Several Lines of Inquiry Into Inquiry Teaching and Learning: Exploring the Affective Outcomes of Inquiry-Oriented Science Teaching

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Abstract
In this paper, we report our explorations of some affective outcomes of teaching science through inquiry. In the process of developing an innovative inquiry-oriented science curriculum, we conducted classes with middle school students (Grades 6 through 8) over several years. In these classes, we discovered some notable affective changes in students, although the focus of teaching in these classes was on conceptual understanding. At the end of our four year intervention with them, we administered self-report questionnaires to the students, and conducted follow-up interviews. We also administered questionnaires to students' parents and peer group to obtain richer data and for triangulation of students' responses. The self-reports and interviews indicate, among other positive changes, increase in students' engagement levels with the topic at hand, their interest in science, self-confidence and participation in science classes. In this paper, we report some of the preliminary qualitative analysis from this study. We also briefly discuss how it informed the design of a subsequent in-depth exploration of affective changes in students in response to inquiry-oriented science teaching.

Keywords: Inquiry teaching, affective outcomes, students' self-reports, middle school

1.1 INTRODUCTION
A consistent theme across recent calls for reform in science education throughout the world is the emphasis on inquiry as a key aspect of teaching and learning science (Haury, 1993; Minner et. al, 2010; National Council of Educational Research and Training (India), 2005; National Research Council (USA), 1996). Most studies investigating effectiveness of inquiry teaching focus on concept acquisition. Outcomes other than concept learning, which make up the wider objectives of science education and general education, need to be studied as well. Our aim in this study was to explore the varied outcomes of teaching science through inquiry. In this paper, we describe the range of outcomes of inquiry science teaching that we explored through several lines of inquiry – teacher's classroom observations, self-reports from students who underwent our inquiry teaching as well as self-reports from their parents and peers.

At the Homi Bhabha Centre for Science Education, we are working on an innovative inquiry-oriented science curriculum research and development project at the middle school level. Methodology of this project (Kawalkar & Vijapurkar, 2008) is such that curriculum development and testing processes are completely intertwined. The curriculum takes shape within the classroom setting; it explores and takes into account several aspects such as students' cognitive readiness, presence or absence of prerequisite concepts and skills as well as their prior experiences related to the concept at hand. In the inquiry science classes that we conduct, in order to be able to transact such an inquiry in the classroom, a lot of attention is necessarily given to classroom interactions to create an environment conducive to eliciting and dealing with students' ideas. In this process, we realised that although the
focus of teaching in these classes was on bringing about conceptual learning, there were some notable, wide-ranging affective changes in students who attended these classes. In this paper, we describe our explorations of these varied affective outcomes of teaching through inquiry that we discovered serendipitously. We present here preliminary results from a post-facto study using students' and parents' self-reports and discuss how this study led to the design of a full-fledged doctoral thesis project.

1.2 REVIEWING THE LITERATURE
1.2.1 What is inquiry teaching?
Though typically inquiry teaching involves active student involvement in terms of hands-on activities, the distinguishing features of inquiry teaching is involving students in asking questions about scientific phenomena, reasoning based on evidence and developing and evaluating explanations (Haury, 1993, 2001; National Research Council (USA), 2000). Rather than merely transmitting knowledge, inquiry teaching enables and supports the learner to construct knowledge (Chin, 2007; Marshall, Smart & Horton, 2009). A summary of the characteristics of inquiry teaching differentiating it from traditional, expository science teaching can be found in Kawalkar & Vijapurkar (2011).

1.2.2 Studies evaluating outcomes of inquiry-based science instruction
While much research has been done to get comparative evidence of effectiveness of teaching science through inquiry over traditional, direct instruction, educational and political debates on the merits of either approaches continues (Anderson, 2002; Cobern, 2010). Many studies and meta-analyses of inquiry teaching inquiry-oriented curricular programs (Anderson et al, 1982; Shymansky et. al, 1990; Minner, Levy & Century, 2010) have been generally supportive of the inquiry approach. However, some have raised doubts (Hodson, 1990) and some researchers have reported an equivalence, at least in terms of conceptual learning (Cobern et al, 2010).

