STEM TEACHING USING PHET SIMULATIONS WITH REFERENCE TO NCERT CURRICULUM DURING PANDEMIC

Dr. Aniket Srivastava  
Dr. Parul Verma  
Dr. Atul Pati Tripathi

Abstract

STEM teaching is always interactive and engaging for the learners and it covers all domains of learning. Its focus on cognitive part of a learner to use his affective domain with psychomotor skills. During covid time simulations enables learners to use open source specially phet simulations as its easy and device independent with offline access for educational purpose. As we all know that NCERT curriculum for science and maths requires variety of STEM modules for online instructional teaching during covid time. Phet covers all stem modules as per the NCERT curriculum, In this paper we have done the mapping for k-12 segment of STEM simulations using phet simulations with a survey of 13 schools using phet sims as an ICT tools for STEM teaching during pandemic.

Keywords: STEM, Covid, ICT, NCERT, k-12, psychomotor and affective domain.

1. Introduction

PhET is a set-up of exploration based intelligent PC sims for instructing and learning material of science, math and earth sciences. PhET sims can be run on the web or downloaded from the PhET site. The reproductions are energized, intuitive, and game-like conditions where understudies learn through investigation. They underline the associations between genuine marvels and the fundamental science, and help make the visual and reasonable models of master researchers open to understudies. PhET reenactments are principally created for and tried with college and secondary school understudies, yet have been discovered to be instructive and a good time for understudies "from grade school to graduate school."Simulation is the imitation of the operation of a real-world process or system over time. The act of simulating something first requires that a model be developed; this model represents the key characteristics, behaviors and functions of the selected physical or abstract system or process. 75% of the schools in India do not have science labs spurred the team into building a virtual science lab platform using computer graphics or simulations. Students are generally interested in games like Pubg, fox or other games, A practical experiment in a lab is only done once. If a student has queries or wants to go through the dissection process again before the exam -phet sims are the solutions.

2. Phet Sims for STEM Teaching

PhET sims are intuitive reenactments of science and math ideas made by the University of Colorado Boulder. Understudies can run these reproductions, controlling various parts of a develop to get
science and arithmetic ideas. Contingent upon the reenactment, understudies may likewise have the option to gather, chart, and investigate information to make determinations of their own. Its a project at the university of Colorado Boulder. Its an open educational resource founded by Noble Prize winner in 20002 Laurete Carl Wieman. It has a comprehensive repository for Physics, Chemistry, Biology, Earth Science and Mathematics that runs through mobile app, progressive web app and desktop application. It has an HTM5 sims as well thats runs easily on any handheld ICT device. Teachers teaching in Schools using NCERT Curriculum finds its easy to explain and cover multiple concepts for STEM teaching.

3. Advantage of Simulations for STEM teaching

- Simulations can allow students to investigate phenomena that would not be possible to experience in a classroom or laboratory.
- Simulations can help students to translate among multiple representations.
- Simulations can help students build mental models of physical, chemical or biological systems.
- Simulations can give students engaging, hands-on, active learning experiences.
- Simulations can serve as a vehicle for collaboration.

4. STEM Teaching during Covid time

4a) Productive constraints

Phet Simulations increases productivity of the facilitators to cover multiple concepts for the online classes with selective digital teaching aid.

4b) Online project as a homework

There are lot of e-projects given on phet website with multiple lesson plans for the students to complete online projects in a form of video based documentary or animation based video.

4c) Pre-class assignment – Introduce new ideas:

During online classes phet sims provide STEM platform for pre teaching platform and maintain new ideas for the instructional teaching with simulators.

4d) Post instruction – develop robust understanding

Phet sims are open educational resources available in mobile app and teachers can share the links and update the post teaching follow up for the instructional based teaching learning process.

4e) STEM Lecture/classroom
5 Phet Sims Usps:

5a) Engaging, open-style play area:

STEM teaching won’t be possible if we don’t provide working model and open play area virtually to interact during online classes. This sims enable learner and facilitators for the interactive working model

5b) Highly interactive:

Phet simulations are highly interactive with drag and drop /touch and play interaction with all ICT tools interaction for online teaching learning process.

5c) Dynamic feedback:

Phet Simulations provide dynamic monitoring and feedback mechanism as it has feature to measure all physical quantity with different scientific tools in order to have a dynamic interaction while playing simulations.

5d) Interaction links to animation:

They are many tile based sub concept and game based tools in one simulations to interact with different animated characters and tools for online teaching learning process using STEM based lesson plans.

