COMPUTER ASSISTED LEARNING IN PHARMACOLOGY: AN UPDATE

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ABSTRACT

The emerging trend of using computer simulations as an alternative to animal experiments to duplicate live dissections is having a greater advantage of lesser involvement of time and labor, and repeatability. Most importantly, Computer Assisted Learning prevents the unethical killing of animals. In vitro-in vivo correlations can be made with the help of pharmacokinetic softwares therefore saving the usage of animals. Reduction in manual intervention and the user-friendly nature of these softwares make their use highly favorable. This article highlights the perception and attitude of undergraduate students towards animal experimentation and Computer Assisted Learning (CAL) in experimental pharmacology. A study conducted in a department showed that 44.74% of students found computer simulation to be more enjoyable and time saving than laboratory practicals. 47.36% think that computer simulation is easier to perform and 42.10% said that Computer simulations contribute more to understanding theoretical concepts like terms, dose and concentration than laboratory practicals. 47.36% said that in computer simulation no experimental errors are observed as in the case of laboratory practicals. The results of the study suggest that students seem to favor the computer assisted learning in experimental pharmacology.

Key words: Computer assisted learning, Experimental pharmacology.

INTRODUCTION

Pharmacology is the study of the manner in which the function of living systems is affected by chemical agents. Practical lessons are an important part of pharmacology curricula of various undergraduate courses, such as medicine, nursing, science and pharmacy. In vitro and in vivo animal experiments have been widely used in the practical lessons to assist students gaining hands-on skills of pharmacological experiments, and more importantly, reinforcing their knowledge learned from lectures and text-books.
An emerging trend as an alternative to animal experiments is use of computer simulations to duplicate live dissections. These have the advantage of lesser involvement of time and labor, repeatability, ease of dissemination of information even over global distances and most important, computer assisted learning does not speak arguments over ethics\(^3\).

Moreover, the computer savvy generation of students takes easily to this method of learning. Encouraging results were obtained in a study of computer simulated pharmacology experiments for undergraduate pharmacy students. Does this point to a radical difference of attitude over distances or is it a nuance of a difference in exposure to modern day technology? Neither reason seems plausible enough. Whatever the causality for such results may be, computerized teaching has certainly penetrated the education system and in due course of time will probably curve a niche for itself in medical research and learning.

The ‘virtual reality’ created by computer based learning has immense potential not only in terms of flexibility and convenience, but also in its unique presentational benefits and provision of personalized learning to the increasing number of medical students. Hence, an initial investment of fund is likely to pay off in the long run. However, without adequate planning and training of staff, the consequences may prove to be disastrous\(^4\).

In the modern century, pharmacology has turned into an emerging area with high career orientation. Recently the undergraduate training in pharmacology has been revolutionized with adoptions of newer teaching tools like group discussions, role plays, using audio-visual aids, clinical and community pharmacology studies. Nowadays, these are being adopted by many colleges at both postgraduate and undergraduate levels. Today, computer assisted learning has become a vital part in the pharmacology curriculum. Recent trends in the developments of information technology support such methods.
Although traditional live animal experiments are invaluable, they do have shortcomings, and their cost effectiveness has been questioned\(^5\). Apart from being time consuming, animal experiments can only test a limited number of drugs at a given period of time. Furthermore, animal experiments, in particular whole animal studies, are often labour-intensive and expensive\(^6\). A variety of computing programs have been developed for undergraduate and postgraduate teaching of pharmacology. Previous evidence has shown that this innovative educational technique, either as an adjunct to the traditional teaching methods such as lectures or as a sole teaching tool for distance education or home studies, facilitates students’ learning and improves overall study outcomes in pharmacology.

Pharmacy students’ perception on using simulated experiments as an alternative to animal experiments\(^1\) however, is unclear. The purpose of this study is to evaluate pharmacy students’ views on effectiveness and utility of computer simulations and to convey information about the useful web resources available for handling pharmacology practical with special emphasis on its advantages and limitations.

