Fostering Functional Understanding In Students Through The Use Of Physics Demonstrations

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Abstract
The topic of Electrostatics in Physics was used to study the effectiveness of demonstrations in promoting functional understanding among secondary school students. One class of secondary school students was used as the test group while another class of students served as the control group; the latter group was taught the topic via the conventional chalk-and-talk approach. Analyses of students' responses to survey instruments as well as of another instrument to gauge content acquisition and functional understanding show that the use of demonstrations promotes a learning climate which is conducive for the acquisition of key concepts and also helps to scaffold students' thinking in a more pronounced manner as compared to the traditional approach. Despite having a better academic standing, the control group performed only slightly better than the demonstration group. Some implications of this study are discussed.

Introduction

There is considerable evidence to show that traditional physics instruction, predominantly based on lectures and manipulation of formulae, to teach concepts is ineffective (Sokoloff & Thornton, 1997; McDermott 1984 & 1991; Hestenes et al, 1992; Halloun & Hestenes, 1985; Welzel, 1997; Pfundt & Duit, 1994). In a typical classroom setting, if students are involved in only such passive learning, it would lead to limited knowledge retention, let alone engaging them in thinking or promoting functional understanding. Research has shown that involving students directly and actively in the learning process promotes meaningful learning (Hake, 1998). The constructivist teaching approaches encourage teachers to recognize the views and ideas that students bring to the class so as to provide experiences that will help them build on their current knowledge of the world (Duit & Confrey, 1996).

Many innovations in Physics teaching have been reported in the literature. One feature/strategy that draws our attention is the use of demonstrations in the Physics classroom. Demonstrations are often used in science classrooms (Glasson, 1989). It has been recognized as a complementary approach to traditional teaching approaches. However, there has been little research on the effectiveness of the use of demonstrations in helping pupils to construct meanings of concepts and promote functional understanding. Studies done by Roth et al (1997) and Shepardson (1994) have recognized the varying degrees of impact that science demonstrations can have on students' learning, and its success has also been thought to be dependent on variables such as social interaction, instructional practice, organizational mechanics and other physical factors.

Little research in this area has been done in Singapore and, in particular, at the secondary level. Moreover, studies in the international literature merely reported subjective perceptions. A rigorous quantitative assessment has so far not been done. Roth et al (1997) reported that demonstration teaching has not effected student learning of the intended objectives on the topic of rotational motion while Shepardson (1994) has reported that "children's understanding were not sufficiently challenged by observing the demonstration or the social interaction that occurred". In a recent research, Mazur et al (2004) concluded that the effectiveness of demonstration teaching is dependent on the mode of instruction. To yield better understanding of the concepts taught, it is necessary to involve students with prediction questions and discussions during demonstration sessions.. Such interactivity would promote greater students' engagement and effective learning.

As Physics teachers, we want our students to develop valid ideas about Physics in the spirit of inquiry and investigation, and this can be triggered by interactive demonstrations in their lessons. The demonstrations are led by the teacher, and it is often accompanied with a list of prompting questions to entice students to think. Its interactivity is upheld by inviting students to predict, observe and finally propose an explanation for the demonstration/phenomenon observed.

In many physics course outlines, it is common to see 'must have' learning objectives – 'Students should develop a good functional understanding of physics'. Functional understanding includes the ability to solve both qualitative and quantitative problems as well as the ability to work with multiple representations of the concepts involved. Conceptual questions are used to test students' ability to apply the concepts learnt. Fundamental to functional understanding is the need for students to develop a sound conceptual understanding of the topic presented. "Teaching by telling is an ineffective mode of instruction. Students must be intellectually active to develop a functional understanding." (McDermott L., 1993). It is necessary to guide students through the reasoning necessary to construct concepts (while making the observations and asking questions) and consequently, to apply them in other situations.

Functional understanding is a worthwhile goal in science teaching. It is promoted by using concepts to explain observations and making predictions as well as by representing the concepts in multiple ways. Functional understanding must be given time to be entrenched through establishing connections, forming linkages and exploring issues in greater depth.

In this study, the effectiveness of demonstrations in promoting functional understanding in physics among secondary school students is investigated. The topic of electrostatics was chosen because of the availability of several demonstrations that can illustrate its multifarious concepts. Moreover, the apparatus for these demonstrations can be easily fabricated or assembled using everyday materials. A deliberate and structured way of presenting concepts through demonstrations, and embedding the session with questions and discussion is used to effect learning. Underpinning innovation and enterprise is the need to ferment intellectual curiosity among students. The learning climate in the demonstration teaching used in this study provides an environment that fosters curiosity, questioning and inquiry.

