Concept of Force Across Different Levels

S.V. Sharma
Regional Institute of Education (NCERT)
Ajmer

Exploration of misconcepts of physics among students at various levels has been of much interest during the last few decades {Saxena (1996), Saxena (1997), Hake (2001), Savinainen and Scott (2002), Jain et al (2003), Barak (2004), Sharma and Sharma (2003), Sharma and Sharma (2004), Jadhao and Parida (2005) and Sharma (2005)}. Prior knowledge of the misconcepts among students can be the basis for generating discussion and planning of strategy to help the students acquire the correct concepts and also make them think in a scientific way. Since pre-conceived concepts have been found to be resistant to change, it is all the more important that they are identified and suitable strategies are employed in the classroom situation to handle them effectively. There are a large number of misconceptions prevailing amongst physics students including the concept of force even after studying physics for a number of years. Examples of a few common misconceptions are given below: (i) force continues to be associated with the body till it remains in motion; (ii) velocity and acceleration are inseparable physical quantities and are in the same direction; (iii) force is in the direction of velocity etc. It is, therefore, necessary to determine such alternative frameworks/ misconceptions before starting any teaching-learning process pertaining to conceptual dimensions of force. Concept of force is very fundamental in basic physics. Its effects are distinctly perceptible in every branch of physics/ science.

A student of science begins formal learning about force from elementary level yet conceptual clarity eludes many for a quite long time. Force Concept Inventory (FCI) has been originally designed by Hestones et. al (1992) to address conceptual dimensions of force and related kinematics. Hake (2001), Huffman and Heller (1995), Hestenes and Halloun (1995) and Savinainen and Scott (2002) have also carried out research investigations using FCI and highlighted its usefulness in evaluating students' understanding even before any formal teaching begins. FCI is an effective diagnostic tool to examine conceptual understanding of basic concepts of force. Keeping aforesaid in view, present study has been conducted on a group comprising students studying physics with a view to investigate their understanding the concept of force. For comparison, postgraduate teachers of physics were also involved in the study. The students associated with this study were drawn from those studying at the higher secondary level (popularly known as + level); Ist, IInd, IIIrd and final year students of B.Sc. Ed. course besides Ist and IInd year students of 2-year B.Ed. course (who were already graduates while some of them were post-graduates). It may be mentioned that four-year

B.Sc.Ed. course is an integrated course offered at Regional Institute of Education (RIE), Ajmer after completion of higher secondary.

Design of the Study (Tool, Sample and Process)

- A questionnaire in the form of Force Concept Inventory, developed by Hestenes et. al (1992) was used as standard tool for administering the test. It comprises 29 questions related to the basic conceptual dimensions of force viz. kinematics, Newton's first law, Newton's second law, Newton's third law, superposition principle and kinds of forces. All questions in it were multiple-choice type, each having five options, except for question number 16. Out of five options one is correct and remaining four are intended to assess suspected misconceptions.
- The tool comprising 29 items was administered on a heterogeneous and random group of students at different centers having well equipped facilities and well qualified and devoted teachers dealing with physics education. Students were instructed to give correct options for multiple-choice questions. There was no time limit fixed for responding to the questionnaire. However, 95 minutes duration was found enough to respond to all items. Details (type of sample, size of sample and level) of the sample are given in Table 1.
- At the next stage of the study six practical (laboratory) activities (I to VI) based on different conceptual dimensions of force were designed. Randomly selected groups of students from each level were asked to perform these activities and identify the specific concept involved in a particular activity. Activity I was related to Newton's first law of motion and students were expected to explain why only the coin at the bottom of a pile of 18 coins ejected out when it was hit by a single coin.

TABLE 1
Details of the Sample

S. No.	*Type of Sample*	*Size of Sample*	*Level of Sample*
1	Class XII students	63	+2
2	B.Sc. B.Ed. I year	15	U.G.
3	B.Sc. B.Ed. II year	25	U.G.
4	B.Sc. B. Ed. III year	23	U.G.
5	B.Sc. B.Ed. IV year	23	U.G.
6	B.Ed. I year	12	G
7	B. Ed. II year	11	G
8	P.G. Teachers	63	P.G.

