STUDYING THE RELATIONSHIP BETWEEN SCIENCE MUSEUMS AND SCIENCE CURRICULUM TAUGHT IN UPPER PRIMARY SCHOOLS IN AHMEDABAD, GUJARAT

SAMRUDHA DIXIT

Introduction

A science museum is one of the most stimulating experiences. Deep gasps, excited glances and mouths open in awe are quite common expressions one can observe in the visiting children and adults alike. What is it about the science museum which gets children excited? Experiential learning can be imparted in the school science laboratory itself. This research was driven by enquiries of what more does the science museum offer in discovering the subject or is it just an amusement space.

The research looks at Science museums (and science centres) as educational spaces where teaching and learning of science happens. It then studies the retention and relevance of what is being offered at science museums as part of experiments and illustrated scientific concepts.

The academic research is part of the semester long MA Education (first year) program as Introduction to Research (ITR) course. The research studied how the visits to science museums were conducted with three types of participants; school students, teachers and museum staff. Total five museums were approached in Ahmedabad and Bengaluru out of which, Khoj Museum in Ahmedabad supported us with the research. The museum had just finished its first year when the field research was conducted in March 2019. Started by Manthan Educational Programme Society (MEPS), the museum has collaborated and partnered with various organisations both national and international. MEPS has been involved with interventions in science education in rural and urban parts of Gujarat for about two decades. Two schools from Ahmedabad were part of the research. The students from 8th grade were selected at random for the research. The methods employed were to understand if the visit to the science museums inculcate conceptual understanding in students to what extent and what is their retention of these concepts or principles after the visit.

Samrudha Dixit is a graduate of Industrial design pursuing MA Education at Azim Premji University. He seeks to investigate the pedagogy methods practised in Indian crafts.

Khoj Museum

The museum building, a repurposed astronomy lab, has three stories with a medicinal plants garden and a geodesic dome shade at the front. The ground floor is the office and waiting space for visitors. The three floors are divided in three themes which the museums change every 8-10 months. All the equipment or exhibits are made inhouse by MEPS with the goal of maximum learning with minimum investment (as they will be replaced within a year). At the time of research, the first floor is a bubble room, with equipment and experiments designed to understand air pressure with soap water, a variety of contraptions and dry ice. The second floor was moving images. This floor showcased a chronological advancement in moving images from flip books to green screen animation. The third floor has been planned to be dedicated for astronomy as an homage to the building's past. The visitors are encouraged to play and experience the exhibits, there are floor mentors for each floor who guide visitors with doubts and give them further information on all the showcased concepts.

Significance of the research

Considering the vast positives of teaching science to students both in schools and in informal spaces, the Ministry of Culture, India has set-up an autonomous organisation National Council for Science Museum (NCSM). They are instrumental in setting up Science Cities, Centres and Innovation Hubs in various parts of the country. "A Science Centre provides the scope of 'doing science' adopting a hands-on approach for which it offers to the visitor a number of experimental options through which they can discover the scientific concept themselves. Such a mode of education has so far proved to be very effective in supplementing formal science education in our country." (Ministry of Culture, n.d.) With the formation of institutions like NCSM there has been a plethora of interventions setting up science centres and museums. The short academic research project questions the relation between teaching-learning science at a Science museum. There has been similar research which tries to quantify science learning at science museums, but not much academic research is in place in the Indian context. During discussions with the school's teachers we realised they were interested in knowing our findings as they would like to know if the visits are of any use and to what extent. Although it needs to be noted that this is a short academic research and is merely a starting point, the research findings highly suggest a need for extensive and much elaborate research in future.

