Designing for Children 2019
- Play and Learn

Designing Educational models for school children

An account of designing model for education kits of NCERT

Prakash, Kumar, Shiv Nadar University, Uttar Pradesh, India, prakash.kumar@snu.edu.in
Prakrati, Pateria, Shiv Nadar University, Uttar Pradesh, India, pp178@snu.edu.in
Sukriti, Agarwal, Shiv Nadar University, Uttar Pradesh, India, sa678@snu.edu.in

Abstract: Education models are useful for educating and illustrating scientific phenomena and theories to children in a fast and effective way. Since the models are interactive, they attract children creating interest and curiosity. They help them experience and understand various concepts in a practical way that they would not forget quickly. It also makes the illustration task of the teachers fast and easier. Acknowledging the role of these models in the teaching process at the school level, National Council of Educational Research and Training (NCERT) is instrumental in developing educational kits for different classes. But, owing to a large number of CBSE schools spread all across the country, it faces many practical challenges related to the dissemination of these models i.e. issues related to transportation and infrastructure, installation, repair, and maintenance, etc. These issues have to be considered while conceptualizing the new models. This paper presents an account of designing a new model for NCERT, meant to illustrate the geographical phenomenon of rotation and revolution to students. It outlines the method adopted for coming up with an effective model addressing different issues. Then, it discusses the process of evaluation of the model and finally concludes with the limitations and future scope of work for the development of such models.

Keywords: Educational model, School children, students, NCERT, Issues, modification, indigenous mechanism, low cost, local material.

1. Introduction

Educational models play an important role in illustrating to children, different scientific concepts, theories, and phenomena pertaining to different subjects like Mathematics, Physics, Chemistry, Biology, Geography, etc. in a fast and effective way. They involve active engagement of students which ensures better grasping of concepts (Freeman et al., 2014; Haak, HilleRisLambers, Pitre, & Freeman, 2011; Newman, Stefkovich, Clasen, Franzen, & Wright, 2018). They not only make the concept-explaining task easier and faster for the teachers but also help students learn faster and better compared to the conventional lecture-based teaching (Haak et al., 2011; Hake, 1998). They enable better visualization and understanding of different concepts among students.Since the models are interactive, spontaneous and live in nature, they attract children creating interest and curiosity, incites discussion between the students, which enhances the learning experience (Smith et al., 2009). They remove the monotony of "understanding by reading from books" method of learning which is susceptible to erroneous interpretation (Schönborn, Anderson, & Grayson, 2002). Through the physical model, students could not only develop an understanding of different phenomena but also construct their own explanations (Lord, 1994). They help children experience and understand various concepts in a practical way, without much cognitive load, which better learning and retention (Sweller, Van Merrienboer, & Paas, 1998). Acknowledging the role of models in the teaching process at the school level, National Council of Educational Research and Training (NCERT), is instrumental in developing educational kits for different classes.

1.1 National Council of Educational Research and Training (NCERT)

National Council of Educational Research and Training (NCERT) is an autonomous organization set up in 1961 by the Government of India to assist and advise the Central and State Governments on policies and programs for qualitative improvement in school education. The major objectives of NCERT and its constituent units are to: undertake, promote and coordinate research in areas related to school education; prepare and publish model textbooks, supplementary material, newsletters, journals and develops educational kits, multimedia digital materials, etc. organize pre-service and in-service training of teachers; develop and disseminate innovative educational techniques and practices; collaborate and network with state educational departments, universities, NGOs and other educational institutions; act as a

clearing-house for ideas and information in matters related to school education; and act as a nodal agency for achieving the goals of Universalization of Elementary Education. The approach adopted by NCERT, for developing educational models for the kits, was a systematic process. It started with workshops where the stakeholders from various domains were called. It constituted of mentors, having in-depth knowledge in the subjects, who would use the model to explain the concept to the students, the officials overlooking the projects, members from different academic institutes who help in developing the prototypes, the school children who participate in the trials and vendors who mass manufacture the models and supply them to NCERT. Initially, the various aspects related to the model, to be designed or redesigned, were discussed. Finally, it was decided which models required to be worked upon. Later, a similar workshop was conducted where the models developed were evaluated for their efficacy and performance.

