VULNERABILITIES OF CONSTRUCTIVIST PRACTICE IN ELEMENTARY SCHOOL SCIENCE CLASSROOM: PRECAUTIONS AND REMEDIES

Nasir Mahmood
IER, University of the Punjab
<mahsirm@ier.pu.edu.pk>

Abstract: Most of the researches in constructivist context have focused upon the comparative advantages it 'offers over other contemporary approaches to teaching. But constructivist's increased reliance on the students taking charge of their learning and direct experiences as the prime source of learning has equally opened the chances for students acquiring logically consistent misconception supported by their direct experience for any reason like insufficiency of their skills, inaccurate instruments or lack of proper guidance. This study has focused of such instances which were potentially vulnerable during two units of grade 5 & 6 science lessons in elementary school and discussed the methods/techniques used by the class teacher to overcome such situation by making students realize their mistake without compromising the essence of constructivist approach. The results showed that this is only possible by inculcating the habit of thinking, self-evaluation and critical reflection among the students while taking up any task. It is the clarity about intended outcome, which is important than the activity itself. Mental engagement should precede the physical engagement in science learning to attain the quality learning. The commonly used techniques by the teacher in this research to develop the above mentioned skill was increased class-talk/dialogue between students-teacher and student-student to make students speak out their minds and evaluate the mind of the other students.

Introduction

Most of the studies carried out in constructivist tradition overwhelmingly looked for the edge constructivism offers over other teaching and learning practices (Kimbrough et al., 1997; Dharmadasa & Silvern, 2000; Osberg, 1997) but there is hardly any study directly addressing the possible vulnerabilities of constructivist teaching for potentially developing or strengthening the existing misconception among the students.

The reliance on students to take responsibility of their own learning by offering learning environments open students to examine all possible alternative concepts to reach a conclusion through direct personal experience before construction of any scientific concepts. But while students are entitled to enriched learning, at the same time there are fears that any misadventures in the science lab may lead to some logically consistent and internally coherent misunderstanding (Nasir, Kono & Morimoto, 2003; p. 278, Nasir, 2002; pp. 281-282). Such misunderstandings can be a challenge to constructivist teachers for their equational viability with other scientific concepts and experiential credibility supported by student's personal experience in the science lab. For example, during an experiment to extract solvent (salt) from solution by the process of heating in grade-5 science class to show that same amount of solvent can be extracted as dissolved. In this apparently simple and obvious experiment, the students were supposed to realize this scientific principle by themselves at the end of the experiment. The result was quite contrary to the expectation as; none of the groups was able to extract the same quantity that was dissolved in the first place. Even a very careful, execution of experiment by the teacher later could not bring the desired result with the provided facilities in the elementary school laboratory to perform the experiment (discussed in detail in results section of this paper).

Many more such instances were noticed during the studies included in this research work. Each of such situation is discussed in this paper for its vitality for constructivist teachers[5], this paper will discuss in depth, such vulnerabilities observed by exploring sources and causes through collection of vulnerable situations from the classroom video recordings and analyzing the classroom protocol to understand the scenarios that lead the teachers and students to being trapped in such situation. An effort will also be made to highlight the strategy adopted by the teacher to tackle each impasse situation and guidelines will be drawn to suggest techniques potentially helpful for such situations.

Objectives

As already made clear in the preceding discussion, the intention is to bring forth the potential vulnerabilities of constructivist practices in classroom by:

1. Collecting and reflecting upon the instances leading to misunderstandings
2. Identifying the possible sources supportive to the development of these misunderstandings; within constructivist pedagogical principles and physical facilities in the science classroom.
3. Drawing precautions and remedies needed to avoid circumstances leading to such misunderstandings as part of constructivist learning environment (teaching plan, classroom environment, and physical facilities).

Method

The data was collected from two units in the curriculum [Germination and Growth (Grade 5), and Solutions (Grade 5)]. The relevant instances were identified for the type of misunderstanding by the students and possible causes for those misunderstandings were identified followed by the laying down of possible precautions and remedies needed to be taken.