**Computer Assisted Learning (CAL) in pharmacology**

Computer-assisted learning is almost similar to the experiential model of learning. Demonstration of the effect of drugs on various models like tissues or on whole animal is an integral and essential part of practical pharmacology teaching for medical students\(^7\). But it requires the usage of a large number of animals and a lot are sacrificed during each experiment even for studying and demonstrating the action of drugs which are already established\(^14\). With our own experience we felt that this affects the mental state of the student also. So it should be the constant effort of a pharmacology teacher to bring down the usage of animals and increase the teaching quality in pharmacy. One of the best ways to reduce this is to utilize the web resources available for the same\(^7\). Like a laboratory class, it must be fully integrated into a module if real benefits are to be obtained. Students need to be taught how to learn from computer-based learning materials and how
to integrate this learning tool in their learning strategy\(^8\). Thus by the use of CAL we can replace the use of animals in pharmacology practical classes.

Both CAL and laboratory practical classes are valuable tools for pharmacological experiments. Further, it is quite time consuming to demonstrate minute details of pharmacological procedures and drug effects to a batch of students and the increasing strength of practical batches is making it difficult to interact with each student\(^9\). Hence CD containing CAL software for teaching animal experiments is becoming a revolution in pharmacological teaching.

CAL deals with a range of computer-based packages, which are focused on to provide interactive instruction usually in a specific subject area. CAL projects are designed in such a way that it helps to provide students with an alternative to traditional lectures\(^9\). These can range from sophisticated and expensive commercial packages to applications developed by projects in other educational institutions or national initiatives to simple solutions developed by individuals with no funding or support to tackle a very local problem. They offer a range of benefits like it is convenient and flexible\(^10\). It has got unique presentational benefits, helps in personalized learning, and helps in achieving the ultimate goal of higher education. A few use of CAL in pharmacology is listed below:

- Pharmacy practical with demonstration of various preparations.
- Demonstrations of routes of drug administration using colorful pictures.
- Learning by role play in therapeutics\(^11\).
- Therapeutic teaching with visual aids.
- Teaching pharmacology theory without visual aids.
- Pharmacokinetic learning with the help of CAL software\(^12\).
- Pharmacodynamic learning with the help of CAL software.
- Community pharmacological case studies.
- Clinical pharmacology case studies\(^12\).
Various types of software have been developed for use in pharmacology courses. These include: simple drill (question and answer) software, electronic books, video material, tutorial type programs, simulations and electronic learning environments for course organization and delivery. These different types of software can be used in different ways to achieve very different learning objectives and gains in teaching efficiency. For example, software can be used: in tutorial and small group teaching, in lectures, to better prepare students for practical work, as a replacement for practicals to provide options within a limited course structure; to supplement lectures and enable students to work at their own pace, to provide ongoing access to self-assessment throughout a course, to aid distance learning, as remedial teaching and to extend the student learning experience in areas which are too expensive or too time consuming or for which staff expertise does not exist.

Evidence indicates that it is insufficient simply to make computer based learning material available to students. Like a laboratory class, it must be fully integrated into a module if real benefits are to be obtained. Students need to be taught how to learn from computer-based learning materials and how to integrate this learning tool in their learning strategy. Teachers need to be supported not only with information about the availability of software but, equally importantly, about how it can be integrated into modules. We are all delivering teaching and facilitating learning in a changing environment and subject to a variety of increasing pressures. It may well be that computer based learning materials may help to maintain a high quality of pharmacology teaching within this changing environment but we need more pedagogical research at the discipline level to establish how this can best be done.

### CAL techniques

Computer assisted learning (CAL) techniques are humane educational aids and teaching approaches that can replace harmful animal use or complement existing humane education. Typically used in combination to meet existing teaching objectives and to provide other educational outcomes that cannot be met through animal experiments, they comprise:
Film and video: Historically films have been used to a large degree within life science education to illustrate those parts of the curriculum that particularly benefit from visual representation, that need further explanation, or that are hard to show in the lab. Most films have over time been replaced by video. Some video material has in turn been used in clips within multimedia software on CD-ROM and DVD. Recent digital technology presents new opportunities to creatively develop and maximize the potential of video-based teaching resources in conjunction with computer software. The digitizing of video is simple and low cost. The editing of digital video, including the addition of auditory comments, stills and graphics, and its copying and distribution, can be managed with average computer hardware, the appropriate software, and basic computer skills. Digitization allows video clips to be accessed quickly and used with ease during a lecture or practical lab, and streams can be provided on the web. Creative use of this technology can provide a highly effective learning aid.

