EPISODIC CONCEPTUALISATION–A POSSIBLE SOURCE OF ALTERNATIVE CONCEPTION ABOUT 'KINETIC ENERGY' AND 'WORK'

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In recent times, 'Episodic Conceptualisation' has been identified as one of the origins of pupils' alternative conceptions. It is hypothesized that the episodic format of the form, content, and mode of presentation of the concepts 'Kinetic Energy' and 'Work' in the textbook as well as in the classroom by the teacher is likely to generate in the minds of the pupils two isolated, mutually independent cognitive structures. It is conjectured that any task, which demands conceptual and/or mathematical correlation between these two concepts, is likely to bring to the fore pupils' alternative conceptions that are reflections of the above 'Episodic Conceptualisation'. The results of the present study do indicate that there are enough evidences to put faith on our hypothesis and conjecture in the framework of these two concept labels.

Introduction

The form, structure and focus of pupils' alternative conceptions (hereafter referred as ALCONs) in the recognizable cognitive structures of pupils and their importance for the teaching-learning process have been well documented in the last two decades through intensive and extensive researches on itemised concepts. Informative reference details in a discipline-wise classification format can be obtained from the monograph by Pfundt and Duit (1994). These studies are interesting to researchers, informative for curriculum framers, and educative for students of science education. But, in a framework of 'research for teaching' and 'teaching for research', the full potential of these findings in helping the classroom practitioner to improve /modify his/her teaching strategies so that pupils can be helped to construct their concepts in a way the teacher expects them to construct, is yet to be realised. In fact, in an earlier paper, Driver (1989) had commented that the efforts to optimise meaningful learning by using these findings in classroom situations have resulted in partial to apparent success.

We suggest that the functional limitation of the efforts could be due to the following reasons.

(1) The individualistic character of ALCONs has remained the main hurdle that has appreciably reduced the applicability of our wealth of knowledge in this area. If, in a class, there are 30 pupils, then theoretically there will be 30 independent ALCONs for each new concept that is going to be taught. Thus, to diagnose these 30 ALCONs and then use them meaningfully through cognitive negotiation so as to help the pupils construct the new concept becomes a Herculean task for the teacher. In some school systems, the number of pupils in a class is actually more than 30 thereby compounding the problem further.

(2) All the techniques available in the literature have been used only to identify the ALCONs and not to diagnose their genesis. This is like identifying a disease without diagnosing its cause. Since it is acceptably true that any prescription is as good as the quality of diagnosis about the cause, it is obvious that suggestions as well as efforts for the use of the research findings (about ALCONs) in a classroom situation will have limited utility in the absence of confirmed evidences regarding the genesis of the ALCONs.

One possible way to remove the two limitations at a single stroke is to attempt to locate the genesis (thereby improving the functionality of a prescription) that is likely to produce a common ALCON in a group of pupils (thereby eliminating the problems created by the individualistic character of the ALCONs).

Hence this study, which makes an effort to reconfirm Episodic Conceptualisation as a possible cause of group ALCONs as identified earlier by Mohapatra (1990), at least in Indian conditions.

Episodic Conceptualisation

Classroom teachers are often heard to say, "We have now finished 'Mechanics'; in the next class we move on to 'Gravitation'", or, similar statements in other discipline areas. This 'atomized' view is seen in the school curriculum, in teaching methods, and even in most of the textbooks, at least in the Indian context. A comprehensive example could be – in textbooks, 'Simple Harmonic Motion' or 'SHM' is included in the 'Mechanics' chapter. 'SHM' is again discussed with a different emphasis in the chapter on 'Waves'. 'SHM' reappears with different variables and thrusts in 'A.C. Circuits'. And, finally, the principles of 'SHM' are again used and discussed under wave theory of 'Optics'. Each unit is treated as an isolated episode and sometimes even as a consumption of identifiably different sub-episodes. For example, in physics textbooks, the unit on 'Mechanics' usually contains kinetics of linear motion, uniform circular motion, and rotation of rigid bodies as different sub-episodes.

How is this episodic format likely to affect conceptualisation by pupils? In a Piagetian sense, each pupil internalises a concept by going through the processes of assimilation, accommodation, and arriving at a state of equilibration. In a Constructivist Framework (Glasersfeld, 1992(a); 1992(b); 1993) these three processes are controlled and effected by the pupil's ALCONs, his/her 'Cognitive Preference' (Tamir, 1985), his/her 'Conceptual Categorisation' (Hewson and Thornley, 1989; Mohapatra, 1999), and finally result in a 'Conceptual Change' (Posner *et al*, 1982; Hewson and Thornley, 1989; Scott, Asoko and Driver, 1991; Mohapatra, 1997). With the acquisition of a new concept through conceptual change leading to equilibration, one of four possibilities may occur:

(a) The boundary of the earlier equilibration may change to engulf the new concept. This is likely to happen when the pupil discovers a cognitive link between the new concept and an extension of the already internalised old concept (Conceptual integration: Hewson, 1981; Posner *et al*, 1982; Villani, 1992; Mohapatra, 1997).