Activity II was also related to Newton's first law of motion and students were expected to discover the importance of wearing a seat belt. Activity III was related to Newton's second law of motion and students were expected to investigate and formulate some ideas about the effect of moving steel ball on a stationary target steel ball (constant mass and changing force, constant force and changing mass and constant acceleration and changing mass). For performing this activity three rolling balls of different masses were given. Target steel ball had the same mass as one of rolling steel ball throughout the activity. Activity IV was related to Newton's third law of motion and students were expected to investigate the role of string in the activity. Also to understand that action acts on one object and the reaction is directed to the other. Activity V was also based on Newton's third law of motion. Here one fixed end of string was replaced with a another pulley. Activity VI was related to Newton's third law of motion. Here students were expected to guess if rotational motion needs something more than force alone i.e., existence of torque ($T = r \times F$).

- Randomly selected groups of students were interviewed individually by asking structured and cross-questions regarding aforesaid practical activities performed by them. Students were also asked to write the reasons behind the identified specific concept involved in particular activity. The interview was conducted with the above students in a friendly atmosphere to supplement the written test and to reveal rationale behind giving particular answer to a question. However, interview sessions were not conducted for teachers. The proceedings were recorded audio and video graphically. The recorded versions of the interviews were transcripted for analysing their responses. Answers of the written test and interview were co-related to draw the inferences.

Analysis of the Responses and Results

Response to each question of questionnaire (FCI) was analysed and discussed in order to understand the reasons of options favoured by the students and teachers. Table 2 gives the analysis of responses related to basic conceptual dimensions of force in a particular question. During the analysis of responses no separate account was kept for male and female students/ teachers. The following conclusions can be drawn:

- All the students and teachers responded to almost all the questions. However, 246 options were left unresponded out of total responses 6,830. In some cases there were very few correct responses e.g., question numbers 5, 9, 15, 16, 17, 19, 21, 22, 24 & 26 (Table 2). Out of total responses 2,178 were over all responded to correctly whereas number of overall wrong responses was 4,406.

- Overall percentage of unresponded, correctly responded and wrongly responded responses is 3.6, 31.9 and 64.5 respectively.
- The average correct response per student is 29.2% whereas for teacher it is 39.4%. There was only a one question, which was answered correctly by more than 95% of teachers (Table 2). About 40% teachers responded to twelve questions correctly.
- There are no significant differences amongst students' responses at different levels, which indicate that there is a difference and wide gap between the learning outcomes as expected from the curriculum given to the students and their real learning.
- In most of cases responses given by the teachers are not much different from the students' responses. This surprisingly and clearly point out that a fraction of teachers' also do carry misconceptions.
- Responses of students at all levels are varying from one option to other. They do not have concrete views regarding selection of a particular option. The same is the case with teachers.
- Responses to all questions of FCI clearly depict the existence of misconceptions regarding understanding the conceptual dimensions of force among students and teachers as well.

Misconceptions were identified on the basis of responses given by students and teachers. Analysis of the responses is discussed below:

Response to question 1 of questionnaire indicates that level of understanding of students at +2 level, I year B.Sc.B.Ed and II year B.Sc.B.Ed. is almost identical. Not a single student has left any option unresponded in this question. However, 3.2 % teachers did not respond to any of the options. It seems to us that teachers have got better understanding regarding this question as can be seen from their correct options. Teachers have opted options as 92 %(C), 3.2% (D) and 1.6% (E). Options (A) and (B) were not opted by any of the teacher. In this question concept of acceleration: mass/weight relation was studied. The correct option in this question is (C). It can, therefore, be concluded that students have moderate understanding regarding aforesaid concept.

Question 2 was related with the understanding of Newton's third law. Students at +2 level did not understand this question very well as no one has opted for the correct option (E). The understanding of this question is very poor amongst II and IV year B.Sc.B.Ed. and I and II years B.Ed students. As far as teachers are concerned only 52.4% have opted for the correct option (E). Surprisingly, students of I year B.Sc.B.Ed. have replied to this question correctly by opting for option E, which is nearly as high as the teachers, that is 53.3%.

