stressful and more motivating learning environment.

Radical Ideas

The survey found also a cluster of radical ideas such as the suggestion to spread the content of the current curriculum over a period of 3 years to reduce stress and allow more space for enjoyable learning activities including practical sessions.

One drastic idea was that of removing completely the practical component of chemistry in the exam and replace it with a paper involving tasks in applied chemistry or data analysis. Others thought that there should be no teacher demonstrations at all during the practical sessions as these tended to be disruptive and would distract students' from focussing on their main laboratory assignments.

Conclusion

This paper aimed at investigating sixth form students' views on their laboratory experience at school, which formed part of their A-level chemistry curriculum, and explored whether it motivates them sufficiently to learn the subject at this level of education.

The analysis clearly confirmed that students found their chemistry laboratory experience even more motivating than the one at secondary level. Reasons include; a greater support and guidance from experienced qualified tutors, the use of well-equipped teaching laboratories and the chance to learn more independently using individual hands-on activities. Students' attitudes were also affected positively by other factors such as being exposed to increasingly challenging laboratory activities, being given the chance to carry out so many different investigations on a regular basis and the increased chance to share and discuss results with teacher and other colleagues.

While younger chemistry students were mostly concerned with a lower exposure to direct laboratory work, safety issues, problems related with teaching and some learning difficulties, A-level students had to deal with a different set of concerns related to their more regular laboratory work. Such issues include the; occurrence of repetitive laboratory activities, the challenges related with frequent exercises in qualitative and volumetric analysis and the examination-related pressures such as time management during the practical and the way the practical component was assessed by examiners.

The students were quite clear in their message addressed to their educators and curriculum developers with regards to their laboratory experience. They feel the need to have a revamped laboratory programme allowing less content and more thinking time, less repetitive activities, new non-examinable techniques, better alignment of chemistry theory and practice, access to external chemistry laboratory settings, increased teacher involvement and student collaboration in the lab, and revised methods of assessment. Some students also wanted to have an improved physical environment allowing students to exploit better this very effective way of learning the subject.

The findings of this study are strikingly similar to those reported by other researchers in science education and confirms that Maltese sixth form students showed the same attitudes and motivation towards the practical aspect of chemistry education as their counterparts in other parts of the world. It is therefore high time that we as educators, and other stakeholders, listen to these students' voices and consider them seriously in future decisions in policy making and curriculum development in a bid to address their educational needs in a more holistic and enjoyable way.

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Bio-note

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