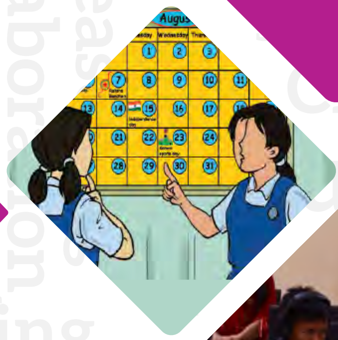
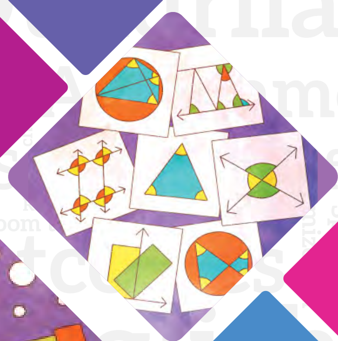



CONNECTED LEARNING INITIATIVE

Report on Learning Outcomes of CLIx Student Modules 2019





An initiative seeded by TATA TRUSTS

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Mizoram University

CERP CENTER FOR EDUCATION RESEARCH & PRACTICE

Report on
Learning Outcomes
of CLIx Student Modules

Centre for Education, Innovation and Action Research

Tata Institute of Social Sciences, Mumbai

and

Massachusetts Institute of Technology, Cambridge, MA, USA

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Executive Summary

This study analysed the learning outcomes from selected CLIx student modules--English Beginner 1 & English Elementary 1, Geometric Reasoning 1, a segment of Geometric Reasoning 2[1], and Basic Astronomy. It examined both, the efficacy of modules by studying the impact on student learning under the best possible conditions as well as the effectiveness, as these conditions were being facilitated in realistic contexts by teachers in their respective schools. The study included observation and analysis of ninth grade students' data from 44 schools (22 intervention and 22 non-intervention) in three different locations in India (Aizawl in Mizoram, Dhamtari in Chhattisgarh and Jaipur in Rajasthan). All of the schools selected for the study were government schools catering to underserved student populations, with some located in rural areas. Following a workshop to discuss module content and pedagogy, teachers in intervention schools implemented the modules for a period of approximately 4 weeks. Teachers in non-intervention schools did not attend the workshop and taught the topic in the way it was taught regularly in schools. The results discussed in this report are from data collected in the form of pre-tests, post-tests, and observations of the classrooms and computer labs.

The study of English modules in Aizawl city showed that student participants in all 6 intervention schools exhibited statistically significant improvement in their listening skills, while participants in 3 out of 6 schools showed significant improvement in speaking skills. The overall comparison of learning gains between intervention and non-intervention schools showed that for listening skills, students' gain from pre to post-test was significantly greater in intervention schools for criteria specified by 2 of the 5 learning objectives. For speaking skills, the gain was significantly greater in non-intervention schools for the criteria of accuracy and adequacy in language. However, classroom observations in intervention schools showed that teacher interventions decreased over time as students took ownership of their learning, collaborating with peers to discuss and produce language. Observations in non-intervention schools showed that all teaching was teacher-led with lesser opportunities for students to produce language.

The study of the 'Geometric Reasoning' module in Dhamtari district showed that overall, student participants in the intervention schools evidenced statistically significant improvement from pre- to post-test, reflecting an increased conceptual understanding and reasoning for Geometry tasks. When analysing gains of individual schools, results indicated that students in 8 out of 10 intervention schools showed this improvement. Analysis of fidelity and extent of implementation in intervention schools showed that schools ranking higher in gains from pre to post-test also evidenced higher levels of fidelity and extent of implementation. The overall comparison of gains between intervention and non-intervention schools showed that intervention school students had significantly greater gains and also showed an increase in performance for all 7 multiple choice questions on the

1 In this study, only the final levels of the Police Quad game were utilized from the 'Geometric Reasoning 2' module. For the remainder of this report, the Geometric Reasoning materials will be referred to as 'Geometric Reasoning 1+' or 'GR 1+.'

post-test, even when they were more difficult than the pre-test. Comparison of classroom observations indicated that while 60% of classroom time in intervention schools was devoted to classroom discussion, 70% of the time in non-intervention schools was devoted to “teacher talk.” Interaction analysis through tally tools used for observation indicated that more students gave extended responses, reasons in support of their answer, and asked doubts in intervention schools; these student behaviors were supported by teachers asking students for reasons and building on their incorrect responses.

Study of the ‘Basic Astronomy’ module in Jaipur showed that overall post-test scores of students in the intervention schools evidenced significant improvement over their pre-test scores, reflecting an increased conceptual understanding of astronomy. The school-wise analysis of gains from pre to post-tests indicated that students in 5 out of 7 intervention schools showed significant improvement. The overall comparison between gains of students in intervention and non-intervention schools showed that gains were significantly greater for those in intervention schools, with improved average scores for 13 items in the post-test. The results of a student survey showed that there were significant differences in students’ attitude and interest towards astronomy in intervention schools, although there was no significant change in students’ beliefs about the supernatural power of planets on people’s lives.

The results of the three sub-studies are discussed with respect to outcomes achieved in terms of student performance on tests as well as classroom observations. The insights about the module design and fidelity of implementation from the studies is discussed along with the role played by students, teachers, principals and researchers in implementation of the module and contribution to the results.

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1.0 Learning Outcomes Study - Overview

1.1 Introduction

The Connected Learning Initiative (CLIx) is a multi-state, multi-partner initiative seeded by the Tata Trusts in collaboration with the Tata Institute of Social Sciences (TISS), and the Massachusetts Institute of Technology (MIT). The goal of CLIx is to create a paradigm shift in educational practices for Indian students at scale by providing high quality learning experiences that focus on authentic, hands-on learning of concepts through ICT-enabled Open Education Resources. The deep understanding of pivotal concepts in science and math, increased skills in communicative English, as well as the development of values, professional skills, and competencies are intended to widen opportunities for Indian youth, thereby enabling them to be successful in further academic studies or in the workforce.

The purpose of this study was to examine the efficacy of selected modules within the science, mathematics, and communicative English subjects with regard to their contribution toward student learning when they were delivered with optimal fidelity to the planned implementation. This study exhibits characteristics of both an efficacy and effectiveness study, in that it examines the modules' impact on student learning under near ideal conditions (efficacy), yet these conditions were being facilitated in realistic contexts by teachers in their respective schools (effectiveness).

1.2 Background

Information and communication technology (ICT) has been considered a panacea for education, and in recent years, multiple interventions in India have developed ICT based material to support teaching and learning in schools. According to a World Bank report (2005), ICTs are widely used to aid education in developing countries in conjunction with increasing demand from both policymakers as well as parents for the inclusion of ICTs.

However, many of the ICT resources in these interventions utilize a "transmission" based pedagogy, and this approach pushes students and teachers into the role of knowledge consumers rather than knowledge creators. Rather than sit and passively absorb information, knowledge creation requires students to participate in opportunities to express their ideas and build on their knowledge. A position paper from the National Focus Group on Educational Technology (National Council for Educational Research and Training [NCERT], 2005) recognises that government sponsored schemes like the Educational Technology scheme and Computer Literacy and Studies in Schools (CLASS) have focused largely on providing the infrastructure in form of equipment but they have been "disseminative," or focused only on giving access to information. There has been little empirical work conducted to formally evaluate students' learning outcomes following their use of ICTs. Transmissive pedagogy and lack of in-depth evaluation research have been the root cause for undermining the role of educational technology as an agent of change in the Indian context.