The sample included 115 (56 boys and 59 girls) students of grade 5 and 117 (58 boys and 59 girls) students of grade 6 of one of the attached elementary school of Tokyo Gakugei University. The data was collected between November 2001-and January 2002 for grade 6 and during April 2002 to February 2003 for grade 5.

The nature of data involved is basically classroom protocols, pre-test & post-test, and teacher's reflection of lessons after each lesson in the form of unstructured interview. Students were given a pre-test before the start of the each unit and post-test at the end of each unit of curriculum under study. As a general format, first part of each question inquired about the knowledge concerning a certain aspect of the concept under investigation and the following part(s) addressed reasoning used to reach that conceptual construct. Classroom protocols were developed from the video recordings for each lesson in all the units mentioned above. The teacher interview was conducted after each lesson and was mainly focused on the activities of that particular lesson. Teacher's opinion was sought about the strengths and weaknesses of the lesson and for tentative plan for the coming lesson.

The appropriate analysis to address the questions of the study is primarily qualitative but quantitative results was used wherever suitable and relevant to support the presumptions.

Results

The results will be discussed by taking up the likely classroom situations/activities vulnerable for leading to a deterioration of scientific concepts followed by the reflections from classroom protocols and teacher interview to describe the strategies used to deal such situations.

Reliance on Experimental Experiences for Knowledge Construction Can Play Either Way The tradition of using experimental inquiries in science is not special to constructivist instruction but has been used in activity oriented learning context for a long time. By tradition class experiments are pre-decided in part by the science curriculum enlisted in the textbooks and performed according to the listed procedure to verify scientific knowledge and develop investigative skills (Osborne & Freyberg, 1985; p. 66) but in constructivist perspective students are free to think about the experimental activities suitable to test their hypothesis in the manner primarily decided by them. The meaningful construction of knowledge for students relies heavily on the opportunities to freely try out their own scientific hypotheses to verify or reject their personal suppositions/beliefs. Thus in constructivist perspective experiments are not pre-decided activities to verify already known results but are seen as opportunities for the learners to check personal hypothesis in order to facilitate individual construction. The conviction of knowledge construction depends on the accuracy of results ending up from the experimental activities in the laboratory. The accuracy of experimental results depends upon the *skill to use the apparatus* and *reliability of apparatus* itself along with clarity of purpose. This section will focus on the effects of the skill to use the apparatus and reliability of apparatus itself as factors causing vulnerability to constructivist instruction in the context of student designed (instead of pre-decided) experiments.

It was observed on more than one occasion during this research that the inaccuracy of the results was caused by the inefficiency of the tools used. The problem becomes even more complex when every group of the students reach the same result which is contrary to popularly excepted scientific view and realized that there is no need to question their results if the results contradicts with students previous knowledge and common sense. Such instances put teacher in a difficult situation because there was apparently no procedural mistake on the part of the students and it becomes difficult for the teacher to find any suitable reason to urge students to questions their findings while they remain committed to constructivist principles.

One such situation arised during the lesson on germination of seeds in a grade-5 (11^+ years) science class. The students were engaged in an experiment to observe the necessary condition for the germination of seeds to happen. Among the several conditions they were trying out, one was that the air is necessary for germinations of seeds. Thus in any experimental condition without air, there can be no germination. Students suggested five methods to investigate this condition and one of the methods was keeping seeds on a wet cotton and placing it in a vacuum for few days to compare with seeds left in open air on a piece of wet cotton (conditions of necessity of light and water were already investigated, thus in this experiment those two conditions were kept constant).

