Critical Issues in Distance Science Lab Practicals

A Study

National Centre for Innovations in Distance Education

Indira Gandhi National Open University

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Contents

1. Introduction

Science is the fundamental driving force for the development of any society. Science education, therefore plays a pivotal role in developing the human resource with the necessary knowledge and skills that are required for a science driven developing society. On the occasion of Inauguration of 96th Indian Science Congress, 2009 in Shillong, Meghalaya, Prime Minister, Dr. Manmohan Singh said "Science education is a fundamental requirement for any modern nation to meet the challenges and avail of the opportunities of our modern scientific and technologic age."[1]

Science education is a compulsory element of today's education system. Science education helps in human resource development for further research activities, is also important for growth and development in essential aspects of health, agriculture, energy, food, travel etc. Science education, thus, plays a vital role in the betterment of human beings in the society and the development of a nation as a whole.

Lab practicals in science education

Science generates theories and laws, which are subject to observations. The laboratory is a vital environment where these observations are carried out. The evidence generated by the observations helps to validate or discard the theories and laws. According to the declaration of National Science Teachers Association, USA, for science to be taught properly and effectively, labs must be an integral part of the science curriculum. Laboratory experiences should help learners learn to work independently and collaboratively, incorporate and critique the published work of others in their communications, use scientific reasoning and appropriate laboratory techniques to define and solve problems, and draw and evaluate conclusions based on quantitative evidence. Labs should correlate closely with lectures and not be separate activities.[2]

In UK the SCORE (Science Community Representing Education), a Science Community Partnership Supporting Education, regularly takes up studies on the importance of lab practicals. The members of SCORE are the Association for Science Education, the Institute of Physics, the Royal Society, the Royal Society of Chemistry, the Science Council and the Society of Biology. In one such study, SCORE brought out several important presented below[3].

According to SCORE, 'practical activities' can be put into three broad groups:

1. Core activities: Core activities include

- Investigations
- Laboratory procedures and techniques
- Fieldwork

2. Directly related activities: These include

- Designing and planning investigations
- Data analysis using ICT
- Analysing results
- Teacher demonstrations
- Experiencing phenomena

3. Complementary activities. Complementary activities include

- Science-related visits
- Surveys
- Presentations and role play
- Simulations including use of ICT
- Models and modelling
- Group discussion

Practical work in science mostly includes the core activities and the directly related activities. The complementary activities are important in supporting the development of conceptual understanding in science through practical work. These three components should be taken into account while designing and delivering science lab practical courses.

Science Education through Open and Distance Learning

Science and mathematics based subjects are traditionally the hardest to teach at a distance because of the lab components. However, the Indira Gandhi National Open University (IGNOU), India, is involved in teaching science and engineering.

For these courses, IGNOU provides self learning print material. In addition, it also provides audio and video cassettes, CDs, face-to-face counseling sessions, interactive radio counseling, and live television programmes through Gyan Darshan channels. The School of Science and the School of Engineering and Technology at IGNOU are responsible for developing various diploma, certificate and degree programmes in science and engineering respectively.

In distance science education learners are called upon to do practicals in study centres under the guidance and supervision of counselor. They train the learners in handling various equipments, apart from encouraging them to take independent unbiased observations. They also explain the concepts which are not understood by the learners while going through their self instructional material. However, the exposure of the distance science learners of IGNOU to the lab practicals is grossly inadequate, comprising only fifteen days in a year. This clearly means that the distance science learners do not get the chance to carry out lab activities over a long period of time to master the techniques. They only get to familiarize themselves with some aspects of lab practicals.

ICT in science education

To overcome many of the challenges of access and quality in lab based courses, attempts have been made worldwide through the innovative use of Information and Communication Tools (ICT). Examples include simulated experiments and virtual labs. The success rate of these attempts of using ICT has been varied. There have been doubts raised on the pedagogical effectiveness of such endeavours. The IGNOU is yet to offer ICT based solutions for its science learners. The possibility of using ICT for distance science study thus needs to be explored at IGNOU.

Objectives of the study

- to identify the difficulties faced by the distance science learners of IGNOU, with special reference to the laboratory practicals**.**
- to gain useful insights into the teaching and learning methods of science practicals in the lab sessions of IGNOU**.**

- to gain useful insights for designing simulated environments for science experiments for the learners of IGNOU.

2. Design of the Study

a. Sample: This study was carried out on the IGNOU graduate science learners from Delhi in their second and final year of study. The sample size was a total of 61 learners.

b. Methodology: A questionnaire was employed for the study (Annexure I). The questionnaire was structured with objective type questions, questions employing the five point Likert scale and open ended questions for suggestions.

3. Results

The data was analyzed and the results are presented below:

(i) Satisfaction with the course materials: The learners were asked about their satisfaction levels with the course materials provided on the programme. The learners were satisfied with the course material with about 54 % saying they were satisfied and about 44 % saying they were very satisfied (Figure 1).

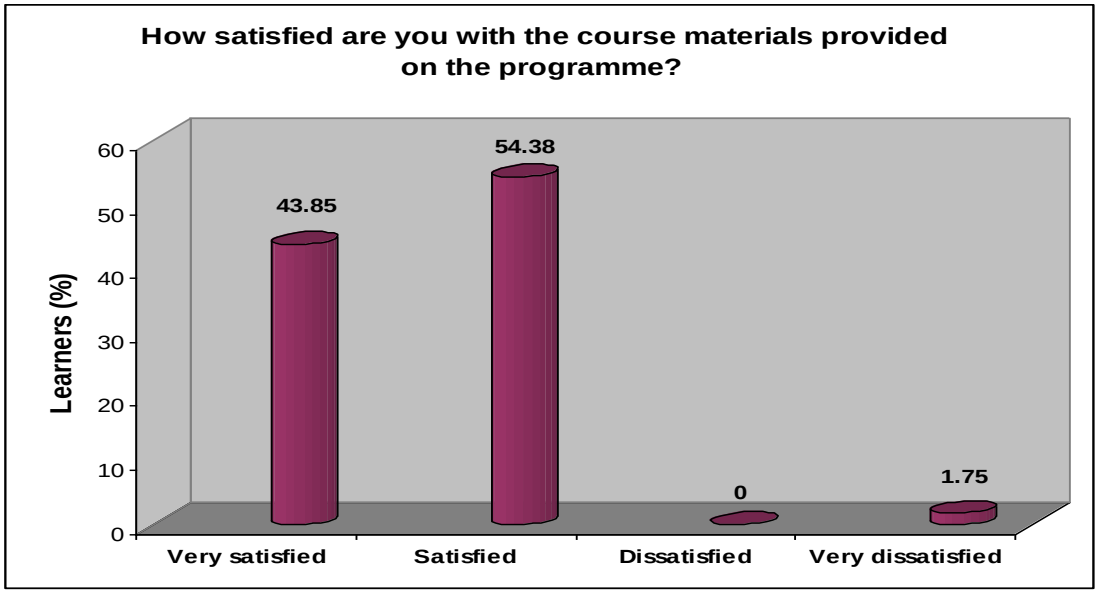

Figure 1. Learner satisfaction with the course material.