TABLE 2

Analysis of responses related to different concepts of force

Concept	*Q.N.*	*Unresponded options*			*Correct options*			*Wrong options*			*% of wrong options*		
		S	*T*	*O.A.*	*S*	*T*	*O.A.*	*S*	*T*	*O.A.*	*S*	*T*	*O.A.*
Acceleration: mass/weight relationship	1	-	2	2	97	58	155	75	03	78	43.6	4.7	33.2
Newton's third law	2	1	1	2	49	33	82	122	29	151	70.9	46.0	64.2
Acceleration; independent of mass/weight	3	1	7	8	31	30	61	140	26	166	81.3	41.3	70.6
Motion under no force	4	6	1	7	86	46	132	80	16	96	46.5	25.4	40.8
Role of force of gravity	5	1	-	1	26	15	41	145	48	193	84.3	76.2	82.1
Vector addition of displacement	6	4	2	6	55	36	91	113	25	138	65.6	39.6	58.7
Vector addition of velocities	7	6	4	10	44	34	78	122	25	147	70.9	39.6	62.5
Newton's first law with constant speed	8	9	2	11	45	24	69	118	37	155	68.6	58.7	65.9
Force due to action-reaction	9	4	8	12	31	08	39	137	47	184	79.6	74.6	78.2
Newton's first law with no force	10	2	4	6	74	34	108	96	30	126	55.8	40.6	53.6
Newton's third law	11	-	2	2	84	28	122	88	33	121	51.1	52.3	51.4
Balancing action-reaction forces	12	-	-	-	72	45	117	100	18	118	58.1	28.6	50.2
Newton's third law	13	3	5	8	51	10	61	118	48	166	68.6	76.2	70.6
Newton's third law	14	5	9	14	39	24	63	128	30	158	74.4	40.6	67.2
Impulsive action-reaction	15	1	2	3	44	17	61	127	44	171	73.8	69.8	72.7
Trajectory of a projectile	16	5	3	8	49	13	62	118	47	165	68.6	74.6	70.2
Gravitational force	17	-	2	2	49	20	69	123	41	164	71.5	65.0	69.7
Constant velocity-balancing upward and downward force of gravity	18	6	2	8	25	25	50	141	36	177	81.9	57.1	75.3

Superposition principle: vector sum	19	5	3	8	73	21	94	94	39	133	73.8	61.9	56.5
Speed (dx/dt) – rate of change of position	20	5	6	11	40	14	54	127	43	170	54.6	68.2	72.3
Acceleration (dv/dt)–rate of change of speed/velocity	21	5	4	9	47	15	62	120	44	164	69.7	69.8	69.7
Motion under gravitational force	22	3	4	7	26	13	39	143	46	189	83.1	73.0	80.4
Trajectory under superposition of two velocities	23	5	5	10	58	39	97	109	19	128	63.3	30.1	54.4
Constant acceleration with parabolic path	24	1	12	13	21	07	28	150	44	194	87.2	69.8	82.5
Constant acceleration	25	6	11	17	56	21	77	110	31	141	63.9	49.2	60.0
Newton's first law with no force	26	11	14	25	21	10	31	140	39	179	81.3	61.9	76.1
Newton's first law speed constant	27	2	8	10	62	27	89	108	28	136	62.7	44.4	57.8
Newton's first law with cancelling forces	28	6	10	16	46	22	68	120	31	151	69.7	49.2	64.2
Kinds of force-friction opposes motion	29	4	6	10	47	31	78	121	26	147	70.3	41.3	62.5

*S stands for students, T stands for Teachers and OA stands for overall

Concept of acceleration; independent of mass/weight, is hardly understood either by students or by teachers as can be seen from the correct options offered by them. Most of responses are other than from the correct option (C). It seems that the majority of the students barely understand the aforesaid concept. However, they have not left any option (except I year B.Ed. students) unresponded in contrast to teachers where 11.1% of them did not respond to any options in question 3.

The concept of motion under no force i.e., Newton's first law was tested in question 4. This concept is understood by most of the students and the teachers as is evident from their correct options. The correct option (B) was opted by 41.3% students at +2 level, 53.2% I year B.Sc.B.Ed., 56% II year B.Sc.B.Ed., 78% III year B.Sc.B.Ed., 56.5% IV year B.Sc.B.Ed., 58.3% I year B.Ed. and 73% teachers. However, none of the II year B.Ed. students has for opted the correct option.