One of the apparatus used for creating a vacuum was a commercially developed vacuum jar introduced by the teacher. The jar was equipped with an air pump to extract all air from inside the jar. The seed was placed inside the jar on a wet piece of cotton and all air was extracted to create vacuum, still the seed germinated after few days. This consequently led the students to conclude that air is not a necessary condition for germination, which was contradictory to popular scientific concept but experimentally and rationally true for that group of students who were part of that experiment. Fig.l is the dialogue from the class protocol concerning the above experience.

The extract shows that although students realized (or made to realize) that air may have entered the jar or was left inside when extracting, the still final comments in the above extract clearly reflect the state of uncertainty. The teacher's methods of questioning students to look for the possible drawbacks in experimental method or apparatus apparently worked in the class for the time being but the extent of true effectiveness of teacher's approach cannot be determined absolutely in material terms. The final comments from the students however showed a lack of conviction to except the necessity of air as a condition for germination.

Another similar event happened when grade 5 students (of the same class) were studying the phenomenon of conservation of weight when solute is dissolved in a solvent. The students dissolved 10 gm of salt in 50 ml (lml=lgm assumed approx.) of water and observed the change in the net weight of the salt solution. It was assumed that an addition of 10 grams of salt should result in equivalent increase in the weight of the solution.

Context: Each group of students, who went for different method to examine the need of air in the previous lesson, recorded their result on the whiteboard and teacher asked each group to explain the results to other students. After the students finished, teacher summarized their findings and questioned their results.

33. T: While writing on the whiteboard, the results for experiments (a) fe to jo (e) [fo, i>, *o* , *x.*, *&* are Japanese alphabets like a,b,c,d,e in English respectively] ...(Teacher says) In method (c) half of the seeds have germinated while other half did not. On the basis of these results we can say air is not needed for germination. Germination happened even in absence of air. Am I right OK!
...[There was discussion among groups and teacher, which concluded in the following manner]..

72. S4: ...might be the air was not fully extracted (from the jar) in method (c)
73. T: Is it like that? Might be it became same like method (b). Yes, S7
74. S7: Same as mentioned by Sugaya (S4), the air was extracted but we don't know if it was really...
75. T: It is not clear if it is extracted fully. So, you mean to say, probably air was left inside.

---

76. T: I see. Therefore from overall result.... Yes (asking SI 1 to respond)

77. S11: I doubt (c), (d), and (e) are still questions? (not clear)

---

98. SI3: Thus, it is not sure to say if air entered the jar or not as (c), is still half-half (number of germinated and not germinated seeds).

Note: *The number at the start of each statement shows the number of utterances in order they were recorded in the class protocol. T=teacher, S^Student and the number following 'S' shows the students number. Actual protocol was in Japanese, this English translation is done with the researcher.*

Figure L- An extract from class discussion-I

The results showed that 9 out of 10 groups observed a loss in net weight, that the solutions weighed less than 60 grams. This lead the students to assume that some of the salt was lost when dissolved in water, which is inconsistent to contemporary scientific rule. The text in figure 2 demonstrates the methods through which teachers dealt with this situation.

The discussion among the students (from utterance 48 onward) opened the way for the teacher to introduce the concept of experimental error and explained the possible causes of the loss in the weight observed by the students but as the activity was not repeated in the coming lesson, therefore, it is probable that some of the students still have doubts left about the scientific principle under study. The teacher himself acknowledged the difficulty of the situation and possibility that such instances may prove a source of creating, developing or strengthening misconception during after class unstructured interview in the following lesson.

> It is hard to convince students when the experimental results are not in accordance with widely accepted scientific knowledge....... felt recently that a lot of communication with individual students is important to question their concepts to make them rethink about misunderstandings. That is why I go to each group when they are engaged in activities (Translation). *(Lesson observation & Teacher's self reflection sheet Lesson no 5/7, Solution, grade-5 class-2, 25/2/03)*

The teacher used the difference in the results of various groups to question the validity of their results. The absence of uniformity in the observed decrease in weight helped students towards thinking of possible error in the procedure of the experiment. The reason suggested by one student (utterance 48) presented the breaking point needed and then teacher and other students used the same line of thinking to evaluate their experimental procedure. This logic worked with those students as it urged them to think and find out the probable cause of not being able to have extracted quantity same as dissolved. This emphasizes the need for development of professional teaching skills of building upon the leads found in students' comments and encouraging the other students to follow the course by shaping teacher talk in innovative and manipulative manner.

