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THE CONDITIONS, CONTEXT AND CHARACTER OF CHILDREN'S QUESTIONS IN AN OUTREACH PROGRAM

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We present an analysis of the questions asked by students of Grades 6-12 during the course of a two-year school outreach program conducted by students from Tata Institute of Fundamental Research (TIFR) Hyderabad and University of Hyderabad. We place this work within the discourse on rote learning and a perceived lack of curiosity among Indian students in traditional school settings. Given the right conditions, students at all levels did express their curiosity through questions. Biology (especially human physiology) and physics (especially astronomy and light) were prominent fields of students' interest. Questions were often derived from everyday phenomena and not easily relatable to the curriculum. Students had questions on religion, society, humankind, and on life and career matters. Explanatory-type questions predominated followed by complex factual and open-ended questions. We identified some context dependencies of these questions. We found curiosity alive and well among students: now it's up to our ability to recognise, characterise, relate and direct that curiosity towards our mutual learning.

INTRODUCTION

Curiosity and questioning among children

Curiosity and questioning are natural to children. Infants express curiosity through looking, expressions, vocalisations, gestures and explorations (Engel, 2014). On learning to talk, children gain a powerful new tool to acquire information about the world. During toddlerhood they persistently and tenaciously seek information through questions and gather informative answers, a tendency that may be significantly shaped by family, society and culture (Engel, 2014). The rapid drop of questioning as children enter school is now well documented (Tizard and Hughes, 1984; Dillon, 1988). In Indian familial and school contexts, children are socialised to accept the authority of elders. Teacher-questioning and children-answering are the norm (Kumar, 1989). The pedagogic authority of the teacher, textbook and the curriculum reign supreme (Clarke, 2001; Sarangapani, 2003). Sarangapani (2003) documents how the teacher's questions are mainly evaluative and factual, and how they serve to establish and maintain the teacher's epistemic superiority and authority over knowledge. Students' questions, if any, are mainly procedural or clarificatory.

The value of questioning

In scholastic contexts, questions are known to improve children's ability to recall, remember and to raise their academic achievement. Studies have confirmed the relationship between curiosity and memory (Gruber, Gelman & Ranganath, 2014) and curiosity and academic achievement (von Stumm, Hell, & Chamorro-Premuzic, 2011). Suppression of children's curiosity is thus a wastage of learning opportunities in school. Meaning is mediated in education mainly through questions. Questions are an essential component of discursive activity and dialectical thinking; they direct learning and facilitate knowledge construction, and are thus a valuable resource for learning (Chin and Osborne, 2008). Inquiry-related curiosity is recognised to play a significant role in driving science learning in both formal and informal learning settings. The inquiry approach, though it draws from research on students' conceptions, may have neglected the students' own voice (Jenkins, 2006), resulting in an inattention to what students are interested in learning, or what they have difficulty in understanding. This gap might be addressed by studying self-generated questions, especially in informal contexts, e.g. as done by Baram-Tsabari and Yarden (2005) and Baram-Tsabari, et al. (2006).

Facilitating students' questioning

Facilitative conditions for questioning include meaningful scaffolds, prompts, curiosity-inducing stimuli and other supporting mechanisms (Chin and Osborne, 2008). Learning through research papers might provide a stimulus for questioning and higher thinking levels (Brill and Yarden, 2003), as also well-designed inquiry-based laboratory tasks (Hofstein et al., 2004). Singh et al. (2018) found spontaneous questioning and discussions among children in a less structured setting; by analysing children's talk and interactions with each other and with a tree (a material context), they documented authentic questions, both explicit and implicit.

School outreach program of TIFR Hyderabad

In early 2017 the TIFR Centre for Interdisciplinary Sciences, Hyderabad undertook an outreach program for three residential schools run by the Telangana Social Welfare Residential Educational Institutions Society (TSWREIS), two Girls' and one Boys' school. The program was conducted during weekends by mainly graduate or integrated master's student volunteers from TIFR Hyderabad (TIFR-H) and University of Hyderabad (UoH). It included classroom and lab sessions on curricular topics with students between Grades 6-12. Over two years 83 volunteers participated in 134 visits: a core group of five volunteers in more than 20 visits, while most attended 9 or fewer visits. Volunteers recorded a brief account of their session in a shared log file. Early on the volunteers remarked on the extreme prevalence of rote learning in the schools. Though students were lively in their interactions, curious about where the volunteers came from, what they were doing in their school, etc., they rarely asked any questions about the science content. The schools' administrators were receptive, and even suggested a 'Project Socrates' to encourage students' questions.