When planned and implemented with constructivism in mind, ICT has great potential to promote change in current pedagogy through disrupting normative practices, like following only a textbook that may not provide authentic experiences, or rote memorization of information that hinders student participation in knowledge-building processes. One of the important recommendations of NCF 2005 has been to integrate ICT as an interactive pedagogy and emphasize the need to “move from a predetermined set of outcomes and skill sets to one that enables students to develop explanatory reasoning and higher order skills” (NCERT, 2005, p.16).

The CLIx learning outcomes study was conceptualised to intensively study learning outcomes from selected CLIx modules in situations where teachers were supported by design teams for implementation. This report presents findings from three quasi-experimental studies measuring student learning outcomes following engagement with English, Math, and Science modules created as a product of the Connected Learning Initiative. The English sub-study of learning outcomes from the English Beginner 1 and English Elementary 1 modules was conducted with 12 schools (6 intervention, 6 non-intervention) in and around the city of Aizawl, Mizoram. The Maths sub-study of outcomes from the Geometric Reasoning 1 module and a portion of the Geometric Reasoning 2 module[2] was conducted with 19 schools (10 intervention, 9 non-intervention) in the Dhamtari district of Chhattisgarh. The Science sub-study of outcomes from the Basic Astronomy module was conducted with 14 schools (7 intervention, 7 non-intervention) in the city of Jaipur in Rajasthan.

1.3 Learning Outcomes

In recent contexts, there have been several interpretations of the term “ learning outcomes,” resulting from the release of an MHRD document entitled “Learning outcomes at elementary stages” (MHRD, 2017). By definition, learning outcomes are statements that describe what students will be able to do, know, or feel at the end of engagement in an activity. The interpretation of learning outcome in most contexts is limited to identifying the performance behaviour, or test achievement of the students as a result of undergoing a particular intervention or activity. This narrow interpretation has been criticised (Gagne, 1984), and others include learning outcomes beyond performance behaviours, such as cognitive, skill oriented, and affective outcomes. In this report, learning outcomes have been defined in the broader sense, including cognitive as well as non-cognitive outcomes along with the skills exhibited by students after engaging with CLIx modules. A brief description of the types of outcomes studied and modes of evidence are given below:

1. Cognitive outcomes such as understanding of concepts and development of mental models in the subjects of maths and science were studied by examining gains in student scores on tests, along with semi-structured interviews of selected groups of students.
2. Non-cognitive outcomes such as student behaviours indicative of collaboration, response to mistakes, autonomy, and self-efficacy were studied by observing students in classrooms.

2 In this study, only the final levels of the Police Quad game were utilized from the ‘Geometric Reasoning 2’ module. For the remainder of this report, the Geometric Reasoning materials will be referred to as ‘Geometric Reasoning 1+’ or ‘GR 1+.’

3. Skills such as digital literacy, speaking English, and listening skills were examined via student/class observations
4. Attitudes towards the use of technology for learning were examined via classroom observations and interactions with students; the science team examined students attitude towards astronomy through a questionnaire

Although each subject had a unique focus of research in the study, there were two questions common to all three subjects:

1. What learning outcomes are evidenced in students who engage with CLIx modules?
2. How do learning outcomes differ between students who engaged with CLIx modules and students who learned the information in the usual way?

It is important to note here that although the study was conceptualized as being specific to student learning outcomes, teachers' learning outcomes also became evident during data collection. These will also be addressed as an important result of the study.

1.4 Methods

In this section, we will describe the aspects of methodology which were common to all three sub-studies conducted by the English, maths and science subject teams.

1.4.1 Participant selection

The sub-studies were conducted in three different locations where CLIx was being implemented in India. The selection of intervention and non-intervention schools for the studies was based on criteria derived through discussion among the subject teams. The criteria for the selection of intervention schools are given below.

1. Functioning computer lab with at least eight computers
2. Relatively close in proximity to allow for frequent classroom observations and reduce the travel time to the schools; However, each team still had to travel up to 2 hours for observations in some schools.
3. Motivated teachers in the respective subject; preference was given to teachers who had attended training and implemented CLIx in the past year
4. Principals who were supportive of CLIx
5. Schools in which the number of students was equal to or less than 60 in grade 9

For non-intervention schools, the selection was done based on the willingness of principals and teachers to participate in the study. Students in non-intervention schools had comparable learning levels to those in the intervention schools and the schools had comparable classroom sizes based on information obtained from the District Information System for Education (DISE) data.

1.4.2 Materials/ Instruments common to all studies

1. CLIx modules: All modules can be accessed at . These digitally enhanced learning materials differed in terms of subject content provided and extent of computer lab time required for implementation, but all were developed incorporating three elements of pedagogy, deemed as the 'pedagogical pillars' of CLIx. The pillars are as follows:
    - Learning through discussion - materials encouraged collaboration among students to answer questions, solve problems, or complete digital tasks. Students were also encouraged to give online and offline feedback to each other.
    - Learning from mistakes - materials presented multiple opportunities for students to answer questions or solve problems, with encouraging feedback given for mistakes and failures.
    - Learning through authentic experiences and assessments - materials used students' everyday experiences as venues to learn theoretical concepts.
2. Pre and Post-tests: Multiple choice or short answer questions used as one measure of student learning outcomes.
3. Classroom observation tools: A set of criteria to evidence student outcomes related to the pillars, non-cognitive gains, and improved skills. In addition, the classroom observations provided information regarding fidelity of implementation and teachers' pedagogies.
4. Teacher's interview tool: A set of questions to gain teachers' perspectives regarding their learning outcomes study experience.

1.4.3 Procedure

1. Negotiation for state and local support: For each subject, a two-page note was shared with state officials describing the objectives, requirements, and procedure of the study. After receiving permission from state officials, intervention and non-intervention schools were recruited. Visits and discussions were conducted with the principals and teachers to be involved, apprising them of the study objectives, lab requirements, and the extra hours needed for teachers and students.
2. Teacher meetings/training: subject teams planned and implemented trainings or orientation for the intervention schools' teachers.

1. Module implementation and data collection: In each subject, the module implementation period lasted approximately 6 to 7 weeks in the field. Data was collected via pre-tests, classroom observations, and post-tests. This was first conducted in the intervention schools, and then repeated (with the exception of module implementation) in non-intervention schools. Data was collected in accord with procedures approved by the Institutional Review Board (IRB) from Tata Institute of the Social Sciences and the Committee On Use of Humans as Experimental Subjects (COUHES) from Massachusetts Institute of Technology.

1.4.4 Data analysis

This will be described in detail within each subject report. The general methodologies utilized were as follows:

1. The names of the intervention and non-intervention schools were anonymised. In this report the intervention schools have been referred to by a code in which the first letter represents the subject (E for English, M for Math and S for Science). The letters following the first letter indicates whether the school is intervention school (IS) or Non- intervention school (NIS). This is followed by the serial number of the school. So, EIS06 represents a school in Mizoram where english modules were engaged by students while SNIS04 represents the non-intervention school in which Astronomy module was taught using textbook in regular fashion in Jaipur.
2. Inter-rater reliability was examined for all scored/coded data
3. Quantitative analysis of pre and post-test data was conducted to 1) determine if students showed any gain in scores between the pre- and post-test, and 2) detect differences between treatment / control groups for cognitive gains. In all sub-studies, the pre-test and post-test data was scanned to identify students who completed both tests. Quantitative analyses included only students for whom both pre- and post-test measures were available.
4. Qualitative analysis of classroom observation data was conducted to detect differences between treatment/control groups for non-cognitive and skill gains. Qualitative analysis was also used to detect differences in teacher and student behaviors.