1.2 The challenges related to Educational models

NCERT, though being committed to the development and dissemination of educational kits, always being struggling to keep the cost to the minimum. There were other practical issues specifically related to models. NCERT provides educational kits to schools all across India and many of the schools are located in remote locations. Firstly, transportation of the kits without damage at such locations is very difficult. Some of the models of the kits are costly as they are imported. If these models were damaged during transportation or demonstration, they couldn't be repaired. The spares parts for such models are, also, not available locally. Hence, the model eventually becomes a waste. So, it is a big challenge to design low-cost models that could effectively illustrate the intended scientific phenomena and principles. It is the need of the hour to come up with models that could be made using indigenous technologies and materials that would reduce dependency on imported technology. This, in turn, will reduce costs and ensure quick repairs or replacements. Some fabricators tried to replicate the imported models to reduce costs.

1.3 "Rotation and Revolution" model for Geography kit

The Model demonstrating "Rotation and Revolution of Earth and Moon" was an important part of the geography kit. It was supposed to illustrate the following phenomena

- Erath revolves around the sun in an orbit and moving in the anti-clock wise direction, completes one revolution in one year.

- Earth also rotates around its axis in the anti-clockwise direction and completes one rotation in 24 hours. The part facing sun experiences day, and the part, away from the sun in dark, experience night.
- Earth axis is tilted at an angle of 23.5°. Due to this, the earth's hemispheric position changes every three months with respect to the sun. During some part of the year, the northern hemisphere is tilted towards the sun or tilted away from the sun, and during other parts of the year, the axis is inclined sidewise with respect to Sun. This leads to the occurrence of four seasons winter, spring, summer and autumn.
- The time of the year, when northern hemisphere's tilt, towards sun, is maximum, it is called summer solstice. When Northern hemisphere's tilt, away from the sun, is maximum, it is called winter solstice.
- The two other positions where the hemispheres are not tilted towards or away from the sun are called Spring and autumn equinoxes.

The model lately used by NCERT was imported. It not only costed high but was, also, unrepairable. Hence, a new model was required which as effective as the former but could be indigenously manufactured in India. But, copying could not help much as partial replication of technology and materials lead to low quality output prone to quick wear and tears. So, there was need to look into design of these models afresh from a new perspective.

2. Methodology

For developing the new model, demonstrating the geographic phenomena of "Rotation and Revolution of Earth and Moon", a systematic approach was taken (Figure. 1).

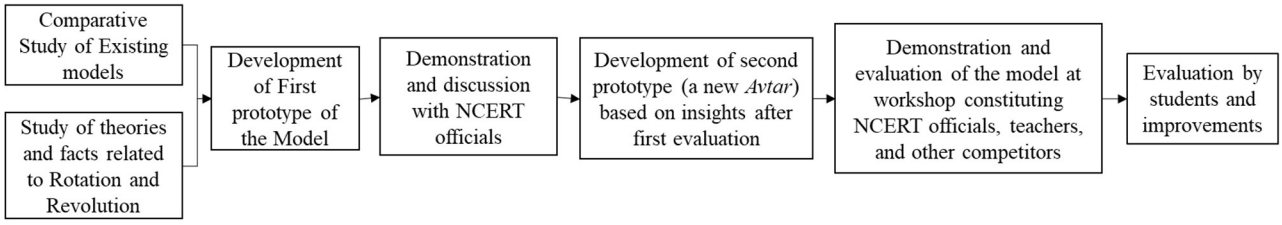


Figure. 1 methodology Adopted for the developing the model

2.1 Study of theories and facts related to Earth's rotation and revolution

In addition to the facts, to be illustrated through the existing model, used by NCERT, other less known facts were also studied. The moon also revolves around the earth in an orbit inclined at an angle of 5° in the anti-clockwise direction. One revolution is completed in around 28 days.

The moon also rotates around its axis in the anti-clockwise direction and completes one rotation in around 28 days.

In addition to this, different parts of Earth also experience the phenomena of a solar and lunar eclipse. When the moon comes between earth and sun, the moon casts its shadow on earth and that part of earth experiences solar eclipse. When the earth comes between moon and sun, the shadow of the earth is cast on the moon that leads to a lunar eclipse. This study gave insights as to what additional facts could be demonstrated through the new model.

