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Learning using Hands-on-Activities Supported by Instructional Videos and Simulations for Basic Sciences

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Abstract

Engaging learners in 'hands-on-activities' is considered to be one of the best practices in teaching as it enables deeper understanding of concepts in science and it help to increase average retention rate. Hands-on-activities can be undertaken either using actual (physical) material or in virtual manner using simulation software. They may be either undertaken independently or under the supervision or guidance of mentor/teacher. Learning of the underlying principles of Science is effective when the students are engaged in the 'Hands-on-Activity' which is supplemented with discussions on various aspects of the activities and theories behind the phenomenon studied. After performing such activity and upon due reflection on the underlying theories and mechanisms playing part in making the activity work, one expects increase in the level of the curiosity in the students which further encourages them to undertake more such activities and make them explain unexplained phenomena for other activities. To conduct such activities, there is no need to set-up big laboratory with expensive apparatus. The proper blending of the traditional method of teaching with the active or participatory teaching-learning method would perhaps be the practical approach to achieve the goal of acquiring the desired learning outcomes and also improve the retention rate of learning in the cognitive, psychomotor and affective domains.

Keywords: Hand-on activity, blended learning, pyramid learning, simulations and modeling

Introduction

The progress of Science takes place on the two legs of 'Experiments' and 'Theorizing'. To explain a phenomenon observed in experiments, a theory is proposed. If such theory is successful in explaining the phenomenon under question, it may further predict newer unexplored effects which may be unearthed through new set of experiments. For example, Rutherford's scattering experiment on gold foil predicted that the atom is mostly consist of void giving rise to a theory or model which envisaged atom to be consisting of positively charged nucleus and orbiting electrons. This further raised question on why positively charged protons do not fly apart (as like charges repel strongly in everyday experience). To explain this disparity Yukawa postulated existence of mu-masons which interact with protons making nucleus stable. These mesons are postulated to be so short lived that they justify short-range nature of the nuclear forces. Later these particles were experimentally observed too. Thus experiment and theory complement and make progress of science possible.

In teaching of Science the learners are expected to undergo training in both Theoretical and Experimental methods. The laboratory components are expected to facilitate the learner to experience the Truth as manifested in the experimental design. The learners are also expected to learn the psychomotor skills like precaution, precision, dexterity, etc. They are encouraged to interpret the observed phenomenon and measure quantities like refractive index of water or glass and point out the sources of possible errors.

While, in principle the curricula designed with experiments coupled with theoretical discussion should facilitate achieving the Specific Learning Objects, on ground the reality is very different. The curricula for science subjects are ill-tuned with experiments not in sync with the theory for any given semester. The learners (and in many case the teachers too) are not aware of the Specific Learning Outcomes which the curricula are expected to achieve. The emphasis becomes more on examinations and less on learning. The joy of learning science curricula gets lost in the process of mechanical delivery of lectures and often stage-managed implementation of laboratory experiments.

In our opinion the science education should be reinvented with emphasis on inculcation of systematic evolution of problem solving techniques, making curricula relevant to the everyday life situation, encouragement of Socratic process of dialogues leading to discovery of the hidden aspect of the subject matter by the students and through systematic training of students in modes of thinking with a special emphasis on creative thinking process. We will briefly visit these lacunae in the following paragraphs.

Our syllabi of the science courses do not train the learners in the art and science of systematic problem solving. The problems are posed to the students who solve them according to their innate ability or talent and in most cases get the difficult problems solved through expert and the remaining lot merely memorizes the steps of solving the problems. There is no drill or training in steps to solve problems in systematic manner, for example, using techniques of heuristics as

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explained by Polya in his path-breaking work "How to Solve It" (1945) [2].

The curricula in Science courses are not connected with the everyday situation faced or experienced by the learners. For example, learners often give confused reply to the multiple choice question drawn from daily life: "In case of collision between a 4 ton truck moving with speed 10 kmph and a 100 kg moped moving with a speed 60 kmph, whether

a) Truck being more massive exert more force on moped.
b) Moped due to higher speed exerts more force.
c) Forces exerted by truck and moped on the other body are equal.
d) More information is required to comment on which body exerted more force".