Models, mannekins and simulators: These non-animal alternatives comprise both synthetic training objects designed to simulate organs, limbs or whole animals, and apparatus for training and simulation of physiological functions or clinical skills and scenarios. The descriptive terms are used flexibly and sometimes interchangeably. In general, ‘models’ refer to objects designed for appreciating anatomical structure; ‘mannekins’, or sometimes ‘phantoms’, are life-like representations of animals or humans designed for clinical skills training; and ‘simulators’ are tools for clinical skills, surgery and critical care practice.

Multimedia computer simulation: The emergence and application of computer technologies have revolutionized science and society as a whole. High-speed processors and powerful software have transformed the way that data is gathered and processed, how biological processes are modeled and explained, and how knowledge is transferred. The opportunities associated with the development of computer-based technology in contributing to effective life science education have grown exponentially within the last decade. The internet, and multimedia software available on CD-ROM
and DVD, is playing powerful roles in many universities, with applications in labs and lectures, tutorials and project work. From virtual dissections and experiments in well-equipped labs that students can perform on-screen, to full virtual reality simulations of clinical technique with tactile facilities, the possibilities of computer-assisted learning are limited only by technical and imaginative boundaries.

**In vitro labs:** Software which includes a virtual laboratory presents a range of equipment on-screen and may offer a very high degree of interactivity. Typically, such programs simulate classical animal preparations and experiments within physiology, pharmacology and critical care. These disciplines lend themselves well to multimedia because of the need to correlate multiple and simultaneous events, and to gain an understanding of the interplay between complex and related phenomena. Simulations provide practice-oriented tasks building on students’ theoretical knowledge.

**Tutorial-type programs:** These programs present, in an interactive and involving manner, information about a discrete pharmacological topic. Since they usually cover only a small area they are relatively easy to integrate into modules of diverse content and level. In many of the programs the path through the information can be chosen by the student who may choose to study in greater or lesser depth. The programs can be used in a variety of ways for self-directed learning, to illustrate lectures, as a replacement for lectures, to provide options for detailed study (e.g. special study modules for medical students), for remedial teaching or as a basis for a tutorial. The programs usually specify learning objectives and may themselves incorporate self-assessment sections with target marks.

It is important however to integrate these set learning objectives and assessment with those for the module as a whole. Some programs incorporate pre-tests to establish baseline knowledge. Student sometimes ignores these or purposely does badly so they can demonstrate improvement. Many are
used in conjunction with other learning resources and it is very difficult to assign a source for any learning which has taken place.

**Software used in experimental pharmacology**

The softwares used in pharmacology are mainly related to minimize the efforts needed in determining the pathway of the drug and consequently its adverse reactions. Further the softwares are extensively used in determining the pharmacokinetic principles of the particular drug in particular individual. The various softwares used are as follows:

**Ex-Pharm:** The software is aimed at helping the UGs understand, remember and recall drug actions. CPCSEA through its letter number CPCSEA/CH/ORG/Pharm/2003 dated 18-06-2003 has directed all the institutions conducting diploma degree courses in pharmacy to use Ex-Pharm, is demonstration software developed by JIPMER, Pondicherry, India. The package contains programs such as effects drugs on the rabbit eye, effects of drugs on the frog heart, bioassay of histamine on the guinea-pig ileum, effects of drugs on the frog oesophagus and effects of drugs on dog BP and heart rate. These programs can simulate drug actions. The user can conduct experiments and collect data. Each program can be run in two modes (a) Tutorial mode (b) Examination mode\(^{17}\).

**X-cology:** This software (developed in Multimedia Director, Flash and visual basic for windows) displays complete video demonstrations of different procedures like isolation and mounting of animal tissues followed by on screen interactive interface to study the effects of various drugs on the isolated tissues\(^{18}\). The details on the experiments involving animal use were divided into different topics to facilitate their presentation and easy navigation through the details. The content was classified into following topics:

- The experimental animals: This section includes biological names of the common experimental animals and their use in experimental Pharmacology.
• The equipments: this topic includes the common instruments used for demonstration of animal experiments.

