

How practicing science teachers amalgamate their beliefs with science

Rohini Karandikar and Aniket Sule*

Science teachers shoulder a major responsibility of introducing students to the discipline, thereby shaping their ideas and developing scientific temper. However, little attention has been paid to determine if teachers have the requisite training to achieve this. The focus of the present study is to demonstrate how physics teachers form mental models to amalgamate pseudo-scientific beliefs related to the moon, eclipses and planets with curricular science. We show that teachers acknowledge the fact that their training in science is sometimes in contradiction with their experiences and religious/traditional beliefs. In such situations, they are likely to go by their religious beliefs over scientific training. We hope the present study will draw the attention of the curriculum developers on the need to engage teachers in order to impart the correct ideas about the nature of science and scientific temper.

Keywords: Religious beliefs, scientific temper, science teachers.

INDIA is a country where several superstitions are largely propagated around astronomical events by political leaders or self-proclaimed godmen. When such ideas are circulated through media, they are likely to be accepted by the public. This jeopardizes the scientific temper of the society, to the extent of modifying school textbooks.

The term 'scientific temper' is contemporary¹. Many rational thinkers, including Jawaharlal Nehru² have defined it in their own words. If we take a common essence of all the definitions, we can paraphrase it as a way of life which expects us to accept any new idea strictly based on reasoning and evidence. A statement on scientific temper released in 1981 sheds light on the national scenario back then, with myths created about our past, astrology, palmistry, food fads and irrational health practices³. Four decades later, we are still battling the rise and havoc of pseudo-science in the country. On the same lines as the statement³, the position paper on teaching of science of the National Curriculum Framework mentions one of the aims of science education as to enable the learner to 'cultivate scientific temper – objectivity, critical thinking and freedom from fear and prejudice'⁴.

Whether the content of the textbooks is in line with this spirit of scientific temper still remains a question. Several concepts in the curriculum can be aligned with scientific temper, e.g. planetary motions, phases of the moon, eclipses, etc. Astronomy is a topic which gathers tremendous public attention and sparks curiosity. In most of

the undergraduate courses, astronomy is not a compulsory course, but is usually offered as an elective⁵. In India, astronomy does find a place in geography and science up to class XII, but few universities have made it a part of their curriculum for undergraduate physics courses. Teachers' experiences, beliefs and understanding of astronomy in Indian classrooms are not studied, barring a few exceptions^{6,7}.

A large number of studies world over have reported on the understanding of planetary motions, phases of the moon, eclipses, etc. among learners as well as the general public. Misconceptions regarding these topics lead to false beliefs and hence impact the scientific temper. For example, Treagust and Smith⁸ were among the first to study students' understanding of gravity and motion of planets. Vosniadou and Brewer⁹ studied the first to fifth grade students' knowledge of the earth. Reiss¹⁰ wrote a comprehensive review on the role of religion in a science classroom. Even in India, we see examples of studies targeting students, teachers or the general public to probe their ideas regarding phases of the moon¹¹, shape of the earth¹², interrelation between science and religion¹³, and conflicts that teachers experience when certain aspects of science contradict religious ideas¹⁴.

Shulman¹⁵ emphasized the need to think about the source of teachers' explanations and their sources of analogies, metaphors and examples. As analogies or metaphors often connect concepts with everyday life, a wrong analogy or metaphor could easily lead to a misconception or false belief. Trundle *et al.*¹⁶ discussed in detail the moon-phase conceptions among teachers. The authors emphasized that teachers and educators shoulder the responsibility of developing a scientifically literate

Rohini Karandikar is in the Curiosity Gym, 6, Singh Road, Fort, Mumbai 400 001, India; Aniket Sule is in the Homi Bhabha Centre for Science Education, TIFR, Mankhurd, Mumbai 400 088, India.

*For correspondence. (e-mail: anikets@hbcese.tifr.res.in)

society. Hence, it could pose a serious problem if teachers hold an alternative conception compared to textbook concepts. The authors also reported a longitudinal study on teachers' understanding of the phases of the moon over several months¹⁶. Their results indicated that several participants continued to hold the correct scientific understanding of the moon phases six months post-instruction, but some of them reverted to alternative conceptions¹⁷. Kanli¹⁸ reported the misconceptions held by teachers in topics like phases of the moon, moon's phase during a solar eclipse and position of the sun in the sky. Through a series of studies, Trumper¹⁹⁻²⁴ reported the conceptions in astronomy among high-school and college students and teachers. In a study on basic astronomy concepts among teachers, Trumper²⁴ recommended reforms in the curriculum to increase scientific temper and develop a critical attitude among students against pseudo-science.