Similarly, the students in most cases failed to find dimensions of a tank to store 500 liters for their houses. Electronics graduate often fail to explain why MP3 format of recording consume less space than WAV format. Not only is the syllabi pathetically disjoined from the life, the implementation of the syllabi at the places of teaching too does not encourage learners to think beyond textbooks.

The classic literature both in Eastern world or the West used to present the subject matter as a debate between two characters who would try to defend opposite viewpoints. For example the Upanishads present subject matter for example, of dualism as dialogues between proponents of say dualism and non-dualism. Galileo's "Dialog" also has characters who discuss the subject of motion of planetary bodies. These dialogues take place with aim only of arriving at the Truth and not to score a victory over the opponent. Socrates used to ask question like "What is bravery? Whether this act is a brave act?" etc. and make the pupil uncover the hidden layers of reality. Unfortunately perhaps due to constraints of limited time in which the teacher has to teach the course such dialogues are missing. The learners are served the content and they do not get the opportunity to discover it through seeing the content through different viewpoints.

The young minds would work more fruitfully if they are trained in Thinking Skills. There are six modes of thinking as elaborated by de Bono (1985) [1] in his seminal works on 'Six Thinking Hats' and on 'Lateral Thinking'. Such techniques when taught in systematic manner might revolutionize the educational world in general. Emergence of such novel innovations like 3D printing enables fast prototyping. Many experts when asked which one area they wish they would change preferably if given chance of initiating their careers as educators respond that creative thinking is a mode of thinking which can be taught and nurtured and they would work on these lines.

In the present communication we would be discussing the application of hands-on activities as a way of developing interest among the pupils.

To study and understand the topics in Emerging Trends in Sciences, the college, universities must have trained manpower-teachers, research workers etc. To develop such manpower is a challenging task. Old methods of learning teaching are not shown to be useful. Passive teachings without hands-on-activities are shown to be grossly inadequate in handling the problem. One fortunately has the modern tools that are developed in last two decades, viz modeling, simulation, active learning, hands-on-activities, audio visual techniques, animations and virtual laboratories, etc. Lot of work has been done in USA and other places, Zollman (2002) [6], Redish (2002) [3], Wieman Carl (CWSEI Copyright © 2007-2011) [5], have studied the problems and shown the methods of tackling the problem. In nutshell these workers have discovered that learning can be made effective and interesting if it is coupled hands-on-activity and engaging the students in dialog form, in understating their requirement of the topics to be studies and solving their own problems as they learn the subject. The students are shown to be repelled by the passive teaching methods. These workers have found that if the subject is explained through hands-on-activity using videos and simulation techniques the students will learn the subject in an interesting, stimulating manner. Average retention rate in 'The Pyramid Learning' tested in 1960 by National Training Laboratories; Bethel, Maine is shown in Figure-1.

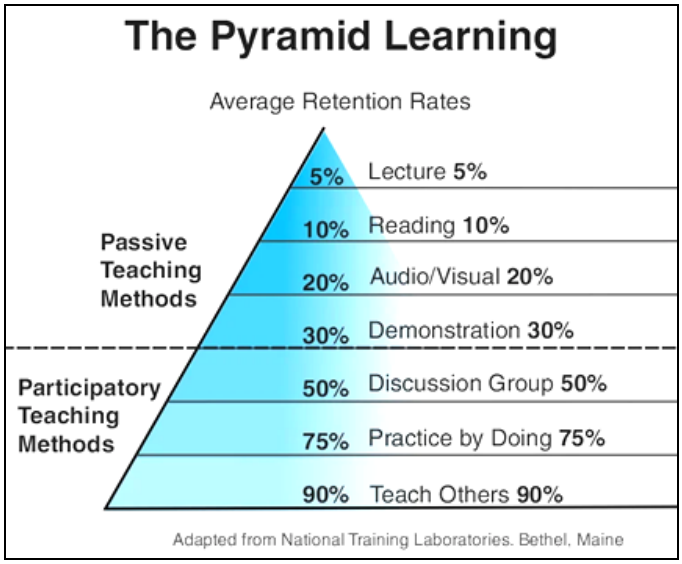


Fig 1: Pyramid Learning

The Pyramid Learning

For F.Y. B.Sc. students we have conducted some activities based on '*The Pyramid Learning*' Methods and collected data from their final examination. Every year improvement shows in the F.Y. B.Sc. result given in Appendix A.