(ii) Inclusion of practical work through lab sessions: The learners were asked if they thought it essential for a science course to include practical work through lab sessions even though the course materials are delivered in a distance mode of education. Almost all the learners said it was essential, with about 75 % saying very essential and about 25 % saying essential (Figure 2).

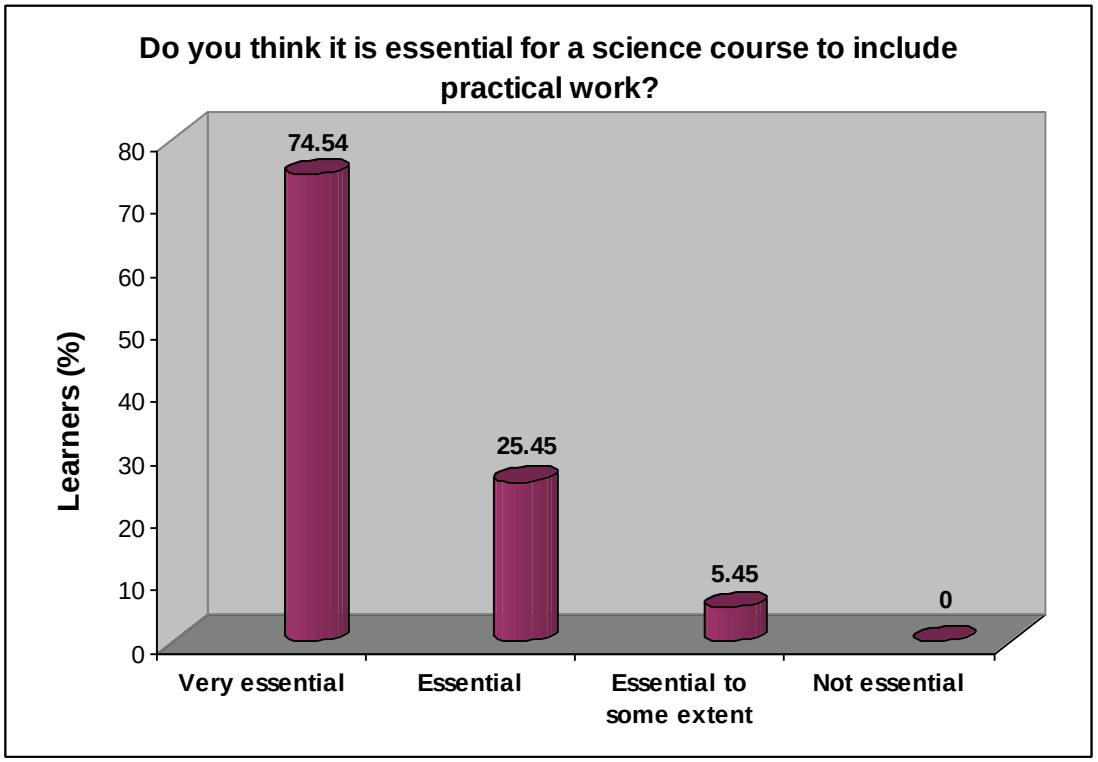

Figure 2. Percentage of learners finding it essential for a science course to include practicals.

(iii) Experience of lab sessions at IGNOU: The learners were asked that since they had undergone lab sessions during the course of their study, what was their experience. They were asked about how the lab experience helped them based on nine parameters viz., a) bring a new perspective of learning science, b) learning how to use experiment tools, c) improving practical skills, d) understanding the course material better, e) prepare for examinations, f) complete an assignment, g) sustain interest in the course subject, h) interact with classmates and exchange knowledge, and i) interact with tutor/counselor.

a. **A new perspective of learning science**: About 58% of the learners said that the lab experience brought them a new perspective to learning science

highly. About 8 % said they were not able to gain any new perspective (Figure 3).

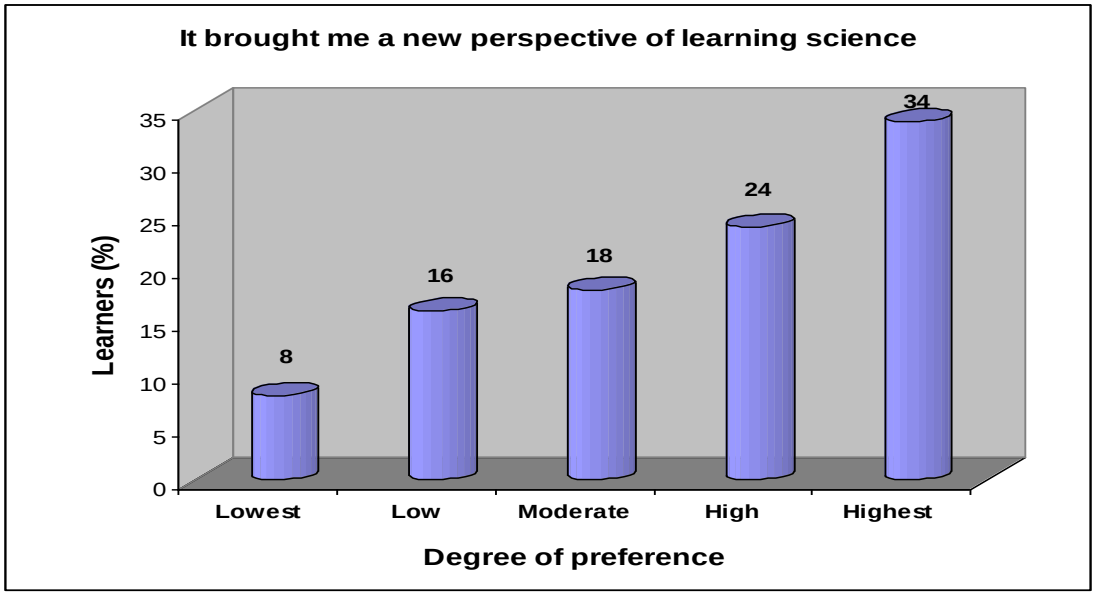

Figure 3. Percentage of learners saying lab practicals brought a new perspective of learning science.

b. **Learning how to use experiment tools**: About 70 % of the learners said that the lab sessions helped them in learning how to use the tools that are required to carry out an experiment (Figure 4).

