INTEGRATION OF INFORMATION AND COMMUNICATION TECHNOLOGY WITH PHYSICS EDUCATION FOR EFFECTIVE LEARNING

P.C. Agarwal
Principal and *Professor* in Physics,
Regional Institute of Education
NCERT, Bhubaneswar
E-mail: pcagca@yahoo.com

V.P. Arya
Assistant Professor
Regional Institute of Education,
NCERT, Ajmer
E-mail: aryavedp@yahoo.com

Introduction

It is well known that technology has affected all walks of our life in a big way. One such technology is Information and Communication Technology (ICT). Gone are the days when we used to struggle for getting timely information and for communicating from one place to another. Today, vast sea of information appears before us and we can communicate instantly to anyone anywhere in the world at one click. ICT has changed everything, be it commerce or rituals or political boundaries or even our way of thinking and education sector is not an exception. With the advent of ICT, changes which were never imagined before have happened in the field of education. Physics is a particular branch of science that deals with the matter, energy and their interactions. In a sense, it is one of the most fundamental branches which affect all the facets of our lives and hence, it is imperative for us to explore the nature through physical phenomena. Most of the time, in Physics, we have to deal with the unseen microscopic world which is beyond our sensory organs and it becomes really difficult to connect with the concepts underlying in those phenomena. Here comes ICT to our rescue, which can take us to an exotic world of Physics. For proper understanding of physical phenomena, interactions and processes, it is highly important to integrate ICT with the concepts of Physics. In this paper, we would like to explore some of the possible ways of integration with few suggestive examples.

Goals of Science (Physics) Education

Education can be best described as a societal activity which requires proper collaboration, cooperation and interaction to explore the already existing knowledge and at the same time, to create something new. Hereby teaching and learning in education are the two facets of the same coin. For effective teaching-learning processes, technology comes as an aid. Science in general and physics in particular require the element of critical thinking. According to a belief, learning best happens when it is individualised because every learner learns at its own pace and own readiness. In spite of their best pedagogical approaches, big size of classrooms poses a hurdle to teachers in implementing individualised learning. Here the shortcoming on the teacher's part may be overcome by the strength of ICT.

No one can deny the importance of science education in the present world for the development of scientific attitude among the people and for overcoming the problems of the world. It can really lead to a more just, more peaceful and more equitable society. Easy access to science education for the masses is only possible through ICT. This has been reflected in *National Curriculum Framework (NCF)* 2005, which advocates that "Information and Communication Technology (ICT) is an important tool for bridging social divides. ICT should be used in such a way that it becomes an opportunity equaliser by providing information, communication and computing resources in remote areas. ICT if used for connecting children and teachers with scientists working in universities and research institutions would also help in demystifying scientists and their work" (NCERT, 2005). Position paper on Science Education by NCERT also categorically says that ICT should be used in such a way that it becomes an opportunity equaliser, by providing information, communication and computing resources in remote areas (NCERT, 2006). It further adds that providing children more direct access to multimedia equipment and ICT, and allowing them to mix and make their own productions and to present their own experiences, could provide them with new opportunities to explore their own creative imagination. The paper stresses in the context of classroom that it should be such that it provokes questioning, discussions and debates and enhances students' metacognitive skills. It is clear from these documents that it is high time to take advantage of ICT in Science Education and we should think for the amalgamation of the two. Now let us know what ICT is and what it can do for us.

Information and Communication Technology (ICT)

ICT contains three words— information, communication and technology. In a way, it is the process of communicating information through technology. When we think of communication, it is a complex process which includes the source, the medium, the receiver and their interaction. Better communication can happen with the help of technology. ICT is generally defined as a diverse set of technological tools and resources used to transmit, store, retrieve, create, share or exchange information. ICT may include computers, Websites, social sites, live and recorded broadcasting media, multimedia, simulations, smart phones, etc. Proper selection of ICT tools for educational purpose is a very important and thoughtful activity which requires critical thinking and one has to keep in mind many factors like content, objectives of content, level of learners, their physiology, learners' demography, etc. Injudicious use of ICT may lead to overburden and frustration among the learners.