Then, towards the end of the first year, two of the volunteers decided to ask two classes of Grade 12 students to give their questions in writing, anonymously if they so wished. To their surprise, these students came forth with a flood of questions on a range of topics, from biology and astrophysics to philosophy and career aspects. In another school, in a session on human physiology, an experienced teacher-volunteer was able to elicit oral questions from students. Later several volunteers recorded questions, through discussion and activity sessions and events like 'Meet A Scientist'. This paper is based on an analysis of the questions data and metadata recorded in the logs from all of these contexts.

METHODOLOGY

Research questions and data

(a) What conditions and contexts can lead to students expressing their curiosity? (b) How do we characterise students' questions in a way helpful to teachers and curriculum developers?

The data is drawn from two years of school outreach from February 2017 to December 2018, during which a total of 134 school visits were conducted by 83 volunteers in three schools that followed State Board curriculum. These included 330 sessions for Grades 6-12. In 63 of these sessions 698 questions were recorded, and 49 questions were recorded in two 'Meet a Scientist' events, making a total of 747 questions analysed here. Of these 477 (64%) questions were submitted by students in written form whereas 270 (36%) were in oral form and recorded in the logs by volunteers. The information in the log records allowed us to characterise the type of sessions ('Discussion-based', 'Activity-based' and 'Meet a Scientist') and to determine whether the question was related or unrelated to the ongoing session. Observations and impressions recorded by the outreach volunteers helped in further understanding the context of the questions.

Coding and analysis

Baram-Tsabari and Yarden (2005) analysed children's questions submitted to a TV program series for 'Field of Interest' (FoI), 'Type of requested Information'(ToI), 'Motivation' and 'Source'. Of these only the first two types of analysis, 'Field of Interest' and 'Type of Information requested', applied to our data since all the questions were asked under specific and known circumstances.

The questions were first coded for FoI though a qualitative bottom-up approach; these descriptors were used as one means to validate a novel top-down coding approach. A long-term objective of our R&D program is to build a searchable database of children's questions. Seeking a standardised system of coding for subject areas we considered various library classification systems, of which the most widely implemented is the Dewey Decimal Classification (DDC) system (23rd online edition; OCLC, 2003). For appropriateness and feasibility of using a book classification system to code children's questions we consulted two librarians in two research institutes. These consultations also helped establish face validity to the FoI coding.

Baram-Tsabari and Yarden (2005) proposed a typology for ToI with six categories: Factual, Explanatory, Methodological, Evidential, Open-ended and Application type of questions. We further characterised these categories using subcategories that brought out better the nature of these questions. The coding scheme is elaborated in Table 1 in the 'Results' section.

Face validity of coding

The FoI and ToI coding schemes were fine-tuned after trials by four researchers on four separate datasets of 40 questions each collected from a different set of students. Then the dataset of 747 questions was coded in a shared spreadsheet (100-200 questions by each coder) after which the numerical FoI and ToI codes were sorted to visualize the questions grouped under each category. The DDC-based FoI codes were each reviewed by two authors followed by another round of face validity testing by a trained librarian for 65% of the data.

The qualitative codes were then used to test the internal consistency of coding. After another two rounds of sorting and agreement among all researchers, the codes for FoI and ToI were finalized.

RESULTS

The numbers of questions varied widely among sessions by different volunteers. Only 24 of the 83 volunteers contributed questions to the database. Out of 698 questions collected in 63 sessions, 468 were contributed by just five volunteers. The majority(64% of the questions) were submitted in written form. The number of questions asked by girls and boys were 587 and 160 respectively, as a result of several factors. There were 228 sessions in the two Girls' schools and 102 sessions in the Boys' school; volunteer and school-related variables may also have contributed to the difference in number of questions, hence no gender analysis is attempted. While interpreting the data however we must remember that 78.6% of the questions are contributed by girls.