Though it is important to consider learning outcomes as multifaceted (outcomes should include not only conceptual and procedural knowledge but also skills that prepare students to be lifelong learners), it is noteworthy that most studies evaluating inquiry teaching vis-a-vis traditional science teaching focus mostly only on conceptual learning (Hmelo-Silver, Duncan, & Chinn, 2007). In science education research, in general, it appears that calls for more emphasis to be placed on affective aspects in science education research have not been met adequately (Alsop, 2004).

Haury (1993) summarises studies on some of the outcomes of inquiry-oriented teaching besides conceptual understanding which include scientific literacy, science process skills, vocabulary knowledge, critical thinking and attitudes toward science. Some other interesting outcomes that have been studied are students' interest in science (Hall & McCurdy, 1990; Palmer, 2010; Kyle et al, 1988; Shymansky, 1990), students' perceived science competence and motivational beliefs about science (Patrick, Manizicopoulos & Samarapungavan, 2009). Minner, Levy and Century (2010) argue that analyses of outcomes other than content learning alone would greatly add to the collective understanding of the full effect of inquiry teaching on students.

1.3 METHODOLOGY
1.3.1 The Setting and Participants

As mentioned earlier, we regularly conducted science classes with middle school students (Grade 6 through 8) to explore their ideas and develop curricular material that support the teaching of science as an inquiry. Students from nearby schools were invited for these classes. No material incentive was offered to participants. The number of applicants was far more than could be accommodated. About 30 students were randomly selected with complete disregard to their past scholastic performance. During the academic year, classes were held in one of the schools after school hours, twice a week for an hour each. During summer vacations the classes were held at our workplace for about 6 weeks, from Monday to Friday, with 2 hours of teaching every day. Students for this study came from 5 schools from a school system following the national curriculum in India; the medium of instruction in the schools was English and there was a mix of students from varied socio-economic backgrounds.

One batch of students (which is the sample for study) attended our classes consistently for four years since the time they had passed Grade 5 till they had passed Grade 8 (from the summer of 2005 to the summer of 2009). A core group of students remained constant while some students went in and out of the program. (See Table 1)

Table 1. Distribution of students according to the duration of time they attended our program

<table>
<thead>
<tr>
<th>Duration of participating in the program</th>
<th>Number of students</th>
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<tbody>
<tr>
<td>1 year</td>
<td>9</td>
</tr>
<tr>
<td>2 years</td>
<td>8</td>
</tr>
<tr>
<td>3 years to 4 years</td>
<td>14</td>
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</tbody>
</table>

Teaching in our curriculum development classes is done by the research group itself: the principal investigator (PI) of the project (an author of this paper) and other short-term project staff. In any given class, there was one teacher, sometimes assisted by another teacher especially during activities. The PI has a Ph.D in science and has taught for several years. The project staff holds a masters degree in science and two of the six who have worked with the project over the years have had formal training in teaching.

A brief description of our classes

Our classes typically involve investigating a phenomenon with hands-on activities by students, mostly in small groups, or demonstrations by the teacher, followed by interactive, whole class discussions. Refer to Kawalkar & Vijapurkar (2011) and (Vijapurkar, 2007a, 2007c) for the kind of topics dealt with in our classes and the lessons developed for teaching them in the inquiry way. Since eliciting students’ ideas is absolutely essential for our project, participation from all the students in class is actively sought; efforts are taken to encourage even the shy students to participate in class discussions and not allow a few vociferous ones to overshadow the rest. Our classes are bilingual; while most of the instruction is in English, students are allowed to talk in either English or Hindi (Indian national language). Multiple modes of expression - written worksheets, models, drawings, discussions amongst groups of students - are used to enable students to express their ideas.
Thus, in addition to providing the necessary cognitive scaffolding to enable students to develop a concept, affective scaffolding in various ways was provided to create an environment in which students' feel safe and motivated to participate (Kawalkar & Vijapurkar, 2011; Vijapurkar, 2009)