ICT in Teaching and Learning

Teaching and learning is a dynamic process which continuously evolves with time. Earlier, a teacher was the only source of information, but now there are multiple sources of information. Transfer of knowledge was thought to be one way process having giver-taker relationship. It is established now that the teacher's role is only as a manager and facilitator of learning and learner constructs their own knowledge and in the dynamic process of learning, continuously learns, unlearns and relearns. Teacher

and ICT have in common the elements of information and communication. There is slight difference among the two— ICT as such cannot take care of pedagogy and teacher has some limitations in terms of individual and fast communication. The shortcomings of the two can be tackled if these are integrated properly. Thereby, teacher and ICT complement and supplement each other. It is worth mentioning that using technology and making use of technology are two completely different things. Using technology means nondirected use of technology. Making use of technology leads to desired results and requires proper planning and proper training on the user's part. Tremendous amount of information and resources are available on Web and other ICT tools, which can stray the users from their desired objectives and can entrap them in eddies of uncertain and spurious facts or processes. A lot has happened in the field of ICT. In fact, it has revolutionised the whole process of teaching and learning. ICT can now be viewed as a virtual or surrogate teacher, who has far surpassed the conventional role of a teacher. Multifold aspects of teaching-learning process (including assessment) are being taken care by ICT in terms of e-learning, online learning and virtual learning. It has really paved a way for democratising the society with equal access of knowledge to everyone and helped in making an information based society.

Why use ICT?

ICT has many things to offer to education. Its evolution is phenomenal. Think of the situation when the teaching-learning process was confined within the school premises. Teachers, library and textbooks were the only sources of information. Compare this with today's scenario where plenty of knowledge is readily available just in the palm of your hand. It has altogether changed the way education was perceived. The list is very long, but following are a few key features of ICT which prompts us to make use of it:

- Accessibility
- Adaptibility
- Flexibility
- Augmented learning
- Cost effective
- Variety of information
- Reduction of communication gap
- Collaborative learning
- Higher cognitive processes
- Individualised education and global outlook
- Creation of new knowledge
- Promotes equity
- Real time (updated knowledge)
- Learner centred approach

NCERT's Initiatives in ICT

The National Council of Educational Research and Training (NCERT), being an apex advisory body to the government for school education has taken many steps to tap the potential of ICT in education. All the textbooks and other printed material developed by NCERT can be accessed online on e-Pathshala and other platforms. The National Repository of Open Educational Resources (NROER) is another

such initiative, where users can find e-content in abundance in the form of documents, audios, images, videos and interactive learning. Knowledge can be brought to the next level of cognition using such platforms. NCERT also telecasts high-quality educational programmes using the GSAT-15 satellite on SWAYAM PRABHA channel. In order to realise the goals of NCF 2005 and Digital India Campaign 2015, NCERT has also developed curricula for ICT in education for school system which aims for preparing the teaching-learning community to participate creatively in the establishment, sustenance and growth of knowledge (https//digitalindia.gov.in/, NCERT, 2017). This curricula is designed to promote creativity and problem solving.

Engaging in Physics Learning through ICT

Now we come to the central theme of the article, i.e., learning physics with the help of ICT. Professor Ootuka of Japan once said that the process of teaching physics will never be as efficient as it might be until good aids are generally available throughout the world (UNESCO, 1972). The time has now come when we are realising this through ICT. Physics is the study of processes related to the non-living world and deals with fundamental interactions and its manifestation in matter and energy. The interactions happening in the regime of microscopic scale are beyond our sensory perceptions and we have to understand them in an abstract manner. This abstractness often poses a great challenge for the learner. Experimentation and verification of the theory or postulate thereby becomes a challenge for the learners in the wake of lack of laboratory facility. Thus, the correlation of the concepts of physics with daily life is really a challange, which pushes the learners back from physics. This situation can be tackled with the help of ICT.

Tremendous efforts have been put around the globe to make physics learning an engaging, joyful, interesting and productive activity. The world of Web is full of the versatile physics material available in text, audio, video, animation, simulation, and multimedia format. Some of the available ICT resources useful for physics learning can be categorised as follows.

Social media

Social media refers to those virtual platforms where one can connect with the people around the globe to communicate, share and create their ideas. To mention a few, we can refer to Facebook, WhatsApp, Telegram, Twitter, LinkedIn, Quora, Pinterest, Google Hangout, Zoom, etc. On these platforms, you can connect to the people of your choice and interest. Suppose we are interested in the learning of electricity and magnetism, then we need to connect with such existing group(s). Synchronous and asynchronous interaction can take place on these groups and we can be updated on the subject. Not only that, we can clear our doubts from the experts in the group. All these platforms are becoming very popular as useful resources for the improvement in learning. Competitive examination related groups can also be found in abundance. Social media is acting like virtual facilitator of learning.

Websites

Computer or mobile with internet connection is a window to the world. Latest and up to date

information related to any field of physics is accessible instantly through the World Wide Web. Many Websites are dedicated to physics education. Few of them are listed below.

- https://arxiv.org/archive/physics
- http://hyperphysics.phy-astr.gsu.edu/hbase/hph.html
- http://planetphysics.org/
- https://www.feynmanlectures.caltech.edu/
- https://phys.org/
- https://ocw.mit.edu/courses/physics/
- https://www.physicsforums.com/
- https://www.nasa.gov/education/materials/

The list given is suggestive. We can explore many more of our choice.