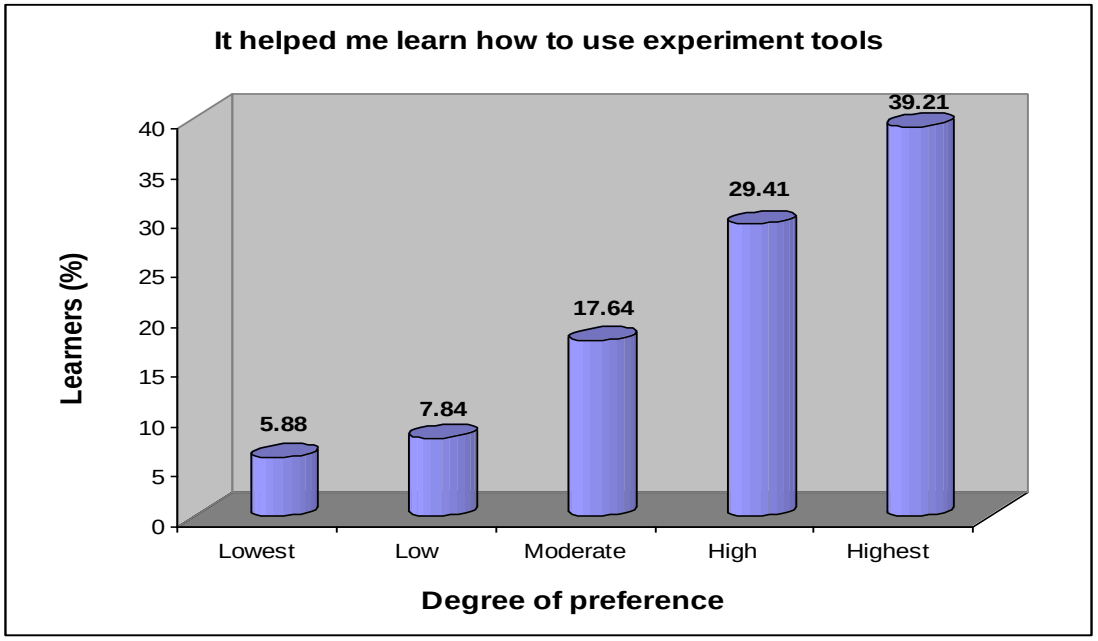

Figure 4. Percentage of learners saying lab practicals helped them learn how to use experiment tools.

c. **Improving practical skills:** About 53 % of the learners said that the lab sessions helped very much in improving their practical skills (Figure 5).

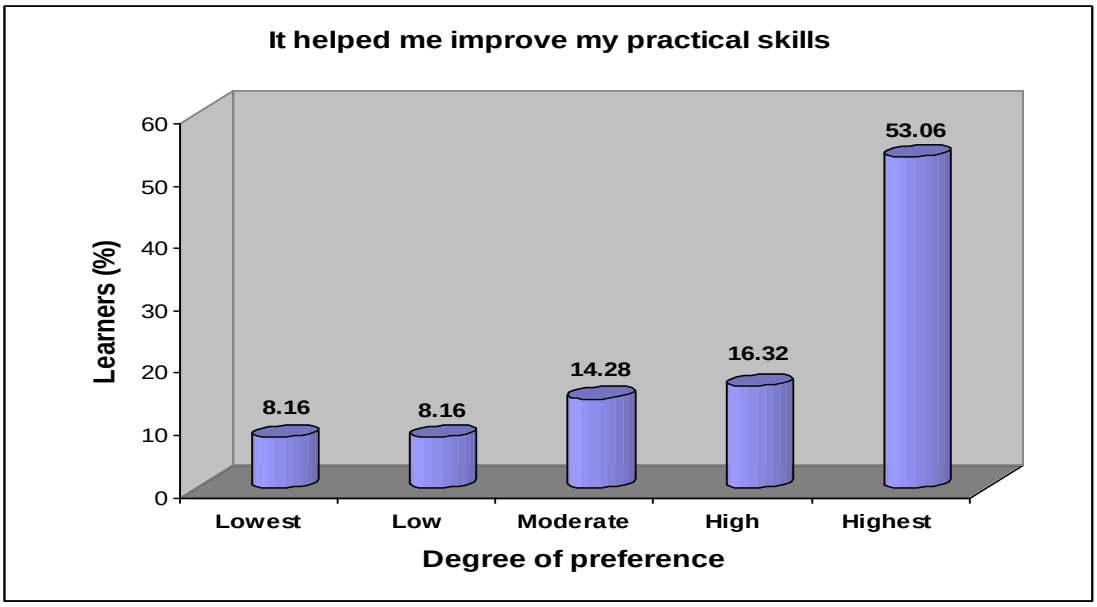

Figure 5. Percentage of learners saying lab practicals helped them improve their practical skills.

d. **Understanding the course material better:** About 65 % of the learners said that the lab sessions helped them in understanding the concepts provided in the course material better (Figure 6).

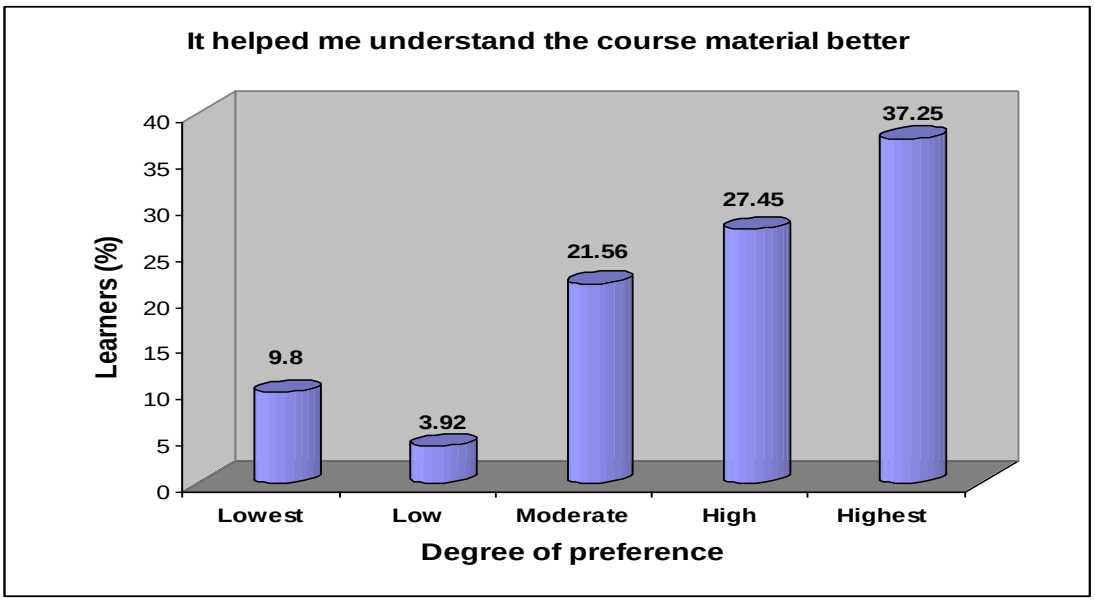

Figure 6. Percentage of learners saying lab practicals helped them understand the course material better.

e. **Preparation for examinations:** About 30 % of the learners said that the lab sessions helped them very much in preparing for the exams. About 52% of the learners said the lab sessions helped them in preparing for the exams from a high to moderate extent (Figure 7).