Question 5 was related with the concept of gravitation. Only 23.8% teachers and less than 26.68 % students opted for the the correct option (D). 8.3% I year B.Ed. students did not respond to this questions whereas rest of students and teachers choose one of the given options. Students' responses at any level were also not much different from the teachers. It seems that understanding of the students and teachers regarding the concept of gravity are not sound enough.

Concept of vector addition of displacement was investigated in question 6. More than 52.0% students of II and IV years B.Sc.B.Ed. as also the teachers have opted for the correct option (B). Whereas others have poor understanding of this concept. However, +2 level and I year B.Ed. students and teachers did not choose some of the given option (<8.3%).

Question 7 in which the concept of vector addition of velocities was examined, the correct option (E) was opted for the by 15.9% +2 students, 33.3% I year B.Sc.B.Ed. 52% II year B.Sc.B.Ed, 43.4% IV year B.Sc.B.Ed, 53.9% teachers and 52% I year B.Ed and 27.2% II year B.Ed. However, none of III year B.Sc.B.Ed. students have opted for the correct option. Unresponded responses were given by 7.9% +2 students, 9.1% II year B.Ed. students and 6.3% teachers in this question.

The concept related with Newton's first law: constant speed was investigated in question 8. This concept was poorly understood by +2, II year B.Sc.B.Ed, IV year B.Sc.B.Ed, I year B.Ed. and II year B.Ed. students. The correct option (A) was opted for moderately by I year B.Sc.B.Ed. students 40% and teachers 38%. Here 3.2% each +2 students and teachers have left unresponded responses. It can be concluded from the responses given by the students and teachers as listed in Table-2 that their understanding regarding this concept is not concrete. Options selected by them indicated alternative views.

Responses to question 9 clearly indicated that the concept of force due to action-reaction is hardly understood either by the students or the teachers as correct option (D) was opted by +2 students 19%, I year B.Sc.B.Ed., 6.7%, III B.Sc.B.Ed. 8.7%, IV year B.Sc.B.Ed. 13%, I year B.Ed. 16.7% and II B.Ed. 36.4% and teachers 12.81%. This question also interpreted in terms of alternative views. II year B.Sc. B.Ed. students have not opted option (D) at all. Percentages of responses of students to this question are given below:

In regard to question 10, related with the understanding of Newton's first law of motion with no force, correct option (B) was opted for by more than 41.7% students except II year B.Sc.B.Ed. and teachers. Unresponded responses were less than 6.3% given by +2 students and teachers only. Other students have not left any option unresponded.

Question 11 was related to the understanding of Newton's third law of motion was moderately understood by the students and teachers as can be seen from their correct responses opted in this question.

It can be inferred from the responses given by the students and teachers that

Options → Students	A	B	C	D	E	UR
+2 level	14.3	23.8	22.2	19.0	17.5	3.2
I year B.Sc. B.Ed.	6.7	33.3	46.6	6.7	-	6.7
II year B.Sc. B.Ed	12.0	32.0	36.0	-	20.0	-
III year B.Sc. B.Ed	21.7	56.5	-	8.7	13.1	-
IV year B.Sc.B.Ed	-	39.2	39.2	13.0	4.3	4.3
I year B.Ed.	-	50.0	16.7	16.7	8.3	8.3
II year B.Ed.	9.1	-	54.5	36.4	-	-

understanding of Newton's third law of motion in different situations was poor in questions 12, 13 and 14.

Concept of action-reaction in the context of a given impulse was investigated in question 15. Responses given by the students and teachers have indicated that the concept involved in this question was barely understood.