Patterns of questioning

Questions posed by the students were coded as either 'related' (R) or 'unrelated' (U) to the topic of the session. In some general or motivational sessions, or when volunteers had simply asked students to write down their questions, the questions were labelled 'spontaneous' (S). The 'related' (R) questions were predominantly (70%) asked orally while the 'spontaneous and unrelated' (S+U) questions were submitted mainly (83%) in written form ($\chi^2 = 208.8$; $p = .0000$). The S+U questions are crucial to our analysis as they elucidate the fields of children's interests, in which they have questions irrespective of the topic of discussion. Among 747 questions raised, 481 (64%) questions were S+U type. Interestingly, the S+U questions mainly arose in the classroom sessions (479 out of 657). In the Activity and 'Meet a Scientist' session's 88 out of 90 questions were related to the session, indicating the success of these sessions in focusing the students' attention and directing their curiosity.

Field of interest (FoI)

After some rounds of qualitative or 'bottom up' coding to get a feel for the data, the questions were coded for 'Field of Interest' using the DDC 23rd Edition, 3rd Summary (OCLC, 2003). Out of the 1000 given divisions the 747 questions fell into 115 divisions. The students' questions, especially of the 'spontaneous and unrelated' kind, arose from their experiences and reflections rather than from academic disciplines. We aimed to place these everyday questions into categories that identified the areas of study that could be brought to bear in addressing them. For example, "Why is the sky blue?" and "Why can't we see gases?" were coded under 'Light and related radiation'; "How were humans born?" and "Why are the faces of human beings so different?" were coded under "Genetics and Evolution". The detailed DDC categorisation offered systematisation of a dataset of very diverse questions, with the flexibility of combining codes as needed. It gave a standardised system of coding that could be extended to large datasets and used by experts while responding.

Questions that could not be answered through natural science or technology naturally fell under humanities and social sciences. General questions about life and death were placed in 'Philosophy and humankind' and on the existence of God were in 'Religion', both under the broader category of 'Humanities'. Questions relating to memory, emotions and dreams were placed in 'Psychology' and questions about money in 'Economics', both as part of 'Social Science'. The humanities and social science categories were merged for the purpose of analysis. Table 1 shows the number of questions in three broad categories of 'Field of Interest', for 481 'spontaneous' (S) and 'unrelated' (U) questions, which reflect the students' own fields of interest, independent of the topic of the class. Frequently occurring subcategories and examples of the spontaneous and unrelated questions are shown. Though the majority of S+U questions (70.2%) were in the 'Natural Science' category, a significant number were related to religion and God, philosophy, psychology and humankind (25.9%).

FoI Question count (Column %)	**S+U count (Column %)**	**Salient sub-fields in S+U questions (%)**	**Example questions**
Social Sciences & Humanities 148 (19.7%)	125 (25.9%)	Religion & God (5.4%) Philosophy & Humankind (4.8%) Psychology (4.8%)	'Is it true that God does wonders in people's lives?' 'Why are mindsets of people different from each other?' 'Why can't we bear prolonged silence?'
Natural Sciences 574 (76.8%)	338 (70.2%)	Biology (37%) Physics (27%) Geology & Palaeontology (1.9%)	'Why do members of a family not share the same blood group?' 'Why are all planets round?' 'Where do we find diesel and petrol?'
Technology 25 (3.3%)	18 (3.7%)	Applied Physics & Engineering (1%) Applied Sciences (0.8%) Biochemical engineering (0.8%)	'Why does a fan have only three blades, why not more than three?' 'Why do clocks rotate clockwise and not anticlockwise?' 'Why is most paper white in colour?'

Table 1: 'Field of Interest' as seen in all questions and in 'Spontaneous and Unrelated (S+U)' questions

Within natural science the predominant sub-category was 'Biology' (37%) within which 'Human physiology, health and diseases' dominated at 20%, followed by 'Botany', 'Zoology', 'Microbiology' and 'General Biology' (taken together) at 17%. Within 'Physics' (27%), 'Astronomy and Astrophysics' questions were 14%, most of which focused on the Earth and solar system; only one question mentioned a black hole, "Is there anything to control a black hole?". Questions related to 'Light and colour' were significant at 7.7%.