(b) The new concept may be accommodated in the domain of the existing equilibration by developing new substrates (Conceptual extension: Mohapatra, 1997).

(c) The new concept may be incorporated straight away in the existing structures (Conceptual capture: Hewson, 1981; Posner *et al*, 1982; Mohapatra, 1997).

(d) A new and different state of equilibration may start to be formed, if the new concept presented is intelligible, plausible and fruitful, but is in dissonance with the existing structures (Villani, 1992; Mohapatra, 1997).

The episodic format of the presentation of different units and sub-units in the textbooks and the classroom is likely to induce the pupil to develop pockets of isolated, unconnected states of equilibration. This form of internalisation and information processing of concepts may be called 'Episodic Conceptualisation' (EpiCon). Claxton (1984) calls concepts internalised by the pupils in this process of conceptualisation as 'mini-theories' as it highlights the fact that the pupil does not have a complete, comprehensive and coherent theory, but has many little islands of knowledge.

It is hypothesized (Mohapatra, 1990) that

(a) In the framework of such episodic cognitive structures, if a pupil is asked a question that needs the simultaneous utilisation of different states of equilibration, then he/she is likely to give responses which will be categorised as manifest ALCONs.

(b) Since such an EpiCon is likely to take place inside a classroom, it will probably affect a group of pupils simultaneously and in a similar way. Hence an effective classroom strategy can perhaps be designed to erase/modify the consequent ALCONs.

(c) Assuming the existence of the phenomenon of EpiCon it is proposed that, whenever a simultaneous application of more than one episode is demanded from the pupil, there will be two processes through which the ALCONs may manifest because of the EpiCon. First, the 'process of misuse'- the pupil may misuse one or more of the concepts. The misuse could be in the form, structure, and/or domain of validity of the concepts. Second, the 'process of nonuse'- the pupil may not use one or more of the relevant concepts and thus may arrive at a conclusion, which will be regarded as an ALCON.

'Kinetic energy' and 'Work': the Background

Children are exposed at a very early age to the term 'energy', if not through textbooks, at least through multimedia advertisements (Indian context), as "Beverage X is the source of my energy." Children see on the TV screen that the person (model) drinks a cup of the beverage X and starts running vigorously, ultimately securing first position in a race. Regular viewing of such advertisements obviously creates in the mind of the child an 'anthropocentric' framework (Watts, 1983; Finegold and Trumper, 1989; Trumper, 1990), i.e. 'energy' is associated with human beings. With this framework a cognitive image where the term 'energy' seems to have close association with a picture of vigorous expression/activity (a la kinetic energy) also gets embedded. Further, the child may also get reinforcement of such an ideational structure from (Elkana, 1967) the Oxford English Dictionary, which defines 'energy' as 'force of vigour or expression' and traces it back to 1599.

In Indian schools, the concepts of 'work' and 'energy' are included in *Environmental Studies* up to Class V in an informal way highlighting the everyday meaning of these concepts rather than their formal scientific meaning. Again in Class VI these concepts are presented in a mixed manner along with 'food' in the chapter on *Components of Food.* In Classes VII and VIII, the concepts are almost absent from the texts. The concepts of 'work' and 'energy' are formally introduced in the science textbook at Class IX in the chapter titled, *Work and Energy.* Starting with the everyday meaning and scientific meaning of the term 'work', work done by a constant force is defined as the product of the force and displacement occurring in the direction of the force. 'Energy' is then expressed in terms of 'work'- "An object having a capability to do work is said to possess energy". 'Kinetic' and 'potential' forms of energy are introduced next. Mathematical expression for kinetic energy possessed by a moving body is derived. Mathematical relation for computing potential energy is also worked out for the case of a body raised against gravity. Also discussed are the transformation of energy from one form to another and the law of conservation of energy (not the law of conservation of energy and work).

Thus, by the end of Class IX, the pupils are expected to have definite ALCONs about energy in general and kinetic energy in particular as well as about work. These ALCONs will ultimately control (Ausubel, 1968) their degree of meaningful learning about 'energy' and 'work', taken in conjunction.