1.3.2 Methodology: Design of the Study and Data sources

At the end of the four year intervention with this particular batch of students (sample for the study we report here), we administered a self-report questionnaire to 31 students and followed up their responses with semi-structured interviews. Through this questionnaire and follow-up interviews, we got feedback from students about our program and probed if they had experienced any change in themselves as a result of attending our program. We, as teachers had observed positive changes such as increase in students' self-confidence, increased participation from students who were initially shy, increase in their engagement and interest in science and better group dynamics. Our aim was to check if students reported similar changes. We also administered a questionnaire to parents asking them if they had observed any change in their child/ friend after attending our program. Thirteen parents responded to the questionnaire. We also administered a similar questionnaire to peers of the students; these 15 students, who had not attended our classes, were in the same grade as students in our classes (passed Grade 8).

For the sake of brevity, we do not include the complete questionnaires and the interview protocol. We only report the salient results from our preliminary analysis. The data reported here is mainly students' response to our open-ended question “Did you see any change in yourself after attending our classes?” followed up with specific questions asking (a) when they had started to see these changes (b) what might have brought them about and if there was any change in (c) the way they studied science (d) in the way they participated in their regular science classes at school (e) in their performance in school exams and (f) their curiosity levels and (g) observation of their surroundings. We also asked students what they liked/ disliked about our classes, what they would like us to add/ remove/ change/ not change; we also asked them to compare our classes with their school classes. Students' responses to these questions not only gave us feedback but also pointed to the aspects of our teaching that led to positive changes in students. The parents' and peers' questionnaires similarly probed changes in students and asked for their conception of our classes based on what they had heard from children attending our classes.

The interviews with students were transcribed and the responses from the students' questionnaire and interviews were collated. These were then analysed through inductive or open coding and categorisation. Parents' and peers' responses were similarly coded and categorised separately at first and then collated and compared with students' responses. The categories are described in detail in the paper, along with sufficient direct quotes from respondents. This thick description along with triangulation of data from multiple sources are validation strategies (Cresswell, 2007) we have adopted for this study.

1.4 RESEARCH FINDINGS

We summarise the changes that students reported to have experienced in themselves as a
result of attending our classes. Parents' and peers' reports corroborated the students' self-reports and provided additions.

1.4.1 Increased interest in Science
A majority of students (23 out of 31) reported that they liked science more than they did before attending our program. These students said that they started to find studying science fun and wanted to know much more than what was given in their school science textbook. They tried out at home the experiments given in their textbook (which are rarely done in their classes at school) and also observed their surroundings much more often and closely than they did earlier, relating science to their daily lives. They read more science-related extracurricular books from the library and watched more science related programs on television. Students' increased engagement in science was reflected in their responses revealing that they observed phenomena discussed in our classes, for months after the topic was taught, (for example, star-gazing to identify stars and constellations and measuring the angular distance between stars or looking at flowers for different types of floral parts). As teachers, we had noticed this kind of heightened and intense engagement with the topic at hand when the whole class, at times, did not want to take a break but preferred rather to continue working on a task.

Students as well as their parents and friends reported that the students initiated more science-related discussions with friends and parents, asked more questions to parents and observed science-related phenomena with them. Four children who were friends of students in our classes also got interested in science and enrolled themselves in our classes. A student said that now, at times, even during the free time between their school classes, they discussed with their classmates what they had learned in science. Also, the parents got interested in science; a student reports that he and his father got up at 5.30 AM every day for several days to go and observe the moon from their rooftop – a project they had been assigned in our classes. Students from the core group who attended our classes throughout the four years reported that their parents supported them by planning their vacations around the dates of our classes or in some cases, opting to not to go out of town for vacations during these years.