By far research on the topic of electrostatics has not dealt on the use of demonstrations though Welzel (1998) has suggested that students' scientific understanding can be developed from lower to higher complexity through provision of extensive experiences starting from investigation and prediction of events. His case studies described 'learning as sequences of individual processes of a development of situated cognition of increasing complexity'. Other studies (Harrington, 1999 and Maloney et al, 2001) usually unveil students' difficulties with the language of the subject – 'What is meant by the term 'net'?' and 'Is 'neutral' a third charge?'. Also, they have identified the possible preconceptions or alternative conceptions that students carry with them during the course of study – 'a neutral object is negatively-charged' and 'only conductors can be charged'.

Research Design

Sample

The participants in this study were 54 pupils (all girls) attending a secondary school. They were enrolled in the Secondary 4 level in the year 2004, and take Pure Physics as one of their science subjects in the GCE 'O' level examinations at the end of the year. Consequently, intact classes were engaged so as not to disrupt their normal schedules. One class was chosen as the control class and they were taught the topic of Electrostatics by the traditional chalk-and-talk approach. The other class was taught the topic only via a demonstration session, and this constituted the test group.

Design of Evaluation instruments

Three evaluation instruments were used in this study. Their design is addressed in this section.

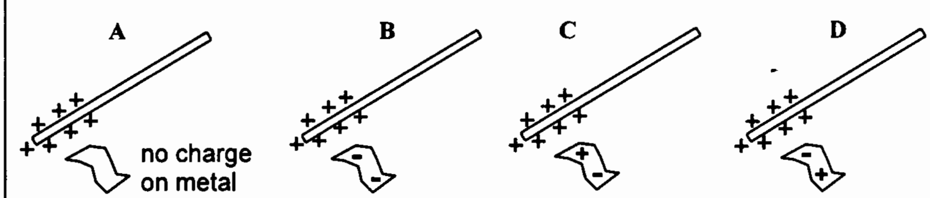
The first instrument aims to obtain a quantitative assessment of the students' functional understanding of the topic of electrostatics. It comprised a cognitive test made up of twelve multiple-choice questions. Attempts were made to formulate items that were relevant to the concepts illustrated in the demonstration session and which are within the framework of the syllabus but does not require a great deal of isolated factual knowledge. In assessing and measuring students' understanding of science concepts, Esiobu and Soyibo (1995) have suggested that test items must test beyond the comprehension level on Bloom's taxonomy. The distribution of test items revealed that all questions were at least at the comprehension level (Table 1). Two experienced Physics teachersconfirmed that the content and validity of the cognitive instrument were appropriate for use in this study. Their minor feedback was incorporated into the final version of the test.

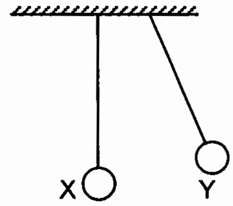
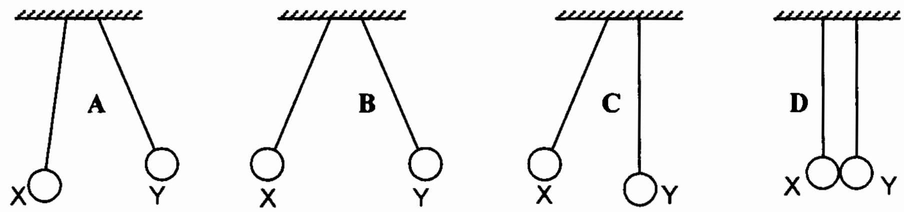
Table 1 Distribution of multiple choice questions based on Bloom's Taxonomy

Cognitive level	Description	No. of Questions
Knowledge	Exhibits previously learned material by recalling facts, terms, basic concepts and answers	-
Comprehension	Demonstrating understanding of facts and ideas by organizing, comparing, translating, interpreting, giving descriptions and stating main ideas.	5 (Qns 1, 2, 3, 8, 11)
Application	Solving problems by applying acquired knowledge, facts, techniques and rules in a different way.	4 (Qns 5, 6, 7, 9)
Analysis	Examining and breaking information into parts by identifying motives or causes; making inferences and finding evidence to support generalizations.	3 (Qns 4, 10, 12)
Synthesis	Compiling information together in a different way by combining elements in a new pattern or proposing alternative solutions.	-
Evaluation	Presenting and defending opinions by making judgments about information, validity of ideas or quality of work based on a set of criteria.	-