The concept of trajectory of projectile was studied in question 16. It may be inferred from the responses given by teachers and students except II & IV years B.Sc.B.Ed. and II year B.Ed. that their understanding regarding trajectory of projectile is not up to the mark. The correct option (B) was given by 20.4% teachers only. The percentages of responses given by the students at different levels are as follows:

Questions 17 and 18 was related to the concept of gravitational force. Responses given to this question have clearly indicated the lack of understanding the concept. The correct option (C) of question No. 17 was opted by 27% +2 students, 40% I year B.Sc.B.Ed, 24% II year B.Sc.B.Ed., 34.8% III year B.Sc.B.Ed., 34.8% IV year B.Sc.B.Ed., 16.7% I year B.Ed., 9.1% II year B.Ed. and 31.7% teachers. The percentage of correct options was even

Options → Students/teachers	A	B	C	D	E	UR
+ 2 level	1.6	27.0	57.1	8.0	-	6.3
I year B.Sc.B.Ed.	-	13.3	86.7	-	-	-
II year B.Sc.B.Ed.	52.0	48.0	-	-	-	-
III year B.Sc. B.Ed.	8.7	13.0	65.3	13.0	-	-
IV year B.Sc.B.Ed.	43.5	47.8	9.7	-	-	-
I year B.Ed.	-	-	50.0	41.7	-	8.3
II year B.Ed.	-	36.4	54.5	9.1	-	-
Teachers	11.1	20.4	39.7	23.8	-	4.8

poorer for question 18. Comparative understanding of this concept of students and teachers seems to be almost same.

Question 19 was related with the concept of superposition of vectors. In regard to this question students and teachers opted for the correct option (B) as 39.6% +2, 59.6% I year B.Sc.B.Ed., 48.0% II year B.Sc.B.Ed., 17.4% III year B.Sc.B.Ed., 56.5% IV year B.Sc.B.Ed., 25.0% I year B.Ed. and 63.7% II year B.Ed. students and 33.3% teachers. These responses indicated clearly the existence of alternative frameworks in the minds of students and teachers as well.

Concept of speed: (dx/dt), rate of change of position, was studied in this question 20. Responses opted by the students and teachers are not much different from each other. The correct option (E) was opted by 15.9% +2 students, 33.9% I year B.Sc.B.Ed, 20% II year B.Sc.B.Ed, 13% III year B.Sc.B.Ed. and 18% II year B.Ed. students and 22.2% teachers. However, 65.3% IV year B.Sc.B.Ed. opted the correct option indicating the better understanding over others.

Responses in regard to question 21 have indicated existence of misconception among the students and teachers as can be seen from their responses (Table 2). In this question the concept of acceleration: (dv/dt), rate of change of velocity, was investigated.

Concept of motion under gravitational force was examined in an question 22. Responses to this question indicated that students and teachers have very poor understanding the concept (Table 3). Such poor understanding of the concept may be attributed either to ineffective instruction or lack of commitment to the subject. It has been pointed out that effective instruction requires more than dedication and knowledge of the subject. It requires technical knowledge about how students think and learn.

Question 23 was related to the concept of trajectory under superposition of two velocities. 61.9% teachers and 46.6% students have responded to this question correctly which indicates better understanding of teachers over students.

Concept of constant acceleration – parabolic path was investigated in question 24. It cane be seen from Table 2 that aforesaid concept was hardly understood either by the students or the teachers.

The concept of constant acceleration was not understood satisfactorily either by students or teachers as is evident from the responses given by them in regard to question 25 (Table 2).

Question 26 was related to the application of Newton's First law of motion with no force. In this question the percentage of correct option (B) given by students and teachers is less than 26.7% in most of the cases. It is worthwhile to note from the following table that the responses given by the students and teachers are varying from one option to other. This indicates the existence of alternative views regarding the concept in their minds.

Options → Students/teachers	A	B	C	D	E	UR
+2 level	19.0	12.7	15.7	23.8	15.8	12.6
I year B.Sc.B.Ed.	6.7	6.7	40.0	26.7	20.0	-
II year B.Sc. B.Ed.	32.0	8.0	8.0	48.0	4.0	-
III year B.Sc. B.Ed.	17.4	17.4	47.8	4.4	3.0	-
IV year B.Sc. B.Ed.	4.3	21.8	34.8	26.1	13.0	-
I year B.Ed.	16.7	8.3	33.3	16.7	-	25
II year B.Ed.	27.3	-	18.2	45.5	9.0	-
Teachers	4.8	15.8	17.5	39.7	22.2	-

Understanding of students and teachers regarding Newton's first law of motion with constant speed was moderate as can be seen from the responses given by the students except for those of II year B.Sc.B.Ed. and teachers in regard to question 27 (Table 2).

