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Computer Simulation of the  
Mandatory Experiments in Leaving  
Certificate Chemistry with particular  
reference to Special Needs Students

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# COMPUTER SIMULATION OF THE MANDATORY EXPERIMENTS IN LEAVING CERTIFICATE CHEMISTRY WITH PARTICULAR REFERENCE TO SPECIAL NEEDS STUDENTS

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## ABSTRACT

This paper investigates the use of interactive computer simulation of chemistry practicals as an alternative to the actual 'wet' chemistry practicals on the Leaving Certificate Syllabus, with particular reference to the support of special need's students. This approach is of particular significance for these students, as for safety and other reasons it may not be practicable to have them carry out the actual experiments.

The paper reviews the role of actual laboratory work in the Leaving Certificate Chemistry syllabus. It examines both the quality and quantity of the laboratory simulation software resources available. The paper reveals a scarcity of suitable software packages and found that those available were lacking in sound pedagogical rationale.

Even with imperfections the difference between the chemistry laboratory practicals and chemistry laboratory simulations is statistically not significant. Despite the limitations of packages, the simulation is clearly useful and potentially of significant benefit to special need's students who are excluded from doing the actual experiment. Finally, this paper puts forward guidelines for the future development of chemistry laboratory simulation resources.

## KEY WORDS

Interactive computer simulation of chemistry practicals, 'wet' chemistry practicals, special need's students, laboratory simulation software.

## 1. BACKGROUND

As practicals in chemistry become a mandatory component of the Leaving Certificate Chemistry, it is essential now more than before, that all students have access to carrying out of these experiments.

## **Chemistry**

Chemistry is the physical science that deals with the composition, structure and properties of substances and also the transformations that these substances undergo. The objective is that there should be two-way interaction between the understanding of chemical concepts and their application. Experimental work as well as providing this two-way interaction serves a variety of purposes.

- To clarify principles discussed in the classroom, by actual working with the materials
- To give the student a feeling of the reality of science by an encounter with phenomena which otherwise might be mere theory
- To make the fact of science easy enough to learn and impressive enough to remember.

To give the student some insight into basic scientific laboratory methods, to let him/her use hands, and to train him/her in their use (Lagowski). The understanding of chemical principles is important, because they are required to explain the role of chemistry in the environment and industry. Practicals are important both pedagogically and socially in any student's development but particularly for special need's students.

### **Chemistry and Special Need's Students**

Special need's students experience many difficulties in mainstream education and in particular chemistry education. Unfortunately, until recently in the ordinary school system, chemistry because of the hazardous potential of its practical component was often deemed unsuitable for special need's students. In some circumstances, it was possible for a student with special needs to work with an able-bodied student in performing the chemistry experiment. Omission of practical subjects is most unfortunate, as they can serve to motivate students with special educational needs.

However as society becomes more litigation conscious the inclusion of special need's students in science laboratory courses, increases the concern for their safety since they often may not foresee potentially dangerous situations developing.

Increasing number of students with special needs may wish to become chemists, and many need to study chemistry to attain other career objectives. Computers could have an important role and particularly interactive computer simulation in facilitating the carrying out of laboratory work for these special need's student.

## **2. LABORATORY SIMULATION SOFTWARE**

It is expecting too much to hope that any computer simulation can support the acquisition of all of the laboratory skills. The actual 'feel' for the equipment and materials is not available. To assess the extent to which the available software supported these skills and fulfilled the assessment criteria for the Leaving Certificate Mandatory Chemistry Experiments is the main focus of this paper.

## **Resources**

This study involved sourcing chemistry software laboratory resources which would allow the students to achieve the objectives of laboratory work. The ideal software resources would be ‘virtual laboratories’ which would support a number of experiments on the same topic. Both the quality and quantity of the laboratory simulation software resources available was reviewed.

Software resources were sourced in two areas:

- Educational Suppliers
- Internet

## **Software Test**

The main task of the next stage of this study, was the testing of a particular piece of interactive simulation software for a particular experiment to ascertain how it compares with performing the ‘wet’ chemistry experiment in achieving the objectives of experimental work and in particular of the experiment itself.