3. T: Let us start with the results of the experiment you did in last lesson. What happened after you dissolved lOgm salt (in water). Let us go in order from group one.
7. SI: 7.5 7.grams...(Increased by)
9. S1: I am certain that 7.5 grams dissolved, 25 grams.
10. T: You mean the weight increased by 7.5 grams
14. SI: Where? You feel this strange/odd? Where that 2.5 grams has gone.
46. T: All of you expected an equal increase. But as you mentioned (pointing towards the student) weight increased by only 7.5 grams, where is the remaining 2.5 grams. Similar (views were expressed by) group 4, 5, 8 and 9.
47. T: It was 10 grams but....
48. S : What do you think about the loss?... What do you all think? Or may be lost part is really lost? Let us think a little about it.
49. T: May be some salt left on the paper (on which they received 10 gm)
52. S : I see...some salt left on the paper
53. T: May be weight measuring mistake....
54. S: What these two have said now is called the problem of experimental skill. Yes...
57. T: It is probable that some water was left stick (with the walls) in the measuring cylinder
62. S: We do study (these types of mistakes) in science but it is not done in elementary school. Ok, to say simply (it is called) "an error"
63. S: An error...
64. T: Yes, it is "margin of error"
66. S: Margin of error?
66. T: It is difference in the experimental (results). Therefore it is called "Experimental Margin of Error"...

Note: *The number at the start of each statement shows the number of utterances in order they were recorded in the class protocol. T=teacher, S-Student and the number following 'S'shows the students number. Actual protocol was in Japanese, this English translation is done with the researcher.*

Figure 2. An extract from class discussion-II.

Conceptual Change Can Go Either Way: Availability of Alternative Choices May Potentially Lead to Logically Consistent Misconceptions If Not Handled Skillfully

When encouraged to think about it, students came up with many different ways of proving their assumptions about scientific concepts. In a class of 40 students when students were suggesting their own methods, it was observed that some of the methods were not well thought about in terms of expected outcomes or relation between expected outcomes and purpose of activity. An outright rejection of such methods by the teachers seemed unsuitable to the spirit of constructivist approach and discouraging to increased student participation but at the same time irrelevance of carrying out such activities was clear in view of the lesson objectives. It will be useful to mention two instances from the lessons here to make the point clear.

The students suggested eight methods to investigate the need of air for the process of germination which were later reduced to five by enabling them to find the similarities in three of the suggested methods to be merged into one and rejecting one method for evident inability to ensure the evacuation of air. Thus finally the students decided to carry on five methods, which were validated and found suitable for investigative value. This reduced the risk of being misled as a result of some miscalculated method, thus avoiding the circumstances leading to creation of misconception.

It is crucial for the teacher to be able to use this technique to save time, avoid unnecessary labor and equip students with the essential skills to design learning activity at their own. The teacher involved in this study also realized the importance of this technique thoroughly for its benefits for both teacher and student.

Detailed discussion and predictions before entering in any activity are helpful in reaching compatible conceptual understanding. (Translation) (*observation & Teacher's self reflection sheet, lesson 6/6, 5-1 Germination, 4-3-03)*

Teacher-students and student-student discussion method was used to evaluate the need, relevance and value of student suggested activities before getting practically involved in doing any activity/experiment.