Students reported an increase in interest in specific subject areas in science which they did not appreciate earlier: biology, chemistry, physics and astronomy. Thirteen students said they now liked biology (earlier some of them “hated” it; one of them still retains the dislike), seven began to like chemistry, six liked Physics now and five like astronomy a lot after attending our program. Students' reasons for starting to like these subjects were the experiments and activities we did in class that made the subject interesting and easier to understand and the lucid teaching that helped them visualise the concepts and appreciate them better. A student wrote about biology “I now realise that biology is not just about remembering (facts), there is so much more to it.”

1.4.2 Change in how students view science and scientists
According to many students, they now related science to everyday life rather than merely viewing it as a subject to be studied at school by default. They have also started to appreciate the history of science. One of them interestingly said, “I started appreciating people who contributed to science... Actually (earlier) I did not take it as a creative thing or something on which we have to concentrate. It was a formality, you're going to school and
you have to read it. But now I respect them (scientists) and I am inspired by them.” Thirteen students reported that they would be interested in a career related to science; while some had decided this earlier on, some got inspired after attending this science program. Students also reported that they earlier had a very limited idea of what scientists do, as one student put it, “I imagined scientists as mixing two chemicals but now realise that there are different sorts of work that scientists do.”

1.4.3 Increased participation in their science classes at school
Not only did students’ participation in our classes increase gradually but they also started to participate more in their science classes at school. Their interest and attentiveness increased, so did participation in terms of answering and also asking questions. Three students reported that now they had less fear of the teacher; one student explained, “First, I used to be really afraid to ask questions to teachers, thinking maybe teacher will scold me but after attending these classes I ask doubts [sic].”

Two of these students explicitly said that this increase in participation in school classes was despite the fact that their school classes remained expository and non-interactive (requiring students to be passive) and that their questions and ideas were not appreciated, even discouraged in some cases. Three students, however, said that given this situation, their participation in school classes did not change much though they participated actively in our classes. They still were anxious while answering in school classes for fear of repercussions should their answers be wrong, something they did not feel in our classes.

Also, as reported by students and parents, their participation in extracurricular science-related activities in school such as doing projects in science, taking part in science quizzes, exhibitions and competitive exams increased.

1.4.4 Change in the way they study science
All the students, irrespective of their academic grades in school, reported that they used to rote-learn or memorise for exams. But after learning science through inquiry, each one of them said they “learn with understanding”, “thought a lot more”, “reasoned out”, “imagine” and “visualise”. Notably, students reported that if they did not understand something or had a query, they now asked the teacher, discussed with friends or family and referred to books in the library. A few students have explicitly said that earlier they would ignore the questions that arose in their minds but now they have to have these “doubts” cleared. Also, they said that now they did not accept the teacher’s explanation as given but have “learnt to question and ask for reasons”. Students now seem to have become self-driven learners as revealed by their statements - “I want to learn on my own”, “I started trying to find answers to my questions myself”.

1.4.5 Improved performance in exams
Students reported that as a result of their increased interest, they found studying science easier and also found themselves devoting more time and effort to studying science. This led to an increase in their marks in school exams. The average marks in science for the batch increased from 77 to 91 (out of 100). The increase was significant for students who scored lesser marks earlier, narrowing the gap between high and low performers in school exams. Even those whose marks did not change reported, as mentioned earlier, that now they did not memorise and wrote answers in their own words unlike earlier when they used to
reproduce answers dictated/ given by their school teachers.

Table 2. Increase in students' marks in science in their school examinations

<table>
<thead>
<tr>
<th>Increase in marks (total 100 marks)</th>
<th>Number of students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Considerable increase (20 to 45 marks)</td>
<td>3</td>
</tr>
<tr>
<td>Moderate increase (8 to 18 marks)</td>
<td>8</td>
</tr>
<tr>
<td>Slight increase (around 5 marks)</td>
<td>3</td>
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</table>

1.4.6 Increase in students' self-confidence levels
In students’ free responses reporting changes in themselves, 4 of the 31 students reported increase in their self-confidence level as a change. When parents were specifically asked if there was a change, and how much of it, in students' self-confidence, 10 parents said that their child's self-confidence increased a lot, 3 said it increased considerably while two said it increased slightly or remained the same.