A sample of the MCQ questionnaire is shown in Figure 1

Figure 1 Sample of MCQ questionnaire

Comprehension Students acknowledge the occurrence of electrostatic induction that warrants the attraction of a neutral object and compare the diagrams (options A – D). also, using the principle of conservation of charge to aid check on understanding.	A piece of metal foil, which is initially uncharged, is attracted by a charged rod. Which diagram shows the electric charges involved? 
Application Students have to identify the concepts involved which raise two possible situations (X is neutral or X is positive), consequently the new situations provided the three factors that demand further consideration of the concepts.	An uncharged ball X is attracted by another ball Y which carries negative charges. Which of the following can increase the attractive force? (1) Put them closer together. (2) Charge ball X positively. (3) Make them in contact momentarily. A (1) only B (1) and (2) only C (3) only D (2) and (3) only

Analysis Students need to examine the situation to surface the correct concept associated (a neutral body is attracted to any charged body) rather than be misled/confused by the likely connection of 'attraction of a positively-charged body, thus repulsion occurs if body is negatively charged'. The diagram allows students the opportunity to examine and break down the scenario, and trace the relevant information.	 Two light conducting spheres X and Y of identical size are suspended by insulating threads from the ceiling. X is uncharged while Y carries positive charges. If Y is released from a certain height as shown above, which of the following best represents their final positions? 

The second instrument was a survey form. The statements in the survey form were crafted by using ideas from the survey literature as well as by drawing on the authors' experiences. Statements were drafted for five categories: *learning climate, learning behaviour, about the session, learning outcomes, and about demonstrations.* Each statement in the survey instrument used a five-point Likert-type scale, ranging from Strongly Agree (SA) to Strongly Disagree (SD). The corresponding numerical measures ranged from 1 for SD to 5 for SA. For negatively worded statements, the numerical measures were reversed. The statements were edited for clarity, ambiguity and redundancy, before trimming them down to an adequate number. The instrument was validated by two university professors and a school teacher who had expertise in survey construction. Their comments were taken into consideration before finalizing the list of statements in the survey form. Construct validity, the degree to which inferences can be legitimately drawn from the operationalization of the theoretical constructs (Trochim, 1999), was thus assured. The theoretical treatment on which these scales are premised thus maximizes content validity adequately. The survey instrument was piloted on two representative groups of students at Secondary 3 level - Cronbach α was in excess of 0.70, and their feedback was used for fine-tuning the instrument further. A space was provided in each survey form at the end to capture the respondents' general comments. .

The third instrument was a qualitative survey of the students' feelings/experiences on the demonstrations, and this was collected through entries in a learning journal. All participating students were encouraged to write, giving their reflections and providing comments on their learning experience within a week. This learning journal was used to provide students an avenue for reflection/introspection on the subject matter and to develop awareness of their own learning.

Procedure
The cognitive ability of the students from the two participating classes was ascertained in a common Physics examination. Table 2 illustrates their mean score and how they were grouped in this study.

Table 2 Mean scores of students in common examination

Class	Group	N	Mean score (%)
Sec 4A	Control group	28	77.0
Sec 4B	Test group	26	70.8

While keeping the classes intact, the assignment of the classes for the purpose of this study shows that the Secondary 4A pupils were obviously better than the Secondary 4B pupils in academic standing as far as their Physics competency is concerned – the former was thus chosen as the control group while the latter formed the test group.

The demonstration session was conducted by an experienced teacher. The session consisted of ten demonstrations that illustrated various aspects of Electrostatics in a holistic manner. A number of these demonstrations have everyday life relevance and applications. The demonstrations were fabricated using simple and easily available materials. After an introduction to the tribo-electric series and common terminologies used in this topic (Harrington, 1999; Maloney et al, 2001), students were invited to predict and observe at the beginning of each demonstration, posed questions to test their understanding and encouraged to clarify doubts on the demonstrated phenomenon during each demonstration. The teacher then presented a clear and explicit explanation to the students before starting the next demonstration. Participants were free to discuss with one another as well, without disrupting the session. In some of the demonstrations, students' participation was required.