The testing was carried out using two groups of students and involved the following:

- Administering a pre-test questionnaire to all students involved
- Administering a pre-test examination to all students involved
- Setting up Control Group and Experimental Group
- Familiarisation of students in Experimental Group with the software package
- Research experiment
- Administering a post-test examination to all students.
- Administering post-test questionnaire to students in Experimental Group

## **Assessment Criteria for Leaving Certificate Chemistry Practicals**

To identify the objectives for experimental work in Leaving Certificate Chemistry, it was necessary to examine each experiment in its three broad phases:

- Planning
- Implementation
- Conclusion / Evaluation

Each of these three phases involved a large number of processing skills, which in turn determined the objectives of practical work for assessment purposes:

### During experiment

- Manipulation
- Observation
- Recognition
- Understanding

Also required

- Presentation of experiment in copy

### **3. STUDY FINDINGS**

The findings are considered under two broad headings:

Quality and Quantity of Resources.

Qualitative and Quantitative Results of Software Test.

#### **3.1 Resources**

The study revealed a scarcity of suitable laboratory packages and found that those available were lacking in sound pedagogical rationale. Of the chemistry resources investigated, laboratory resources only accounted for 21% of the total chemistry software accessed. 2.5% of these laboratory resources were based on the 'virtual laboratory' concept which is considered to be the most appropriate software for achieving the objectives of laboratory work.

Possible reasons why the resources are still scarce in this area could be:

- Limited Multimedia Availability
- Highly Specialised Subject Area
- Lack of Market Demand

#### **3.2 Software Test**

Features of the project implementation that should to be recognised for the purposes of the evaluation was this research was carried out on 'able bodied students' whose whole physical and mental aspirations towards computers will be different to the students' with special needs.

It is against this background that the findings of the research experiment are analysed. The analysis is carried out in the context of the special need's students and their needs in the laboratory.

### **Assessment Results**

A study using laboratory simulation software that had many imperfections was carried out on a group of students. The assessment results from this group of students were compared with the results of another group of students who performed the practical in the chemistry laboratory. This set of findings revealed that the differences in the assessments between chemistry laboratory practicals and chemistry laboratory computer simulation were not statistically significant.

### **Advantages of Chemistry Laboratory Computer Simulations**

There were many advantages in performing chemistry practicals on the computer.

The three principle areas were:

- Errors
- Results
- Rate of Experimentation

### **Errors**

Errors could be made without disastrous consequences. This in itself could be a very valuable learning experience for any student, able-bodied or disabled. It was easier to rectify an error on the computer than when they were performing it in a chemistry laboratory. 'Undoing' is an added bonus because the student has to make decisions on where or how the error arose. This involves thinking, questioning as well as other cognitive processing. As well as the mind being active, the student perceives a greater sense of autonomy about the experiment. This negative experience in the chemistry laboratory becomes both a positive and enriching developmental cognitive process for all students working on practicals on the computer.

### **Results**

The quality of its quantitative results is superior to those produced from practicals in the laboratory. Its accuracy in measurement and the precision in identification of the end-point of the experiment all contributed to this important feature of all experimental work performed on the computer.

### **Rate of Experimentation**

Practicals can be carried quicker on the computer. This facilitated many repetitions of the same experiment to ensure even greater accuracy as well presenting the student with a greater opportunity to note the more salient features. The students have the time to perform all procedures of an experiment whereas in the laboratory, the each member of the student pair take different procedures within the experiment.

These intrinsic features of good computer software support interactive computer simulation of laboratory experiments in chemistry as a possible resource for all students. Other possible advantages for interactive simulated laboratory software include:

### **Experiments without Restrictions**

The computer has the potential to facilitate a more extensive and yet a more complete experimental study. It would be possible for the student to consider the chemical investigation over a wider and yet a more precise range of values. It is even possible to carry out the chemistry study over ranges which otherwise would be hazardous in the chemistry laboratory. The risk element that once formed part of all practical work, and which has now been replaced by more 'clinical' chemistry experiments as a result of the more rigorous 'safety' restrictions imposed on all aspects of work in laboratories, can be restored to chemistry laboratory work on the computer.

### **Adding Clarity to Experiments**

The concepts underpinning practical work are often lost in a haze of extra procedures which have to be performed so as to carry out the practical. Suitable laboratory software in chemistry could have the potential to just investigate this concept in an experiment. Another dimension of investigative work in chemistry is the effect of a parameter on a chemistry experiment but this study often proves difficult because of other interfering parameters.