• Experimental techniques: This section includes the information on manual skills and routine procedures involved in the experimental pharmacology such as collection of blood samples, preparation of drug solutions and routes of drug administration\(^9\).

The experimental section contains exhaustive details like video demonstrations on isolation and mounting of different tissues from experimental animals, an interactive interface to study effects of different drugs on isolated tissues, procedures to carry out bioassays and experiments on whole animals related to screening and evaluation of drugs\(^9\). A better understanding can be achieved through the figure 1, 2, 3 and 4.

**Basic Psychopharmacology (v2.0):** This package, developed at the University of Galway (Republic of Ireland), introduces the student to psychopharmacology. It is divided into 3 subjects containing a total of 11 activity modules. The student first learns about the neuroscientific foundation of psychopharmacology (blood-brain barrier, drug entry into brain, electrophysiological mechanisms, biochemical mechanisms), then continues by considering some of the clinical applications of psychopharmacology (hypnotics, anxiolytics, antidepressants, antipsychotics). In the final subject of the package, the student looks at research methods used in psychopharmacology, including laboratory techniques, use of animal models and their limitations, and some of the problems of clinical trials.

**Acceptance and implementation of computer assisted learning (CAL) techniques in education**

Although alternatives are now widely available, and have replaced many animal experiments, in some regions the number of animals used in education seems to be decreasing only slowly. Many factors contribute to the acceptance of alternatives, but acceptance is just a starting point. Many challenges have to be addressed before alternatives are actually introduced. For successful introduction of alternatives the following steps should be considered: Awareness of alternatives;
analysis of needs; acquiring the appropriate alternatives, preparing staff, support and the location, the actual implementation and finally the evaluation before proceeding\textsuperscript{20} as represented by figure 5.
METHODS

This study is based on a survey conducted among students of Department of Pharmaceutics, Institute of Technology-Banaras Hindu University. Department have opted computer assisted learning in experimental pharmacology since July 2009 for undergraduate students. In this survey a questionnaire was prepared having six questions and distributed among pre-final and final year students of the department. The Pharmacological experiments were performed by using X-Cology and Ex-Pharm softwares\textsuperscript{19}. The questionnaire was prepared to compare the pharmacological laboratory experiments with Computer Assisted learning as given in table 1.

Statistical analysis: Mean ± standard error of mean (SEM) were calculated for the observed values. Statistical analysis was performed by one way analysis of variance (ANOVA) followed by Student-Newman-Keuls test. Software used GraphPad Prism 5 software was used for statistical analysis.
RESULTS

The present study comes with a fruitful outcome and is shown through table 2 and figure 6, 7, 8, 9, 10, 11, 12 in which the pie charts represent students view over the six different questionnaires in terms of $SA =$ Strongly Agree; $A =$ Agree; $NO =$ No Opinion; $D =$Disagree; $SD =$ Strongly Disagree. One-Way ANOVA showing significant difference of $SA$ ($P<0.05$) and ($P<0.01$) to $NO$, $D$ and $DA$. 
DISCUSSION

Practical exercises in pharmacology fulfill certain educational objectives. Handling an animal and dissecting it helps to build the psychomotor skill of a student. On the other hand it is not necessary that these experiments be carried out by the students “first-hand”, if the goal was to build the observational, analytical and interpretative skills of a student, as these objectives largely relate to the cognitive domain. It is possible for a faculty member to demonstrate these experiments and let the students observe the results and interpret them. Computer Assisted Learning can be very useful in such a setting\textsuperscript{20}. CAL also offers a stimulus-variation from the routine teaching methodologies. Attempts have been made by many teachers of pharmacology to improve teaching methods. The result of the present study emphasizes the value of CAL in development of experimental skills and understanding of theoretical concepts. 37.84 % of total number of students surveyed in Department of Pharmacuetics, Institute of Technology-Banaras Hindu University thinks that computer simulation is the best alternative to laboratory practical. The statistical analysis of the data shows that number of students favoring computer assistance learning is significantly more than the other students.