The test group was invited to a 60-minute demonstration session in a well-equipped science laboratory on a normal school day. Prior to this, the students were not exposed to any formal teaching on the topic but were merely informed of the title of the session. After the demonstration session, the students were required to complete the MCQ questionnaire in 20 minutes, followed by the survey instrument. The 20 minutes allocated for the completion of the MCQ test follow the norms used by the Cambridge University Examination Syndicate's General Certificate Examination (Ordinary Level), where each MCQ item is given 90 seconds for answering.

The control group, were exposed to the syllabus requirements of the topic, including all related concepts, experiments (theoretical) and problem-solving, using the traditional chalk-and-talk approach. The teacher did not show them any demonstrations in their lessons, though they could try any one as suggested in the textbook themselves. They completed the same MCQ questionnaire after being taught the topic. In order to provide all participants with equitable learning experiences, the control group was then invited to the same demonstration session during another normal lesson. After this, they completed the survey form.

20 minutes was allocated for completion of survey form, and all students were encouraged to respond freely. This was done so as to elicit as much information as possible on the students' thoughts and insights on the sessions.

Both groups were also invited to reflect on the session, write entries in their learning journal, and hand this within a week of attending the demonstration session.

Discussion

An assessment framework based on a multitude of instruments – content test, survey form and learning journal, has been found to be useful in gauging the effectiveness of demonstrations in the teaching of physics. These instruments have permitted a holistic perspective of the various research issues to be obtained.

(a) MCQ questionnaire

Cognitive assessment in the MCQ test seeks to examine the level of conceptual understanding attained by the control and test groups. The correct answer to each question in this instrument requires conceptual understanding rather than a memorized response. The maximum score is 11 and the mean is obtained by averaging the scores of the group. Table 3 shows the distribution of scores for the various groups.

Since the subjects are academically highly able, there is a high tendency on their part to find out the answers/solutions to the MCQ questions via various means if a pre-test was administered prior to the demonstration session. Thus, the use of the traditional pretest-posttest approach was not used for this group of students. Only one content test, and that too, after the demonstration session was thus used.

Table 3 Distribution of scores for MCQ and t-test data

				df = 52	
Group	N	Mean	S D	t	p
Test group	26	7.23	1.37	- 0.596	0.675
Control group	28	7.46	1.50		

It can be seen from the mean scores that both groups have performed satisfactorily, with the test group having done slightly below that of the control group. A t-test on the comparison of test scores (see Table 3); indicated that there is no significant difference between the performance of the test group and the control group. However, it is premature to conclude that the effect of demonstration teaching is absent as the control group is academically stronger in comparison. A possible reason for the result could be that the students in both groups may have alternative conceptions of the topic that were not resolved, given the short time of 60 min. Further analysis was conducted using ANCOVA to compare the MCQ scores of the Electrostatics test, with the students' achievement scores (taken by all Secondary 4 physics students) as the covariate. There was no significant difference. It is worth reiterating that the control group has not given a better performance despite their high mean achievement score (Table 2).

(b) Evaluation of effectiveness of demonstrations

For the purpose of our study, we aimed to assess the effectiveness of demonstrations in contributing towards the development of students' functional understanding in Physics. In this context, the emphasis has been only on the use of simple statistical analyses and reliability analysis of the data captured by the survey forms. The use of more sophisticated analyses as well as the study of other factors are not the focus of this study, and are thus not addressed

Internal consistency of the survey instrument was obtained by extracting the Cronbach Alpha coefficient (Cronbach, 1951). For all groups, the coefficient exceeds the norm of 0.70 recommended by Nunnaly (1978), and thus indicates good reliability of the survey instrument developed (Table 4)

Table 4 Means and Cronbach Alpha Coefficient for various groups

Group	N	Overall Mean	Means for Sub-scale*				Cronbach Alpha coefficient
			I	II	III	IV	
Test group	26	4.22	4.26	4.19	3.85	4.47	0.87
Control group	28	4.05	4.07	3.96	3.82	4.29	0.87

**Sub-scale categories: Category I – Learning behaviour, Category II – About the session, Category III – Learning Outcome & Category IV - About demonstrations.*

Descriptive statistics captured by the data for the survey instruments are shown in Tables 5.