2.0 English Beginner 1 and English Elementary 1 Modules - Mizoram

2.1 Introduction

The National Focus Group on English (2005) recognises the significance of English in globalisation and in supporting personal, social, and professional aspirations of youth in a young and growing economy. NCERT studies highlight inadequate opportunities for students to develop English listening and speaking skills. Their studies revealed that only 20% of teachers thought it is important to train students in listening and speaking, and the remaining 80% thought that English teaching is English writing (NCERT, 2012). In India, the emphasis of such studies has largely been on English listening skills, with studies showing that a Computer Aided Language Learning (CALL) environment improved listening and produced more effective comprehension than traditional classroom (Pasupathi, M, 2013; Lakshmi, and Sunder Reddy, 2015). Thus far, however, there is a dearth of literature on the impact of CALL on speaking skills and learning behaviours in the Indian context.

This study examined how a systematically designed English language intervention in select schools in Mizoram impacted students' listening and speaking skills through engaging in activities requiring active knowledge production. More specifically, the investigation focused on the following research questions:

1. What is the impact on students' listening and speaking skills following engagement with the CALL platform in comparison to students who study English in the traditional manner?
2. What are the learning behaviours that can be observed when using the CALL platform?

The study tested the hypothesis that listening and speaking skills of secondary school ESL learners will improve as they work in pairs in a CALL lab that provides them with opportunities to listen intensively to, and speak in, English. This one-month long study employed a mixed methods approach, using both qualitative and quantitative data to study outcomes with a sample of close to 200 students in Aizawl, Mizoram. This sample size and time duration are much larger than most studies that have been reviewed in research literature (Zhao, 2003), making this study unique and relevant in the context of studying the learning outcomes of listening and speaking skills using CALL in India.

2.2 Methods

2.2.1 Participants

Six intervention and six non-intervention schools were selected, using criteria as described earlier in section 1.4.1. One batch of Class IX students in each of the six intervention schools participated in the study with active support from their teacher as facilitator. A 'batch' of students in an intervention school was defined as a group that could be accommodated in a lab with an ideal computer to student ratio of 1:2, and in certain unavoidable cases, 1:3. The batches were a mix of boys and girls, randomly selected to participate using a true random generator app. An equal number of students were selected from the comparison schools using the same process.

After matching students' pre- and post-tests, the number of students in the six intervention and five comparison schools for the listening test was 100 and 75 respectively. For the speaking test, there were 99 students in the intervention schools and 77 in the comparison schools. Data from one non-intervention school was eliminated from analysis due to improper identification that resulted in the inability to match students' pre- and post-test scores.

2.2.2 Materials

2.2.2.1 CLIx English modules

For this study, the selected students in intervention schools were exposed to one unit of two different CLIx English modules over a period of one month (Figure 2.2a and 2.2b). The units English Beginner 1 and English Elementary 1 were chosen as they are pitched at the suitable language and cognitive levels of Class IX students in Mizoram. A description of the modules is shown in figure 2.1 below. The objectives and the key design aspects of the Module is given in Appendix A.1.

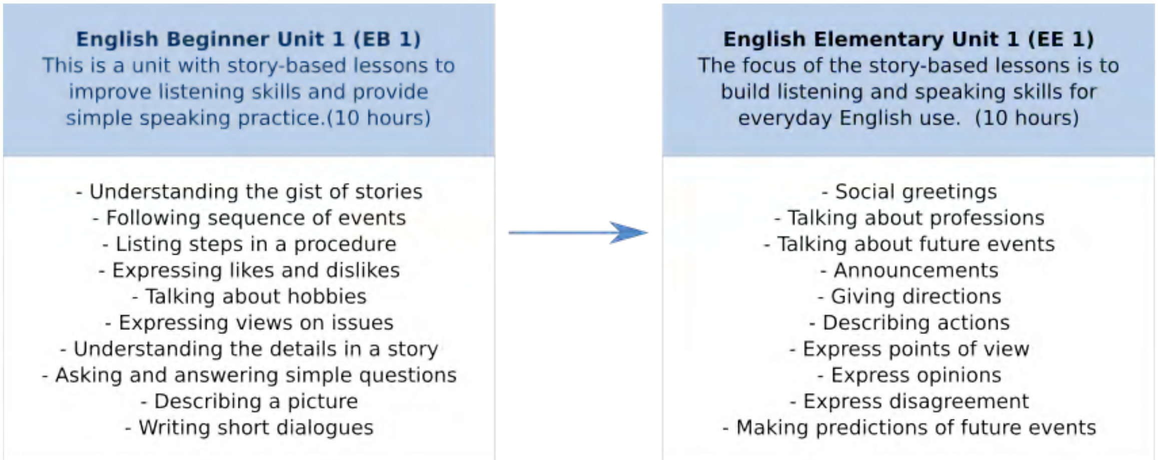


Figure 2.1: Activities of CLIx English modules

Figure 2.2a: Students in Mizoram engage in listening activity of English Beginner 1 module

Figure 2.2b: Students in Mizoram exploring the English Beginner 1 module

2.2.2.2 Listening and speaking skills tests

Sub-skills for listening and speaking were assessed through administration of oral pre- and post-tests. One hundred twenty-one students from intervention schools and 101 students from non-intervention schools participated in the listening test while 119 students from intervention schools and 88 from non-intervention schools participated in the speaking test. Finally data from 100 intervention and 75 non-intervention was analysed for listening test and 99 from intervention and 77 from non-intervention was analysed for speaking test. The learning outcomes measured after students completed the two units, English Beginner Unit 1 and English Elementary Unit 1, are shown in the table below. The outcomes and their corresponding test questions measured student proficiency at the A1, A2, and B1 levels of the Common European Framework of Reference for Languages (CEFR).

Table 2.1. Outcomes assessed for listening and speaking skills

Listening Skills	**Speaking Skills**
Students will be able to: • Identify the topic of a short conversation related to routine things/familiar matters • Recall specific details in short spoken conversations • Follow instructions when the speech is slow and clear • Infer meanings of words from their contexts of use • Infer links and connections between events	Students will be able to respond to social greetings, queries about the self and their surroundings and express personal opinions with: • Adequate information • Fluency of speech • Accuracy in response • Spontaneity • Relevance to the ongoing exchange

An example of a question designed to test an outcome related students' listening skills was "This road has lots of traffic. I can see cars, trucks, motorcycles, scooters and auto rickshaws. Which vehicle did you NOT hear in the list? a) Cars b) Bicycles c) Scooters d) Auto rickshaws" The listening skills test consisted of 10 questions that were scored as correct/incorrect. The maximum score was 10 (See Appendix A.2 for listening skill test).

An example of a question that-tested an outcome related to students' speaking skills was "Hello. I'm Lavanya. I'm a teacher. Can you tell me something about yourself?" The speaking skills test consisted of eight questions that were scored using a rubric created by the English team. Students' responses to each question were scored according to five criteria--spontaneity, relevance, fluency, accuracy, and adequacy. A score of 0, .5, or 1 could be given for each criterion, thus resulting in a maximum score of 40 for the entire test (See Appendix A.3 for speaking test and Appendix A.4 for scoring rubric).