Moving images

Astronomy

Bubble

Conceptual framework

This short research revolved around the interaction of students with scientific equipment for experiential learning. The relation they hold with each other on the grounds of science education governs the research and its conceptual framework. The research had devices ways to study understanding of scientific concepts than asking directly. NCSM identifies science museums, science centres and innovation labs with varied functions and expects them to work in tandem. This report considers all the three under the head of the science museum, although the focus is on the museum where students and visitors can interact with the exhibits for teaching and learning science. The following were studied as part of the research framework:

1. At museum

a. Student – floor mentor interactions
   The way the floor mentors introduced the scientific concepts of the exhibits.
   The Q & A between the students and the mentors.

b. Students – exhibit interactions
   The student's perception of the exhibits, info graphics and installations.

c. Teacher – exhibit interactions
   How do teachers experience the exhibits?

d. Students – teacher interactions
   Do the teachers and students interact at the museum about the classroom activities. What were these interactions?

2. At School

a. Teacher perspective on students understanding after a science museum visit.

b. Students retention of scientific concepts.

Objective

To find the overlaps between the science curriculum and the science centre/ museum exhibits. Then to assess do they aid teaching and learning science in schools.

Research questions

In what ways do schools integrate visits to science museums in their science curriculum of 8th grade?

- What activities are done pre-during-post visit to science museums by teachers?
- In what ways have the students internalised the scientific concepts experienced in the science museums?
- To what extent do Science Museums are being used for teaching and learning science in schools?

Variables:

- School/Board type, school schedule and Financial aid.
- Access and distance to the Science museum.
- Museum schedules, program availability, capacity of accommodating students.
- Teacher working experience in years, gender, Training received from Science Museum.
- Sampling of the students.

Literature review

"*We do not learn from experience... we learn from reflecting on experience*"
(Dewey J., 1910)

A science museum has been identified as a source for learning by the NCERT, NCSM and Ministry of Culture. Although during the literature study it was found that the perception of science museums is distinctly different from the organisations. As per NCERT's prescribed educational framework "sites of curriculum that are physically located outside the school premises are just as important ... These are sites like local monuments and museums, natural physical features such as rivers and hills, everyday spaces such as marketplaces and post offices." (NCERT, 2005). It also prescribes that visiting informal spaces like Science museums should not be treated as 'extra' curricular activity but part of the subject curriculum. Such integrated visits with the curriculum foster scientific vigour and temperament in students. Learning science in India is more than just learning the fundamentals of the subject. As a nation rich in diversity of cultural, social and religious wisdom. There are numerous interpretations of the natural world around us.

Many of them have lost their reasoning over time and fallen prey to superstition. NCERT's National Focus Group report for Teaching Science brought up various collaterals where teaching science can make a difference in society. They acknowledged that science curriculum can be instrumental in closing the society's gap in gender, caste, region and even religion. Equipping people to higher learning and opportunities.

As part of Indian Ministry is promoting the work science museum do, "a Science Centre provides the scope of 'doing science' adopting a hands-on approach for which it offers to the visitor a number of experimental options through which they can discover the scientific concept themselves. Such a mode of education has so far proved to be very effective in supplementing formal science education in our country." (Ministry of Culture, n.d.). The role and expectations from the science museum have been laid out by these documents but there is an ambiguity on the receiving end i. e., schools. As mentioned earlier there hasn't been ample research in the Indian context, there have been some extensive studies globally.

"Researchers in the field claim that bridging activities (between schools and science museums) increase the impact of students learning in out of school settings" (Bamberger & Tal, 2008). Although an intriguing viewpoint emerged during the review. Many researchers have found that students do not learn new concepts through museums, but museums are essential to reinforce the ideas and accommodate the nuances of the concepts. "As science-centre director Tom Krakauer recently quipped, museums teach the public "what they almost already know" (Falk, 1999). An experiment (Davidsson, 2015) asked visitors on what they knew all they knew about science. It was found that the participants gave elaborate answers to the concepts but denied learning the new concepts during their tour. This is an essential finding to the proposed research as it states the importance of the need for schools and museums to work in tandem to aid better understanding of scientific concepts. It must be also discussed that the role of the educator is not only confined to pre-visit preparation. 'To optimize students' attitudinal and cognitive gains, teachers should assume an active role during the visit, calling students' attention to a given phenomenon, asking them to explain the phenomena under observation, providing support and "scaffolding" between students' existing concepts and the exhibits' (Morentin & Guisasola, 2014). The accommodation of the concepts happens through conversations around the exhibits. One research (Bamberger & Tal, 2008) found that when graduate students guided schools' students through a science museum. It was seen that the school students got motivated to ask questions when the graduate students shared their projects and understandings.