2.2 Study of other fields that might be directly or indirectly helpful to Model development

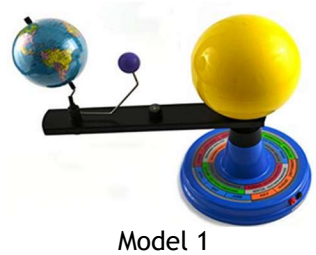
In addition to the study of existing models, a study was done to look into various low-cost toys. These designs use simple scientific principles to develop small inexpensive solutions. The component is simple and materials used are those, which are available locally. Though, it did not demonstrate any concept directly but they had a surprise element and they always attracted children to put the parts together through their intuition. We also looked into the multi-media learning material used by many educational apps like Byjus, etc. They used different animation to show the effect. But such apps generally charge some amount for the illustrations for every view. Also, learning a concept by getting involved in it in real time has better grasping as compared to a 2D-experience which is generally a one- way communication.

2.3 Understanding requirements of different stake holders

Before designing the new model, it was necessary to understand various stakeholders for the new design. Though there were a large number of stakeholders including the government, NCERT officials, Teachers, students, fabricators, transporters, etc. students and teachers were the main stakeholders directly involved with the new solution. As far as teachers are concerned, the main requirements were to provide a solution which is easy to install and repair, and capable of illustrating the maximum number of concepts. The students, on the other hand, are curious, zealous, mischievous and full of energy. They are intelligent, and always ready to experiment and do things by themselves in a way different from what is prescribed. Hence, for the students, the model should not be very complex and must have the play element. it should also be able to recover from any error committed while handling it intentionally or unintentionally.

2.4 Study of existing solutions

To demonstrate these geographical phenomena, various models are available in the market every model has certain limitations. A comparative study of these models was done with respect to certain aspects i.e. efficacy in demonstrating the concepts, the price, availability, reparability. The models, available in the market and websites, were studied in and examined critically for their pros and cons (Table 1.). The models of different types were taken for study. During the critical analysis of the existing models, it was found that most of the models were pretty costly and they were mostly imported models that imply repairing is not possible in case of wear and tear. The permanently sealed mechanism indicated that they need to be replaced in case of any damages. Also, it was realized the models in which had an open mechanism would create more interest as they provide additional information about how the model would works. A thorough study of model 4 presently used by NCERT was also studied to understand various mechanisms used to demonstrate the concept. An effort was made to look into how it could be modified to make it cheaper and more effective in demonstrating related concepts.

Models	Pros	Cons
 Model 1	The model demonstrated almost all the concepts related to rotation and revolution of the earth. The glowing sun could demonstrate the concept of eclipses. And, the chart on the base could demonstrate different seasons. It was small and compact, easy to package and transport.	The model did not demonstrate the anticlockwise rotation of the moon around its axis. The model was not meant to be repaired as the mechanism of the model was permanently sealed. If there was any malfunction, it could not be repaired without breaking the cover. Also, it was an imported product and cost around Rs.9000.
 Model 2	The model demonstrated almost all the concepts related to rotation and revolution of the earth. The concept of eclipses could also be demonstrated. And, the chart at the disc with a pointer could demonstrate different seasons. The model could be repaired as the mechanism was visible.	The model did not demonstrate the anticlockwise rotation of moon around its axis. The model looked bulky due to the projecting gears. Also, it was an imported product and cost around Rs.2400.
 Model 3	The model demonstrated almost all the concepts related to rotation and revolution of the earth. The glowing sun could demonstrate the concept of eclipses. And, the chart on the base could demonstrate different seasons. It was neat, small and compact, easy to package and transport.	The model did not demonstrate the anticlockwise rotation of the moon around its axis. Most of the parts were concealed. Also, it was an imported product and cost around Rs.12550.