There have been a number of studies (Watts, 1983; Duit, 1984; Bliss & Ogborn, 1985; Gilbert & Pope, 1982, 1986; Trumper, 1990, 1993, 1996, 1997; Finegold & Trumper, 1989) on pupils' ALCONs about energy. Attempts (Watts, 1983; Trumper, 1997) have also been made to categorise the ALCONs into classes. However, to the best of our knowledge, no work is reported in the literature which makes efforts to locate pupils' ALCONs as well as their genesis in the conceptual interface between 'kinetic energy' and 'work', although this is an important area since energy is defined as the ability to do work.

Episodes involving 'Kinetic Energy' and 'Work'

The following sub-episodes, involving kinetic energy and work, were identified by

- analysing the science textbooks (NCERT) of classes VI to X,
- observing actual classroom teaching,
- discussing with practicing teachers, and
- interviewing pupils of the above classes.

Each sub-episode is followed by a heading 'Result', which indicates the thought process (as revealed through interview) of the pupils because of the internalised sub-episode and also highlights the details of misuse and/or nonuse of an episode by the pupils.

E1: Kinetic energy of a body depends on its velocity.

Result

(a) Velocity is the only key factor of kinetic energy of a body (This indicates misuse of E1).

(b) Some pupils are of the opinion that same kinetic energy means the same velocity (This indicates misuse of E1).

(c) Contribution of mass of a body to its kinetic energy is rarely taken note of (This indicates nonuse of the fact that kinetic energy of a body depends also on its mass).

E2: Work is defined as the product of the applied force and the displacement of the body in the direction of the force.

Result

(a) Work – Force ´ Distance traveled [This indicates (i) misuse of E2, (ii) nonuse of the vector property of force and displacement, and (iii) misusing 'distance' as synonymous with 'displacement'].

(b) As a corollary of (a) above – If a body travels through a distance due to the application of a force, then work is done even if the displacement is zero or the angle between the applied force and displacement is 90°.

(c) For work to be done there must be application of a visible force like a push or a pull (This indicates nonuse of the statement that 'Energy is the ability to do work' and consequently, a body having energy can do work).

E3: Conversion of potential energy to kinetic energy in the case of vertical free fall of a body.

Result

(a) Bodies released from the same height will attain the same velocity on reaching the ground. So, they will have the same kinetic energy [This indicates misuse of E1 and effects of 'Result' (b) and (c) of E1].

(b) If two different bodies are thrown vertically up and have the same kinetic energy at the moment of throw, they will rise to the same height (This indicates misuse of E1 and E3).

E4: Because of E3 the concept of gravity and gravitational force becomes a sub-episode in the cognitive domain of work and kinetic energy.

Result

(a) Larger body means larger gravitational force and hence larger velocity resulting in higher kinetic energy (This indicates misuse of E4).

E5: Because of E2, the concept of force becomes a sub-episode in the cognitive domain of wok and kinetic energy.

Result

(a) Same force acting for the same time leads to same amount of work and same kinetic energy (This indicates misuse of E1 and E2).

(b) It is difficult to stop heavier bodies in motion (This indicates misuse of E2 and the concept of force).

(c) As a subset of (b), above conclusions about the effect of force of friction (introduced in Class VIII) are similar to (b) above.

E6: 'Energy', in general, and 'kinetic energy', in particular, and 'work' are different episodes.

Result

(a) Difficult to conceive about the inter-conversion of kinetic energy and work (This indicates nonuse of E1, E2 and the concept that 'Energy is the ability to do work').

Method

Tool

The tool consists of six problems (Annexure – I). All of them are conceptual ones although some of them carry numerical data about masses of objects involved in motion. Each question has three choices as responses and the subjects were asked to tick the one that in their opinion was the correct response. Care was taken to provide some space after every question, requesting the subjects to write down the reasons for ticking any particular response. This provision was made to probe their thought process. One (Q.4) out of the set of six questions was intentionally framed in a form similar to that in the prescribed textbook with the intention of peeping into the stabilised imprint in the minds of the pupils as produced by the textbook. The tool was finalised after initial try out on a sample of 50 pupils of Class X.

Sample

The sample consists of 334 pupils of Class X drawn from 5 schools, in and around the city of Bhopal. Care was taken to include government schools and schools run by private trusts. All the schools chosen were affiliated to the Central Board of Secondary Education (CBSE), New Delhi, India. This choice was prompted by the following considerations.

- The medium of instruction in all these schools is English. This uniformity is likely to minimise differentiated ALCONs arising out of linguistic differences.
- All the schools follow the same textbooks and hence the effects that are likely to manifest due to different textbooks are almost eliminated.
- As part of the conditions of affiliation, the science teachers of all these schools are graduates who have gone though at least one year of professional teacher training programme. This is likely to bring some normative effect on the teaching inputs and styles of teaching science in these schools.