Type of requested Information (ToI)

Table 2 shows the categories of ToI, example questions and the numbers in each category. 'Explanatory' type of questions predominated (54.6%). The 'Factual' questions (overall 27.0%) were mainly complex. The next largest category (12.8%) was of open-ended questions addressing apparent contradictions or seeking opinions, predictions and futuristic possibilities on a range of topics from supernatural and spiritual aspects to open-ended advice on personal issues. Interestingly very few questions asked for evidence or applications.

Context-based distribution of ToI

The sessions with questions and the number of questions collected in each (sessions: questions) included 'Meet a Scientist' (2:49), classroom sessions (63:657) and activity sessions (3:41). Interestingly during 'Meet a Scientist' most of the questions (73%) were of factual type; during classroom sessions the explanatory questions dominated (60%) while during activity sessions procedural and methodological questions were the most frequent (54%) (χ = 285.49; $p < 0.00001$). The classroom sessions also had a significant proportion of open-ended questions (20%).

Category (question count, percentage)	Subcategory (percentage) and example questions
Factual (201, 27%) *Questions seeking factual information (what/ who/ when/ where/ which); simple, complex and specific academic guidance*	**Simple (7.9%)**: 'What is meant by nitrification?'; 'Name the carboxylic acid used as a preservative?'; 'Which is the coldest place (on Earth)?' **Complex (16.5%)**: 'What are the advantages and disadvantages of solar energy?'; 'Can we see all cells within a fruit?'; 'Can a person be born without reproduction?' **Seeking guidance (2.5%)**: 'How can I become a poet?'; 'Why should we study reflection?'; 'How to prepare for 10th public exam?'
Explanatory (408, 54.6%) *Questions seeking explanation of a phenomenon, process or event. (How and Why questions). The subcategories include seeking explanation for the origins, causation, function, etc.*	**Origins (3.9%)**: 'How is a star formed?'; 'How did life begin on Earth?'; 'How did the Earth come into existence?' **Causation (35.3%)**: 'Why do we get irregular periods, pain at the time of menses and cysts in uterus?'; 'Why does a chameleon change colour?'; 'Why do men get bald more in comparison to women?' **Function / Mechanism (8.9%)**: 'Why does our brain have nerves, what is the use of it?'; 'How is soil formed?'; 'How can we replace plastic with other things on the earth?' **Connections and contradictions (4.7%)**: 'Why do we intake only oxygen and not nitrogen?'; 'Why plants are called living things when they do not move?'; 'Why is technology growing (so rapidly) on Earth? What are its benefits and disadvantages?' **Practices and Conventions (1.9%)**: 'Why don't we start counting from zero?'; 'Why is the school bus yellow in colour?'; 'Why do hospitals have a + symbol?'
Procedural / Methodological (37, 5%) *Questions seeking description for a specific procedure or methodology, including scientific experiments, medical procedures, theoretical subjects, everyday life issues etc.*	**Related to subject of study or an experimental demonstration in class (3.6%)**: 'Is there any process to harden the foam to form a sponge?', 'Why does dividing by zero give a 'not defined' value? Shouldn't it be zero?'; 'Why do we use only bacteria, for demonstrating microbial growth experiments?' **Related to practice of some field (within science, technology and economics) (0.5%)**: 'How do doctors replace the heart?'; 'How do astronauts go into space?'; 'How do scientists find the elements?' **Related to life issues/everyday world/environment (0.8%)**: 'What should we do to decrease pollution?'; 'How do people with (physical) disabilities swim?'; 'Why does corruption go on in our country? How can we stop it?'

Category (question count, percentage)	Subcategory (percentage) and example questions
Evidential (3, 0.4%) *Seeking evidence*	'How can we believe cells grow?'; 'Who is God? How? Why? I don't want to see but I want proof or a particular reason'; 'How do we know that 'atom' is the smallest constituent of matter?'
Open-ended (96, 12.8%) *Questions seeking opinions, suggestions, predictions as well as contradictions within existing facts, futuristic possibilities, supernatural and spiritual aspects, and open-ended advice on matters*	**Counterfactual (1.1%)**: 'Why do we want money?'; 'How can a poor one become a rich one?'; 'Why don't people live in other planets?' **Predictive (0.4%)**: 'What will happen if planets stop revolving?'; 'What would have happened if there were no bacteria on the planet?'; 'How long do cancer survivors live?' **Futuristic (1.9%)**: 'If mars get polluted where do we go in the future?'; 'What will Chemistry do in the next 20 years?'; 'Can we produce electricity from plastics?' **Seeking general advice (3.6%)**: 'How can we learn all the concepts of optional subjects?'; 'How to remember everything?'; 'Why do we remember all the things other than studies?' **Existential (1.7%)**: 'Why do we have to be born and die after spending some years on the Earth?'; 'Are humans of any use for the Universe?'; 'Why are we born and why do we die?' **Spiritual / supernatural (4.1%)**: 'Is God there or not?'; 'Why do people believe in superstition?'; 'Does the devil exist?'
Application (2, 0.26%)	'We would love to have our school powered by green energy. Could it provide electricity for our school? Is it long lasting?'; 'How will this experiment help in our daily life?'