Objectives

With the background of the pseudo-scientific ideas being propagated and studies on misconceptions in astronomy, we see a strong connection between teachers' beliefs and the need for the cultivation of scientific temper among learners. Teachers' alternative conceptions spring from misinterpretation of knowledge during their own training. If the same could be avoided, it would help develop scientific temper. We particularly look at how teachers adopt concepts from school science curriculum to augment their justification of superstitions. Naturally, it leads to the ultimate question: if educators are able to employ science curriculum to support superstitions, is the curriculum failing to teach the very process of science?

Methodology

The study was conducted with 33 teachers who were participants at a teacher training programme for astronomy at Homi Bhabha Centre for Science Education, Mumbai. Almost all teachers in the sample held at least a Bachelor's degree in physics, with a few exceptions who were mathematics graduates. All teachers responded to a questionnaire which sought their beliefs on certain social issues and scientific claims. The scientific part of the questionnaire consisted of 2 prompts and 12 assertions. For the two prompts, teachers were asked whether they agreed or disagreed with the claims presented in them. The teachers were also asked to write an explanation for their response. For each of the 12 assertions, teachers were asked if they agreed or disagreed on a five-point Likert's scale, with 1 being 'strongly disagree' to 5 being 'strongly agree'. The aim of the questionnaire was to probe teachers' social beliefs and views on certain cases and assertions based on astronomical events.

Teachers' responses were tabulated and a smaller sample of seven teachers was selected for a focused group discussion (FGD) of nearly 3 h. This selection was based on the clarity of teachers' responses, with an aim to draw a representative sample. The FGD was led by one of the authors (moderator), while the other author acted as an external observer. The FGD was audio-recorded and transcribed verbatim for analysis.

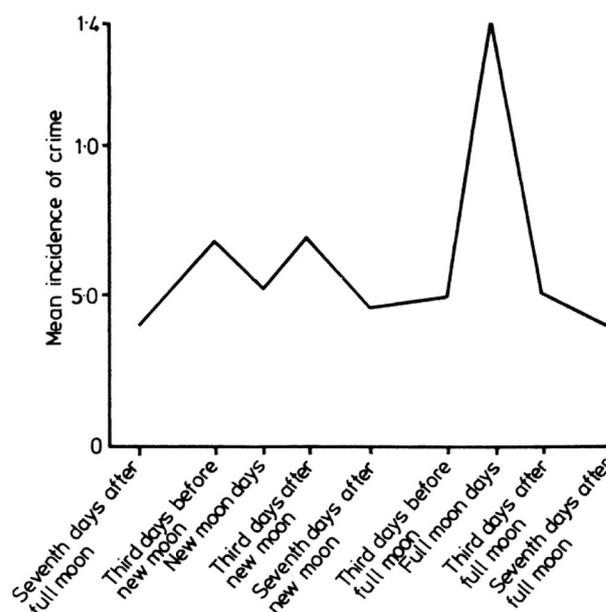
Prompt 1

A certain study was done to probe the effect of full moon on crime. The researchers collected data spanning a period of 4 years on crimes committed on full moon, new moon and some days before and after full moon and new moon. Figure 1 is a graphical representation of the data. Researchers saw a correlation and claimed that increased incidence of crimes on full moon days may be due to the increased gravitational pull of the moon and its effect on human body. Do you agree or disagree? Explain why (the graph taken from ref. 25).

A person with scientific temper would answer that the gravitational pull of the moon cannot have any effect on human body. The correlation seen here may be explained by some other trends of human behaviour, or may be a mere coincidence.

Teachers' responses to the prompt

The participating teachers were asked whether or not they agreed with the said research findings or not, and to



Changes in mean incidence of crime on different days of lunar month

Figure 1. Plot presented along with the claim²⁵.

explain their reasons. Out of 33 teachers, 24% clearly articulated unscientific arguments in their responses and another 21% were unsure. Only 36% of teachers wrote clear arguments to state why this conclusion cannot be supported.

Teachers who gave unscientific arguments provided ‘gravitation’ as a reason to justify their belief. This was an expected response as the prompt itself told the participants that the authors of the said paper claimed that gravitations was the correct reason. Additionally, the prompt being adapted from a medical journal makes it sound credible. Other than ‘gravitation’, teachers also mentioned the following as reasons for agreeing with the claim:

- Moon’s gravity affects the human body.
- Gravitational pull might cause secretion of hormones or chemicals which controls the brain.
- Direct–indirect relation between body and position of the moon and sun’s gravitational pull, called psycho-science.
- Increased gravitational pull affects the human body.
- Personal experience during full moon.
- Configuration of moon causes certain changes in the body.
- On full moon, peoples’ mind is calm due to bright light.
- No effect of moon, devil dominates a person.