Table 5 **Descriptive statistics for Test Group and Control Group**

No.	Item	Mean (± Standard deviation) Test Group	Mean (± Standard deviation) Control Group
Learning Climate			
1	This mode of lesson delivery created a classroom climate conducive for my learning.	4.07 (± 0.26)	4.19 (± 0.40)
Learning Behaviour			
2	The session (a) captured my attention,	4.39 (± 0.50)	4.51 (± 0.51)
	(b) focused my thinking and	3.79 (± 0.69)	4.11 (± 0.64)
	(c) maintained my interest.	4.36 (± 0.49)	4.41 (± 0.57)
3	The demonstrations enhanced my understanding of the key concepts in *Pressure*.	3.75 (± 0.59)	4.00 (± 0.68)
About the Session			
4	The probing questions raised during the session had helped me to (a) scaffold my thinking and	3.64 (± 0.56)	3.93 (± 0.62)
	(b) foster my conceptual development.	3.79 (± 0.57)	3.93 (± 0.55)
5	The session was fun and engaging in terms of lesson delivery.	4.43 (± 0.50)	4.56 (± 0.51)
6	The number of demonstrations in the session was just nice.	3.96 (± 0.19)	4.37 (± 0.49)
Learning Outcomes			
7	During the session, I was encouraged to explain / account for each demonstration / phenomenon.	3.93 (± 0..54)	3.96 (± 0.59)
8	The session built up the confidence in me in learning and explaining the scientific concepts in Physics.	3.75 (± 0.52)	3.78 (± 0..70)
9	Through this session I am made more aware of my own thinking and learning.	3.79 (± 0.57)	3.81 (± 0.68)

No.	Item	Mean (± Standard deviation) Test Group	Mean (± Standard deviation) Control Group
About Demonstrations			
10	Demonstrations are a waste of time. **(R)**	4.36 (± 0.49)	4.56 (± 0.51)
11	Demonstrations should not be integrated into traditional physics teaching. **(R)**	4.36 (± 0.49)	4.67 (± 0.48)
12	Use of simple items in the demonstrations made the concepts easier to understand.	4.10 (± 0.42)	4.30 (± 0.54)
13	Live demonstrations are better than 'video' demonstrations.	4.36 (± 0.56)	4.37 (± 0.69)

(R) – reversed score item

Some of the important findings emerging from this study are as follows:

- The interactive and active environment involving the use of demonstrations in teaching the topic of electrostatics has promoted understanding of these concepts among students, as reflected by the mean of about 3.7 for Items 3 and 4 for the Test Group and of 4.0 for the Control Group. The fostering of understanding through structured questioning and teacher scaffolds pitched at appropriate levels for each of the demonstrations does play a role in this regard. Such meta-cognitive strategies encourage reflective practice as well as promotes scientific inquiry in students. It also facilitates conceptual inter-relatedness as well as develops thinking skills among students.

- Students in both the groups perceived that the learning climate in the demonstration teaching session is better than that in the traditional teaching session as it is less threatening and more fun and engaging. With regards to the learning climate, the means for Items 1 and 5 are 4.3 for the Test Group and 4.4 for the Control Group – thus testifying to the perception of the efficacy of the use of demonstrations.

- The mean of at least 3.7 for all items in the Learning Outcomes segment suggests that better learning outcomes have been achieved with demonstration teaching as it has set up an active learning environment where students are presented with opportunities to question and challenge themselves on their ideas and concepts. This articulation and construction of deeper understanding have enhanced students' level of confidence in learning and explaining scientific concepts as well as promoting awareness of their own thinking.

- The overall mean value of at least 3.8 for all groups (Table 4) clearly illustrates students' positiveness towards the use of demonstrations in the lesson. The participants in the control group have shown greater appreciation of the session than those in the test group.

- All groups unanimously agreed that demonstrations should be integrated into normal physics teaching, and that it creates an environment that is conducive for their learning through the invoking in them of positive learning behaviours such as high interest levels and attention spans, as well as providing scope for focusing on their own thinking, (Item 2 refers).

Of interest to note is that the mean scores of the various statements for the control; group is greater than that of the test group. It seems that the control group, who have been taught the lesson using the traditional approach and later exposed to the demonstration teaching appreciate the utility value of demonstrations for learning and acquisition of concepts more than that of the test group.