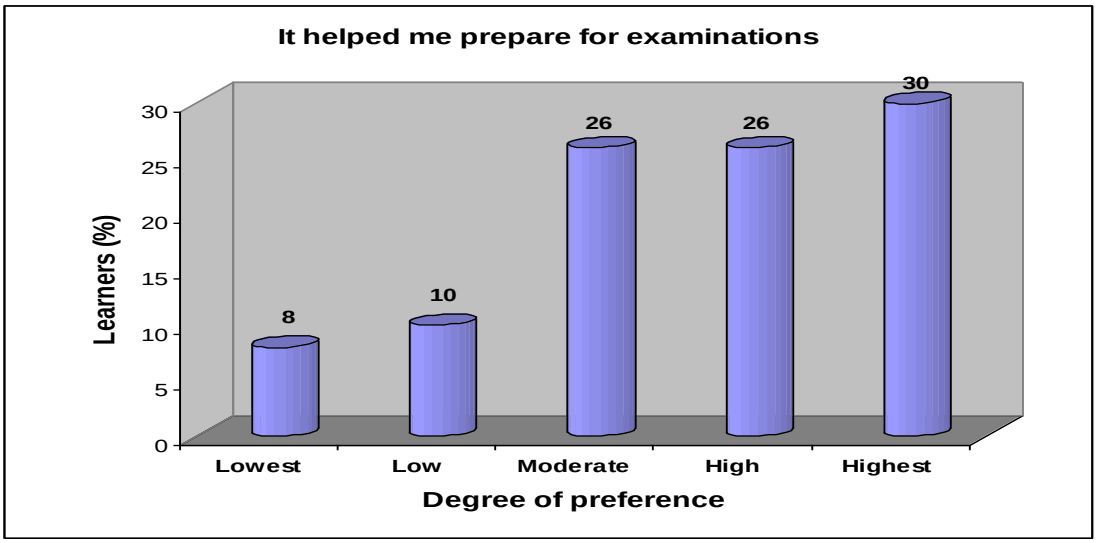

Figure 7. Percentage of learners saying lab practicals helped them prepare for their exams.

f. **Complete an assignment:** About 50 % of the learners said that the lab sessions helped them in completing the assignment whereas about 32 % of the learners said it did not help much (Figure 8).

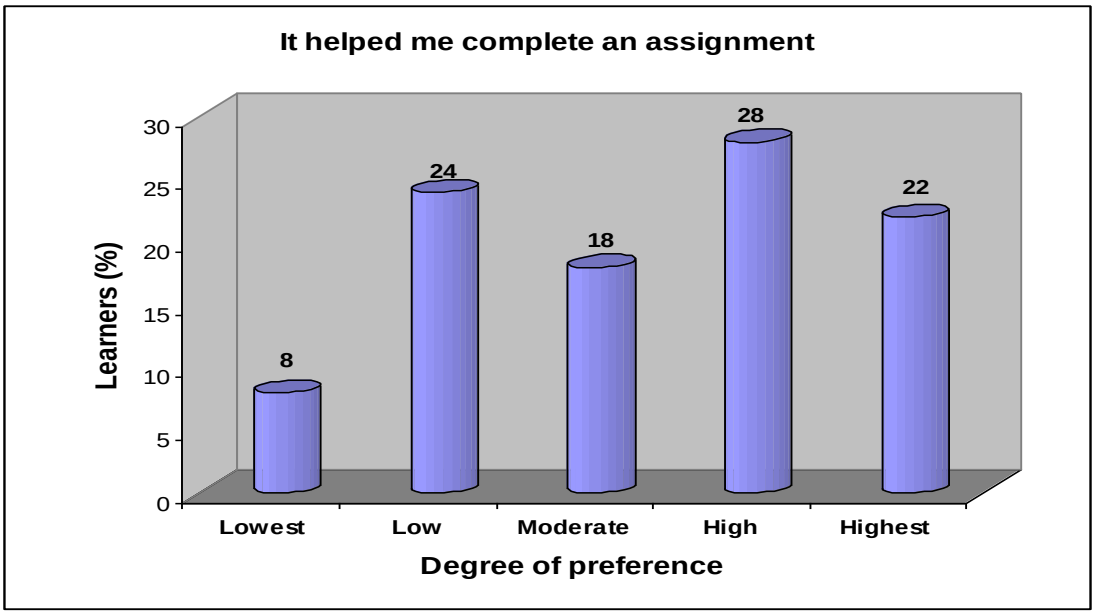

Figure 8. Percentage of learners saying lab practicals helped them complete their assignments.

g. **Sustain interest in the course subject:** About 72 % of the learners said that the lab sessions helped them in sustaining interest in the course, with about 46 % learners expressing high satisfaction (Figure 9).

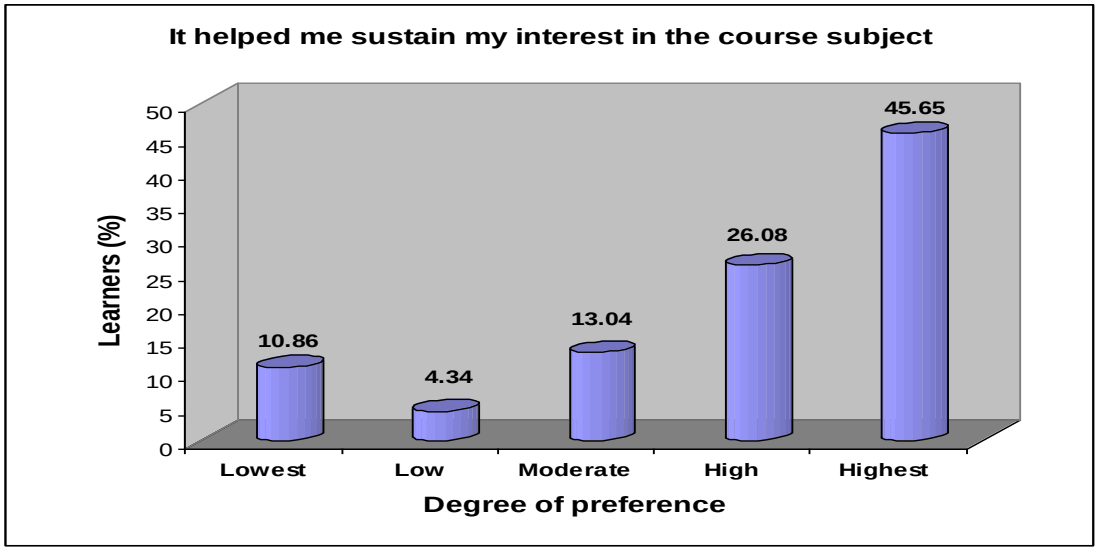

Figure 9. Percentage of learners saying lab practicals helped them sustain interest in the course.

h. **Interact with classmates and exchange knowledge:** About 58 % of the learners said that the lab sessions highly helped them to interact with their classmates and gave them the opportunity to exchange knowledge (Figure 10).