Teachers’ responses to the assertions

The questionnaire consisted of 12 assertions based on astronomical events and people’s beliefs. Here, we will focus on two assertions: ‘One should not eat during any eclipse’ and ‘The positions of the planets have an influence on the events of everyday life’. Teachers were asked to respond using a five-point Likert scale. The responses available to teachers were: (i) strongly disagree, (ii) probably disagree, (iii) not sure, (iv) probably agree, and (v) strongly agree. Figure 2 is a bubble plot that shows the

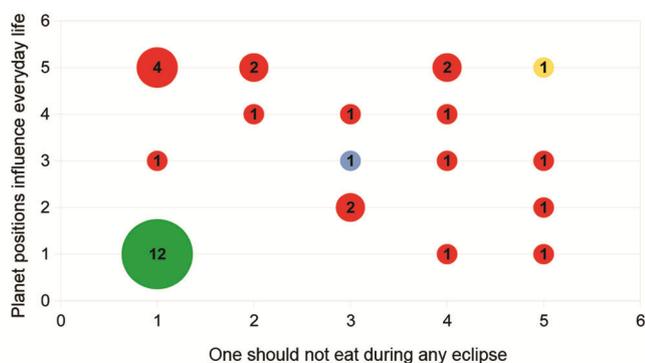


Figure 2. Bubble chart for the response of teachers to the assertions ‘one should not eat during any eclipse’ on the x-axis and ‘planet positions influence everyday life’ on the y-axis.

responses of teachers using the following colour scheme: green – he/she strongly disagrees with both the assertions (1, 1); yellow – he/she strongly agrees with both the assertions (5, 5); blue – he/she is not sure of both the assertions (3, 3) and red – he/she chooses any combination other than 1, 1; 3, 3 or 5, 5. The numbers on the bubble indicate the number of teachers who responded with the corresponding combination for assertions on the X-and Y-axes.

For these assertions, a scientifically sound response would be 1 (strongly disagree) on the Likert scale for both the assertions, i.e. planetary positions do not influence everyday life and there is no scientific reason for not eating during eclipses. Thus, green colour indicates scientifically correct response for both assertions, yellow indicates scientifically incorrect but self-consistent response and red indicates inconsistent mental models leading to the correct response for one assertion but incorrect/unsure response for the other. The bubble chart indicates that although 36% of the teachers’ responses were inclined towards scientific temper (strongly disagree), majority (57%) showed at least one response for the two assertions being non-scientific. The distribution of these data points further necessitated the need to evaluate teachers to understand the reason for their responses on the particular assertions. Thus, the seven teachers who had also provided an explanation for their response were engaged in a FGD.

Insights from the focused group discussion

The questionnaire brought to light the teachers’ beliefs and their reasoning on certain issues connected to their everyday lives. In the FGD, the claims were read out one by one (prompts) and the seven teachers (T1–T7) were requested to share their views on them. Briefly, teachers were asked if they agreed or disagreed, and then to explain the reasons of their beliefs. After all the seven teachers had responded, they were allowed to challenge each other’s views on the particular claim.

When the first prompt on relation between full moon and crime was considered for the FGD, majority of the teachers believed that the moon does exert a gravitational pull on humans. T4 mentioned that arthritic people face severe problems during full moon. Here, the moderator asked if the magnitude of gravitational force changes on full moon considering the equation of the gravitation. Further, if the magnitude is changing, the change corresponds to which variable in the said equation? T4 responded that the human body’s mass will not be affected, but the mass of moon and sun may change and that may affect human beings. T3 added that ‘there is no moon on new moon day hence, it is easy to commit a crime on new moon day. The fact that we are seeing a spike on full moon day but not on new moon day supports the article’s claim’.