1.4.7 Improvement in English and mathematics
Interestingly, students reported that their fear of mathematics decreased, they improved in it and for some, their marks in maths in school exams also increased. Some students found that their fluency and vocabulary in English as well as marks in English improved. With enhanced speaking skills combined with increase in self-confidence, students now voluntarily participated in elocution/speeches and anchoring in school programs. A student explained that in our inquiry-based science classes she had to think how to express her views all the time and this, combined with help in overcoming her shyness, led to improvement in her language and expression.

1.4.8 Behavioural and personality changes
Students reported that from the interactions in our classes, they learned to conduct themselves better in the classroom situation even in school. We paraphrase some responses: one student said the habit of following the simple rules in our classes made it possible for everyone to speak in class without chaos; it resulted in him respecting rules in general and his conduct in the classroom became better - now he does not shout out answers but is patient till he gets his turn to speak; three other students said that instead of talking and playing pranks in class during teaching at school they now pay attention and enjoy learning. Remarkably, a student said “Earlier I used to get angry, now I don't get angry that much” and attributed this change to the way the teacher and children interacted in our classes.

The new-found common interest in science that students formed in these classes led them to forge friendships. One group of four students reported that now whenever they learn something new or have any question in mind they discuss it in their group.

The teachers of our classes had also noticed that over time, in our classes students were better able to work with others in a group. Though initially girls and boys were very resistant to working in the same group during activities/experiments, this resistance gradually faded. The group dynamics in many groups in the class changed over time such that the shy ones also participated openly and the overtly dominating students gave others in the group a fair chance to participate.
1.4.9 Aspects of our teaching perceived as significant by students
Inclusion of experiments and other practical work and being “interesting”/“fun”/“exciting”, according to the students, were the two major characters of our classes that were different from their regular science classes at schools. The other main difference was the teaching method and the teachers. They described the instruction in our program as a way of teaching in which “the subject was presented in an interesting way” and in which “experiments were used to understand the things better rather than just for the sake of practicals [sic]”. When asked specifically what the students liked about our classes, besides the hands-on activities, half the class (15 of the 31 students) said that they liked “the way of teaching” while an almost equal number (13) said that they liked “working in groups” for experiment and during discussions. “Interactions” with the teacher and among the students, and the class “discussions” and “debates” was the next popular aspect liked by 10 students. Four students mentioned that they appreciated the teacher’s friendliness and patience with them. Some of the other aspects liked by students were freedom to ask questions and discuss with their classmates, an equal opportunity to speak, autonomy (they could ask the teacher to change the topic/ could pick between topics), intense involvement of students, students’ friendliness, the homework given, rules of the classes, stories of discoveries and language exercises like writing poems. One thing that some students mentioned that they did not like was that the same topic was continued for a long time. We agree that this was a problem since we were developing the curriculum and iterative trials were needed.
Students’ responses and their increased participation in our classes indicate that we were able to create a supportive social context in which they felt their ideas were accepted and valued. We think these are perhaps the factors that led to the affective changes that students report.

1.5 DISCUSSION AND CONCLUSION

1.5.1 Discussing the results
Watts and Alsop (2000) point out that to ignore the affective domain is to exclude consideration of a seminal part of the learning that takes place in science learning. The focus of this study was to explore the wide-ranging affective changes in students as a result of going through inquiry science teaching. From the students’ and parents’ responses it is clear that one of the main changes in students is the development of their interest in science. The heightened interest level generated in our classes led to higher level of students’ engagement in science even after our classes ended.