Participatory Teaching Methods which we have used to conduct the students activity is discussed here. It should be noted that the Savitribai Phule Pune University (S.P.P.U.) has revised the syllabus of B. Sc. from the year 2013-14. According to syllabus of B. Sc. Physics and Electronic Science, from F.Y. to T.Y., four experiments in laboratory course are additional activity. This activity could be demos of experiments, demos using computer simulation or animation, mini-projects, hands-on-activities and study tour, all with report writing. Under this activity, from last 6-7 years, F.Y. students developed different projects on various concepts related to their syllabus. All physics/electronic science students must complete two hands-on-activities with write-up. Each hands-on-activity is equivalent to two practicals.

Based on this activity we have conducted Sunday Science Activity for high-school students from 11 Dec. 2016 to 15 Jan 2017.About 150 F.Y. students-volunteers showed demos to invited schools on 6 Sundays only. Near-about 2000 students from 20 schools (including adivasi and rural area) visited the exhibition.

In the year 2018, in first semester almost all F.Y. students completed their projects. In second semester, with involvement of all science departments (physics, electronic science, chemistry. life sciences, bio-tech, computer science, mathematics, statistics), we selected few projects and asked

students to make charts (1x1 m^2). We trained few F.Y. students to explain the selected projects with the help of few M. Sc. students. After this activity we have arranged one month Science Exhibition for school students from 12th Dec. 2018 to 8th Jan. 2019. The Exhibition was totally free of cost. About 2400 students from various schools and colleges (including teachers, parents) visited and enjoyed the activity. A group of 75 volunteers showed the demos to about 200 students per day under the guidance of 3 staff members. In 20 working days total of 454 F.Y. students with 20 M. Sc. Physics (Part-I) student-volunteers and 34 Staff Members contributed in the exhibition. Exhibition was divided into two sessions,

1. Exhibits in श्रमचिंतनबाग in open space (i.e. Lab without wall), and
2. Videos of hands-on-activities (Virtual Lab) in Seminar hall.

Thus the participants were also divided into two groups. Each session was for one & half hour, and then it was exchanged.
Exhibition was started from 12th Dec. 2018 in working days, without disturbing any college schedule. Prof. Dr. Dilip Kanhere, F.A.Sc., Distinguished Professor, Centre for Simulations and Modeling, S.P.P.U., Pune was the Chief Guest of Inaugural function. Exhibition time was from 8.30 am to 11.30 am. It is regular F.Y. practical time. All F.Y. students (about 450, including computer science and bio-tech students) get trained from 12th Dec. to 15th Dec. 2018 when they do not have their regular practicals scheduled. In the next week (17th Dec. to 22nd Dec. 2018) Junior/Senior College students and School students from our campus visited to the exhibition to get more practice for a new group of volunteers. Then 10 schools visited to the exhibition from 24th Dec. 2018 to 8th Jan. 2019. The Valedictory Function was held on 8th Jan. 2019. Dr. Prashant Tope, Coordinator, Sub-Centre S.P.P.U., Nashik, was the Chief Guest of the function. Overall all students and visitors enjoyed the activity.
Aim of this project is to develop, foster and enrich a large expert core group of college science students as mentors/facilitators for science popularization. There are numerous studies, both abroad and India also, which show that the sciences can be best understood if the students do hands-on-activity along with theory. Also the concepts of science can be assimilated better if the students discuss concepts with their colleagues under the guidance of their teachers. The objectives of the project are stated as below:

Objectives

- Inspiring the students through the joy of self-discovery in science learning using hands-on-activities.
- Motivating the inspired students to become mentors/facilitators.
- Testing effectiveness of the active learning.
- Designing the website to induce students to learn science through hands-on-activities.

By conducting this activity from last seven years, substantial change shows in F.Y. Physics result, exhibited below in the bar diagram. Our aim is to get deep knowledge with maximum marks in each subject for all students, thus to get 100% result.
Therefore, from this year, we are starting this activity in our college for all science subjects to earn extra credits in Choice Based Credit System (CBCS).