The graph cited in Figure 1 implies a correlation. The authors of that article justify the correlation by associating a scientifically sound explanation to the phenomenon. Teachers readily accepted the causal relation and provided arguments to defend it. Another belief from the FGD was that ‘if the moon can cause tides in the ocean by its gravitational pull, then the moon could also affect the human body, which is 65% water’. To navigate the discussion, the moderator gave additional prompts, like ‘Can you quantify the gravitational pull of the moon on humans and compare it with other terrestrial pulls? How can one prove that gravitation affects human (criminal) behaviour? Is it possible that the moonlight on a full-moon night makes it easier for the criminals to act? Can the gravitational effect of full moon be seen on every human? Why is there no peak on new moon day even though the sun and the moon are on the same side, exerting a larger combined pull?’ The discussion ended in a divided opinion with four teachers reaching the conclusion that this correlation is not enough to claim causation, whereas two teachers continued to argue that the moon will exert ‘some kind’ of force on human beings, but they could not explain what that force will be.

Assertion 1: One should not eat during any eclipse

During the FGD, this claim engaged the teachers in an animated discussion. While few teachers believed that there is no scientific evidence for any radiations affecting food, others strongly believed some radiation emitted during eclipses does affect food. We list here various arguments put forth by two teachers, T2 and T3, in support of this belief:

- During eclipses, rays are interrupted leading to pollution which affects food (T3).
- My grandmother taught me about the Sun’s rays getting blocked during an eclipse (T2).
- Temperatures in India are usually higher, which may result in spoilage of food (T2).
- Same is the reason why a tulsi (basil) leaf is usually kept in the stored food during an eclipse (T2).
- I do not know exactly, but something is blocking someone (T3).
- There should be some reason, that is why so many people are doing it (not eating during the eclipse; T2).
- (On prompting by the moderator, if crops should be destroyed after an eclipse.) Only cooked food will be affected, not uncooked food (T3).

T7, whose thinking was in line with scientific temper, countered the ray-blocking argument by giving an example of cloudy/rainy days. This discussion also led us to probing the teachers’ ideas on what causes spoilage of food, food poisoning, etc. It was realized that these physics teachers had difficulty in explaining biological causes

of food spoilage. This highlights the disconnect between the curriculum and life experiences for most people.

Assertion 2: The positions of planets have an influence on the events of everyday life

Eleven out of 33 teachers believed that planets have an effect on human beings. In the FGD, while the entire group believed that horoscopes are unnecessary, four out of seven teachers strongly believed that positions of planets affect humans. Here again, ‘gravitation’ was mentioned as the reason why planets affected humans. The moderator (M) then initiated a discussion which was as follows:

M: There are nine of us here (in this room). Jupiter is there in sky right now. Will it have a different force on each one of us, depending on our birth date?

Most teachers: ‘Yes’.

T6: If mass and our distance from Jupiter are different for everyone, then Jupiter will also have a different effect on everyone.

M: Assume the mass of people in the room from 50 to 100 kg, distance between Jupiter and Earth being about 600 billion metres and the separation between people in the room being less than 2 m. Do you wish to reconsider your view? Square of 600 billion metres is in the denominator.

T6: That distance also (will) affect.

T3: In horoscopes, where does GmM (GmM refers to numerator part of the equation for gravitational force between two bodies) come? We say the ‘positions in horoscopes’ (not GmM).

M: (in the horoscopes) Which planet in which zodiac? Distance from Jupiter is 600 billion metres. Distance between any two people in this room is around 2 metres. So, will Jupiter’s gravity be different mathematically?

T2: Not mathematically, but yes from personal experience.

M: Consider the denominator of 600 billion metres squared.

(M talking to two teachers): You both are sitting here. Is he (the other person) exerting gravitational force on you? Would that be more than the gravitational force exerted by Jupiter? The distance is very very large, so force will be very very small. If gravitational force is the reason,

would we worry more about who is sitting next to us than the planets?

T2: This experience is beyond mathematics.

Throughout the FGD, it appeared from the teachers' views that gravity or 'some other' force by the moon or the planets does affect humans and their behaviour. The beliefs of some teachers do not take the physical parameters into consideration. Their beliefs were purely based on personal conviction, and they did not feel any need for validation. The universal nature of science did not matter, according to them.

Discussion

The FGD indicated that teachers who did not hold a strong opinion were open to new evidence and were able to analyse it. As the sample is drawn from teachers who were voluntarily participating in an astronomy-related training programme, we expected this group to have a better understanding of the content and process of science than a random sample of teachers. The teachers strongly attached to alternative beliefs conceded at the end of the discussion that their beliefs may not be consistent with scientific knowledge, and that they need to introspect. As the concepts mentioned by the teachers are already available in the curriculum, the classroom can become a space for students to initiate such discussions and build their own arguments. Teachers can pose such questions to scaffold classroom discussions.