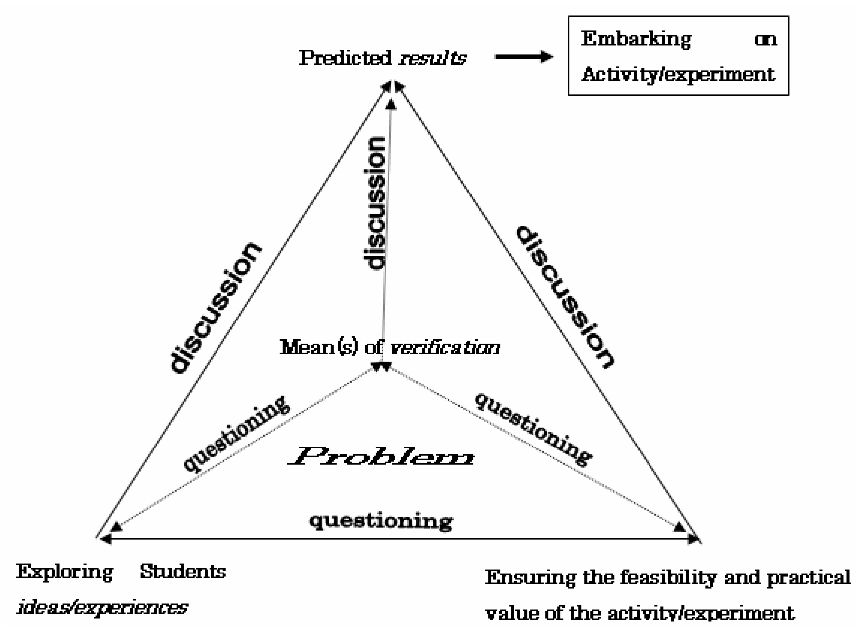

Figure 3. A model for pre-activity/experiment preparedness.

Figure 3 shows the tetrahedral model used during this research to guide the students' discussion leading to analysis and evaluation of student proposed activities before embarking on them. In the first place problem was posed to the students and they were asked to express their experiences about the phenomenon prior to studying it formally. This helped in bringing out the students prior knowledge or perceptions about the phenomenon under study. Then students were asked to suggest methods to verify their experiences or predictions in connection to the suppositions made as result of personal experiences or based on the listening of others experience. The teacher helped them to connect the activities to the objectives of lessons. This practice facilitated in laying down the groundwork and brought out whatever students have in mind or they had made from listening to the experiences of fellow students. At this stage the students were encouraged to analyze their suggested methods against the intended outcomes of the activity. This allowed the students to think loudly about the rationale behind their suggested activity and this loud thinking helped them to identify the merit of their suggested activity in comparison to activities proposed by others and objectives of the lesson. This increased the possibility of self-realization of discrepancies, if there were, or similarities among various suggested method and result in alignment among different groups of students. Therefore, students were focused about the purpose, course and predicted outcomes of their activity. The possibility of success and students engagement was observed to be increased reasonability in this manner.

Interesting Lesson Do Not Necessarily Result in Construction of Knowledge

Interest only ensures the willful engagement of the students in the lesson activities but constructivist learning cannot be taken as an obvious result of higher interest only. The situation was faced during the lessons with grade 5-3 (Grade 5 class 3) students in which students dissolved salt in water (making solution of salt and water) and observed the solution to come up with the questions about what they want to study more about the solutions or properties of solution. The expectation was that they would come up with question about how much salt can be dissolved. Does dissolving salt have any elation to the temperature of the water or to the quantity of water? Where does the salt disappear to? But a different line of thinking was observed when some of the students (8 students from total 38 initiated this discussion) showed interest in observing the haziness observed while salt was being dissolved in water and assumed it worthwhile characteristics to investigate further.

Instead of questioning the relationship of students' observation to the objectives of the lesson, teacher legitimized it by supporting student to observe this haziness/mistiness in depth by suggesting comparisons of haziness/mistiness of the solution for when different kinds of sugar (sugar cubes, brown sugar, coffee sugar etc.) were dissolved in water. This changed the whole dimension of the lesson and it took two-class lessons (4 teaching hours) to realize the uselessness of the investigation in terms of the objectives of the lesson. In lesson four, the students were redirected to the basics and questioned about the relationship of investigation of misty nature of solution and lesson objectives (as evident in the excerpt from class discussion shown in Figure 4).