From the analysis of the responses to question 28, it is evident that the level of understanding of students and teachers on this concept is at an average level. (Table 2). This question was related to Newton's first law of motion with involving forces that cancel each other.

Question 29 was related with the concept of kinds of forces: friction opposes the motion. Responses to this question have indicated better understanding of teachers over students as can be seen from percentage of following correct option (C) opted by students and teachers:

It is worthwhile to note from the above analysis of the students' and teachers' responses that there is a section of students and teachers who do carry misconceptions. This is despite the fact that all teachers are well-qualified. It can also be seen from the analysis of

Options → Students/teachers	A	B	C	D	E	UR
+2 level	19.2	26.9	33.3	9.5	11.1	-
I year B.Sc.B.Ed.	26.7	33.2	26.7	-	6.7	6.7
II year B.Sc.B.Ed.	12.0	60.0	24.0	4.0	-	-
IIIyear B.Sc.B.Ed.	26.1	39.1	13.1	4.3	17.4	-
IVyear B.Sc.B.Ed.	17.4	30.5	34.8	8.7	4.3	4.3
I year B.Ed.	33.3	33.3	16.7	-	-	16.7
II year B.Ed.	9.1	36.4	27.3	9.1	18.1	-
Teachers	7.9	22.2	49.2	11.1	-	9.5

the responses given by students that their views for opting for an option for a particular question are not concrete. Same is the case for teachers. This may be attributed to the existence of alternative frameworks in their minds. Similar results have also been reported by earlier studies regarding the existence of alternative frameworks associated with various concepts (Saxena (1996), Saxena (1997), Hake (2001) and Savinainen and Scott (2002)). The existence of misconceptions among the teachers has serious implications and likely to be passed on to their students (Sharma and Sharma (2003)). Teachers may, therefore, take this into account. They may try to identify alternative frameworks in the initial stage and to provide a curriculum that takes care of such types of frameworks of the students. This is especially important from the viewpoint of successful teaching and meaningful learning. For a prior knowledge of the misconcepts/ alternative frameworks among students can be the basis for generating discussion and planning of strategy to help the students in acquiring the correct concepts and also make them think in a scientific way.

Students' Frameworks

Analysis of responses obtained through interviews and written answers indicates following students' alternative frameworks regarding understanding the basic conceptual dimensions of force:

Students recognise

- Push or pull as force and
- Any thing, which can be changed or displaced.

Force causes

- Motion when it is applied in an unbalanced manner,
- Change in position, displacement, velocity,
- Change in motion, and direction and
- Change in state of body, distortion, configuration, affecting shape of the body.

Force is related with motion

- F=ma (acceleration is produced by velocity or vice versa),
- More (larger) force means more (larger) velocity or vice versa.,
- Force is directly proportional to motion. Without force there is no motion and
- Force is a cause, which produces motion. Motion is an effect.

Motion means presence of force

- Any body undergoes displacement force is present there.
- No force, no motion.
- Force continues to be associated with the body till it remains in motion.

Constant force results in constant velocity.

Largest force determines motion.

Force acts on a body only in horizontal direction not in vertical direction.

If force is applied on different points, rotational motion is observed.

Greater mass having greater velocity and travelled greater distance.

Implications of the Study

Investigations into students' and teachers' ideas pertaining to the conceptual dimensions of force were conducted over groups comprising the following:

- Those who were studying the concepts this year (+2 level).
- Those who have passed +2 level last year and done related experiments this year.
- Those who have studied concepts beyond the ones being tested and are going to graduate.
- Those who are already graduates and post-graduates and have studied the concepts in theory as well as done related experiments during their courses studied earlier.
- Those who are already post graduates and are teaching the concept theoretically and practically for more than 12 years or so.

Responses were obtained using a questionnaire having multiple-choice questions, questions to be answered giving reasoning and asking the students to perform activities during which they were interviewed. Written responses as well as audio and video recorded versions were analysed after preparing their transcription. These responses indicate that there is a difference and a wide gap between the learning outcomes as expected from the curriculum given to the students and their real learning at all levels. It is also noted that there are no significant differences amongst students at different levels. Surprisingly, teachers are also not exceptions to above inference in some of the conceptual dimensions of force. There can be a number of reasons for examples:

- Transactional strategies may not be effective.
- Concepts may not be internalised because of students' sticky nature and naïve behaviour.
- Students may not find content interesting enough and correlating concepts with practical experiences.
- Students may not be able to apply their knowledge in unfamiliar situations for finding solutions.