**Benefits:** Large animals like dog and cat are difficult to handle during demonstrations in the laboratory. Software programs for Computer Assisted Learning (CAL) have been designed by some of the pharmacology departments to overcome these limitations. These programmes mimic the actual experimental set up in the laboratory\textsuperscript{21}.

- CAL is an effective method of teaching practical aspects.
- Many experiments can be demonstrated in a short time\textsuperscript{20}.
- Avoids use of animals\textsuperscript{20}.
- Exercises difficult to be conducted in the laboratory can be demonstrated using CAL\textsuperscript{21}.
- No experimental errors are seen as in laboratory exercises.
• Achieving learning objectives easily\textsuperscript{21}.
• Understanding of the subject has improved as a result of using these simulations\textsuperscript{21}.
• Students prefer 1.5-2 hours per practice.
• Large majority of students have expressed the advantages such as reduction in use of animals, clear visualization of drug effects\textsuperscript{15}.

\textbf{Limitations:} Since no direct interaction with living tissue is involved, therefore fun of making observation is missed\textsuperscript{22}.

• Students might easily forget details. Experiments performed in laboratory are easier to remember.
• These experiments use prefixed doses. Therefore, variations in response as observed in living tissue cannot be observed\textsuperscript{22}.
• It requires expertise to handle problems related to computers.
• CAL is an expensive method of teaching\textsuperscript{22}.

\textbf{Problems in tissue based experiments:} One of the major problems of performing tissue based experiments is the variability in tissue response. There are certain other limitations while carrying out the routine animal experiments. A few of them include lack of ready availability of animals, cost of purchasing and maintaining them are major constraints in many institutions, and also large animals like dog and cat are difficult to handle during demonstrations in the laboratory etc\textsuperscript{23}. Although traditional live animal experiments are invaluable, they do have shortcomings, and their cost effectiveness has been questioned. Apart from being time consuming, animal experiments can only test a limited number of drugs at a given period of time. Furthermore, animal experiments, in particular whole animal studies, are often labour-intensive and costly\textsuperscript{21}.

\textbf{Student response:} The general impressions gained from students regarding both the computer simulation and the actual laboratory practical were good. The overall view was expressed that they
found the two exercises interesting and educationally beneficial. It was found that there was no distinguishable opinion as to the usefulness of the simulation towards the practicalities of setting up the experiment. Moreover, this conviction was not markedly affected by the reproducibility designation (i.e., good, medium or poor) for each group as a whole.

Both CAL and laboratory practical classes are valuable tools for education in biomedical disciplines like the pharmaceutical sciences. The role of computer simulation however, should not be to totally replace ‘hands-on’ experiments in the laboratory, but to provide students with the opportunity to be exposed to variables in a different medium to those experienced in a real experiment\(^2^4\). The value of such an approach can only be augmented by manipulation of simulated variables in order to generate numerical or graphic data coupled with active mental and/or written formulation of concepts and hypotheses on the part of students. It is therefore essential that the merits of both forms of teaching are considered and that a balance is struck in the armory of the educationalist\(^2^5\). This can only be to the advantage of students receiving such equity.

Computer assisted learning (CAL) appear to be feasible and effective as a major part of practical lessons of pharmacology. Given the learning objectives of pharmacology practical lessons in pharmacy students is to enhance students understanding of the subject, computer-simulations may serve as an alternative to the traditional live animal experiments. Hence the computer simulation techniques can be implemented in other universities also.
REFERENCES


TABLES

Table 1. Student questionnaire on CAL (Computer Assisted Learning) and laboratory based Pharmacological practical.

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Question</th>
<th>SA</th>
<th>A</th>
<th>NO</th>
<th>D</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Computer simulation is more enjoyable and time saving then laboratory practical.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Computer simulation is easy to perform then laboratory practical.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Computer simulation contributes more to understanding theoretical concepts viz. Terms, dose and concentration then laboratory practical.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>In computer simulation no experimental error are seen as in laboratory practical.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>I would prefer to have done the experiment with computer simulation then laboratory practical.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Computer simulation is the best alternative to laboratory practical.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SA= Strongly Agree; A= Agree; NO= No Opinion; D=Disagree; SD= Strongly Disagree.
Table 2. Response of students in student questionnaire on CAL (Computer Assisted Learning) and laboratory based Pharmacological practical.