"The classroom preparation before the visit to the science museum plays an important role for children to be able to make connections with science museum exhibits. Similarly, during the science museum visit, the children should be encouraged to ask questions, explore things that they find interesting. The questions children come up with should be linked to their life and classroom teaching. This creates an opportunity for children to control their learning. During the exploration, the museum guide and the teacher would stay around and see their role as mediators in the process of learning science" (Tai et al. 2005; Cox-Petersen et al. 2003). The teachers should play a central role as they understand the child best and can draw an association between science museums and things taught in science class. The teachers end the trip to the museum with a wrap up visit by taking specific photos, drawing, talking with the museum personnel and so forth. The teachers should follow up the visits in the classroom by asking children to share their museum experience in a group and connect it with the classroom teaching." John H. Falk (1999) in "Museum as institution of personal learning" affirms the above statement that "most learning that occurs in museums, has more to do with consolidation and reinforcement of previously understood ideas than with the creation of totally new knowledge structures." Research into science museums and field trips indicates that it is necessary to integrate the visit in lesson planning to optimize the learning (Falk & Dierking, 2000). Maite Morentin and Jenaro Guisasola (2014) in "The role of science museum field trips in the primary teacher preparation" point out that "The peer-peer interaction in the science museum promotes learning. Museums generate interest among students by relating to their interest and encouraging them to revisit museums and use it as a resource of learning." Falk (1999) makes the following research finding: "After completing their visit, visitors of all ages were able to demonstrate a significantly greater understanding of the multiple life processes that all living systems share." The research brings out another interesting point that various other factors also contribute to construction and development of children's knowledge. These factors include interacting with parents and other people in enrichment and extracurricular activities and in more informal interactions at home; reading books; watching television programs; playing with and disassembling electric and motor driven toys; and participating in school and museum-based experiences. John Hennigarh Shuh in "Teaching yourself to teach with objects" (1982) makes the following point: "Unlike the print materials (books), the objects are age and grade neutral. In other words, it is not required for the students to attain a specific proficiency to see and engage with objects in an educationally engaging manner. This is not to say that every object will generate equal appeal for students at all levels. Children of different age groups will interpret the objects distinctly as per their own life experience and observation skills.

Subsequently, they will assign meaning to it. Learning to use objects with children enables them to do a careful and critical observation of the world. It helps children to ask probing questions and provide them the opportunity." In a review of the literature, Smylie (1994) discussed the redesign of teachers' roles and the school as a workplace. He indicated that, in order to promote change and increase effectiveness of teachers and schools, "professional communities" need to be created. The Professional Development School (PDS) model enriches the classroom learning community by bringing in university resources, preservice interns and faculty, as well as resources and personnel from the community such as museums and science centers.

Wellington (1990) examined features of museums that are most effective in developing visitors' interest in and understanding of science. He pointed out that the overall atmosphere of informal science learning, including features such as "voluntary, un-structured, non-assessed, open-ended, and learner-centered", led to interest and learning. Cláudia Faria and Isabel Chagas (2012) in "School-visit to a science centre: student interaction with exhibits and the relevance of teachers' behaviour" found out that "students interacted with the modules for very short periods of time, giving the impression that they were "shopping around". Acting this way, they visited many modules for very brief periods of time: 50% to 59% of the visits to a module lasted less than one minute and 73% to 90% lasted less than two minutes." In a literature review, Jarvis and Pell (2005) suggested that to optimize students' attitudinal and cognitive gains, teachers should assume an active role during the visit, calling students' attention to a given phenomenon, asking them to explain the phenomena under observation, providing support and "scaffolding" between students' existing concepts and the exhibits.

The literature provided an insight in how science museums perform in educational activities. The findings of the researches were considered for validation through various methods adopted by this research.