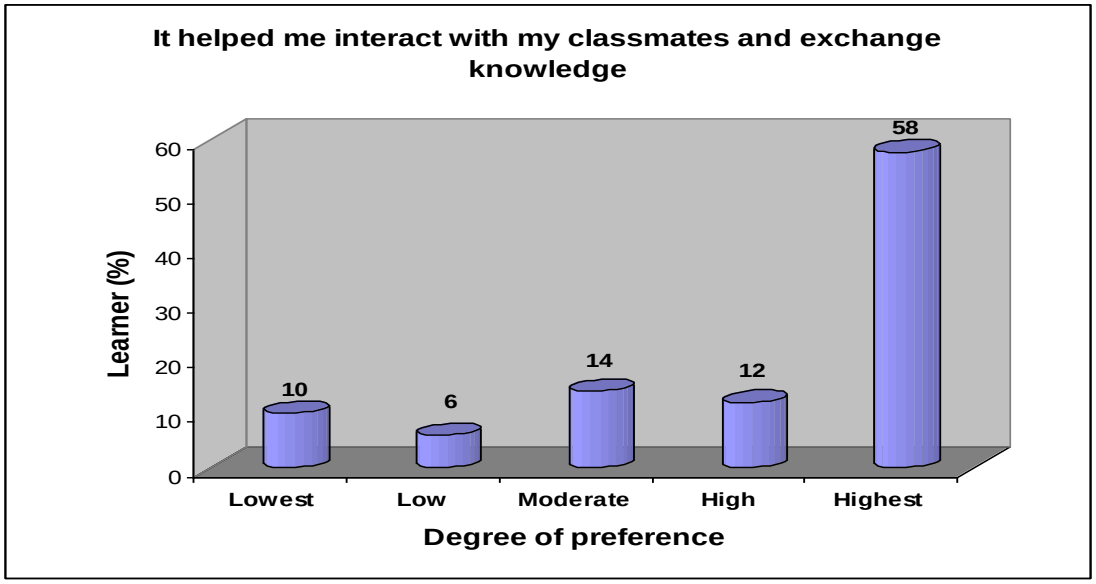

Figure 10. Percentage of learners saying lab practicals helped them interact with peer groups and exchange knowledge.

i. **Interact with tutor/counselor:** About 56 % of the learners said that the lab sessions highly helped them to interact with their tutor/counselor (Figure 11).

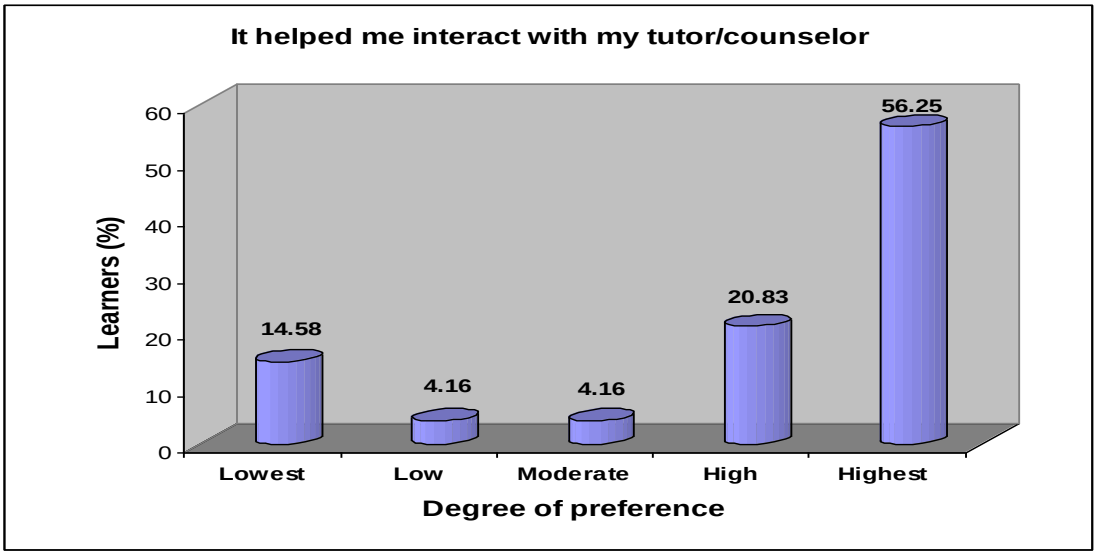

Figure 11. Percentage of learners saying lab practicals helped them interact with tutor/counsellor.

(iv) Range of support provided in the laboratories: Almost all learners were satisfied with the support provided in the laboratories with about 35 % saying highly satisfied and about 59 % saying satisfied (Figure 12).

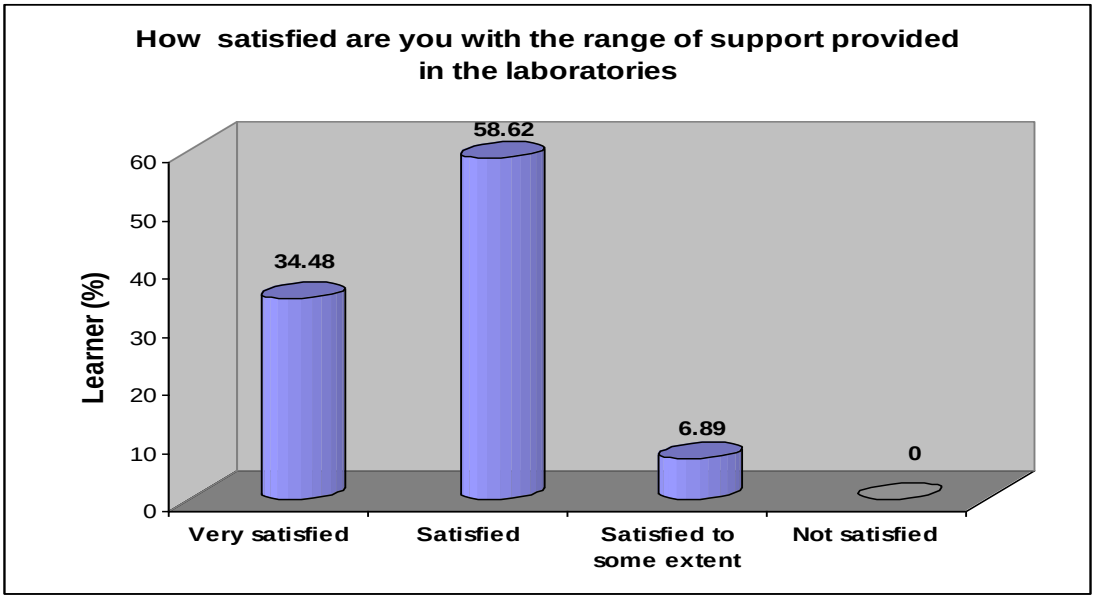

Figure 12. Percentage of learners expressing satisfaction levels with the range of support provided in the laboratories.