Student Solar Ambassador (SSA) Workshop

On the eve to mark 150th anniversary of Father of the Nation Mahatma Gandhi, Gandhi Global Solar Yatra (GGSY), Solar Urja through Localization for Sustainability (SoULS) and IIT Bombay organized Student Solar Ambassador (SSA) Workshop on 2nd Oct. 2019. Under this workshop, more than 1 Million Students were assembled their own solar study lamps across the globe and were pledged to Non-Violence towards Environment. As a part of this activity our College has organized training programme for various school/college teachers in association with Science Forum, Nashik. Near about 80 teacher-volunteers were trained and assembled solar study lamps with the help of videos under the guidance of experts from IIT Bombay. Then we have conducted SSA workshop on 2nd Oct. 2019 for Nashik zone. More than 5000 students from 34 schools and colleges were participated in the SSA workshop assembled their own solar study lamps. Thus it is possible to conduct SSA workshop for 1 million students all over the World on 2nd Oct. 2019 only through the technic of Blended Learning that combines online digital media with traditional classroom methods.

Future Changes in Light of New Education Policy

In the National Education Policy 2020, to make learning effective, interactive and enthusiastic, we have to convert all Text-Syllabus into Video-Lectures in a lucid way with the help of Teachers, Experts and Technical Team by adding Hands-on-Activities. Make Video-Lectures open to all. Students can go through videos and teacher has to work as a Mentor to explain each topic/concept through Hands-on-Activity.
Initially, we can start this activity by selecting few topics from the syllabus and continue it every year by adding new topics/concepts. We have started this activity in our College in association with Science Forum, Nashik from last few years. This activity shows improvement in F. Y. B. Sc. (Physics) result is given in Appendix A. It indicates that, students' involvement is necessary for making interactive videos on Hands-on-Activity made by them and they become more familiar with the Video-Lectures because of their own involvement.

Appendix A

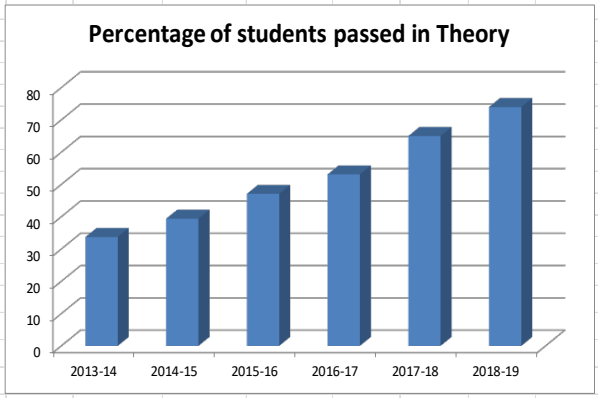
HPT Arts & RYK Science College, Nashik-422005

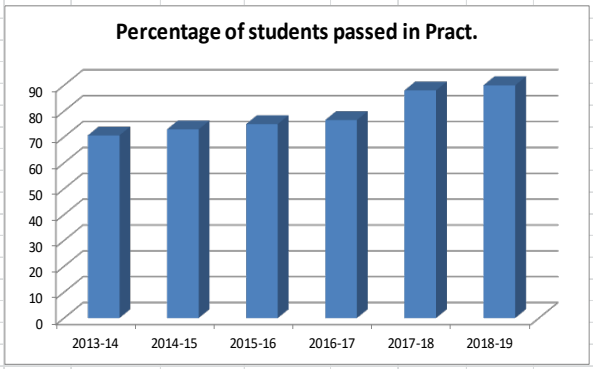
Department of Physics

F. Y. B. Sc. Physics Result Analysis

F. Y. B. Sc. Physics Div. A

Year	Theory %	Pract %
2013-14	34	71
2014-15	39	73
2015-16	47	75
2016-17	53	77
2017-18	65	88
2018-19	74	90