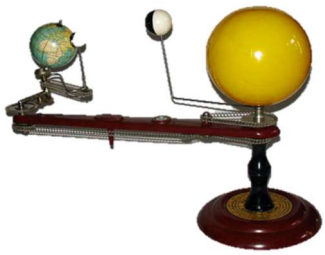
 Model 4(Model, lately, used by NCERT)	The model demonstrated almost all the concepts related to rotation and revolution of the earth. And, the chart on the base could demonstrate different seasons. All the parts were visibly attached using chain and sprockets. The model could also additionally demonstrate the process of power transmission and the desired direction of rotation. It also showed that only one side of the moon is only visible to earth. It was neat and compact and visually balanced.	The model could not demonstrate the occurrence of eclipses. Though the mechanism is well visible there was no availability of the material in case of wear and tear as it was also an imported model. The cost of the model was also around Rs. 12,000-15,000.

Table 1. Critical study of different model types

2.5 Design brief

Based on the findings of different studies and discussion with different stakeholders, following objectives were set for achieving through the new solution

- The model should effectively demonstrate different concepts
- Cost of the model should be lower
- It should be manufactured
- It should be easy to use
- It should be easy to repairs
- It should be easy to packaging and Transporting
- It should be easy to assembly and disassembly

2.6 Development of First prototype

After the study of the present models, the model lately used by NCERT was taken as the base reference. We tried to replicate various mechanisms of the model using indigenous materials. Different modification possibilities were explored through rough sketches.

Deconstruction: The whole model was deconstructed into parts. Each of the parts was studied for its structure and the sub-function, it accomplished i.e. the number of teeth on sprocket, the mechanism for rotating earth at 23.5 while revolving around the sun, the mechanism for simultaneous rotation and revolution of the moon around the earth.

Selection of indigenous low-cost material: Different parts of the existing mechanism were tried to be made using locally available material. The sophisticated chains and sprockets were replaced by locally available timer gears and chains that accomplished the same function. A set of idlers was used to obtain the desired rotational direction of the moon and earth. Ensuring

rotation of on its inclined axis was also a big challenge that was overcome by designing a special type of gear system where the inclined axis is in contact with the internal bevel gear through another bevel.

2.7 Demonstration of model and discussion with NCERT officials

The prototype of the model was shown to NCERT officials demonstrating various geographical phenomena related to rotation and revolution. Some of the feedback given by the officials were as following:

- The force required to rotate the handle was higher and required to be reduced as the model is to be used by the school children
- The cost of the model was further reduced
- The model has to be made less bulky and lighter
- Possibilities of quick repairs by a local person in case of breakdown to be explored
- Possibilities of incorporating other concepts like moon's orbital inclination of 5 to be explored

2.8 Development of the second model

The success in integrating indigenous material and positive feedback for further refinement gave many insights on how the model could be more effective in terms of looks, function, ease of use and cost. Since a significant level of effectiveness was achieved, the effort was made to bring perfection in the final model.

Extensive use of new material: To make the product stronger, lightweight and visually appealing, the wood material was replaced by nylon. Nylon rod was, also, used in the first prototype for making the special mounting and center column. In the final prototype, all the members were made into nylon. It was stronger, easily Machin able and its off-white color gave an amazing look to the model. It also made the model light weight-reducing possibility of toppling. A heavy circular disc of metal was also added to the base to make it heavy.

Use of New mechanism: One of the clear shortcomings of the prototype was the amount of effort required to rotate the model. This was overcome in the final model by providing bearings at all the rotating members.

New functions: While exploring possibilities of demonstrating new concepts, based on the prior study of the existing models, the illustration of the eclipse and inclined moon orbit were also incorporated in the final model.

Toy-like look: The material made in off white nylon gave it the look of a toy. The material like thread and lights are some common things, which children could associate to. Also, colorful representing showing different seasons made it more attractive.

2.9 Demonstration and evaluation of the final model

The final prototype of the model along with the initial prototype was demonstrated in a workshop conducted for evaluating different educational models. The workshop constituted of higher officials and members of Division for Educational Kits NCERT, Teacher representatives from different classes, from all over India and representatives from a different academic institution who participated with their models and fabricators empaneled to NCERT. The model was evaluated on the same criteria, which were outlined during the prior workshop i.e.