(c) Learning journal entries

The form of feedback leveraging on learning journal entries has been found to be very productive and insightful. There does not appear to be references in the literature reporting on the use of learning journals in studies involving demonstrations. It was chosen over interviews since it posed little inhibition on the students' responses/feedback and also plays down the time factor and physical set up necessary for setting up interviews. The learning journal was not compulsory for all, but many chose to hand it in, which goes to show that the session has affected them to a certain extent. All reported having enjoyed the session and had found it 'interesting, challenging and fun' and 'captivating and engaging'. It is evident from the entries in the learning journal that students are thinking more confidently, critically and creatively.

Echoed Mindy: *"Stimulates me to ask more questions regarding the concept and as the saying goes, 'questioning is an indication of learning''* and Clarrisa: *"the question and answer time... allowed us to enquire areas we were unsure of"*.

Clearly, the students are motivated, and the demonstrations had set them thinking, searching for a plausible explanation to the immediate situation as well as triggering their critical thinking skills.

The 'live-ness' of demonstrations in the class affords a sense of authenticity and credibility; students are inclined to subscribe more readily to the lesson/concept. Said another student: *'the 'seeing is believing' feel is the main thing in science that makes us grow curious and interested in knowing why and what caused something to happen'.* Besides being convincing, it impacted them with a long lasting effect, as Jenny highlighted: *"more intriguing and memorable, it helped me remember the concepts"*.

Wrote Shi Yun: *'I think demonstrations enable us to link the concepts and ideas learnt with our daily life. This brings the information learnt in the textbook to life and we are then able to see it happening in reality'*. The students generally appreciated the everyday context provided in most of the demonstrations. Many others reiterated the notion that this could improve their observation of everyday phenomena. 'The precautions we took could be explained and other electrostatics hazards, say during pumping gas...' Sara chipped in:. The use of common materials gave them confidence to want to try the demonstrations themselves, as Gladys remarked: *"the apparatus he prepared was some simple things."*

The quality and characteristics that the teacher demonstrator contributes to the session significantly enhanced the effectiveness of the demonstration, too. Christl wrote: *"his explanations were lucid and complemented the session very well"*

These anecdotal student accounts further indicate that the approach used in this study was successful in increasing students' conceptual understanding of the topic of Electrostatics as well as increasing their interest and positive-ness towards the study of Physics.

The following representative entries from the students' learning journal further reiterate the effect that the session had on them:

Control Group
Gynweth : *The illustration of concepts using demonstrations enabled me to get a clearer perspective and enhanced my learning greatly. I can clarify my doubts on the spot. The usage of demonstrations also left a greater impression on me enabling me to remember the concepts more easily by relating to them.*

Zhaojing: *By 'seeing' static electricity in action, I was better able to visualize and understand the theories taught in class. Demonstrations are an interesting complement to traditional lessons, and by applying concepts learnt to try and explain the observations during the demonstration, it can help me grasp concepts of the topic.*

Yuxin: *I found the demonstration with Van de Graaf generator and the paper bits the most captivating. The effects were more spectacular, one with spark visible and another nvolving lots of motion. It was a 'hair raising' and enriching experience that helped to spark my interest for the topic.*

Test group
Amy: *The demonstrations allowed us to understand the concepts on Electrostatics much better through a visual and kinesthetic way.*

Ziyi: *The demonstrations helped me to understand and remember the concepts, especially ideas such as charge flow and induction.*

Feiya: *I also managed to clear several misunderstandings I had previously regarding the topic,as well as learn many new details about static electricity.*

Ying Sze: *The principle behind why hairs appear to stand on end when one of our classmates stood near the Van de Graff generator is similar to that of how the ends of two optical pins placed on the same pole of magnet splay out. The similarities between the 2 topics enabled me to draw better connections.*

Other Findings:
'*I find that it is a very innovative method of decoration that is easy to clear up and yet it is still appealing*', Louise commenting on the 'message' formed by adhering colourful balloons to the wall. Certainly some innovative spirit is released and stirred in few others idea(s) for service projects; '*to put what I've learnt into use, I even used balloons to show children ... the magic balloon trick!*'

Pertaining to this topic, the use of the charge generator has made the session highly interactive.
So commented Charmiane: "*to have hands-on opportunity which further grounded our basic concepts and understanding.*" and Licia: "*help us to remember ... involved audience participation*".

Some students in their journal entries raised some pertinent issues and recommendations on the use of demonstrations in teaching.