5e) Explore and discover:

STEM teaching emphasize on construct based understanding for the discovery based learning approach to enable the facilitator to take learner from abstract to concrete or from unknown to known conceptual explanation.

5f) Connection to real world:

STEM modules is all about real world connection. Real life applications are integrated easily among the learners using phet simulations for the digital natives to interact easily for daily life science concepts.

5g) Visual & conceptual models:

Phet Visual and conceptual virtual models enable the teachers to cover multiple concepts for the learners. While explaining one simulations teachers can cover different concepts for the student as per the STEM lesson plan.

6. Phet NCERT curriculum Mapping
| Sl. No. | Phet Physics Sims                  | Suitable Class | Concepts                                    |
|--------|-----------------------------------|----------------|---------------------------------------------|
| 1      | Atomic Interactions               | 8 To 12        | Atomic Structure                            |
|        |                                   |                | Force, Torque, Weight                       |
|        | Balancing Act                     | 4 To 8         | Mass Gravity                                |
| 2      | Balloons And Static               | 3 To 6         | Electrostatics                              |
|        | Bending Light                     |                | Optics: Light, Wave, Wavelength, Intensity  |
| 3      | Electricity                       | 7 To 12        | Wave, Wavelength, Intensity, Velocity, All Three Laws Of |
| 4      | Force, Torque, Weight             | 5 To 10        | Motions, Projectile, Force, Accelerations, Decelerations |
| 5      | Build An Atom                     | 8 To 12        | Atomic Structure                            |
| 6      | Charges And Fields                |                | Electrostatics                              |
|        | Color Vision                      |                | Optics: Light, Wave, Wavelength, Intensity  |
| 7      | Friction                          | 6 To 12        | Force, Mass, Friction                       |
| 8      | Friction                          |                | Surface, Newton Laws                        |
| 9      | Forces And Motions                | 9 To 12        | Displacement Force                          |
| 10     | Basics                            |                | Surface, Newton Laws                        |
| 11     | Gravity Force Lab                 | 9 To 12        | Acceleration                                |
|        | Hooke's Law                       |                | Hooke's Law, Distance                       |
| 12     | John Travoltage                   |                | Displacement Force                          |
| 13     | Molecules And Light               |                | Electrostatics                              |
| 14     | Faraday's Law                     |                | Optical Properties Of Molecules             |
| 15     | Ohms Law                          |                | Electricity, Charge                         |
|        | Resistance In A Wire              |                | Voltage, Current, Resistance, Electron      |
| 16     | Rutherford Scattering             |                | Flow, Charge                                |
| 17     | Wave On String                    |                | Radioactivity                               |
| 18     | Under Pressure's tern             |                | Wave Properties                             |
| 19     | Gerlach Experiment                |                | Magnetism And Its Law                       |
| 20     | Resonance                         |                | Positive And Negative                       |
| 21     | Radiating Charge                  |                | Ion                                         |
| 22     | Projectile Motion                 |                | Wave Properties                             |
| 23     |                                  |                | Resonance                                   |
24 Pendulam Lab 8 To 12 Energy
25 Normal Modes 9 To 12 Wave Properties
                Keplars Law, Planet
26 My Solar System 6 To 12 Movement
                Density Mass Volume
27 Density 6 To 10 Relationship
                Collision Momentum
28 Collision Lab 9 To 12 Energy
29 Calculas Grapher 9 To 12 Wave Functions
                Law Of Floatation, Pascal Law, Pressure
30 Buoyancy 6 To 10 Law, Buoyant Force
31 Blackbody Spectrum 9 To 12 Blackbody Properties