- Effectiveness of model in demonstrating different concepts
- Cost of the model
- Local manufacturability
- Ease of use
- Ease of repairs
- Ease of packaging and Transporting
- Ease of assembly and disassembly

3. Results

The final of the review of the model was very positive as it largely fulfilled most of the criteria. The members were very happy and excited to see the quality of the outcome and its precision in indicating different solstices and equinoxes. There was a total of 7 models in the category at the workshop and none demonstrated as many concepts as this did. Along with showing the rotation and revolution of earth and moon with exact directions, it demonstrated moon inclined orbit, the occurrence of eclipses by adding electric bulb inside the sun. It also demonstrated additional information related to the principles of string and pulley.

For the cost of the model, due to the use of inexpensive materials used, the cost of the model has come down to 3000, which could further decrease in manufacturing.

Since all the rotating parts had bearings, the model moves effortlessly with the touch of a finger and even if it is rotated in the opposite direction, the system won't malfunction. As far as the repair was concerned, the most wear prone part is threaded which could be replaced easily.

Also, since all the parts are made locally, any damaged part could be easily replaced. Since the model is very compact and many of the parts can be easily assembled and disassembled, making it fit for transportation and installation.

In spite of welcoming the new model, the members showed concerns over the use of threads which according to the was extremely vulnerable. Thus, getting a suitable substitute the threads could be replaced. The model was also to be evaluated by the school children in the coming workshop of NCERT to have their feedbacks.

4. Discussion and Conclusion

The process of designing an educational model for NCERT was insightful in many ways. It was quite apparent during the process that designing educational kits for children was not a child's play. Working closely with NCERT on educational kits, revealed that most of the models used, were to demonstrate certain scientific theories in a mundane way and there was not much connection between the real-life experience of children and the models. The models required to be relooked into to make then more children centric based them the real-life experiences they can relate to.

There is a need to innovate the existing educational model to make it much livelier that attracts children and enables them to grasp concepts faster. There could be different approaches to it. it could be in terms of making the models more interactive by using motors and sensors or it could also be through using immersive technology for demonstrating concepts. Another approach to interest children could be to design the kits in DIY formats. Many big players like Byjus, "Logico" and "Disney" are already into the fray for developing educational toys.

Also, the educational model is required to be relooked into at regular intervals and updated to make them more contextual. There is also a possibility of presenting model related explanation in a puzzle-like format that is intriguing and enable better learning.

Educational kit design, also, offers a large scope of research work in the area of developing inclusive educational kits which could be used by the normal population as well as children with visual impairments.

Acknowledgement

I would like thank Dr. Ashutosh Wazalver, Head, Division of Educational Kits, NCERT for his support and cooperation and giving the opportunity to be a part of educational model development process. I would also like to thank other participants from NCERT and other organizations for their important feedbacks and suggestions.

References:

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences of the United States of America*, *111*(23), 8410–8415.

Haak, D. C., HilleRisLambers, J., Pitre, E., & Freeman, S. (2011). Increased structure and active learning reduce the achievement gap in introductory biology. *Science*, *332*(6034), 1213–1216.

Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics*, *66*(1), 64–74.

Lord, T. R. (1994). Using Constructivism to Enhance Student Learning in College Biology. *Journal of College Science Teaching*, *23*, 346–348.

Newman, D. L., Stefkovich, M., Clasen, C., Franzen, M. A., & Wright, L. K. (2018). Physical models can provide superior learning opportunities beyond the benefits of active engagements. *Biochemistry and Molecular Biology Education*, *46*(5), 435–444.

Schönborn, K. J., Anderson, T. R., & Grayson, D. J. (2002). Student difficulties with the interpretation of a textbook diagram of immunoglobulin G (IgG). *Biochemistry and Molecular Biology Education*, *30*(2), 93–97.

Smith, M. K., Wood, W. B., Adams, W. K., Wieman, C., Knight, J. K., Guild, N., & Su, T. T. (2009). Why peer discussion improves student performance on in-class concept questions. *Science*, *323*(5910), 122–124.

Sweller, J., Van Merrienboer, J. J. G., & Paas, F. G. W. C. (1998). Cognitive Architecture and Instructional Design. *Educational Psychology Review*, *10*(3), 251–296.