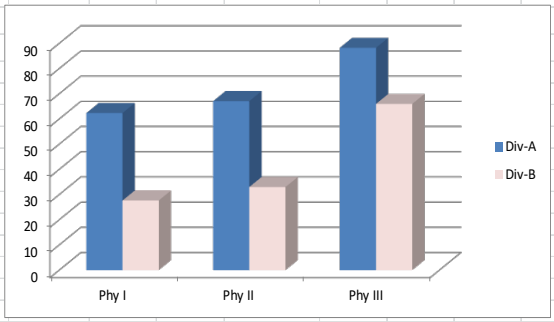
Div. B: Result improvement by adding Hands-on-Activity

Div-B	2017-18	2019-20
Phy I	28	42
Phy II	33	52
Phy III	66	87

F. Y. Physics Theory & Practical (Div A & B)

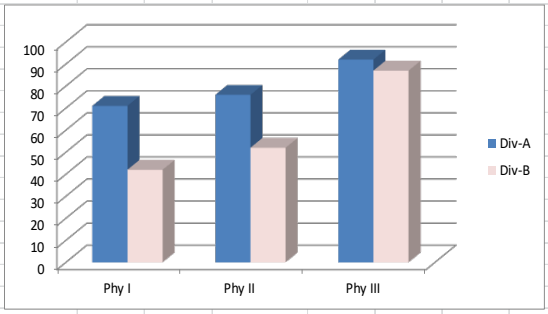
Div A : Learning through Hands-on-Activity

2017-18	Div-A	Div-B	A & B Avg
Phy I	62	28	45
Phy II	67	33	50
Phy III	88	66	77



Hands-on-Activity is added for Div. B also

2018-19	Div-A	Div-B	A & B Avg
Phy I	71	42	57
Phy II	76	52	64
Phy III	92	87	90



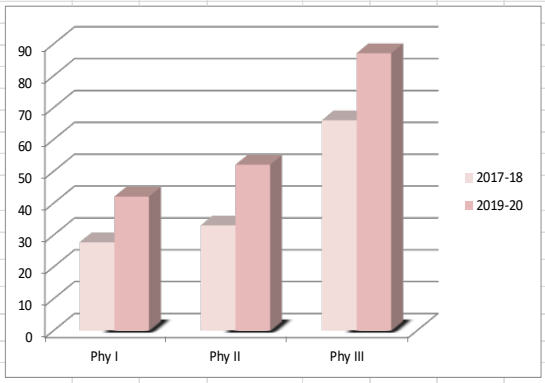


Fig 2: Analysis of F.Y. B. Sc. Physics result

Appendix B

(1) Joint activity with Science Forum, Nashik

- Conducted one day Science and Technology Awareness Workshop on 10th Dec. 2014 in Podar International School with the help of F.Y. B. Sc. students as volunteer-mentors.
- Demonstrated Robots with the help of F.Y.B.Sc. Students in Nashik Industries Manufactures Association (NIMA) Power 2016 Exhibition from 27 to 30 May 2016.
- Sunday Science Activity for high-school students from 11 Dec. 2016 to 15 Jan 2017 (6 Sundays) with the help of 150 undergraduate students' volunteers. Near about 2200 students from 20 various schools (including rural area) visited this activity.
- Celebration of National Science 2017 (Day 28th Feb.) at Harsul, Dindori, Trimbakeshwar and many other places.
- The Project 'Art of Science Learning' is selected for State level Avishkar 16-17 computation. This project is based on 'Sunday Science Activity'.
- Two Day Joint Workshop of College Students & High School Science Teachers in association with National Academy of Sciences India (NASI)- Pune Chapter on 14th& 15th July 2017.
- Hands-on-activities demos arranged for F. Y. B. Sc. Students on three Sundays: 13, 20 & 27 Aug. 2017.
- Volunteers showed demos at 87th Annual Session and Symposium on "Symposium on Basic Research - its role in national development", NASI-Pune Chapter, at S.P.P.U. campus, Pune on 10th Dec. 2017.
- Participation in Gokhale Education Society Centenary Year Exhibition 12 to 18 Feb. 2018.
- One-Day Joint Workshop of College Students & High School Science Teachers in association with National Academy of Sciences India (NASI) Pune Chapter on 5th July 2018.
- Science Association of H P T Arts & RYK Science College in collaboration with Science Forum, Nashik, Anant Vidnyan Vedh Pvt. Ltd., Nashik & National Academy of Sciences India (NASI), Delhi – Pune Chapter conducted one month Science Exhibition for school students from 12th Dec. 2018 to 8th Jan. 2019.