> ***Context:*** The students finished the experiments of observing the state of haziness by dissolving various solvents like sugar cubes, brown sugar and boric acid but still students are investigating more as there was no clear result from present experiment. Teacher seemed to be out of ideas.
>
> T: ...My question here is while their you saw mist or not?
> SI: mist was there when I put the sugar and even I did not stir.
> S2: No. it is not (implies mist was not seen)
> T: What do you mean? During mixing or after the mixing...
> S2: It did not come out.
> S2: That is great.
> S3: It came out.
> T: ....What we should do? It is last lesson about the phenomenon of misty nature of solution but...should we leave it like that?
> T: Can we conclude here?
> S4: We cannot S5- We cannot
> T- Watanabe Yuriko (name of student), what do you think? S6: Yes
> T: What do you think?
> *S6'-* can we (experiment with solutes) other than these?
> T: for example...
> T: we can see the mist when salt and sugar is dissolved. Is it ok to conclude the lesson regarding misty nature of solution at this note?

Note: *The number at the start of each statement shows the number of utterances in order they were recorded in the class protocol. T=teacher, S=Student and the number following 'S' shows the students number. Actual protocol was in Japanese, this English translation is done with the researcher.*

Figure 4. An extract from class discussion-Ill.

A fresh start was virtually made from the very first step and caused the time loss and confusion in the students mind Although the students' interest in the lesson was clear from their insistence on continuing the experiment and active participation in the discussion but in terms of learning value or conformity to the lesson objectives, it was not a very fruitful experience. It was the realization of student interest, which led the student to continue with this activity as he mentioned in his after class interview.

> The students) remained highly interested all through the lesson and look enthusiastic to carry on with this observation... *(Lesson observation & Teacher's self reflection sheet, lesson 1/9, 5-3 Solution, 4-2-03)*

The translation of interest into learning requires clarity of purpose and continuous monitoring of relevance of class activities to the objectives decided in the beginning of the activity. The lesson driven only by students' interest may not always lead to the constructivist learning.

The teacher needs to remind and keep the students focused on their objectives. When discussing with teacher after lesson three in an informal interview about his views of handling such situation, he said:

> The students could not justify why they want to continue with the activity of investigating misty characteristic of solution...I think even the students decided the objectives of the lesson by themselves but all of them were not necessarily clear about what they will be doing. We must have had participation of all students in deciding the lesson objectives and overall image of the whole unit of study... *(Lesson observation & Teacher's self reflection sheet, lesson 3/9, 5-3 Solution, 17-2-03)*

Activity Learning is a Necessary But Not Sufficient Condition for Learning: Culture of Loud Thinking and Discussion is Imperative

Activities in constructivist learning are thought about and designed by students in contrast to the other pedagogies where teacher suggest the activities. This shift towards student-initiated activities can be an additional advantage for the constructivist teacher if supplemented with "thinking ahead of doing" policy. Otherwise it is probable that there will be equally negative effects on students learning if used in a manner usually used in pre-constructivist pedagogies.

The ability to perform an activity/experiment successfully was usually regarded as activity-oriented meaningful learning till now but it is seen that most of the time the successful completion of an activity/experiment ensures procedural awareness rather than understanding of science. Driver discussed this in the first chapter of her book, *Making Sense of Secondary Science: Research into Children's Ideas* (Driver et al., 1994; p. 7). But she discussed it in the context of activities mostly described in the textbook or suggested by the teacher, which have a pre-decided course to follow and serve a limited purpose of confirming conventionally accepted scientific rules. Therefore the most likely purpose was to make students go through the procedure which enabled scientists to formulate or discover some scientific rules. In constructivist learning activity /experiments are not meant to provide students with a skill to verily the already established rules through performing activities purposely devised to support conventional scientific knowledge but to provide students chance to critically examine their perceptions about scientific phenomenon and evaluate scientific perceptions of others to successfully construct scientific understanding of concept under investigation. The understanding thus reached may be compatible with popular scientific understanding or may differ partially but students will be in better position to use their scientific knowledge in real life and building bases for pursuing more complex scientific phenomenon.