- Even the physical facilities in these schools are above an optimal minimum, again because of the same affiliation conditions.
- Last, but not the least, the discipline in all these schools is above satisfactory level and, as a result, rarely classes are dropped because of uncalled for reasons.

In Table 1, NCERT stands for National Council for Educational Research and Training, the apex body of the Government of India looking after the quality of school education, KVS acronym for Kendriya Vidyalaya Sangathan, and JNVS is that for Jawaharlal Navodaya Vidyalaya Sangathan, later two being the school systems also under the Government of India.

Administration

In the trial administration, it was observed that pupils took about 30 minutes to complete the test. Thus, the test was administered in a regular class in presence of the class-teacher and in a pupil friendly atmosphere.

Results and Discussions

The following can be easily discerned from the tool.

(a) The first question calls for the understanding of conversion of kinetic energy to work against the frictional forces of the brakes. But, from the pupils' point of view, several sub-episodes, like kinetic energy, work, frictional forces, their effects keeping in view the different masses of the two vehicles etc. come into play.

(b) The second question, though seems to be familiar from the point of view of the pupils, is actually different in the sense that pupils study the conversion of kinetic energy to potential energy only in the case of a body falling freely under gravity. Thinking this to be a similar phenomenon they may even tick the third option, thereby forgetting that potential energy of a body raised to a height 'h' is mass dependent because this potential energy is the work done against the gravitational force.

(c) In the third question they are again confronted with the situation of work being converted to kinetic energy. However, in the context of work, the concepts 'force' and 'distance' are so deeply embedded in their minds that they are likely to forget the role of

Table 1: School-wise number of students of Class X constituting the sample

Name of the school	No. of pupils	Remark
Demonstration Multi-purpose School (DMS)	57	Run by NCERT
Kendriya Vidyalaya No. 1 (KV 1)	74	Run by KVS
Kendriya Vidyalaya No. 2 (KV 2)	58	Run by KVS
Carmel Convent (C C)	101	Run by private trust
Jawaharlal Navodaya Vidyalaya (JNV)	44	Run by JNVS

time interval here and be guided by their episodic conceptualisation [Refer 'Result' (a) of E5].

(d) Question 4 should be most familiar to them as it has a direct correspondence with what is taught in the class, but data regarding masses will perhaps excite their minds another episode involving force and mass apart from the episode of conversion of work to kinetic energy.

(e) Question 5 is again a variation of what they have studied and it brings into play the episode of initial kinetic energy along with the episode of free fall.

(f) Questions 1 and 6 have the same conceptual structure but the situation in Q.1 is familiar to the pupils and that in Q. 6, is unfamiliar. This unfamiliarity may activate different episodes in different pupils. Hence the pattern of responses of Q. 1 and Q. 6, though expected to be similar, is likely to be different.

Percentage of pupils preferring particular responses are presented in Table 2. In Table 2 asteriked responses are the correct ones.

After the test was administered, the pupils preferring incorrect responses were engaged in group discussions. The indications received from written explanations by the pupils and the group discussions about the interplay of episodes are shown in the last column in Table 2. In some cases it was discovered that pupils arrived at even the correct responses by employing wrong reasons, an example of which is given below.

Researcher : Against Q. 2 you have ticked the response (a) as correct.

Pupil : Yes, Sir.

Researcher : Congratulations, that is the correct answer.

Pupil : Thank you, Sir.

Researcher : But let us discuss this a little more. How did you arrive at this answer?

Pupil : Sir, it is very simple.

Researcher : What is so simple about it?

Pupil : Sir, if the body is light, a force will produce a greater velocity in it. (*)

Researcher : Greater velocity or greater acceleration?

Pupil : Sir, ultimately it amounts to the same thing. (**)

Researcher : Then...........

Pupil : Sir, if the velocity is greater, then the body will rise to a greater height.

Researcher : But in this case, the force which is acting due to gravity is downwards and the body is moving upwards.

Pupil : (Thinks) ... Sir ... Yes ... Sir ... But ...

Researcher : So, what is 'But'?