2.2.2.3 Classroom observation tool

In addition to the development of listening and speaking skills, the study also looked at certain classroom behaviours of students and teachers that may aid and expedite language learning. The assumptions were that, during the process of language learning in the CLIx lab, the students would be able to use technology with greater ease, use technology scaffolds, collaborate with peers in completing tasks, recognise and correct language errors made by themselves and their peers, and move from imitation to production of original language content. The classroom observation tool comprised a free write, in which observers would record all that was happening in the classroom (See Appendix A.5).

2.2.3 Procedure

In the intervention schools, there were four female teachers who had previously implemented the CLIx English modules, and two male teachers who were new to the platform as well as module implementation. All of the participating teachers had attended the yearly training.

Before commencement of the study, a 1-day workshop was conducted with the teachers to discuss and orient them to the ideal implementation design. Teachers were also given regular inputs and feedback during the study, to ensure that they reflected on and conducted CLIx classes according to the design envisioned by the team.

Research interns were trained by CLIx Research coordinators to administer tests, score the tests, and conduct classroom observations. The CLIx team calculated inter-rater reliability to establish reliability of scoring, using measures described in the next section.

2.2.4 Data analysis

The listening and speaking tests were scored by trained research interns. Scores for the listening test were calculated by noting the total number of correct responses, whereas scores for the speaking test were based on the total points awarded on the scoring rubric. Following scoring procedures for the speaking test, the English team examined inter-rater reliability on a representative sample of 42 audio recordings of pre- and post-tests across the intervention and comparison schools. The results showed an extremely high level of agreement on four of the five criteria for assessment, and a high degree of agreement on the fifth criterion.

The pre- and post-test scores for the listening and speaking tests were then analyzed as follows:

1. A paired t-test was conducted to determine if there were significant pre- to post-test gains in scores for students in each intervention and non-intervention school. This test was conducted first to examine change in students' total score for the listening or speaking test, and then again for each of the sub-categories, or criterion within each test.
2. An independent t-test was then conducted to compare pre-post gains between the intervention and non-intervention schools to determine if the gains were significantly different. This test first compared students by their total score, and then by their scores in each of the sub-categories, or criterion.

The classroom observations were coded and plotted visually to trace a change in learning behaviour, with special attention to whether students moved from imitation to production with greater ease in use of technology over time. The codes for the observations were developed based on the outcomes of interest as stated in the research proposal and from coding an anonymised selection of observations (See Appendix A. 6 for the codes developed).

Three observations were coded from each school--from the first week, mid-study, and the last week--to capture the temporal nature of learning behaviours across the period of the intervention. Initial codes were generated and defined to serve as the basis for coding of the remaining observations by the members of the English team. The codes were refined after a few rounds of checking for inter-coder agreement. The finalized codes were placed under the major themes of teacher actions, student actions and technology. For this report, the student actions that were analyzed include the number of instances of peer collaboration for listening (PC-L), peer collaboration for speaking (PC- S), discussions (Di) and the number of instances students used scaffolds (Sc) in the platform. The above codes were queried and quantified to enable the team to chart a trend of behaviours that could talk to the students' scores.

2.3 Findings

2.3.1 Pre- and post-tests

Figure 2.3 shows overall results for the six intervention and five non-intervention schools on listening and speaking tests.

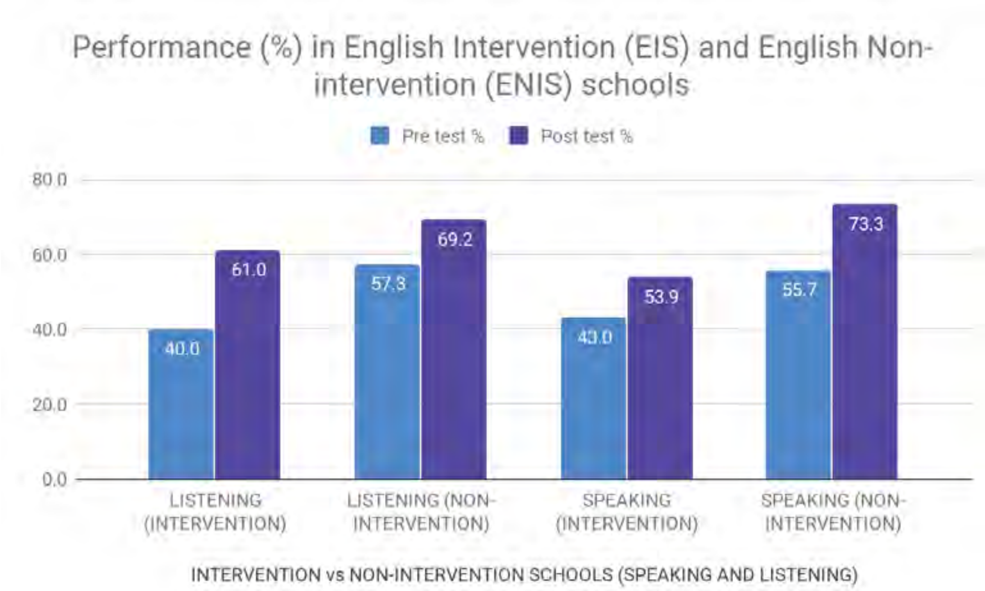


Figure 2.3. Pre- and post-test performance for English listening and speaking

- The gain for listening skills was greater in intervention schools when compared to non-intervention schools.
- The gain for speaking skills was greater in non-intervention schools
- The pre-test scores for intervention schools were much lower as compared to non-intervention schools, indicating lower initial levels of listening and speaking skills of students from intervention schools.

2.3.1.1 Listening

- In each of the intervention schools, gains between the pre-test and post-test were significant, $p<.03$, indicating that students' listening skills improved during the period of the study (See figure 2.4).
- In the non-intervention schools, students' pre-post gains were significant in three of the five schools--ENIS3, ENIS4, and ENIS5 at $p <.01$ (See figure 2.3).
- When comparing the gains of students in intervention schools to gains of their counterparts in non-intervention schools, there was a significant difference between the two groups, $p=.0036$. Overall, students in intervention schools showed a significantly greater increase

in listening scores than those in non-intervention schools.

- An analysis of items that tested specific objectives--students' ability to identify the topic of a short conversation related to routine things/familiar matters and recall specific details in short spoken conversations--showed greater improvement in the intervention than in the non-intervention schools. As shown in table 2.2, scores for items related to other objectives listed in the study show comparable gains.

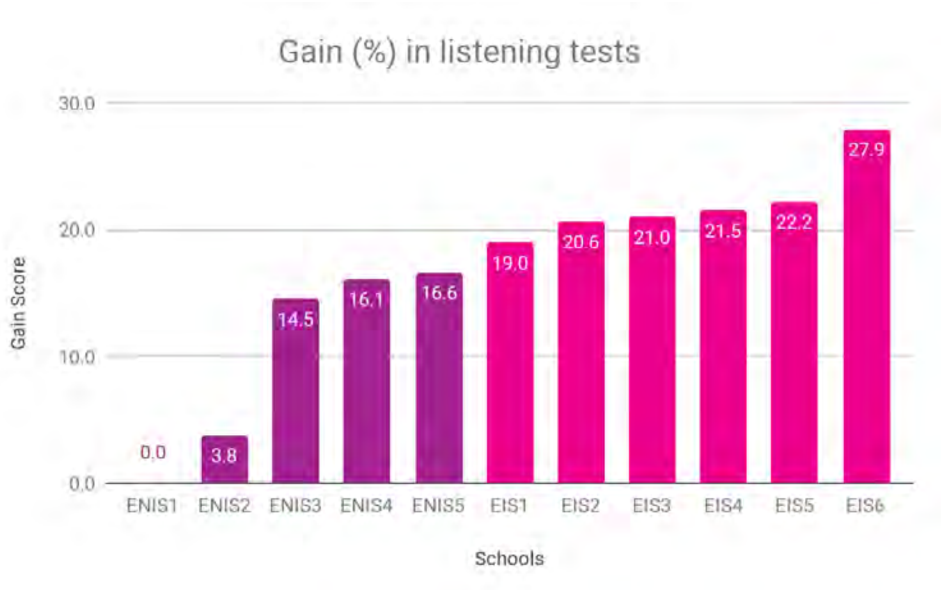


Figure 2.4. Pre-post gains (%) for listening skills in ascending order.