Motivation is defined as a process that initiates and maintains learning behaviour (Palmer, 2009) and interest (selective preference or focused attention for a domain of study) is considered to be an effective motivator. Students’ responses show evidence for the three components of motivation described in the literature (Velayutham, Aldridge & Fraser, 2011) – learning goal orientation, task value and self-efficacy. Students’ report that they now enjoy learning and doing science rather than memorising for examinations as they did earlier, before going through our inquiry teaching. This indicates development of a learning goal orientation (focusing on learning, understanding and mastering concepts) as opposed to performance or extrinsic goal orientation (which focuses on demonstrating competence);
the increase in marks in school examinations has been a by-product of students' engagement. Students' responses clearly indicate that they are now able to relate what they learn in science to daily life which shows that they assign a high task value to science learning. Students report that they find science easier to understand, are able to participate in science classes as well as science-related discussions and events in out-of-class contexts; this points to their increased sense of self-efficacy. Putting in increased efforts and persisting to find answers to their queries are indicators of self-regulated learning, which is another important aspect of motivation.

Importantly, the affective changes that students reportedly developed in our science classes appear to have transferred to other domains and contexts: the learning of subjects besides science, their school classrooms, extracurricular activities in school not necessarily related to science, interactions with their family and peer group. These changes reported by the students are supportive of theories of intrinsic motivation which propose that students are inherently driven to develop themselves as a result of the pleasure they derive from achieving higher levels of understanding but need supportive conditions to maintain and enhance this motivation (Ryan & Deci, 2000). We believe that the intellectual engagement during learning through inquiry, fun but disciplined and structured, is of intrinsic value to the learners. It caters to students’ curiosities and supports them in resolving conceptual conflicts in the inquiry classroom. This kind of intense engagement requires persistent effort and attention from the student along with cognitive as well as affective support from the inquiry teacher. Therefore, we argue that cognitive engagement and affective changes of the kind reported in this paper go hand in hand in the process of learning science through inquiry.

1.5.2 Strengths and Limitations of the study
This study reports a range of affective outcomes of teaching science through inquiry, which have not been reported earlier. The post-facto nature of this study is strong evidence of how marked the affective changes were, that we were motivated to conduct the study. Also, as pointed out earlier, these outcomes were found despite the focus of the project being on conceptual learning. The teaching was not designed for specifically bringing about these affective changes; they were among the significant outcomes of a project that concentrated on conceptual learning. This finding should help garner additional support for teaching science through inquiry since it suggests that the teacher need not put in any extra effort for all these outcomes, spanning various domains, apart from teaching concepts through inquiry.

It was through the open-ended self-reports from students that we were able to uncover the wide variety of outcomes of inquiry teaching. The responses from students were corroborated by teachers’ observations from the classroom as well as self-reports from parents and peer group for out-of-class behaviour and interactions.

Limitations of this study too largely stem from it being a post-facto study of the changes that took place over time during inquiry science teaching. Since questionnaires were administered only after the intervention, baseline information from students was not available for comparison. Being a post-facto study, it could not address the effect of confounding variables like maturation and Hawthorne effect (the effect of having an
intervention of any kind itself bringing about an effect) though we explicitly probed the reasons for these changes during interviews with students; they attributed these changes to our program of inquiry teaching. Further research on this issue needs to address these limitations and also probe the characteristics of inquiry teaching that might play a part in bringing about the outcomes described in this study. We have undertaken an in-depth study of the range and scale of affective outcomes of teaching science through inquiry, in the form of an ongoing doctoral research project inspired and guided by the present study.

1.5.3 Concluding remarks
In conclusion, our study shows the range of affective outcomes of inquiry science teaching. We believe that investigating this wide variety of affective outcomes could be a useful strand of research, one that adds another perspective to the comparison between the methods of teaching science. Since inquiry teaching does require more effort on part of the teacher, highlighting the array of outcomes possible through inquiry teaching will lead to a wider acceptance of this teaching method both by teachers and policy makers.

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References