Qi'En (C):*I think the demonstrations are too attractive that we did not pay attention to the explanation given and focus only on the demonstration itself.*

Amy (T): *However, as not too many concepts were covered, I feel that it is quite okay.*

May (T):*Tutorial and hands-on, demonstration would complement each other ensuring fun yet effective learning.*

You Min (T): *Ideally, both methods could be utilized but an appropriate balance must be struck to maximize learning.*

Natalie (T):*I feel it should be used to sum up students' concepts after a series after lessons. This would help to flash out what the students had learnt and would anchor their concepts firmly.*

Clarissa (C):*Demonstrations might be a little too time-consuming and might not be practical to use it all the time.*

Implications

Through this study, we have identified a number of contributing factors that can aid in the development of functional understanding in students when using demonstrations for teaching.

The role played by the teacher is rather important. He/She is the stimulator of curiosity, an attribute that is important for capturing students' attention through suspense or mystery. Students are thus motivated to see the real purpose of the demonstration. The teacher challenges the students with ideas, encouraging them to think critically about their explanations. Being the resource person, he/she assembles the demonstration materials , practice these before hand and has cognizance of the limitations of time within the framework of curricular considerations. A dose of humour when presenting demonstrations is certainly not out of place as it can enrich the flavour of the session!

Consideration must also be given to the choice of demonstrations. In this context, the following remarks are pertinent:

- If a series of demonstrations are to be used, then these demonstrations should revolve around a single concept (Shepardson, Moje & McClelland, 1994). For example, there were three demonstrations in our study that focused on the movement of electrons resulting in charging an object by different means; the students were able to make the appropriate conclusions on their own through observations and without any teacher guidance. No conceptual confusion arose as they predicted correctly the outcome of the third demonstration.

- Extend their conceptual learning by building from a simple to a complex level. Initial demonstration was on charging a plastic sheet with woolen cloth, followed with electrostatic induction, attraction and repulsion of bodies, then exposure to application/phenomena. This sequential process builds the students' thinking gradually towards an ability to apply / explain more sophisticated events. This powerful strategy does help students to analyze their thought processes and hence upgrade their functional understanding.

- The level of interactivity may compromise the intent of the demonstration.

> Tell me, I forget
> Show me, I remember
> Involve me, I understand ~ Confucius

Involving students in demonstrations engage them in learning. However, if increasing excitement camouflages the original intent, then learning may be marred to some extent.

The need to provide a conducive environment for demonstration teaching needs no reiteration. This includes cognizance of the following factors:

- the physical set-up of the classroom, which allows all students to have both visual and audio access to the demonstration event, and

- good pacing of the session, as is reflected in the smooth flow of different demonstrations interlaced with teacher-students sharing and questioning.

We are not advocating that demonstrations should replace traditional teaching, but that it could be judiciously incorporated into normal lessons so that it could further assist students in making sense of certain concepts in more depth. This helps to reduce the cognitive load required to understand concepts in the traditional manner.

Limitations
The findings in this study are not conclusive. Only one class of test students and another class of control students were used. There is a need to increase the sample size further. Several areas in the research design deserve attention. This study used only female students from the gifted stream, consequently the observations may not be replicable/transferable for students with varied academic standing and gender difference. Involving concepts of electrostatics only, it would be useful to see whether this approach leads to similar results in other physics topics.

Conclusion
It might be hasty to conclude that demonstration teaching has been effective in developing the students' functional understanding based on this study. However, we believe that this method has effected some useful conceptual changes in our students as viewed through the lens of constructivism. In the context of probing student understanding, observations of

the outcome of the demonstration is crucial as it forms the link between the prediction and explanation stages, and the process requires interpretation arising from one's prior experiences. This provides a window into the students' own personal views and ideas through which they can be challenged to construct meaningful learning.

The demonstration teaching session promotes peer interaction where students are free to argue, make mistakes, and challenge each other. According to Piaget (1994) this peer interaction plays an important role in the equilibration process whereby students are motivated to resolve the discrepancies between what they already know and what they observe. Thus, demonstrations afford opportunities for students to work on a task, co-constructing knowledge by building on each other's ideas and, in doing so, gain a greater conceptual clarity and arrive at a shared understanding.