(v) Aspects of support the learners liked or disliked: The following feedback was provided by the learners on the aspects of laboratory support they liked or disliked:

Like

a) The laboratory environment is very useful for learning as it gives practical exposure to the subjects
b) Direct interaction with faculty is very useful as we get cooperation and guidance and all possible help from them
c) Way of teaching during the entire session is good
d) Vivas are taken time to time

Dislike

a) The lab practicals are carried in one lot and time period to understand the vast content is very less.
b) Frequency of lab course is less.
c) We dislike the lack of time.
d) IGNOU should give more time for guided practicals.
e) Only 14 days were not sufficient and IGNOU should make their own labs instead of using labs of other universities.
f) The lab classes should be arranged in time.
g) Dislike the policy of minimum number of learners compulsory for the practical sessions.
h) Proper instruction is lacking.
i) We require competent teachers who can help us do practical efficiently.
j) More efficient tutors and more material in lab are required.
k) Usually instruments provided by the study centres are of poor/defective quality and sometime insufficient in quantity.
l) Apparatus are not sufficient to fulfill our needs.

(vi) Areas of lab support, which could be improved: The feedback from the learners suggest the following areas of lab support that could be improved:

a) More interaction of the teachers with learners regarding practicals. Especially, in chemistry practicals, the teacher guidance should be increased
b) Time span of the lab sessions should increased. It should be distributed along the whole year.
c) The time should be flexible because most of the learners of IGNOU are working and for them it is very difficult to give 15 continuous days for practicals.
d) If it is possible to lab schedule should be with regular counselling sessions, so that we can easily clear the lab course Give more time for doing any practical which are essential for further study in these fields.
e) Lab practicals should be conducted on Saturdays and Sundays so that employed persons can attend.
f) Instruments and number of labs for each course should be increased.
g) More instruments with better technology should be provided that would help us to learn more.
h) The material provided for the practical are not proper and sufficient, chemicals for practical are usually not available. These should be taken care of.
i) Some experiments which are cancelled and which are difficult to perform should be eliminated from the course.
j) Virtual lab, computers and teaching aids should be provided to the learners.

(vii) Advantage of lab experiments over computer simulations: About 70 % of the learners said that lab experiments had an advantage over computer simulations. About 30 % said that lab experiments did not have any advantage over computer simulations (Figure 13).

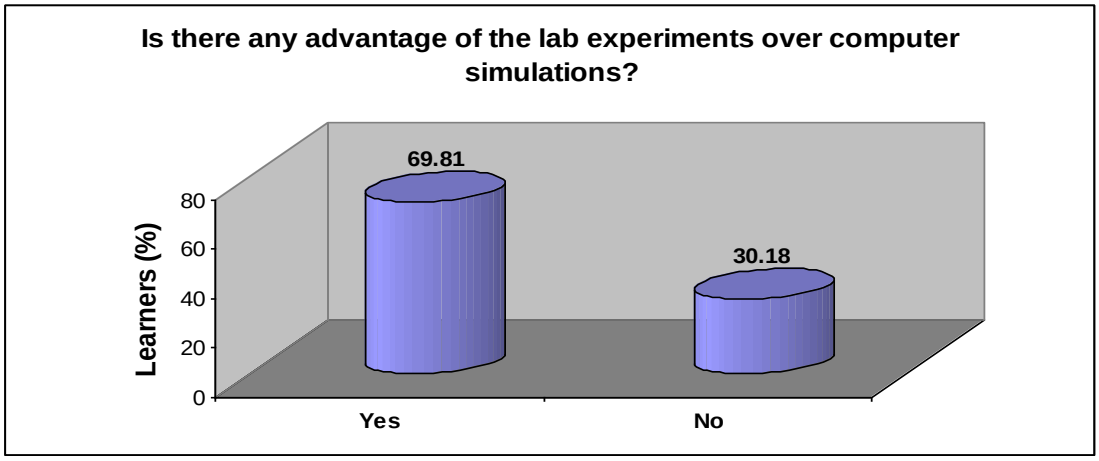

Figure 13. Percentage of learners agreeing or disagreeing to the advantage of lab experiments over computer simulations.

(viii) Supplementing lab experiments with simulations: About 63 % of the learners said that lab experiments should be supplemented with simulations (Figure 14).

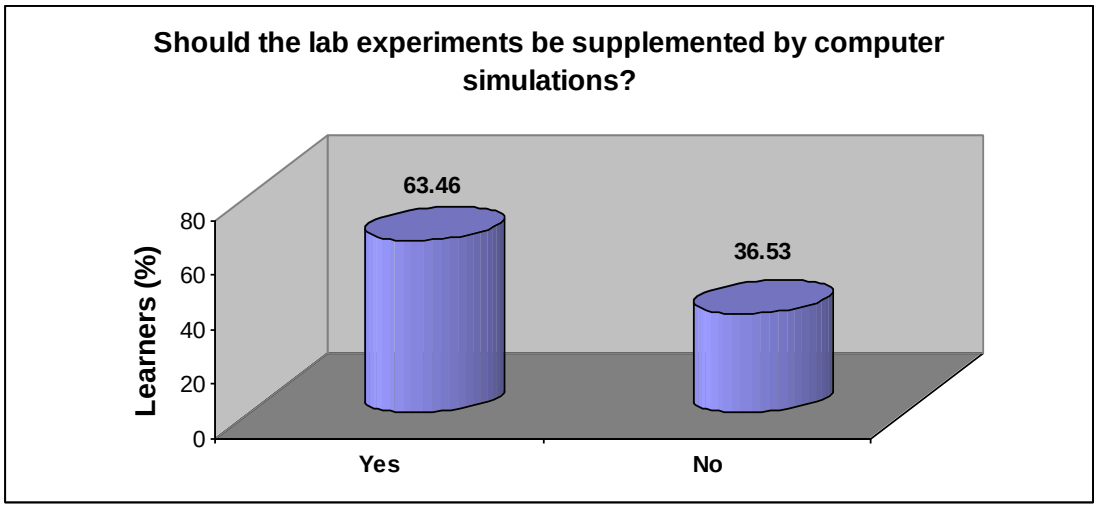

Figure 14. Percentage of learners agreeing or disagreeing to supplementing lab practicals with simulations.