Table 1

| Sl. No. | Phet Chemistry /BiologySims | Suitable Concepts | Class           |
|---------|-----------------------------|------------------|-----------------|
| 1       | Acid Base Solutions         |                          | 7 To 12 Acid And Base |
| 2       | Atomic Interactions         |                          | 8 To 12 Atomic Structure |
| 3       | Baloons And Static Electricity |                         | 4 To 6 Charge And Electricity |
| 4       | Beer's Law Lab              |                          | 8, 9, 10 Acid And Base |
| 5       | Build An Atom               |                          | 8, 9, 10 Atomic Structure |
| 6       | Concentration               |                          | 8, 9, 10, Chemical Equilibrium |
| 7       | Isotopes And Atomic Mass    |                          | 8, 9, 10 Chemical Kinetics |
| 8       | Molarity                    |                          | 8, 9, 10 Solution And Solubility |
| 9       | Molecules And Light         |                          | 8, 9, 10 Chemical Kinetics |
|         |                              |                          | Relative Molecular Mass And |
| 10      | Molecule Shape              |                          | 9, 10, 11 Mole |
| 11      | Molecule Shapes Basics      |                          | 9, 10, 11 |
| 12      | Ph Scale                    |                          | 11, 12 Chemical Kinetics |
| 13      | Ph Scale Basics             |                          | 11, 12 |
| 14      | Reactant Products And Leftover |                         | 8 To 12 States Of Matter |
| 15      | Ruther Ford Scaterring      |                          | 11, 12 Chemical Kinetics |
| 16      | Balancing Chemical Equations |                        | 8 To 12 Chemical Equations |
| 17      | Blackbody Spectrum          |                          | 11, 12 Chemical Kinetics |
|         |                              |                          | Colour |
| 18      | Human systems               |                          | vision,n 3,5,9,11,12 |
Table 2

| Sl No. | Topic                        | Phet | Mathematics | Suitable Concepts |
|--------|------------------------------|------|-------------|-------------------|
| 1      | Area And Perimeter           | Area Builder | 3,4,5,6     | Area And Perimeter |
| 2      | Numbers And Operations       | Arithmetic | 1 To 5      | Basic Operations Of Mathematics |
| 3      | Numbers And Operations       | Balancing Act | 2,3,4       | Number Line |
| 4      | Numbers And Operations       | Fraction Matcher | 3 To 5     | Fractions |
|        | Function                     | Function Builder | 6 To 12   | Functions |
| 5      | Geometry                     | Graphing Lines | 3,4,5       | Shapes |
| 6      | Geometry                     | Least Square Regression | 3,4,5,6,7 | Shapes |
| 7      | Trigonometry                 | Trig Tour | 8,9,10,11, Trigonometry-Introduction |
| 8      | Calculus                     | Calculus Grapher | 9 To 12    | Co Ordinate Geometry |
| 9      | Geometry                     | Curve Fitting | 8,9,10      | Co Ordinate Geometry |
| 10     | Data Analysis And Probability| Estimation | 8 To 12     | Shapes And Their Properties |
| 11     | Data Analysis And Probability| Mass Spring Lab | 6 To 10   | Data Handling, Graphs |
| 12     | Data Analysis And Probability| Pinko Probability | 9 To 12  | Probability |
|        |                               | Vector Addition | 7,8,9      | Non-Linear Equations |
| 15     | Statistics                   | Vector Addition | 11,12      | Vector Addition |

Table 3

7. Teachers Responses for STEM Modules:

Our study on the effectiveness of integrated STEM revealed so far that students in an integrated STEM learning environment increased their engagement, are able to achieve the same or a higher performance level and have a more positive attitude towards science and technology. Our research on the implementation of the instructional approach for integrated STEM showed that school context, teachers’ attitudes, teachers’ involvement in the development of the new approach and learning materials are linked with instructional practices in integrated STEM. We have done a survey in 13 schools with STEM coordinators using google form to understand the feasibility and usability of Phet Simulations:-
as per figure 1 teachers are putting good amount of effort for STEM teaching using phet simulations. The impact of our study is substantial. There is a wide agreement that integrated STEM-education may address todays’ technological and global challenges, but it is still an underdeveloped research field. Based on empirical evidence we address the needs of the field by developing an instructional approach and learning materials for integrated STEM education and are able to make recommendations for the field to guarantee a successful implementation of this approach. In addition, our research contributes to the scientific research literature, because we perform a longitudinal study and develop instruments to measure classroom practices, but also cognitive and non-cognitive outcomes related to integrated STEM education.
As per figure 2 more than 84 percent of teachers using phet sims according to their lesson plan. Schools and instructors to "give each understudy admittance to excellent science instruction." Unfortunately, numerous understudies with incapacities are not accepting admittance to high-quality science instruction – eighth grade understudies with incapacities are more than twice as prone to be underneath essential accomplishment in science than their friends without incapacities. To give great admittance to science schooling for all understudies, science schooling learning materials need to address the issues of understudies with and without incapacities. In We more so acquaint difficulties with the progression of instruction research comprehensive of understudies with incapacities, and welcome the more extensive material science schooling research network to join endeavors to create and examine learning open doors for this frequently neglected understudy populace. By far most of K-12 understudies with handicaps are shown actual science or material science as a rule instruction study halls, as opposed to in particular settings. Science instructors are regularly overpowered with the test of getting ready properly separated guidance for the variety of understudies in their study hall.