(2) Joint activity with Marathi Vidyan Parishad, Nashik Division

- F. Y. B. Sc. Students were involved in the workshop on 5th Sept. 2015 at Mumbai 'Marathi Vidyan Parishad'.
- Visited 20 high schools to demonstrate various experiments based on Light with the help of F.Y. B. Sc. Students volunteers in 2015-16.
- Conducted two Workshops on Hands-on-Activities for 100 high school students, in the months of Nov. and Dec. 2015.
- Conducted Workshops on Hands-on-Activities for 60 students in Orchid International School, Nashik, in June. 2016.

(3) Joint activity with IIT Bombay and Energy Swaraj Foundation in association with Science Forum, Nashik

- Student Solar Ambassador (SSA) workshop attended at IIT Bombay on 2nd Oct. 2018 with 45 Jr. College students.
- SSA workshop conducted on 2nd Oct. 2019 for Nashik Zone. More than 5000 students from 34 schools and colleges were participated in the workshop. Near about 800 students of our college were participated in the SSA workshop. More than 1 Million students participated all over the world.
- SSA training workshop was conducted for teachers from various schools and colleges from Nashik and Jawhar. Near about 80 teachers from 34 schools and colleges were participated in the workshop.
- ३५ सौर दिवे संच, आदिवासी पाड्यावरील 'सुमती ज्ञानपीठ अभियान संचालित आश्रमशाळा पिंपरी ता. त्रिंबकेश्वर जिल्हा नाशिक येथील १२० विद्यार्थ्यांना *रविवार,* दि. २ फेब्रुवारी २०२० रोजी 'दिवे बनवण्याच्या प्रशिक्षणासह' *दिले.*
- ३२ सौर दिवे संच, 'वनवासी कल्याण आश्रम महाराष्ट्र संचालित नूतन माध्यमिक विद्यालय कुकुडणे गुहीं (ता. सुरगाणा जि. नाशिक) येथील ६४ विद्यार्थ्यांना *शुक्रवार,* दि. ७ फेब्रुवारी २०२० रोजी, 'दिवे बनवण्या च्या प्रशिक्षणासह' *दिले* आहेत.
- Online participation in SSA webinar on 2nd Oct. 2020. More than 1 Million students participated all over the world.

1. Inauguration of Science Exhibition on 12th Dec. 2018, (श्रमचिंतनबाग)

2. Science Exhibition in Shram Chintan Baag

3. Demos by Dr. Dilip Kanhere

4. Demos by Dr. Dilip Kanhere Valedictory Function was Dr. Prashant Tope, Coordinator, Sub-Centre S.P.P.U. Nashik

5. Demos by students to Dr. Prashant Tope, Dr. Ramesh, Varkhede, Prin. V. N. Suryawanshi

6. Prin. Vasant Barve, Anil Kshatriya observing demos

7. Teachers and students are attending Valedictory

Fig 3: Sunday Science Activity for high-school students from 11 Dec. 2016 to 15 Jan 2017 (6 Sundays). Solar Workshop at Adivashi area Ashram-Shala Pimpari, Trambak and Guhi, Suragana, Nashik

Childrens assembling the lamps on 2 Oct. 2019; Science Forum, Nashik

Fig 4: Student Solar Ambassador (SSA) Workshop at HPT Arts & RYK Science College, Nashik on 2 Oct. 2019.

Conclusion

In this paper, we discussed at length a novel approach of teaching science curricula using participatory paradigm engaging learners through hands-on training, discussions and teaching others. Our experience as a supplementary intervention in formal learning for first year undergraduate students and various other non-formal settings is documented here. We noted that the group (labeled as Division A) which underwent hands-on participatory approach scored 62, 67 and 88 percent in three physics courses in comparison to 28, 33 and 66 percent for the control group (marked Division B) in the 2017-18 academic year. We also note that the Government of India's National Policy on Education 2020 has emphasized learning-by-doing in science education for effective and efficient delivery of content.

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