### **'Chemistry' of Experiments**

'Virtual laboratory' chemistry software could have the added benefit of elucidating the 'chemistry' behind the experiment. This could be incorporated into the logical sequence of the experiment, and as the practical proceeds the student could also follow the chemistry 'metamorphosis'. This added dimension could be made available to students when they have successfully completed and understood the procedure.

### **Advantages and Special Need's Students**

Students with special needs largely depend on their intellectual ability in many aspects of their lifestyle. As outlined above, computer simulation of laboratory experiments has the potential to present the special need's student carrying out these experiments, with the opportunity of experiencing these extra very important educational insights into chemistry. Consequently, the student has a deeper insight into the facts, theories and concepts that is chemistry.

### **Disadvantages of Chemistry Laboratory Simulation Software**

There are still many disadvantages associated with the use of chemistry laboratory computer simulation software, but as its performance gets closer to the reality of 'wet' chemistry laboratory work, these become less and less. Many of these disadvantages may not necessarily be disadvantages for the special need's student.

### **Physical Activity**

The students perceived that to experience experimental work in chemistry that you must get a 'feel' for both the chemicals and the equipment. It was the experience of the students in the experimental group that being physically active meant that they were more involved in the experiment and more involvement meant that it was a greater learning experience for them.

In terms of the chemistry subject, these are very significant disadvantages of the software, but in terms of laboratory assessment, it would not impinge on assessment results. For some special need's students the lack of tangibility might be the accepted norm of their everyday life while for others a certain amount of 'feel' might be possible. Eitherways, it should not affect their assessment taking account the following criteria as outlined above.

### **Boredom**

Accruing from computer based laboratory simulations is a more significant disadvantage, the element of weariness that manifests itself as a result of the repetitious nature of many aspects of experiments performed on the computer. As the computer is usually the only means of communication for most special need's students, their attitude towards the computer would be different to the able-bodied student's attitude, and what is perceived as boredom for the able-bodied student could be a challenge for the special need's student.

### **Future Careers**

Of great importance is the fact that the lack of experience in the laboratory due to performing practicals on the computer might also affect one's future career in the laboratory. For the special need's student, because they form a certain percentage of any company's employment, his/her career opportunities may not be affected, as they will be accepted for their limited skills.

Students whose efforts in the laboratory are sharply restricted by a disability are not necessarily barred from careers involving laboratory work. Many successful chemists direct experimental programmes without the need to perform laboratory manipulations themselves. Often they work with data obtained using methods outside their immediate experience and equipment they may never have seen. Also as a percentage of the equipment in all industrial processes is computerised, they may not unnecessarily be unduly disadvantaged by lack of real laboratory experience and in fact they may be even at an advantage because of their greater computer skills.

### **Safety**

The student performing the chemistry laboratory has a 'greater awareness of safe procedures' than the student performing them on the computer. This valid observation was not made in the post-test questionnaire perhaps because there were no specific hazards associated with the particular experiment being examined. This is one significant aspect of experiments, which cannot be experienced by students performing their chemistry practicals on the computer.

### **Disadvantages and the Special Need's Student**

These are very significant disadvantages in the area of both chemistry and chemistry laboratory work. Taken in the context of laboratory assessment as employed in the Leaving Certificate Chemistry, these would not disadvantage the special need's student in his/her laboratory work assessment. However, it is the 'feel' and the physical activity which chemistry laboratory work possesses that causes the buzz in chemistry as one gets to appreciate all the facts, theories and concepts that make up chemistry.

From a special need's students perspective, these may not be disadvantages. These are all the perceptions of able-bodied students and teacher. Also, as some of these students may never have been presented with the opportunity of carrying out practicals before, performing them on the computer may be what they perceive to be the 'feel' and the physical activity. Nevertheless, it should definitely instill in the special need's students a greater appreciation for chemistry and incite in them a greater enthusiasm for the subject.

### **Chemistry Laboratory Computer Simulation as an Educational Resource**

As a chemistry resource, its use in the area of special needs education is to be recommended.

It also has potential in other areas of chemistry:

- Use as a self-study chemistry resource
- Use in schools lacking chemistry laboratory resources
- Use for revision purposes.