Table 2.2. Comparison of performance of intervention and non-intervention schools according to defined objectives for listening skills

		Obj. 1 (Q1&2)	Obj. 2 (Q3&4)	Obj. 3 (Q5&6)	Obj. 4 (Q7&8)	Obj. 5 (Q9&10)
Non-intervention	Average gain	-.43	.65	-.25	-.20	.31
	Std Deviation	.72	.76	.92	.80	.77
Intervention	Average gain	.19	.91	-.05	.08	.38
	Std deviation	.77	.98	.98	.91	.94
Intervention vs Non-intervention	P-value	<.0354*	<.0608	<.1667	<.0355*	<.5826

2.3.1.2 Speaking

- In 3 of the 6 intervention schools, the pre-post-test gains were significant; This was true for all of the non-intervention schools (See figure 2.5).
- When comparing the gains of students from the 6 intervention schools with gains of student

from the 5 comparison schools, there was a significant difference (p=.0301). Students in the non-intervention schools showed a significantly greater gain when compared to those in intervention schools.

- When the five criteria (Spontaneity, Accuracy, Fluency, Adequacy and Relevance), were analyzed separately, students' post-test scores were significantly better than the pre-test scores for both the intervention and non-intervention schools. However, when the pre-post gain was compared between the intervention and the non-intervention schools, the non-intervention schools showed a significantly greater gain for only the Accuracy and Adequacy criteria. Comparisons for the other criteria reflected comparable gains (See table 2.3).

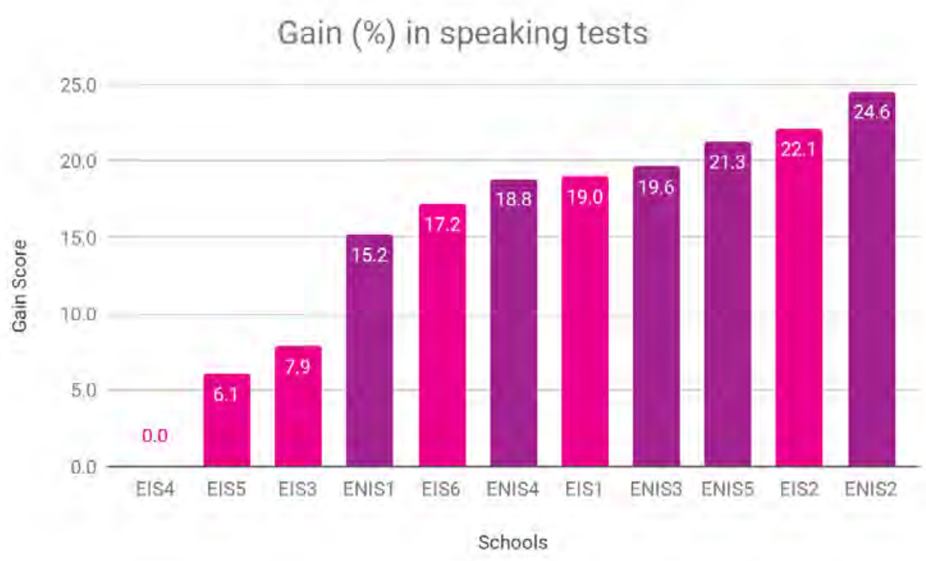


Figure 2.5. Pre-post gains for speaking skills in ascending order

Table 2.3. Comparison of performance of intervention and non-intervention schools on speaking test based on defined criteria

		Total Spontaneity	Total. Relevance	Total Fluency	Total Accuracy	Total Adequacy	TOTAL
Non-intervention	**Average pre-test score**	5.75	5.62	3.98	3.23	3.79	22.40
Non-intervention	**Average post- test score**	7.00	6.81	5.30	5.48	5.52	30.13
Non-intervention	**Average Gain**	1.24*	1.18*	1.32*	2.24*	1.72*	7.73*
Non-intervention	***p* value(t Test)**	<.001	<.001	<.001	<.001	<.001	<.001
Intervention	**Average pre-test**	4.46	4.72	2.93	2.18	2.87	17.18

		Total Spontaneity	Total. Relevance	Total Fluency	Total Accuracy	Total Adequacy	TOTAL
Intervention	**Average post-test**	5.55	5.39	3.96	3.72	3.65	22.27
Intervention	**Average Gain**	1.08*	0.67*	1.02*	1.54*	0.77*	5.08*
Intervention	***p* value(t test)**	<.001	<.001	<.001	<.001	<.001	<.001
Intervention vs Non-intervention	***p* value (t test)**	.840	.243	.213	.022	.0003	.035

2.3.2 Classroom observations

The English research team developed 70 codes to categorize behaviours observed in the communicative English classrooms. The figures that follow depict the number of instances of peer collaboration when listening or speaking, discussions, and students' use of scaffolds in the CLIx lab.

2.3.2.1 Intervention Schools

In a majority of cases, there is a directly proportional relationship between the number of discussions among students and positive engagement, initiatives taken by students, collaboration in language tasks and students' production of content. Also observed was a correlation between active implementation and intervention by the teachers and the students' comfort with the course that enabled them to take initiatives autonomously in task completion. Figure 2.6 shows students discussing while using English Beginner 1 module. The teachers at Intervention School EIS1, EIS2, EIS3 and EIS4 had implemented the modules in the last two years and were conversant with the practice. The students in their schools register greater engagement with the modules. EIS5 and EIS6, as first time implementers, show a more sporadic engagement with the students, registering fewer instances of initiatives and language production in comparison to the other schools.

Figure 2.6. Teacher observing students' activity on the module

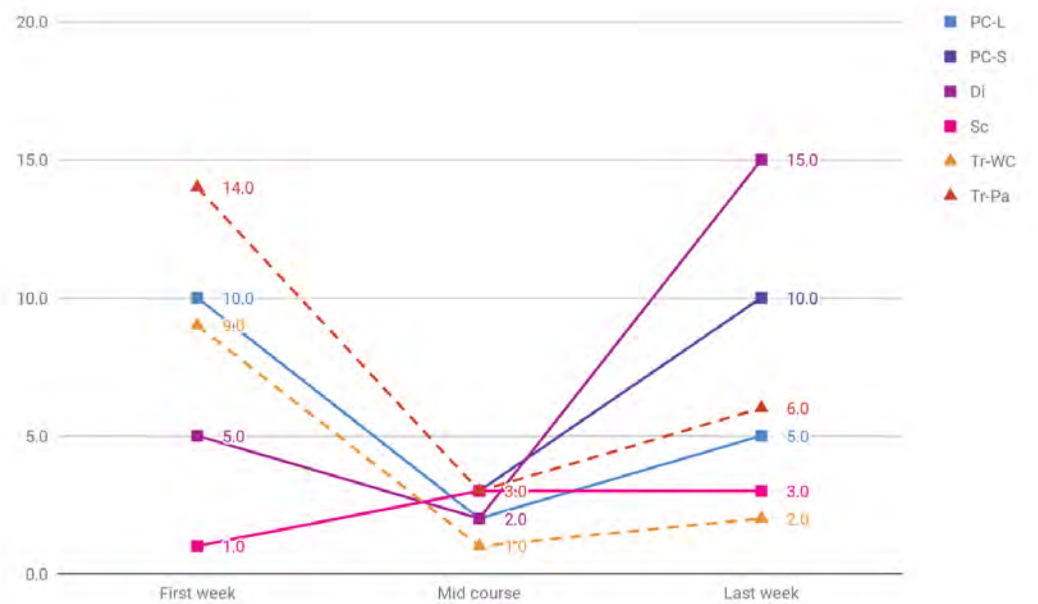


Figure 2.7. Student and teacher classroom behaviors (EIS3)