Methodology

The research used a mixed method for collecting the data. Qualitative to study the scientific understanding of the students and qualitative to gauge their retention from the visit to science museum. The participants of the research were divided in two spaces; the school and the museum. The methodology was realised through the following steps:

1. Connecting with science museums – As the research was to be conducted on the museum exhibits and the schools visiting it. It was necessary that the museums understand the research project. In all five museums were approached out of which only one museum extended their support towards the research.

2. Research at museum – there were five research activities conducted:
   a. Exhibit analysis
      The school textbooks were studied to see if they complement the museum's themes and exhibit.
   b. Pre- and Post-visit interviews of students
      During one of the school's visits to the museum, based on the literature studied, this method was framed to study the retention of new concepts in students. Same questions were asked in relation to the scientific concepts covered in the museums before and after the visit to the museum. Their responses were recorded for analysis.
   c. Semi-structured observation
      During the students' visits to the museum, the interaction between student-exhibit, student-teacher, student-floor mentor and teacher-exhibit were observed.
   d. Questionnaire for the museum staff
      General information questions about the background of the staff.
   e. Interview with the museum staff.
      The questions were about their perception of student/school visit and science education.
3. Identify schools – With discussion with the museum staff we found the school which have recently visited the museum. This was a snowball activity; Four schools were approached out of which two schools agreed to participate in the research. Both were low fee private state board schools; one was English medium while the other was Gujarati medium.
4. Research at school – data was collected from 29 students and 6 teachers from 2 schools.
   The activities conducted were:
   a. Questionnaire and test for the students
      The questionnaire was divided in three parts:
      i. General information about the students, her/his background.
      ii. Objective questions which tested the memory retention of the scientific concepts introduced at the museum.
      iii. Application questions which tested if the students had understood the scientific concepts.
   b. Interview with the students
      The interview was to know the student's perception of the museum.

c. Questionnaire for the teachers
   This had general information about the teachers and their experience at the museum. There were four science teachers and two other subject teachers, out of whom only five had visited a museum with the students.

d. Interview with the teachers
   The interview was structured to get how teachers perceive museums and if they felt the need to integrate it with their curriculum or lesson plan.

5. The documented raw data was transcribed and converted in tabular format. These were then processed by categories and finding the mean standards of the data keeping the conceptual framework as reference. The analysis was then discussed with respect to the literature reviews to formulate the conclusion.

Ethical considerations

The research ensured that all ethical considerations were met. Written consent was taken from the participants prior any research activity. The nature of the research project and measures for keeping the data private were also communicated to the participants.

Limitations

As a short academic research, the constraints of time and engagement with the participants were limited. This research was conducted in March 2019, when most of the schools had their academic year end examinations lined up. There were three repercussions of these, firstly as this leg was snowball only two schools were ready to participate in the research. Secondly, the student sample during the questionnaire was not random. Only the higher scoring students could participate in the research. The reason given to us was that these students can cover up the missed class and the others should focus on the studies. Although because the sample size was about 15 per school the results were not entirely biased. Lastly, in one of the schools the time allocated was limited for all the activities, and was less than what was needed. Only one out of five museums approached were ready to give access for the research to be conducted. It needs to be noted that this is the only museum which has guided tours by floor mentors. This was taken as an opportunity to validate certain literature written on guided tours.

As the school visiting the museum came in a group of about sixty for a duration of only 2 hours. Conducting pre-post interviews with semi-structured observations were compromised. The pre-post interview was successfully conducted for 10, 5th grade students but only a handful of 8th grade students who were the focus area.

Analysis

The analysis is based on the mixed method of research. The participants were teachers (either science teachers or teachers who had visited with the students), students (who had visited the science museum recently) and the museum staff.