On this basis, with improved 'virtual laboratory' software, there certainly seems to be the potential to meet the requirements of special need's students for the mandatory experiments at Leaving Certificate Chemistry. Secondly as this investigation was carried out on a small group of students, the conclusions although arguably very positive, are not substantive enough to make any valid conclusions. The positive outcomes certainly justify further research in this area.

## **4. FUTURE RECOMMENDATIONS**

Students with special needs as a result of their disability may experience difficulties in chemistry namely:

- 1) isolation from the social activity that is part of the group work in practicals
- 2) difficulty in acquiring important experimental skills

It is these difficulties, in particular, which the use of laboratory simulation software could alleviate. Good interactive simulation software has the potential to allow them to actively participate in all phases of experimental work:

- Planning
- Implementing
- Concluding / evaluating

This in itself could lead to more effective social integration into chemistry practical work for the special need's student.

The second is a learning difficulty, which is essentially logistic and can be solved, to an extent, by laboratory software. To what extent these difficulties are alleviated will depend on the quality of the software.

### **Simulation Software for Chemistry Practicals**

We recommend future resource developments in the area of interactive computer chemistry laboratory simulation. This, being an evolutionary process would demand continuous and ongoing evaluation by appropriate personnel. In software educational resource development, it is imperative that pedagogy leads and technology follows.

Software used in the practical area of chemistry is of a very specialised nature and accurate and appropriate representation of experimental procedure is foremost in its development. Ideally a chemistry teacher needs to be involved in the development of these resources and in particular in their design. Each storyboard of the design needs to be supported by sound pedagogical rationale, which is best understood by a chemistry teacher. The difficulty that arises is that if this teacher does not fully understand the storyboard philosophy, then technology and chemistry cannot concur satisfactorily to meet the objectives of the laboratory simulation software. The ideal would be for a chemistry teacher with a good technological background to be involved not only in its storyboarding but be available as a consultant at all stages of its development.

For the interactive simulation chemistry laboratory software to achieve the objectives of laboratory work (Boud, Dunn and Heggarty), the researcher would suggest that the 'virtual laboratories' be developed that would support a range of experiments on the same topic. Virtual chemistry laboratory software has the potential to achieve the reality of the chemistry laboratory for the special need's student.

For the mandatory experiments, four virtual laboratories could be developed in the following areas:

- 1) Analytical chemistry
  - Qualitative chemistry
  - Quantitative chemistry
- 2) Separation techniques
- 3) Organic chemistry
- 4) Investigative chemistry

Other recommendations to add reality to the software:

- That the software would permit the same procedures to be followed that are followed in 'wet' chemistry
- Three dimensional interface with 'real' equipment
- Virtual 'hand' availability

### **Future Research**

It is considered essential in the integrating of students with special needs into mainstream education, that all students can use the same resources. Apart from achieving effective integration, it also permits the same objectives to be achieved by all students, able-bodied and special need's students, which is the essence of the whole study. In research into such software, it must be recognised however that the requirements of able-bodied

students, whose whole physical and mental aspirations towards computers, are different to those of students with special needs. It would therefore be recommended that in any further study in this area that resource evaluation be carried out on able-bodied students working in groups; on special need's students working in groups, and able-bodied and special need's students working together in groups.

### **Conclusion**

The primary purpose of this paper was to investigate how computer simulation could facilitate integration of special need's students into chemistry education and in particular into chemistry practical work. Information Technology is now widely accepted as a vital component in expediting this integration. Computers can readily cater for students with many special educational needs, therefore expanding both the educational and career opportunities of all those with special needs. Computers can help to remove barriers that once were their challenge, whilst at the same time providing an active, enjoyable and motivating educational experience. Special need's students can, through the interactive virtual laboratory, experience the 'complete' world of chemistry.

This study indicates that the use of interactive simulation laboratory software as a substitute for 'wet' chemistry practicals in Leaving Certificate Chemistry is a possible alternative for special need's students for the hazardous practicals. The findings from the Research Experiment, even with the mediocre software available at present for this purpose, were that it had the potential to realise all the assessment criteria for the Leaving Certificate Chemistry Assessment.

However, interactive computer simulation of laboratory work can serve a useful purpose even in its present state and it must be regarded as having significant potential in the future in particular for special need's students.

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