The need to address this problem was felt during the initial stages of this research while working with grade 6 students when they were studying the role of air in the process of burning. While exploring their previous experiences and knowledge it was found that despite of putting off spirit lamp by covering the flame with glass lid many times during experiments, very few students were aware of the reason behind the action. When they were asked about why covering the flame with glass lid turns it off, more than 25% of the students could not explain the reason.

In another daily life situation experienced by almost all students participating in this research was the burning of logs during camping was for outdoor cooking. They were presented with two formations of wooden logs and asked which one is easier to burn and why? More than 28%

percent of the students were not able to describe the correct reason although majority of them (98%) knew that formation in Figure 5 is easier to bum.

Figure 5. Opening made between logs

Figure 6. No opening made

This reiterates the fact that simply "doing" an activity ensures nothing more than physical involvement in the process, which is not the aim of constructivist learning. This problem can be dealt with by asking students to think loudly, share their thinking with the other class fellows to evaluate their conceptions and question others to empower them to do the same. Culture of "loud thinking" is powerful resource to go beyond learning procedural skill from the activities in science learning and use them as source of knowledge construction.

The Concentration of Class Talk/Discussion Among the Few Willing May Isolate the Students Less Motivated Towards Class Discussion

An analysis of four lessons from Germination of seeds for Grade 5 (between May 13, 2002 and June 20, 2002) was carried out to show the width of students' participation. The lessons selected (last lesson) for the analysis were based on their nature to have the capacity for wider student participation. Students were supposed to review the findings during all previous lessons and conclude about the needed conditions for germination of seeds. Therefore it was more likely to have more students participating in the discussion. A lesson from grade 5-1 was also included in the analysis because of extraordinarily high students participation rate, which was not observed in any other lesson (the lesson was about discussing experimental results after two weeks of sowing the seed). The students shared their results with other groups and discussed the findings of the other groups of students to collectively draw conclusions acceptable for all of them.

Table 1 show that almost half of the students whether participated occasionally or did not participate at all in the class talk. This hampers the constructivist ambition of reaching out all students and reflects that contrary to constructivist aim of reaching out all students practically isolates less willing students.

Table 1

Extent of Students' Participation in Class Talk/Discussion

Grade-class (Number of students)	Date dd/mm/yy	Lesson number	Number of students participation by frequency		
			More than once	Once only	Never
5-1 (38)*	03/06/2003	2/6	32 (84%)	4(11%)	2(5%)
5-1(38)	17/06/2003	6/6	25(66%)	7(18%)	6(16%)**
5-2 (39)	13/06/2003	6/8	18(46%)	6(15%)	15(39%)
5-3 (38)	17/06/2003	7/8	18(47%)	4(11%)	16(42%)

Note: for 5-2 lesson 7 and 8 was about growth of plants and for 5-3 lesson 8 was about growth of plants. This lesson had maximum student participation among all lessons**one student was absent on that day.

Constructivist lessons rely on the students' participation more than other contemporary pedagogy, thus initiation is mostly on the students' end contrary to teacher pointing towards the students to respond. It makes it easier for the willing students to participate only, while traditionally shy students feel at ease without being asked to share their ideas. If teacher does not make intentional effort to involve all students in the class talk, the students who are shy or unwilling to participate may be isolated even more than traditional lessons.