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Question</th>
<th>SA</th>
<th>A</th>
<th>NO</th>
<th>D</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Computer simulation is more enjoyable and time saving than laboratory practical.</td>
<td>9</td>
<td>17</td>
<td>2</td>
<td>2</td>
<td>8</td>
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<tr>
<td>2.</td>
<td>Computer simulation is easy to perform than laboratory practical.</td>
<td>17</td>
<td>18</td>
<td>0</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>3.</td>
<td>Computer simulation contributes more to understanding theoretical concepts viz. Terms, dose and concentration than laboratory practical.</td>
<td>16</td>
<td>5</td>
<td>11</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>4.</td>
<td>In computer simulation no experimental error are seen as in laboratory practical.</td>
<td>12</td>
<td>18</td>
<td>3</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>5.</td>
<td>I would prefer to have done the experiment with computer simulation than laboratory practical.</td>
<td>8</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>6.</td>
<td>Computer simulation is the best alternative to laboratory practical.</td>
<td>5</td>
<td>14</td>
<td>7</td>
<td>7</td>
<td>5</td>
</tr>
</tbody>
</table>

SA= Strongly Agree; A= Agree; NO= No Opinion; D=Disagree; SD= Strongly Disagree. Total number of students: 38
FIGURES

Figure 1
Figure 3
Figure 5

Awareness

Analysis of needs

Preparing staff
Preparing support
Preparing location

Acquire program

Implementation

Evaluation and proceeding
Figure 6

Response of Questions

Number of Persons

SA, A, NO, D, SD
Figure 7

Percentage of students

- Strongly Agree: 23.684%
- Agree: 44.736%
- No Opinion: 5.263%
- Dis-agree: 5.263%
- Strongly Dis-agree: 21.052%
Figure 8

Percentage of students

- Strongly Agree: 44.736
- Agree: 47.36
- No Opinion: 5.263
- Dis-agree: 2.631
- Strongly Dis-agree: 0
Figure 9

Percentage of students

- Strongly Agree: 42.105
- Agree: 28.947
- No Opinion: 13.157
- Dis-agree: 10.526
- Strongly Dis-agree: 5.26
Figure 10

Percentage of students

- Strongly Agree: 31.578
- Agree: 47.368
- No Opinion: 7.894
- Dis-agree: 7.894
- Strongly Dis-agree: 5.263
Figure 12

Percentage of students

- Strongly Agree: 13.157%
- Agree: 36.842%
- No Opinion: 18.789%
- Dis-agree: 18.789%
- Strongly Dis-agree: 13.157%
FIGURES CAPTIONS

**Figure 1:** X-Cology software demonstrating tissue response on kymograph.

**Figure 2:** An interface showing video demonstration showing isolation and mounting of frog heart\(^{19}\).

**Figure 3:** An animation showing the mechanism of action of an antihypertensive agent (taken from a tutorial-type software package).

**Figure 4:** An interface showing video demonstration of effects of drugs on dog blood pressure and heart rate.

**Figure 5:** Flow diagram of steps to be taken for the introduction of Computer assisted Learning (CAL).

**Figure 6:** Each column represents the mean ± S.E.M. value of student response. Superscript * and \(^{5}\) denotes statistically significant different. (\(^{5} = P<0.05\) SA vs. NO, D and SD), (* = P<0.01\) A vs. NO, D and SD). (One way ANOVA followed by Newman-Keuls Multiple Comparison Test).

**Figure 7:** Computer simulation is more enjoyable and time saving than laboratory practical.

**Figure 8:** Computer simulation is easy to perform than laboratory practical.

**Figure 9:** Computer simulation contributes more to understanding theoretical concepts viz. terms, dose and concentration than laboratory practical.

**Figure 10:** In computer simulation no experimental error are seen as in laboratory practical.

**Figure 11:** I would prefer to have done the experiment with computer simulation than laboratory practical.

**Figure 12:** Computer simulation is the best alternative to laboratory practical.