To bridge the gap between what we teach and what is learnt the following steps are suggested:

- Theory and practicals (laboratory experiments) must be integrated. Routine experiments have to be replaced with innovative experiments. Interaction with the students while performing experiments must be established and extended to real situations. For planning the teaching strategy, we must develop such situations where students encounter logically inconsistent situation.
- Students should be made familiar with common scientific processes viz. observation, identification, classification, discovering relationships, performing measurements, experimentation, establishing cause effect relationships, interpretation of results, inference, prediction and making hypothesis

and testing the same. Special attention may be paid to processes of science during teaching and aim should be to make students keen observers with an eye for details, recognition of similarities and differences, inquisitiveness, develop understanding of concepts of force, processes involved and find applications of the same.

- Teachers may set the subject matter clearly and key features of conceptual dimensions of force must be identified before delivering to the students. It may also be ensured that students develop sufficient application skills and problem solving techniques through simple and exemplary questions/ problems.
- Teachers may identify alternative frames related to the concept of force in the initial stage and provide a curriculum that takes into account the existing alternative frames. Accordingly, their thought structures may be studied and modified.
- Teachers may plan their lessons, activities, questions and other resources to focus on understanding and application of the basic concept of force. A feedback from the students at the end of the lecture may be taken to facilitate self-analysis of the lecture that may follow. Other fellow teachers may also critically analyse the feedback. Finally remedial measures may then be taken by teachers to rectify the misconcepts of the students.
- Teaching-learning process should be made joyful by not limiting it to rote learning and also making it less stressful and burdensome. It may be related with life outside the school and beyond textbooks. It may also relate to the various scientific, environmental, technological aspects besides inculcating a scientific temper. Day-to-day experiences may be incorporated into the classroom activities.
- Constructivist learning situation may be created during curriculum transaction (NCF-2005). Classroom experiences should be linked with experiences outside the classroom situations. Teachers should move beyond the position of having a general awareness that students are having difficulties with the concepts of force to being able to interpret the students' thinking more analytically so that they are in a better position to plan and to implement the next stage of teaching.
- Active engagement of students in construction of knowledge through relevant activities has to be facilitated. Active engagement involves enquiry, exploration, questioning, debates, application and reflection, leading to theory building and the creation of ideas/ positions. Schools must provide opportunities to question, enquire, debate, reflect, and arrive at concepts or create new ideas (NCF-2005).
- The teacher's own role in student's

cognition has to be enhanced by allowing students to ask questions that require them to relate what they are learning in school to things happening outside, encouraging students to answer in their own words and from their own experiences, rather than simply memorising and getting answers right in just one way.

- 'Intelligent guessing' may be encouraged as a valid pedagogic tool. Quite often, students have an idea arising from their everyday experiences or because of their exposure to the media, but they are not quite ready to articulate it in ways that a teacher might appreciate. It is in this 'zone' between what you know and what you almost know that new knowledge often takes the form of skills, which are cultivated outside the school, at home or in the community. All such forms of knowledge and skills must be respected.
- Diagnosis and remedial teaching may be introduced. Physics teachers' education programmes may be revamped in such a way that teachers' must get an opportunity for removing their misconceptions and frequently updating themselves with the new concepts of the subject.

It can be concluded from the examination of the students' and teachers' responses that there is a fraction of students and teachers who do carry misconceptions. This is despite to the fact that all teachers are well qualified. The existence of misconce-ptions among the teachers has serious implications and likely to be passed on to their students. There is thus a very strong case for frequent in-service training/refresher courses of reasonably long duration for teachers in order to improve their efficacy. It is also suggested that teachers should try to identify alternative framework in the initial stage and to provide a curriculum that takes into account the existing alternative frameworks of the students. Students must be taught in such a way that classroom experiences should be linked with experiences of outside the classroom situations. Day-to-day experiences should be incorporated into classroom activities giving real feeling of oneness between the society and learning. The students should be encouraged to express their frank views and feelings about the teaching –learning process. Teachers must resort to remedial measures accordingly.

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