YouTube

YouTube is an online video-sharing platform of Google. It is one of the most explored ICT tool with billions of users. If we type any topic related to physics here we will get a huge number of videos, audios and animations which can be chosen as per our requirement and interest. Use of multimedia in these YouTube videos makes them very interesting and ever-engaging.

Simulations

Simulation is emulating the things in such a way that it represents the real process. Many a times it is very difficult to perform the real experiments due to the constraint of time, money or security. In such cases, simulations are very important to get insight of the real experiment. For a subject like physics, where experimentation is the key aspect of learning, simulation is a boon. Interactive simulations are even more important, where the learner can feel the result of experiment with the variation of one or more independent variables. This feel is otherwise very uncommon with scarcity of resources and time. Excellent efforts have been done by many for developing physics simulations. Phet is one such initiative developed by Colorado University.

Interactive simulations of Physics on phet (https://phet.colorado.edu/en/simulations/Category/physics) deals with the sub branches of Motion, Sound and Waves, Work, Energy and Power, Heat and Thermodynamics, Quantum Phenomena, Light and Radiation, and Electricity, Magnets and Circuits. Thoughtful and easy to perform simulations are provided here. We would like to discuss (give an oversight of) two representative examples. Firstly, we discuss a simulation on Hooke's law for two spring system. A snapshot of this simulation is given in Fig. 1. It can be visualised here that we have two springs of spring constant 400 and 300 N/m, respectively with common applied force of 50 N. The common extension in both the springs is 0.071 m. Individual restoring forces developed in two springs are 28.6 and 21.4 N, respectively. Here, you can vary the stiffness of two springs and get a dynamic feel of individual restoring forces. You can also vary the applied force on the spring system. In a way, this dynamic play of a physical process is of great educational value.

In another example, we consider the simulation shown in Fig. 2, which is a snapshot of the simulated Young's two slit experiment. Here we can choose the frequency (wavelength) and amplitude of light

source. We can also vary the slit width and the separation between two slits. Resultant wave interference pattern is shown on the screen with intensity distribution curve also along the vertical locations on the screen. Also we can note that all maxima are not of same intensity. In fact, a central maximum is followed by secondary maxima. Such a control of parameters in terms of different light sources and different slit width and slit separation is otherwise very difficult to realise in actual experiment of Young's double slit interference. Coloured wave pattern is additional benefit here. These simulations not only are performable, but they also contain the concerned theory, related text, discussion forum and evaluation strategies of learning.

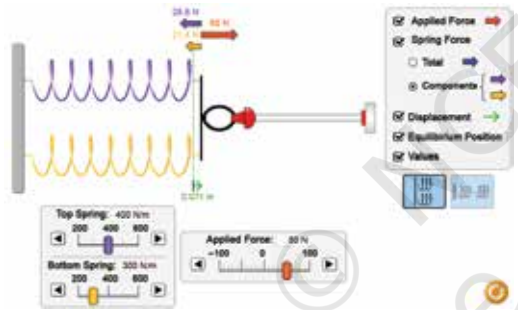

Fig. 1. Hooke's Law for Two Spring System

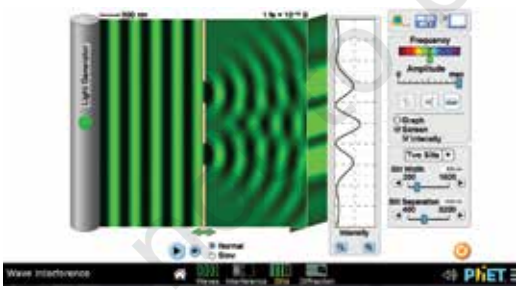

Fig. 2. Young's Two Slit Experiment

These types of physics simulations are now expanding rapidly with the availability of Free Open Source Softwares (FOSS). Few more physics simulations can be explored at My Physics Lab (https://www.myphysicslab.com/). Many more examples of physics simulations available are Advanced Simulation Library, Algodoo, Open Source Physics, Physics Abstraction Layer, Step, etc. Many of them are open-source software, which gives full control to the users free of cost.

Open education

Access to the physics education has now become very easy with no need to attend the lectures in the educational institutes. Concepts or courses of your choice are available online and that too with very good quality. National Repository of Open Educational Resources (NROER) (https://nroer.gov.in/) is one such platform where one can learn at any pace at her/his will. Plenty of diverse learning resources are available here. DIKSHA (https://diksha.gov.in/explore) is another such platform where a variety of learning material can be accessed for school level physics.