(ix) Doing experiments through simulations. A majority of the learners (83 %) said that they had not tried doing experiments with simulations (Figure 15).

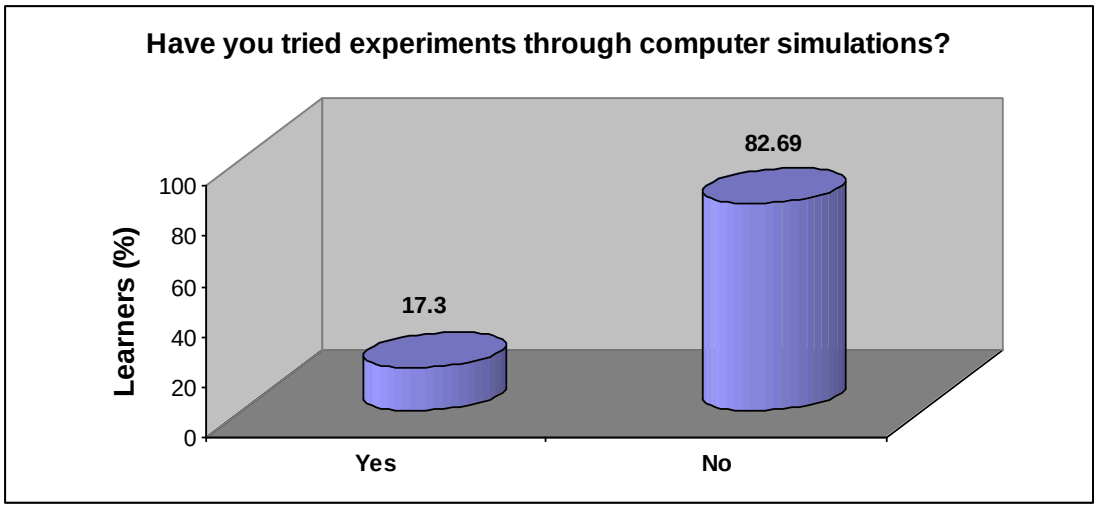

Figure 15. Percentage of learners who tried experiments through simulations.

(x) Do simulated experiments make science learning difficult or easy?: About 74 % of the learners said that simulated experiments make learning science easy whereas 26 % said that it makes learning difficult (Figure 16).

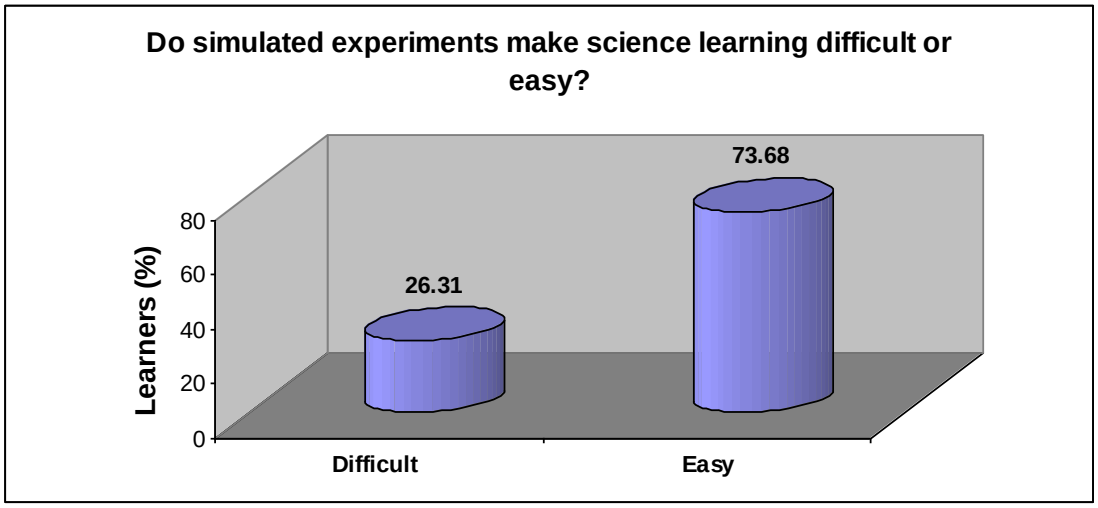

Figure 16. Percentage of learners saying simulated experiments make science learning easy or difficult.

(xi) If you found it difficult to learn from simulated experiments, what could be the possible reasons?

- It will be easy to understand but practically we will not be able to perform.
- Lack of proper information.
- The way of going through these experiments is difficult.

- The study centre doesn't provide this facility.
- Extra syllabus

(xii) Please give your suggestions on how simulated experiments can be designed to make them more learner friendly:

- The experiments should be made according to the learners and also it is important that the counselor should be helpful.
- More efficient information and instruction must be provided.
- It is better if we are able to ask our questions through mails etc. and a person is able to answer them.
- Availability of computers and study centre cooperation is required

(xiii) If you have encountered any kind of difficulty during practical sessions, please mention here:

- It is difficult to take continuous 15 days leave from the job and it would be better if the practicals should be taken on Saturdays and Sundays.
- Insufficient time for practicals.
- Practicals were not arranged in time due to which I lost my precious one year.
- Teachers are not available on time.
- Lab instruments are either not available or not working properly.
- Lab Assistants are not supportive. They don't care about IGNOU practicals because they are employees of other universities.
- Rude behaviour of staff.
- Do not get the proper attention like regular learners.

(xiv) If you have any suggestion to make the science practical sessions of IGNOU more effective and interesting, please mention below:

- Science practical sessions would be effective when the sessions are increased and all learners should have access to the sessions.
- Increase the number of labs for each course and one or two study centres must be made specialized for practical courses.

- The practicals should be held on the weekends and once or twice in a week to enable continuous learning and sustain our interest.
- Written work should be less.
- The need of the new generation should be catered to. More learner-learner interaction should be encouraged and motivation factor should be there.
- IGNOU should maintain and arrange its own laboratories, so that learners get enough time and space to complete the practicals.
- The duration of lab session should increase so that we get enough time to gain mastery in every section.
- Should have and its own effective staff in all the study centres
- The IGNOU study centres should be fully computerized.
- Every study centre should have practical classes.
- Introduce problem solving classes after practicals.
- The practical sessions can become more interesting if the duration is reduced.

4. Discussion

Teaching and learning science at a distance has been a challenge for both the teachers and learners of IGNOU. Several issues are critical in teaching-learning of science through distance education. These include the pedagogical, managerial and technological issues.

Pedagogically, the science course material of IGNOU has been strong, and this has been substantiated by the learners in this study. Almost all the learners are satisfied with the course material (Figure 1). The theory and lab parts are well written by experts in the subject, taking care of the pedagogical principles of distance learning. The lab activities include the core activities such as investigations, laboratory procedures and techniques, and fieldwork in many cases. Directly related activities, such as demonstrations and experiencing phenomena are also taken care of by the counsellors and through ICT, such as Gyan Darshan and Edusat Sessions. Training in designing and planning

investigations, and analyzing results are also imparted in the counselling and lab sessions.