The concepts touched upon in the FGD, namely phases of the moon, eclipses, planets and gravity are very much a part of the NCERT curriculum. As most of the State Board curricula in India are aligned with the NCERT curriculum, we looked at how the above-mentioned concepts appear in the NCERT curriculum. We observed multiple instances where the teachers' responses included direct references to these concepts. However, most of the information is presented in a factual manner in textbooks and does not provide opportunities for the learner to analyse and assimilate these ideas.

Other than textbooks, beliefs in the society also influence critical thinking. Narlikar *et al.*²⁶ have already published a statistical study conclusively debunking astrological predictions. In spite of this, astrology is currently gaining a strong foothold in the society. Several customs in families are based on the astrological predictions or 'auspiciousness' of occasions. This is another reason for teachers to believe strongly that there is some grain of truth in astrology. Teachers' responses in favour of astrology could be due to its traditional origins, further biased due to their own experiences while seeking astrological interventions for problems such as health issues. The Indian textbooks are particularly mute on astrology,

as that discussion is deemed too controversial. Thus, it is left to the students and teachers to create a mental model which accommodates both their curricular knowledge (like astronomy) and traditional beliefs (like astrology), further posing a threat to the scientific temper. Learners often reconcile their models with the view which best suits their experience or their family views, which could be astrological.

Figure 1 shows a clear spike in the incidence of crime on full moon days. In science, we often collect data, observe correlations and then build a theory which fits the data. The implicit assumption in this process is that the theory is consistent with the overall framework of our understanding of nature and hence does not require additional proof. However, when we do not state this assumption explicitly, learners of science often consider that 'any' theory which fits the data would be equally valid. Thus, in their mind, correlation automatically implies causation. Data presented in the form of statistics, graphs, charts, etc. make readers abandon doubt, as they lend credibility to the (incorrect) causal connection proposed. Hence, the figure paints a perfect picture for connecting crime and phases of the moon. Most of the pseudo-science is propagated, at times even published, by simply showing the correlation between two otherwise unrelated phenomena.

Another example of choosing unrelated facts from the textbooks and weaving a mental model on that basis is the argument that 'The earth (surface) consists of 70% water, the human body also consists of 65% water. Thus, if the moon can exert gravitational pull on oceans, then it might as well have similar effect on the human body'. These arguments appear as convincing to most people as they do not quantify the forces referred in the arguments. Estimating the numerical value of the forces involved would show that they differ by several orders of magnitude, and that the latter is negligible compared to many other forces we encounter in our daily lives. One can additionally argue that such effect of gravity should be impersonal and should not differ from person to person. Chapter 10 on 'Gravitation' of the ninth class grade NCERT textbook mentions 'that an apple thrown up falls towards the earth, but the earth does not move towards the apple'. The chapter even proclaims the reason for this as 'the mass of an apple is negligibly small compared to that of the earth'. But, this powerful insight is often ignored in classroom instructions.

The arguments for not eating during an eclipse appear to be very much influenced by traditional practices, which was explicitly mentioned during the FGD. During the lunar eclipse of 2018, a popular news channel mentioned that 'cooked food contains water and water attracts radiation'²⁷. This might have led the teachers into believing that only cooked food and not crops get affected during eclipse. Teachers' views on eating during an eclipse implied an unclear understanding of food spoilage. Food

gets spoiled due to growth of microorganisms which enter it through soil, air or water. A clear understanding of the reason for eclipses, parameters which actually change during an eclipse and food spoilage could help in eliminating the myth on not eating during eclipses. The school textbooks usually have separate sections on physics, chemistry and biology. This makes it difficult to connect the topics on eclipses (astrophysics) and food spoilage (biology).

The present study shows the need for newer approaches in engaging teachers using role-play, prompts or seeking explanations based on the scientific method. If these interventions are successful in clarifying certain ideas like 'magnitude of the gravitational force of planets on humans' or 'stable environmental conditions during eclipses', then we envision a change in teachers' mental models to be aligned with scientific temper.

We strongly believe that it is the curriculum which should inculcate the ability to think critically. Engaging teachers in critical discussions on the current beliefs (scientific and pseudo-scientific) prevalent in the society would be a good step in that direction. In this way, they could develop a scientific outlook and apply it in their classrooms. Additionally, questions on critical thinking to connect science with everyday life can be provided as separate boxes or towards the end of certain chapters in textbooks. Here, it is crucial that teachers must not shy away from controversial discussions. Although this appears quite idealistic, such discussions would not only ensure development of scientific temper, but also ease off the challenge of 'debunking myths' for the future generations.

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