Figure 2.7 shows the relationship between teachers' intervention in the learning process and the students' initiative in one intervention school. While there were a greater number of instances of the teacher aiding student learning during the first week observation (Tr-WC, Tr-Pa), the number of instances reduces in the mid-course and end-course observations. There is a corresponding increase in the number of instances of student collaboration when speaking (PC-S) and student positive engagement in discussion (Di). In addition to the example above, these behaviors were observed most keenly in EIS 1, 2 and 3, and those teachers followed an implementation process that maintained maximum fidelity to design. In contrast, EIS 5 and 6 did not implement the modules with as much fidelity to design as the former schools. While there was a definite increase in students' speaking skills in EIS 5 and 6, it was not reflected in students' scores to the same extent as in EIS 1, 2 and 3.

2.3.2.2 Non-intervention Schools

The observations reflected a predominantly teacher-led classroom with not many opportunities for students to collaborate or produce language, when compared to the CLIx lab in the intervention schools. There were also higher numbers for the codes capturing non-engagement with the lesson. Whole class instructions and whole class responses register higher numbers. These results indicate a difference in the nature of the learning spaces wherein the CLIx English lab allows students greater opportunities to listen to and speak in English, as compared to the regular English classroom that appears to be strongly teacher-led.

2.4 Discussion

The pre to post-test listening and speaking scores registered a significant gain in the intervention schools. This indicates that students improved their ability to listen closely for meaning, comprehend what they hear, and speak better. Gains were observed in the non-intervention schools as well. For listening, the intervention schools showed a significantly higher gain from pre- to post-test than the non-intervention schools, thereby suggesting a positive impact of the modules on the students' listening skills. The significant gains for the two objectives in the intervention schools as compared to non-intervention schools indicates that the CLIx modules have enhanced students' familiarity with the language to achieve global and local comprehension of speech. It has also enabled them to notice language and choose appropriately.

For speaking skills overall, students gained from pre- to post-test in the intervention and non-intervention schools alike. However, when examining individual school performance, the pre-post gain in score was significant for all of the non-intervention schools whereas the gain was not significant for 3 of the 6 intervention schools. The overall average gain score for speaking in the non-intervention schools was significantly higher than in the intervention schools.

Based on the current study and existing literature on speaking skills, it is imperative to understand this phenomenon, especially in light of the higher gain that the intervention schools have shown in listening skills, which supports the modules' efficacy. Unlike reading, writing, and listening that are measurable cognitive skills, there is scant research on speaking skills from the perspective of communicative English. Research has indicated the difficulty in establishing, with any reliability, the nature and/of change in speaking skills in learners. This is primarily because speaking is an interpersonal skill that is influenced by multiple variables like socio-economic contexts, exposure to language and resources in and/or outside the classroom, opportunities to use the language more frequently, individual competence, and stress factors in the environment, among others (Harmer, 2001, Brown, 2000).

Upon comparing schools in the two groups, only the criteria of adequacy and accuracy showed a significantly higher gain in the non-intervention schools. Accuracy and adequacy are criteria that are covered in the regular classroom as well. The criteria of fluency, spontaneity, and relevance relate to interpersonal communication and registered comparable gains between the intervention and non-intervention schools in this study. These criteria require greater exposure to language and opportunities to speak more often.

Classroom observations reinforce the outcomes and literature stating that increased language input is necessary for learners to gain proficiency in a language. The focused input in English provided by the modules is arguably one reason for the higher gain score in the listening skills of students in the intervention schools as compared to the non-intervention schools. The increase in speaking scores of students in the intervention schools supports Swain's Output hypothesis that suggests that opportunities to use language is necessary to enable learners to gain proficiency. This is reflected in the number of instances where students have produced language.

The associations between teachers' and students' classroom behaviors highlight the process-oriented nature of language learning and the way a teacher's role in the classroom enables lifelong learning practice. Instances where teachers allowed students the opportunity to tackle a task independently have recorded students' greater engagement with the modules and correspondingly higher production over a period of time. This was reflected as confidence in students' behaviour, seen as an increase in number of instances of student initiatives, peer collaboration in listening and speaking tasks, and positive engagement with the modules.

There emerges a strong correlation between students' learning outcomes and classroom transactions in the intervention schools where opportunities for students to attempt activities independently--scaffolded by teachers' presence, facilitation and timely intervention--can lead to confident users of the language. Working on a CALL platform in a blended mode has proved to be an effective method for enhancing listening skills in these schools, which is reflected in gain scores of the intervention schools. Providing sustained opportunities to speak with peers in a safe learning environment and with support from teachers can also lead to an increase in confidence and communicative abilities of students. It is imperative, however, that such opportunities continue over a sustained period of time, ensuring that students do not lose practice and stop using the language.

2.5 Conclusions and Way Ahead

This study demonstrates that when a CALL module is implemented with high fidelity to design, there is increased opportunity to listen to and speak in English which was associated with a gain in the listening and speaking outcome of learners. This work addresses a gap in current literature on large scale studies on issues of listening and speaking skills in India. The study also demonstrates that language learning processes can lead to gains in listening and speaking skills.

The study is circumscribed by some limitations. The language levels of the students across the 12 schools were not comparable at the onset of the study, though surveys indicate that the students are from comparable socio-economic and cultural backgrounds. This is also an established limitation in large scale quantitative studies in language learning research. Since language learning is an interpersonal skill and a process, most studies, especially those pertaining to speaking skills, have focused on small scale case studies because the number of variables that determine a students' performance in speaking are numerous. This study encountered similar problems with respect to speaking skills.

However, further work is being done on the current data in which we compare the scores between two-three intervention schools to analyse and investigate reasons for their difference in gain scores (though the current increase in gain scores are statistically significant). As a process oriented course that stresses learning methods as the key to effective learning, classroom observations are being analysed with vigour to identify variables that contribute to learning gains. The teachers' role and facilitation practices are also being studied for a deeper understanding of practices in a language classroom. A delayed post-test in the 6 intervention and 6 comparison schools has also been conducted to check for conditions that can support retention in learning.

3.0 Geometric Reasoning Module - Chhattisgarh

3.1 Introduction

Geometric Reasoning was the first module designed by the CLIx Mathematics team. In the team's initial interactions with teachers, many reported finding formal geometry, especially proofs, the most difficult topic to teach in the high school mathematics curriculum. Diagnostic case-studies conducted by the mathematics team through an assessment tool and interviews (Srinivas, Rahaman, Khanna, Bapat, 2016) indicated that high school students who were assessed identified basic shapes by comparing them to visual prototypes, rather than by their properties. This signified the need for a module to develop students' capacity to reason and focus on properties of shapes.