Pupil : Sir, I do not know. But I know A's velocity will be more and it will rise to a greater height. (***)

The response, (*), clearly shows the activation of E2 and manifestation of an ALCON. Response, (**), is also an ALCON arising out of conceptual

Table 2 : Percentage of pupils preferring each response, question-wise
(The asteriked responses are the correct ones)

Q. No.	Suggested response symbol	Percentage of pupils preferring each response						Episodes involved
		Various schools						
		DMS	KV1	KV2	CC	JNV	All Schools	
1.	a	21.0	40.5	39.6	51.5	45.4	41.0	E5, E6
	b	50.8	43.2	37.9	27.7	27.3	36.8	E2, E6
	c*	28.0	16.2	20.7	16.8	27.3	20.6	
2.	a*	73.7	71.6	56.9	80.0	61.4	70.6	
	b	26.3	17.6	25.8	14.8	31.8	21.5	E4, E5
	c	1.8	13.5	17.2	3.0	6.8	8.1	E3
3.	a	64.9	48.6	53.4	42.6	47.7	50.3	E1, E2
	b*	26.3	28.4	22.4	28.7	29.5	27.2	
	c	12.3	20.3	29.3	13.8	18.2	18.3	E2
4.	a	15.8	44.6	13.8	34.6	34.1	29.9	E1, E2, E6
	b	68.4	40.5	55.1	34.6	45.4	46.7	E1, E2, E6
	c*	15.8	13.5	31.0	31.7	13.6	22.4	
5.	a	70.0	40.5	48.3	60.4	43.2	53.3	E4, E5
	b*	10.5	4.0	6.4	10.9	9.1	8.2	
	c	17.5	52.7	43.1	24.7	47.7	32.7	E4, E5
6.	a	42.0	54.0	55.2	49.5	54.5	50.9	E2, E5, E6
	b	52.6	23.0	24.1	31.7	25.0	31.1	E5, E6
	c*	3.5	14.9	18.9	16.8	20.4	14.9	

continuity (Mohapatra and Bhattacharya, 1989). The response, (***), shows an ad hoc element in the conceptualisation scheme of the pupil.

Some of the identified key ALCONs arising out of the episodic nature of internalisation of the concepts 'kinetic energy' and 'work' in this study are the following.

- The loaded truck will travel a longer distance because its mass is more and it will be difficult to stop it.
- Two bodies of different masses thrown vertically upwards with the same kinetic energy will rise to the same height because their kinetic energy is the same.
- If two bodies are acted upon by the same force for the same time they will have the

same kinetic energy as the time for which the force acts is the same.

- If two bodies are acted upon by the same force until they travel the same distance, then the lighter body of the two will have greater kinetic energy as its velocity will be larger.

- If two bodies are released from the same height with the same kinetic energy, then both will reach the earth's surface simultaneously since the height of release is the same.

At this time, it is worthwhile to look at the responses to Q.4, which we thought was most familiar to the pupils. Even in this case, about 15 per cent to 30 per cent pupils of various schools and 22 per cent when all schools are taken together, have ticked the correct response. For the rest 78 per cent their episodic conceptualisation has controlled their responses. This again indicates the strong effects of episodic conceptualisation. We also note in passing that in some cases the percentages do not add up to 100. This is so because in those cases some pupils did not tick any of the responses.

Conclusion

By a fairly broad-based strategy we have identified in this study the structures of the episodes/sub-episodes in the minds of pupils in the domain of interaction of the concepts 'kinetic energy' and 'work'. Through discussions with the pupils and their written explanations, the possible ALCONs generated by these episodes/sub-episodes have been located. The interplay of the episodes/sub-episodes (which are perhaps unconnected structures in the pupils' comprehension domain) when more than one of them is simultaneously activated, is then investigated to diagnose manifest ALCONs. The tool used for this comprises six conceptual problems. Consequently, it did not put any demand on the skills of the pupils such as

- numerical computation,
- transforming symbols in formulae to numbers by substituting the given data, and
- interpretation of the results, obtained through numerical calculations.

Thus, any ALCONs, which are likely to arise out of the pupils' deficiencies in these skills, have been minimised.

To eliminate the ALCONs, the following strategies are suggested, which can be used to promote meaningful learning and reduce episodic conceptualisation, in this context, to the minimum.

- Enough emphasis be given on the interchangeability of 'energy' and 'work', in general and 'kinetic energy' and 'work', in particular, keeping in view the accepted definition that energy is the ability to do work.

- Activities be developed to demonstrate the above interchangeability. As for example, pupils may be asked the following:

  — We know that a duster on the table has potential energy equal to *mgh*, where *m* is the mass of the duster and *h* is the height of the table. Since 'energy is the ability to do work', design an experiment to show that the duster can do work.

— Thought provoking, interesting and challenging conceptual problems may be given. As for example,

— When a bow is taut, it is said that the bow has potential energy. Describe how this energy is transformed to work.

— A steel ball is rolling on a table having friction. After travelling some distance it comes to rest. In the above process describe who is doing work.

Of course, each of the problems used here as test items of the tool may also be used as problems in a classroom situation.

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