Table 2

Inter-relationship between ToI and FoI

Does the type of information requested (ToI) vary according to the subject area in which the question is asked? Figure 1 indicates that 72% of questions in 'Biology' and 60% of questions in Physics were Explanatory in nature. On the other hand, questions in 'Humanities & Social Sciences' were majorly of open-ended type (48%). A minimal proportion of Open-Ended questions appeared in other subjects, except 'Chemistry'. The Type of Information requested significantly varied by subject areas ($\chi^2 = 302.14$; $p < 0.00001$).

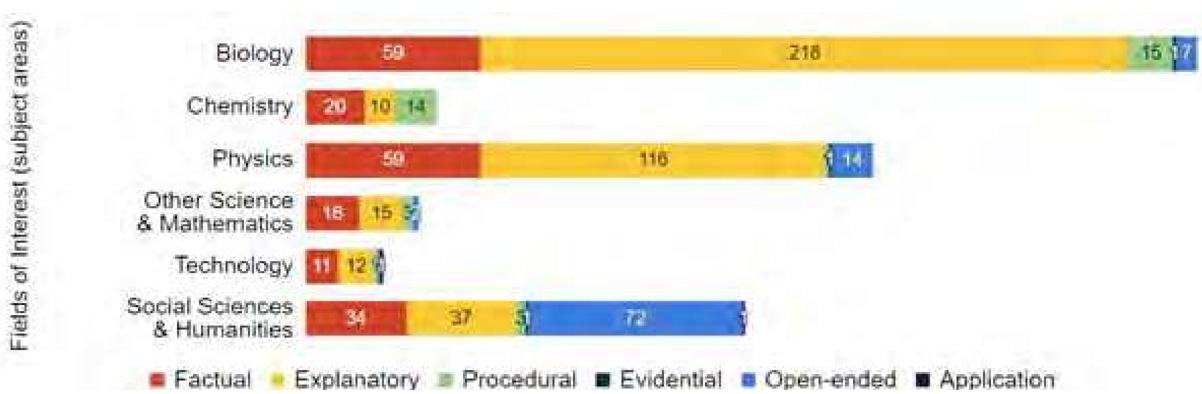

Figure 1

CONCLUSIONS AND FUTURE DIRECTIONS

A significant result from this study is actually implicit in our data. It is about the ease with which many of the volunteer-teachers could break the stereotypical classroom pattern of 'teacher questions - student answers'. Volunteers noted the non-hierarchical nature of the dialogue and the realistic possibility of response which encouraged questioning. It helped that they had an explicit mandate to solicit and record students' questions. The volunteers were highly capable graduate and masters science students and, in one case, a reflective, experienced teacher. All were themselves curious, had access to information sources and, most importantly, were part of a supportive community of scientists and science learners. Other favourable conditions included written and anonymous questions, meeting scientists (for factual queries) and science activities (for methodological queries).

The task of addressing students' questions is barely begun. In the next phase of the outreach program the database of students' questions in specific areas is made available to the volunteers as an aid to prepare their sessions on the basis of students' spontaneous interests. On a wider scale students' questions have implications for curricula in science and social studies, after the database gets inputs from more diverse groups of students. Learnings of the outreach program has led to a collaborative R&D project with Eklavya (Madhya Pradesh), aiming to create the 'Sawaliram' website with a digital repository of students' questions from various contexts and language backgrounds from across India. This repository will be part of a multilingual interactive open source platform to collect, answer and analyse children's questions. The web platform would host resources for parents, educators, curriculum developers and researchers on the topic of curiosity and questioning among students.

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