Online Education

Online education has crossed the spatial and temporal barriers. Interested learners of any age and any region from around the globe can enroll for online courses and enhance or update their learning. This has become possible with MOOC courses available on SWAYAM (https://swayam.gov.in/) portal developed by Ministry of Human Resource Development, Government of India. These courses contain video lectures, reference material, discussion forums and assessment items developed by the experts in their field. These courses are open to those people also, who just want to attend for self-learning and are not interested to be credited.

Virtual Laboratories

Experimental facilities are not available to many because of financial or other constraints. Here comes a concept of virtual laboratory where a variety of experiments can be performed anytime anywhere on virtual online platforms. Components of experiments are present in these laboratories in the same way as they are in the real experiments. For a country like India, where 70.64 per cent of secondary schools and 57.14 per cent of higher secondary schools only have the adequate science laboratories (NCERT, 2016), virtual laboratories are great supplements for a reasonably good feel of experiments. One such initiative of the Government of India is through the vlab (http://www.vlab.co.in/broad-area-physical-sciences), where many physics experiments can be performed. For school level physics experiments, you can visit https://www.olabs.edu.in/?pg=topMenu&id=40&, where varieties of experiments are available. To mention a few—Vernier calipers, screw gauge, spherometer, simple pendulum, surface tension, inclined plane, Young's modulus, Newton's law of cooling, internal resistance of a cell by potentiometer, focal length of convex and concave mirrors, focal length of concave lens, refractive index of a liquid, conversion of galvanometer to ammeter, AC sonometer, transistor characteristics, etc. These experiments consist of theory, procedure, simulator, video, viva-voce, resources and feedback sections making these labs engaging and useful.

Mobile and Mobile Apps

Integration of ICT in the learning was thought to be a big challenge until now, when internet connectivity was limited to desktops, laptops and notebooks with meagre accessibility to the general public, but after the launching of smart phones the scenario has changed completely. Users of smartphones have increased phenomenally approaching 500 Million in India and the number is still increasing. These smartphones are really smart. Operating systems usually Android, iOS or Windows, give them a variety of features which allow them advance computing speed, touch screen, increased audio-video quality, installable apps, etc. These smartphones are just like laptops and in some cases even more than that. You can access any learning resource with them as in internet linked computer. Moreover, plenty of learning apps can be installed very easily. These apps are very interactive and allow you to control your learning to explore the unexplored things.

Fig. 3: Orion Constellation through Skysafari App

As a representative example, we can think of Celestia or Skysafari App, where we can take a virtual tour of the sky. Variety of astronomical objects, such as, Sun, its planets, moons of planets, stars, asteroids, constellation of stars, etc., can be explored in real time. It can give us a thrilling experience of virtual tour of the sky without any telescope. Orion, one of the prominent constellation can be seen here in Fig. 3, which is a screenshot of the virtual tour from Skysafari. Many such physics learning apps can be explored as per your requirement. We can now say with more faith that ICT is ready to assist in democratising the learning of physics.

Augmented Virtual Reality

These are novel technologies which project the reality in virtual world and enhance the reality. They can also be seen as a continuum between real and virtual environment. Concept based visuals and activities can be developed using Augmented Reality. These activities are interactive in nature where students have enough opportunities to participate and control the proceedings of the activity. They can be viewed using a mobile phone or an iPad with a camera. You need to just direct the mobile camera to a surface with high contrast. Now you can go to such a scenario created in virtual space as if a laboratory is before you and you are performing original Rutherford experiment of alpha particle scattering and controlling various parameters such as foil to screen distance and moving detector at various angular locations. Events like launching of an artificial satellite can also be experienced and understood using this technology. The virtual world generated by augmented reality thrills the user with elevated sensory experiences which become more interesting when a person can control and manipulate also the presented scenario.

Conclusions

Inclusion of ICT in physics education in schools at secondary and higher secondary stage is not a choice now. Use of ICT in teaching-learning process of physics has gone to an unprecedented level in the recent years. Variety of ICT media and ICT tools are helping our understanding to grow with enhanced possibilities of interaction and individualised learning to happen. However, it should be borne in mind that ICT is a tool to empower the instructional processes and it should not be allowed to become a master. Proper integration of content and pedagogy with ICT can lead to the desired learning of physics as per set learning objectives. On teachers' part, it is imperative that they are mentally prepared to integrate the ICT for facilitating the learning of physics in a better way. This can only happen when they are equipped with the ICT tools and are in consonance with the fast changes happening in the ICT technology. Judicious use of ICT can lead to the achievement of higher order cognitive abilities in physics with increased interest and creativity. Lastly, it should be reemphasised that ICT is not a substitute for the teaching-learning process of physics but a helping hand and one should not undermine the experiences gained by performing actual experiments.

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