The objectives of the Mathematics Learning Outcomes study were:

- To study the effect of the CLIx Geometric Reasoning I+ module on high school students' understanding of Geometry
- To study the effect of the CLIx Geometric Reasoning I+ module on the learning environment[3] of the classrooms where it was implemented.

Based on the above objectives, the study explored the following research questions:

- RQ 1: How did the CLIx Geometric Reasoning I+ module affect high school students' understanding of
    a. the concept of shape
    b. properties of plane shapes - in particular, that of quadrilaterals
    c. hierarchical class relationships amongst quadrilaterals
- RQ 2: How did the observed learning behaviour of the students going through the CLIx Geometric Reasoning I+ module differ from that of their peers who learnt the same content without the module?
- RQ 3: To what extent did the implementation of the CLIx Geometric Reasoning I+ module support the following practices in the classroom:
    a. ensuring a safe space for students to make mistakes and learn
    b. encouraging peer discussion and 'math talk' amongst students

In addition to analysing the effect of the Geometric Reasoning module on students' learning, this study also intended to support ideal implementation by teachers in the field. The team worked

3For our purpose, we use the term 'Learning Environment' to mean the ethos and culture prevalent in the classroom, ways in which the teacher organizes and uses the educational setting and resources to facilitate learning, and also the ways in which the students respond to these.

closely with them in their classrooms to support the desired pedagogical practices and help implement the module in an ideal manner, making optimal use of all the resources - hands-on, digital and the workbook. The CLIx pedagogical pillars of providing safe space for learning from mistakes and through collaboration with peers were essential components of a high-fidelity implementation, and teachers were supported to adopt these pillars in their classrooms to provide an ideal learning environment for students.

3.2 Methods

A mixed method approach involving a quasi-experimental design was adopted for the study. The location of the study was government high schools in semi-urban and rural areas of the Dhamtari district in Chhattisgarh.

3.2.1 Participants

Ten intervention schools were chosen from the 30 government-run schools in this district. The CLIx modules had been implemented for the past three years in this district. However, the Geometric Reasoning module was implemented only a year ago in all intervention schools except MIS03, a new CLIx school where implementation started during only the past one year. The non-intervention schools were chosen from among a larger pool of control schools that are part of the CLIx overall evaluation (Baseline - Endline) study using latest DISE (District Information System for Education) data to match for average pass percentage in Grade 10 examinations and the number of students in ninth grade. The comparability of pass percentages of these two sets of schools (intervention and non-intervention ones) was examined using an independent samples t-test, and there was no statistically significant difference for the given criterion. Details related to the selected schools, participating teachers, and students are given in Appendix B.1.

3.2.2 Materials

3.2.2.1 Geometric Reasoning Modules I and II

The Geometric Reasoning modules focus on reasoning and the processes of learning mathematics rather than the common classroom practice of rote memorisation of properties, definitions and proofs. The modules align with the prescribed curriculum through the Grade 9 textbook topic of “Quadrilaterals”. They are blended modules with both digital and classroom activities, and are accompanied by a specially designed student workbook. The CLIx Geometric Reasoning modules are based on the van Hiele framework (van Hiele, 1986) (See Appendix B.2), which helps teachers discern students’ level of progressive thought in geometry and identify tasks and activities at each level that can help students progress to the next higher level of thinking (Battista, 2007). Although the framework mentions 5 levels, only 4 levels are accessible at the school level.

Several researchers have suggested engaging high school students in tasks related to van Hiele Levels 1 to 3 before moving to formal reasoning tasks, calling it as “Spadework prior to deduction in Geometry” (Shaughnessy & Burger, 1985). The CLIx Geometric Reasoning modules (GR I and GR II) attempt to assist students with this spadework by developing their thinking from the existing levels (typically Level 1) up to Level 3, which is the threshold of formal deductive reasoning. The Geometric Reasoning modules, thus, focus on reasoning in a non-threatening game-based environment, and expect students to collaborate and learn through reasoning and communication of mathematical ideas (See Appendix B. 3 for overall objectives of Geometric Reasoning modules and key design aspects). The tasks in the modules were designed to strengthen concepts as well as vocabulary. They also help students to develop an understanding of abstract hierarchical relationships among shapes based on properties. As stated earlier, only GR I and a portion of GR II were utilized for the learning outcomes study, henceforth referred to as GR 1+. The description of the units and sessions in the Geometric Reasoning 1+ and their objectives are given in Appendix B.4. Figure 3.1 & 3.2 respectively show the conducting of digital activities inside the computer lab and hands-on activities inside the classroom.

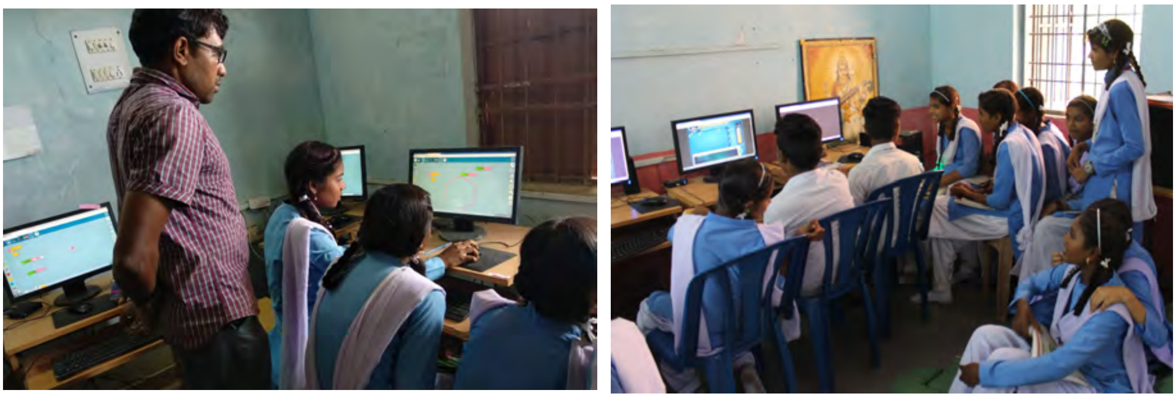


Figure 3.1. Digital Activities of CLIx Mathematics modules

Figure 3.2. Non-digital Activities of CLIx Mathematics modules

3.2.2.2 Pre- and post-test

The items in the pre-test and post-test were drawn/adapted from Shaughnessy and Burger. Content validity of the pre-test and post-test was supported by expert review of the items, with changes made based on their feedback (See Appendix B.6 for Pre-test and Appendix B.7 for Post-test). The tests contained two parts: Part A with 8 multiple choice questions (MCQs), in both the pre and post-test, and Part B with 6 constructed response items in the pre-test, and 8 such items in the post-test. The test items were mapped with van Hiele levels of geometric reasoning progression. The items in the pre and post-test were not identical, but comparable in terms of the construct or reasoning that was evaluated, except the last two questions. These questions were identical in both tests. The pre and post-test were piloted in two different studies before being used in this study. Based on students responses and interactions with the students, some of the items were modified after the pilot-test.

3.2.2.3 Observation tools

The math team developed a classroom observation tool that consisted of a space to record teacher and student behaviors (freewrite), along with tallies that enabled observers to record specific activities. The freewrite provided space to note the time for events such as Teacher Lecture mode (TL), Class Discussion mode (CD), Individual Work mode (IW), small Group (or Pair) work mode (GW), any Other (O). The tallies recorded different actions of students and teachers corresponding to implementation of the pedagogical pillars. Some of the student actions noted included the number of times a student asked a doubt, engaged in reasoning, or engaged in extended reasoning. Examples of teacher actions that were recorded are number of times a teacher ignores a student question or doubt, or number of times a teacher builds on incorrect responses.