The learners of IGNOU, when asked about their lab experience, came out with extremely enthusiastic response about the lab sessions. The opined that the lab sessions helped in understanding the subject better (Figure 6) and also in sustaining their interest in science (Figure 9). The learners said that the experience brought a new perspective in learning science (Figure 3) as they were able to observe the phenomena themselves. They were able to learn how to use the tools and techniques and have a hands-on experience (Figure 4). Doing experiments enhanced their learning. Their skills were improved to a great extent (Figure 5).

The complementary activities such as science-related visits, models and modeling, and group activities are not commonly carried out in distance science learning through IGNOU. This aspect needs to be addressed carefully for a holistic learning experience.

The use of ICT in lab activities is very less, owing to several factors such as lack of infrastructure in IGNOU study centres, inaccessibility of the learners to these infrastructures etc. These issues will be covered below in the managerial aspect.

Managerially, the discrepancies in implementing science education at IGNOU seem to be quite glaring as evidenced from this study. IGNOU does not have labs of its own. The practical sessions of IGNOU are held in selected colleges of conventional Universities all over the country under a memorandum of understanding. The practical sessions in a year are held only for fifteen consecutive days. These two aspects of the practical sessions pose great challenges for the IGNOU learners as this study found out.

First, there is a slight sense of alienation among the learners of IGNOU when they go for practical sessions in the colleges. Several learners said that the staff of the colleges were rude and unsupportive to them. Second, the learners are not provided proper lab infrastructure by the colleges. The learners face a lack of

equipments, chemicals and other such tools that are necessary to carry out the experiments. Third, the equipments are old and the learners cannot access the latest equipments that are necessary for their continuous knowledge keeping in tune with the latest scientific know how. Fourth, the learners do not have access to computers for studies and analysis in the study centres. This limits them from accessing digital repositories, knowledge stored in CDs and simulations. These issues need to be addressed at the earliest between the management of IGNOU and the colleges.

The science learners strongly feel that the time of fifteen consecutive days provided for practical sessions is very less. It does not allow them sufficient time to understand the techniques and master them. It does not allow them time to design their own experiments and carry them out. The time is so short that they tend to forget their knowledge and skills needed during the exams. Several learners are working and it becomes impossible for them to take leave from their jobs for fifteen consecutive days. The learners also pointed out in this study that there is a lack of management in the programme schedule and communication to the learners, due to which they suffered. These challenges that the science learners face in the course of their learning need to be sensitively sorted out. The problems faced by the learners of IGNOU are unique and this calls for unique and innovative managerial solutions.

Technologically, IGNOU has made advances in employing ICT in imparting science education. The Gyan Vani, Gyan Darshan and Edusat sessions provide the learners with scientific knowledge through talks, interviews, documentaries of phenomena and experiments etc. However, the science courses at IGNOU are yet to design and develop computer and internet based learning, such as online learning, simulations and virtual labs.

Simulated lab experiments are envisioned to provide the learner with skills and knowledge required to use real equipments in a real laboratory. If simulated lab experiments are properly designed, it might help those learners, who do not have access to laboratories all through the year, in practicing their practical skills at their convenience. This study explored some options regarding the use of simulations in lab practicals. When the learners were asked if simulated

experiments should be used, a majority of them said that the simulations should be used for supplementing the course material (Figure 14). They suggested that the simulations should be suitably designed based on the requirements of the learners.

Today science education is imparted in the world through real labs combined with virtual labs and remote labs[4]. There are several advantages and disadvantages of real, virtual and remote labs. The real labs provide interaction with real equipment and realistic data besides interaction with guides and peers. The disadvantages of real labs as faced by distance learners is that there are time and place restrictions. Further, there are managerial and infrastructural problems as described above.

The disadvantages of real labs can be mitigated to a small extent by supplementing with simulated experiments in virtual labs. The simulated environment of virtual labs is pedagogically good for explaining the theoretical concepts in an interactive mode. It is cost effective as well. Although the disadvantages include non-interaction with real equipment and lack of guide and peer collaboration, it can be used in many areas. They provide a safe learning environment for experimentation with dangerous equipments and chemicals.[5] The Howard Hughes Medical Institute has developed a commendable website with several virtual labs[6]. Some of the virtual lab series produced by Howard Hughes Medical Institute are "The Transgenic Fly", "The Bacterial Identification Lab", "The Cardiology Lab", "The Neurophysiology Lab" and "The Immunology Lab". The internet abounds with similar websites that provide virtual labs and simulations[7].

Serious experimentation with remote labs is going on worldwide. The Massachusetts Institute of Technology is developing iLabs- internet accessible online labs[8]. The aim of iLabs is to enrich science and engineering education by greatly expanding the range of experiments that learners are exposed to in the course of their education. Unlike conventional laboratories, iLabs can be shared across a university or across the world[9]. The iLabs vision is to share expensive

equipment and educational materials associated with lab experiments as broadly as possible within higher education and beyond. Such innovative facilities can be easily adapted and made available to the learners of IGNOU.

5. Conclusion and Recommendations

The above discussion leads us to conclude that the issues and challenges in the way of science learning at IGNOU are mostly managerial and technological in nature. The pedagogical part is quite strong but the complementary activities of lab practicals, which comprise presentations and role play, simulations including use of ICT and group discussion should be included to increase holistic learning and understanding of the science subject. It is possible to take care of these pedagogical issues to a large extent through ICT.

The findings in the study point to several discrepancies in managerial aspects that need to be addressed. These discrepancies can be strenghthened through technological innovations to some extent. Based on the above findings, the following are recommended.

Recommendations

1. The infrastructure of the science labs needs to be revisited. Wherever necessary, it should be ensured by the management of IGNOU and the college concerned that the requirements of the learners, such as equipments, chemicals etc. should be met well.
2. The computers and internet facility at the study centres should be made available and accessible to the science learners. This would help the learners to digitally analyze their data, and also to access educational resources, simulations, virtual and remote labs through the internet.
3. If possible, the total days of lab sessions should be increased. Also, instead of fifteen consecutive days, it should be spread over the entire duration of the course. The weekend days should be included for the convenience of the learners.
4. Effective solutions should be developed using ICT for management of information regarding lab practicals, such as the topics of the day, date and

time of the lab sessions and exams, name and phone number of the counselor, the names of the group members, and any other related information. The information should be sent to the learners on their mobiles and emails.

5. ICT based solutions should be developed for holistic learning through simulations, where the learner can learn anytime from anywhere at their own pace. This will supplement the lab practical sessions and make the learner more informed about the state of the art technology being used in current science and technology all over the world.

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