As per figure 3 more than 90 percent teachers agreed that they have variety of sims available for covering concepts. Science instructors are frequently overpowered with the test of getting ready properly separated guidance for the variety of understudies in their study. Comprehensive advanced learning materials that can be adjusted on-the-fly to meet the requirements of every understudy in the study would altogether decline the trouble, cost, and time needed to plan separated guidance for understudies with incapacities, while expanding open doors for all understudies to participate in cooperative science rehearses. Comprehensive learning materials can likewise give extra advantages by providing highlights that can be helpful for all understudies, paying little heed to capacity. To help address the difficulties of making open intuitive material science assets, the PhET Interactive Reproductions venture has occupied with an activity to plan, create, and research comprehensive material science reproductions (sims).
As per figure 4 92.3% agreed with the user-friendliness of phet simulations during pandemic.

As per figure 5 it shows project based learning is easy with the help of phet sims during covid time. Comprehensive advanced learning materials that can be adjusted on-the-fly to meet the requirements of every understudy in the study hall would fundamentally decline the trouble, cost, and time needed to get ready separated guidance for understudies with handicaps, while expanding open doors for all understudies to take part in shared science rehearses. Comprehensive learning materials can likewise give extra advantages by providing highlights that can be useful for all understudies, paying little mind to abilityd settings. By participating in basic exploration, making models, sharing
rules, speaking to intuitive assets inside the openness field, and building up an organization of substance designers making comprehensive assets, the PhET venture is driving endeavors to make comprehensive highlights for profoundly intelligent computerized learning assets. We imagine a future where all intelligent material science learning assets are open, and equipped for supporting understudies with incapacities in comprehensive material science homerooms. Significantly, we imagine a network exertion to make the examination establishments, plan practices, and specialized framework to uphold material science educators and educational plan designers in making their learning materials more comprehensive.

![Pie chart showing student offline practice](https://hrdc.gujaratuniversity.ac.in/Publication)

**fig 6**

as we can see in figure 6 more than 90 percent students are aware of phet offline access.
As per figure 7 it clearly shows PhET Sims covers the NCERT curriculum as mapping already mentioned in table 1, 2 and table 3. As instructors, understudies, and families move to far-off learning because of COVID-19, PhET Interactive Simulations are an extraordinary asset for drawing in students in STEM practices and ideas. All sims are free (open) training assets. Under every recreation page, you will discover "Instructor Resources" including over an aggregate of 2,000+ exercises accessible. Educators and guardians can make a free client record to get to exercises.

![Pie chart showing 92.3% yes and 7.7% no responses to using PhET Sims for covering multiple concepts.](image)

As we can see in figure 8 more than 90 percent teachers are finding PhET Sims easy for covering multiple concepts. The PhET Interactive Simulations venture is tending to an excellent test that is confronting countries over the world: teaching the up and coming age of researchers, mathematicians and designers who can create imaginative innovations to help tackle the present nearby and worldwide issues and that drive monetary development — just as creating expansive science and math proficiency in our undeniably innovation based society. Various companion looked into contemplates show that customary K-12 and school study hall guidance and educational plans in the sciences are all the while ineffectual at propelling and fascinating understudies with regards to science, and at building up the profound theoretical comprehension of science, the logical cycle abilities, and master perspectives on science. Comparative outcomes are found for math. Over the world, advancements in science and innovation are driving financial development and propelling social orders. Neighborhood compelling STEM training is basic to enrolling, holding, and graduating the STEM experts expected to satisfy these positions.

8. Conclusions:
A significant part of the STEM simulations based teaching is pointed toward pulling in underrepresented populations. Students are fundamentally less inclined to seek after a school major or profession. In spite of the fact that this is the same old thing, the hole is expanding at a huge rate. Student understudies are additionally bound to seek after designing and innovation fields, while understudies favor science fields, similar to science, and earth science. Ethnically, Asian understudies have generally shown the most elevated level of enthusiasm for the STEM fields. What isolates STEM from the during covid time for customary science and math instruction is the mixed learning condition and demonstrating understudies how the logical technique can be applied to regular daily existence. It shows understudies computational reasoning and spotlights on this present reality utilizations of critical thinking. As referenced previously, Phet sims based STEM instruction starts while understudies are exceptionally youthful. It covers major concepts of Science and mathematics of mostly all curriculum including Indian NCERT based curriculum for teaching learning process.
References

[1] https://marcprensky.com/writing/Prensky%20Digital%20Natives,%20Digital%20Immigrants%20-%20Part1.pdf

[2] http://nationsreportcard.gov/science_2011/g8_nat.aspx?subtab_id=Tab_6&tab_id=tab2#chart. Retrieved 8/06/2014.