Quantitative research analysis

The questionnaire set for students had general information of the students and questions related to the scientific concepts introduced at the science museum. In response to the literature review the latter had application and memory-based questions. The application-based questions were to observe if the students have understood the scientific concept and the other to observe if the students retain newly introduced information/knowledge. The following is the analysis of the student's questionnaire based on their visit to science museum 19 students scored an average of:

- 67% in objective tests designed to test their memory (Highest: 100%, lowest: 36%).
- 60% in application test designed to test their scientific understanding of concepts (Highest: 83%, lowest 0%)
- The test was of 10 marks
  Standard deviation: 1.7; Mean 6.5
  Students falling in bell curve: 12 of 19 (63% between 4.8 to 8.2)

  Gender
  - Boys (10) averaged 75%
  - Girls (9) averaged 53%

  Students whose both parents are:
  - School pass outs (7): 64%
  - Higher education (7): 60%

  Students whose are working:
  - Both work (4): 69%
  - Homemaker (12): 64%

The teacher's questionnaire was to see how the teacher perceives the science museum visit, their awareness and if they integrate it in their curriculum. Following is the analysis of teacher's questionnaire:

- Out of 5 teachers who accompanied the students only 1 was a science teacher.
- No classes were conducted which linked with the museum before the visit.

- Out of 4 science teachers interviewed, 1 had never visited a science museum.
- 3 out of 6 teachers visited the school for the first time with the students.
- Out of 2, one school had 60-100 students visiting in one trip.
- All the teachers feel that the time given presently (2-3 hours) is not enough and should be increased.
- 1 out of 4 teachers felt that experience at science museums is not retained.
- The teachers believe that the quality of exhibits contributes the most in student's conceptual retention.
- The teachers believe that students cannot learn on their own at a science museum.

The analysis of the questionnaire filled by three museum staff members reviled:

- The curator's perspective on most liked and disliked exhibits matched with the visiting students.
- The curator finds it essential that the teachers are prepared for the visit and the guided tours make a big difference in student learning.
- 30-60 was the ideal group size for the guided visit.

Qualitative research analysis

There were two sets of interviews with the students. First was the pre- and post-visit to the science museum. In response to the literature review which claimed students do not retain new information, questions were asked to students relating to the scientific concepts of the exhibits at the museum to see what they knew before and after the visit. The analysis showed:

- Many children knew the answer/concept (for example, why can't we see stars in the day?) but there was no significant increase in their answers in the post-test.
- Regarding the moving images room, a few students could retain the terminology introduced during the guided tour like green screen or 1/16 of a second (speed of our eyes to capture images).
- The exhibit which was new for them (bubble room), caught their interest, it was found that most of them liked it and nobody disliked it.

The other set of interviews with the students were more elaborate. One school had visited the museum a month ago whereas the other only a week ago. Analysing their responses showed:

- Students wanted to learn science for the understanding of the world around, for general knowledge, career prospect and nation development (in order of priority).
- During the categorisation of the reposes on how their experience was, the most marked category was amusing, followed by new learning.
- Out of 23, 12 students learned something new from the museum visit. Only 2 could associate it with the science taught at school. Others liked the museum because they could do the experiments themselves.

	Prior knowledge	Interest	Didn't understand
Bubble	5 of 23	13 of 23	2 of 20
Astronomy	7 of 23	5 of 23	6 of 20
Moving Images	3 of 23	5 of 23	6 of 20

- The above table show how many of the students knew something about the scientific concepts exhibited at the museum, how many were interested (as per the room themes) and how many students did not understand what was explained or experienced at the museum (as per the room themes)
- More than half the students could relate to some scientific concepts in their daily life which they experienced at the museum.

The interview with the teachers showed us that:

- The teachers appreciate the experiment driven nature of the museum and provide opportunity for learning. The models made it easy for teaching certain abstract scientific concepts.
- The museum offers science learning which is essential but extracurricular. This also breaks the tendency of rote learning.
- Pre preparation wasn't done to maintain the student's curiosity, but they were followed up after the visit. (an average of 63% scored by the students, the visit was a few months old).
- No preparation of link with curriculum (67% scored by the students, the visit was a week old).
- The teachers support the presence of a more knowledgeable one to guide the students during their visit.

The interview with the museum staff revealed:

- Based on their observations and expertise the museum staff followed a format school museum visit. They first let the students explore the space with the exhibit with no instructions for about 5-10 minutes. The floor

mentor explains all the exhibits, after which they are free to re-explore the exhibits.