Discussion

It is evident from the results that constructivism can be potentially salutary in improving the quality of learning in science but at the same time can be equally detrimental if implemented without achieving the prerequisite correspondence between intent of learning science and practices in classroom. Its strengths can be its vulnerabilities if freedom offered in constructivist pedagogy are not coupled with responsibilities. As evident from the results that even when students themselves decided their mode of leaning they were not clear about the intended outcomes from their self-suggested activities. It means that simply making students in-charge of their learning by making them think about mode and activities of learning best suitable for them does not represent constructivist practice unless students also learn to use scientific activities as a source of knowledge construction rather than simple factual verification of established scientific rules.

The teachers are required to inculcate the habit of thinking, self-evaluation and critical reflection among the students while taking up any task. It is the clarity about the intended outcome, which is important than the activity itself. Mental engagement should precede the physical engagement in science learning to attain the quality learning. The common feature found in the techniques used by the teacher during this research to avoid the above-mentioned vulnerabilities was the increased class-talk/dialogue between students-teacher and student-student to make students speak out their minds and evaluate the minds of the other students. It is very easy for the students to be distracted by some apparently very interesting phenomenon during science activities but it should be the continuous vigilance of the teacher to keep them clear about the purpose of the activity and relevance of their observations to the intent of the learning. A continuous practice of such vigilance by the teacher will ultimately embed the self-evaluative abilities in the students, which in turn make them constructivist learners.

There is hardly any specialized training in our teaching training programs for the teachers to deal with variety in individual students' experiences and manipulate them to steer towards intended outcomes. The results here urge us to reorient our teacher training programs to enable teachers to engage students in purposeful dialogue leading to build clear awareness of what they intend to learn from a certain science learning activity before physically performing it.

Another important dimension to be added to science teaching is denying the blind faith in the experimental results as the source of knowledge construction. Students should be told to examine the reliability of experimental results. Teaching students about the possibility of experimental error in science and how to minimize it and the means to avoid such errors by comparing results across the different groups engaged in similar activities and repeating the experiments/activities to find the inconsistencies in the results is inevitable. This helps in developing scientific mind and helps students understand science in the broader sense of scientific paradigm.

Finally, it should not be taken for granted that every student in the class will be an enthusiast participant in the class discussion, experience sharing and doing experiments. There are always students satisfied with just listening to others and reluctant to express themselves even when they have something to share. It is teacher's responsibility to make sure the participation of less motivated students by encouraging them to speak out their mind and assigning them responsible role in class activities that can motivate them to overcome their passiveness. If not taken into account the class discussion will be limited to a group of willing students only, excluding the comparatively passive majority and still look apparently very active and like a student-centered classroom.

References

Dharmadasa, I. and Silvern, S.B. (2002). Children's conceptualization of force: experimenting and problem solving. *Journal of Research in Childhood Education, 15(\),* 88-103.

Driver, R. et al (1994). *Making sense of secondary science: research into children's ideas (2003 reprint).* New York: Routledge Flamer

Kimbrough, D. R., Magoun, M. A. & Langfur, M. (1997), A laboratory experiment investigating different aspects of catalase activity in inquiry-based approach. *Journal of Chemical Education, 74(2),* 210-212.

Nasir, M. (2002). *Changes in the Students' Understanding of the Phenomenon of "Burning" in the Constructivist Classroom of Elementary School*, paper presented at 26th Annual Meeting, *Japan Society of Science Education,* 13-15 September, Shimane. Japan. Pp. 281-82

Nasir M., Kono Y., & Morimoto S. (2003). Changes in the Students' Understanding of the Phenomenon of "Burning" in the Constructivist Classroom of Elementary School. *Journal of Science education in Japan, 27(4),* pp. 268-279.

Osberg, K. M. (1997). *Constructivism in practice: the case for meaning making in the virtual world,* [on line] Unpublished PhD. thesis submitted to University of Washington. Available at: http://www.hitl.washington.edu/publications/r-97-47/osberg.rtfas on: April 21, 2005.

Osborne, R. and Freyberg, P. (1985). *Learning in science: the implications for children's science.* Auckland; Heinemann publication