[2] Kahn, S. & Lewis, A.R. (2014). JSTE, 25(8), 885–910.

[3] Kolowich, S. (2010). Inside Higher Ed. Retrieved from https://www.insidehighered.com/news/2010/06/30/kindle. Retrieved 7/10/2020.

[4] http://phet.colorado.edu/. Retrieved 7/10/2020.

[5] http://phet.colorado.edu/en/simulation/travoltage. Retrieved 7/05/2017.

[6] Smith, T.L., Lewis, C. & Moore, E.B. J Technol Pers Disabil. 5, 225-238.

[7] Moore, E.B., Smith, T.L. & Randall, E., in Universal Access in Human-Computer Interaction. Users and Context Diversity. UAHCI 2016. Lecture Notes in Computer Science, edited by M. Antona and C. Stephanidis (Toronto, Canada, 2016), p. 112.

[8] Smith, T.L., Lewis, C. & Moore, E.B., in Proceedings of the 18th International ACM SIGACCESS Conf on Computers and Accessibility (Reno, NV, 2016), p. 319.

[9] http://diagramcenter.org/accessible-dynamic-scientificgraphics.html. Retrieved 11/11/2020.

[10] https://www.w3.org/TR/wai-aria/.

[11] http://www.icdri.org/technology/ecceff

[12] mhrd.gov.in

[13] https://ncert.nic.in/pdf/focus-group/science.pdf

[14] https://ncert.nic.in/pdf/shikshak-parv/Use%20of%20Technology%20Shikshak%20Parv%20JShinde.pptx

[15] https://ncert.nic.in/pdf/publication/journalsandperiodicals/indianjournalofeducationaltechnology/IJET_july2020.pdf

abbreviation
1. ICT  Information and Communication Technology
2. STEM  Science Technology Engineering and Mathematics
3. Phet  Physics for Educational Technology
4. Covid  Corona Virus Disease
5. NCERT  National Council of Educational Research and Training
6. Sims  Simulations

Appendix

12/2/2020

STEM Teaching Using Phet Sims

Dear teachers thanks for your participation during lock down. Please give your valuable feedback for our research.

* Required

1. Email address *

2. Level of effort for conducting STEM classes using Phet by you *Mark only one oval per row.*

   Poor Fair Satisfactory Very good

3. STEM teaching is easy using Phet sims as per your lesson plan *Mark only one oval.*

   yes No

4. Teachers use different types of simulation for online classes *Mark only one oval.*

   yes No

Excellent

Level of effort you put into the course

https://docs.google.com/forms/d/1tGnN_V7UHUpG_bUMpoCPkrQH9ICZIUR3Ofc7ZCo9n6I/edit

1/3

12/2/2020

STEM Teaching Using Phet Sims

5. Students and teachers can easily interact with Phet simulations *Mark only one oval.*

   yes No

6. Project based learning is easy using Phet sims for online classes during covid time?
Mark only one oval.

yes No

7. STEM Lab session covers gamified learning after online class during covid Mark only one oval.

yes No

8. Students can do their offline practice frequently using phet sims Mark only one oval.

yes No

9. Scientific temperament for STEM module is easy to develop while using phet sims Mark only one oval.

yes No

https://docs.google.com/forms/d/1tGnN_V7UHUUpG_bUMpoCPkrQH9ICZlUR3Ofc7ZCo9n6I/edit

2/3

12/2/2020

STEM Teaching Using Phet Sims

10. Phet session covers the ncert curriculum science and mathematics modules upto certain extent

Mark only one oval.

yes No

11. Online teaching during Covid time enable teachers to use simulations for covering multiple concepts

Mark only one oval.

yes No

12. Teachers Name and class

This content is neither created nor endorsed by Google.

Forms

https://docs.google.com/forms/d/1tGnN_V7UHUUpG_bUMpoCPkrQH9ICZlUR3Ofc7ZCo9n6I/edit

3/3
Amity Institute of Information Technology, Amity University, Uttar Pradesh

&

Dr. Atul Pati Tripathi
Program Head, Teaching and Learning, GSTGEC, Gujarat