- The museum strongly felt that the science museums should not align with purely what is taught at schools. Their aim was to aid students bridge the gap between theoretical science taught at schools and science of everyday life.
- The science museum was free for government school and the fees for private school was close to government funded museums.
- The idea of periodically replacing the themes was to excite students who have visited before and as well as who will be visiting again. It also pushed the museum to reinvent their themes and implement their observations ensuring they don't stagnate.

Textual analysis

As both the participating schools were Gujarat State Board, the science textbooks were studied. As it was observed during the pre-post visit interview students remember what they have learned from previous grades too. Textbooks of three grades were students 7th, 8th (the students' present grade) and 9th. The following are the notes for the analysis:

- The objective of the textbooks as mentioned in the preface was, 'This principle marks a departure from the legacy of book learning which continues to shape our education system and is creating a huge gap between the school, home and community' (Vaghela, et al., 2013).
- Only two chapters were directly linked to the exhibits, 'air pressure' in 8th and 'our solar system' in 7th grade.
- The textbooks were developed in 2013 and are still used after six years.
- The textbooks classified its content in seven techniques: Activity, Questions, Group activity, Project work, Only for information, Exercise and Think.
- The textbook mentioned, 'There is air in our body. The pressure of air inside the body and in surrounding is balanced so we are not crushed' (Vaghela, et al., 2013).

Discussion

There were two findings in the literature review which this research had probed in. Firstly, it was the claim that students or visitors do not learn new concepts at science museums, but the earlier concepts are just reinforced with the experiential learning. The other was the need for a guide to give an insightful experience. The research analysis suggests that both the inferences mentioned are in tandem. The museum had a clear policy for floor mentors who guided the children about concepts, associate the concepts with daily life

activities and the link with scientific concepts and theories. It was found that although most of the students visiting did not know about the concept of bubbles, they could correlate it from their chapter from air pressure. It also showed that their memory retention of the key ingredients to make soap water was also high, rejecting the claim that science museums can only reinforce pre introduced concepts and theories. It needs to be accounted that the format of the museum was well informed about various learning methods. The explore-learn-reexplore technique seems to have worked considering over students scored over 60% in the tests which was based on a two-hour visit. Considering one school had visited the museum a month ago the results seem remarkable.

The other issue which came to light was the complexity of including museum visits in curriculum. Due to the administrative constraints the visit to the science museum is independent of what is being taught. Adding to it only the teachers who are free accompany the students, making the student-teacher interaction obsolete as the teacher may or may not know about the learning graph of these students. This also causes lack of association with what is being experienced at the science museum and taught at school. Lastly it was observed in the scores the difference in scores between boys and girls. It marks a necessary probing to validate the result again with a larger sample and find the causes for such drastic difference. It was observed that the students in one school were divided in groups of boys and girls. Although the mentors treated both the groups with same attention, a further study is required observing the nuances between the two.

Conclusion

One of the teachers had confessed to us that it took me several classes to explain the solar system and eclipse, but the students understood in a jiffy at the museum. The research has been insightful for the schools, science museum and us. The field research itself triggered thought-provoking conversations amongst the participants. A few teachers also mentioned that they would visit the museums again and try to integrate it in their lesson plan. With the analysis and finding it can be concluded that the perception of NCSM and NCERT of science museums as teaching and learning space is acknowledged but not clear or assertive. The research demonstrates the retention of both memory-based and application-based understanding of scientific concepts amongst the students. It also proves that students were able to link the concepts to their daily life activities; one of the goals of science education. In comparison to the observations in other museums the research also reinforces the necessity for a guide or mentor during the visit.

Suggestions

The research suggests awareness programs for teachers about science museums. Having information about their local museums will allow them to plan their lessons such that they can use the science museum as a teaching learning resource. Also, in cases of museums which do not facilitate tours or guides it can be that the science teachers accompany the students so that they can connect the classroom learning with the experiential learning.

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