Also, this study suggests the potential for the development of a teaching strategy which incorporates demonstrations. The teacher must be mindful of various considerations when it comes to the integration of various teaching strategies with demonstrations to make the combination productive to promote student learning. Science teaching, therefore, needs to develop functional understanding in students, rather than encouraging rote memorization or avoiding conceptual issues in favour of procedures and activities. It is also apparent that the use of demonstrations aid in surfacing alternative conceptions in students' scientific knowledge.

Teachers need to recognize the availability of many demonstrations for science teaching as well as the potential of this instructional tool to generate positive learning outcomes in students' learning. There are strengths and some weaknesses in adopting this approach for teaching, which awaits each teacher's discovery. Though the session described an apparent teacher-centric activity, carefully planned timings were allocated for construction of understanding through predictions, question and answers, and explanations.

In summary, this study has shown that demonstrations can be an important vehicle for promoting functional understanding in physics among students. Its potential for fostering cognitive gains when allied with traditional teaching is significant!

References

Cronbach, L.J. (1951). Coefficient alpha and the internal structure of tests, Psychometrika 16, 297-334.

Duit, R. & Confrey, J. (1996). Reorganising the curriculum and teaching to improve learning in science and mathematics. In D.F. Tresagust, R. Duit, & B.J. Fraser (Eds.), Improving teaching and learning in science and mathematics (pp. 79-93). New York and London: Teachers College Press.

Esiobu, G.O. & Soyibo, K. (1995). Effects of concept and vee mappings under three learning modes on students' cognitive achievement in ecology and genetics, Journal of Research in Science Teaching, 32, 971-995.

Glasson, G. (1989). The effects of hands-on and teacher demonstration laboratory methods on science achievement in relation to reasoning ability and prior knowledge. Journal of Research in Science Teaching, 26, 121-131.

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

Halloun I. A. & D. Hestenes, (1985). The initial knowledge state of college physics students, American Journal Physics, 53,1043 – 1056.

Hestenes D., M. Wells & G. Swackhamer, (1992). Force concept Inventory, Physics Teacher, 30, 141 – 158.

Maloney D. P., T. L . O'Kuma, C. J. Hieggelke & A. V. Heuvelen, (2001). Surveying students' conceptual knowledge of electricity and magnetism, Physics Education Research, American Journal Physics Supplement, 69(7), S12.

Mazur E., C. H. Crouch, A. P. Fagen & J. P. Callan, (2004). Classroom demonstrations: Learning tools or entertainment? American Journal Physics, 72(6), 835.

Harrington R, (1999). Discovering the reasoning behind the words: An example from electrostatics. Physics Education Research, American Journal Physics Supplement, 67(7), S58.

McDermott L., (1991). Millikan Lecture 1990: What we teach and what is learned – Closing the gap, American Journal Physics, 59, 301 – 315.

McDermott L., (1993). Guest Comment: How we teach and how students learn—A mismatch? American Journal Physics, 60, 295 - 298.

McDermott L., P. S. Shaffer & M. D. Somers(1994). Research as a guide for teaching introductory mechanics: An illustration in the context of the Atwoods's machine, American Journal Physics, 62, 46 – 55.

M Welzel, (1997). Student-centred instruction and learning processes in Physics, Rèsearch in Science Education, 27(3), 383-394

Nunnaly, J. (1978). Psychometric Theory, New York: McGraw Hill

Pfundt, H., & Duit, H. (1994). Students' alternative frameworks and science education. 4th edition. Kiel: IPN.

Piaget, J. (1964). Cognitive development in children: Development and learning, Journal of Research in Science Teaching, 2, 176-186.

Roth, W.-M., McRobbie, C.J., Lucas, K.B. & Boutonne, S. (1997). Why may students fail to learn from Demonstrations? A social practice perspective on learning in Physics, Journal of Research in Science Teaching, 34, 509-533.

Shepardson, D.P., Moje, E.B., & Kennard-NmcClelland, A.M. (1994). The impact of a science demonstration on children's understandings of air pressure. Journal of Research in Science Teaching, 31, 243-258.

Sokoloff D. R. & R. K. Thornton, (1997). Using interactive lecture demonstrations to create an active learning environment, Physics Teacher, 35, 340 – 347.

Subramaniam R. & Yeo K. H., (2002). Integrating demonstrations in the teaching of science. In Yap K. C., Toh K. A. & Goh N. K. (Eds), Teaching Science (pp. 48 – 55). Prentice Hall (Singapore).