The lab observation tools also consisted of the freewrite. In this context, the freewrite focused on what the teacher said to the entire group of students in the lab and to small groups. The lab observation tools also included two rubrics, or tally tools. The first one recorded the level of individual student engagement in a group, such as control of the computer mouse, or extent of mathematical vocabulary use. The second rubric assessed the classroom as a safe space for making mistakes by tallying students' behaviour when responding to mistakes, such as asking teacher for help, discussing with peers, or giving up.

3.2.3 Procedure

The tools and resources for the study and strategies for interaction with teachers were based on insights from a pilot study in M Power Library and Study Centre in M-East ward of Mumbai (a resource centre catering to students from low socio-economic strata).

To help teachers in intervention schools to implement the module in near ideal conditions, the CLIx mathematics team organised a 2-day workshop specifically for these 11 teachers (but 1 teacher from MIS03 was absent), contributed to planning the lessons, discussed the lesson plans in advance, resolved content related doubts, gave feedback about areas for improvement for lessons after observation, and helped teachers plan flow for the next lesson during school visits. However, at no point did the team members themselves do any active teaching. The team also helped by providing support or helping teachers to troubleshoot when students were learning navigation of the platform and login. All students who participated in the study received a physical copy of the student workbook designed for the Geometric Reasoning (GR I+) module; the workbook contained tasks to help students reflect, think about, and reason on the activities done. The activities conducted in the intervention and the non-intervention schools during the study and the type of data collected is listed in Appendix B.5.

3.2.4 Data Analysis

The data entry of the students' responses for the Multiple Choice Questions (MCQ) items was done by the mathematics team members; data were rechecked and then cross-checked by other members of the team. Students' incorrect or missing answers were awarded a "0" score. The scores were compiled for individual schools and then collated into two groups for intervention and non-intervention schools. Descriptive analysis was conducted to determine students' mean pre to post-test gain. Then statistical analyses using a series of t-tests were conducted to determine if 1) students' pre to post-test change in scores was significant (referred to as 'absolute gain/loss'), and 2) if the mean of students' absolute gain (or loss) was significantly different between the intervention schools and the non-intervention schools. Absolute gain scores and normalised gain scores were calculated for each school and the schools were ranked based on these scores.

For classroom observation analysis, the free write tool was used to note the time spent in minutes on each activity by the teacher. Two observations from the top 6 performing schools were selected[4] and average time spent on different activities like teacher talk, classroom discussion, and individual work by all intervention school teachers was calculated. The same exercise was carried out for non-intervention schools and data was plotted in the form of pie charts. Teacher and student behaviors recorded on the tally tool as a frequency count were also analysed for all intervention schools and non-intervention schools. Differences between the student and teacher behaviours in intervention and non-intervention schools were noted.

3.3 Fidelity of Implementation of the GR 1+ Module

A summary of the different ways in which the module was implemented in the 10 math intervention schools (henceforth referred to as MIS01 to MIS10) is presented in table 3.1 below. These differences help to explain inter-school variations in the results. The parameters used to assess fidelity of implementation are shown in columns 2-5. Extent of implementation was assessed via teachers' self-report, class observations, and students' progress in the workbook. The scoring rubric is shown in table 3.2. The column labeled "Category (Fidelity + Extent)" in table 3.1 indicates the level of fidelity of implementation and the extent of implementation using three categories High (H), Medium (M) and Low (L). For example, the entry "HM" indicates a high degree of fidelity to the module design but a medium extent of implementation. The "Response category" column indicates the extent of responsiveness of a teacher to the observers comments and feedback, again reflected using categories of High (H), Medium (M) and Low (L).

4except for one Non-intervention school

Table 3.1. Scores for fidelity and extent of implementation - Intervention schools

School	Parameters to assess fidelity of implementation					Total score in extent of implementation (0-8)	Category (Fidelity + extent)	Response to feedback and support (0-4)	Response category
	Adherence to module plan and objectives	Use of resources as per recommendation	Enabling desired learning behaviours	Facilitation of digital activities	Total score on fidelity (0-20)				
MIS01	3	2	6	4	15	4	HM	3	H
MIS02	2	1	3	3	9	3	MM	2	M
MIS03	1	0	1	0	2	0	LL	0	L
MIS04	3	4	5	4	16	8	HH	2	M
MIS05	2	1	4	3	10	0	ML	0	L
MIS06	3	3	3	4	13	4	MM	3	H
MIS07	2	2	3	0	7	2	ML	2	M
MIS08	2	0	4	1	7	6	MH	3	H
MIS09	3	2	1	3	8	8	MH	2	M
MIS10	4	4	6	6	20	8	HH	4	H

Table 3.2. Scoring rubric for fidelity and extent of CLIx implementation

	FIDELITY			EXTENT			RESPONSE TO FEEDBACK & SUPPORT		
SCORE	0 - 6	7 - 13	15 -20	0 - 2	3 - 5	6 - 8	0	1-2	3-4
CATEGORY	Low (L)	Medium (M)	High (H)	Low (L)	Medium (M)	High (H)	Low (L)	Medium (M)	High (H)

When considering the scoring rubric above, a fair degree of variation in implementation was observed in the 10 intervention schools, particularly in the categories of ‘Fidelity’, and ‘Extent of Implementation.’ Analysis shows that ‘Fidelity’ of implementation was high in 3 (30%) of the 10 schools, medium in 6 (60%), and low in 1 (10%). The ‘Extent of Implementation’ was high in 4 (40%) of the 10 schools, medium in 3 (30%), and low in 3 (30%). There were various reasons for the low extent of implementation - ranging from low teacher motivation to a persistent power outage issue.

3.4 Findings

3.4.1 Pre and post-tests

Overall, 507 students from 10 intervention schools and 565 students from 9 non-intervention schools participated in the study. Data from 466 (91.9% of total) students in the intervention schools and 499 (88.3% of total) in the non-intervention schools were used for analysis. Data was used from only the students who did both the pre and post-test.

Although both groups showed learning gains from the pre to post-test, the quantum of gain was significantly larger in the intervention group. Also, on examining the performance of individual schools, it appeared that in general, the intervention schools showed better gains than their counterparts who did not go through the module. These, and other findings related to the performance of students are discussed in the sub-sections that follow.

3.4.1.1 Overall Learning Gains

An analysis of the seven geometry-related MCQ items (Q1-7[5]) in the assessments showed that the intervention group started with a lower average score than the non-intervention group, but ended with a better score in the post-test due to a significantly larger gain as shown in Figure 3.3. The 10 schools in the intervention group had an average score of 29.77% (SD = 20.03) in the pre-test and 43.19% (SD = 22.69) in the post-test. The 9 schools in the non-intervention group had an average of 33.92% (SD = 20.31) in the pre-test and 36.73% (SD = 20.49) in the post-test. The pre to post-test gain, or difference between the scores from pre to post-test (13% gain) of the intervention group was statistically significant, $p<.0001$, whereas the difference between the pre- and post-test scores in the non-intervention school was not significant (3% gain). The difference between the gains from pre to post-test in the intervention schools to that of the non-intervention schools was found to be significant, indicating that the learning gain in the intervention group was significantly higher than that of the non-intervention group ($p <.001$).

5Of the 8 Multiple Choice Questions, the last one, Q8, was a logic question unrelated to Geometry, and hence not used in this analysis.

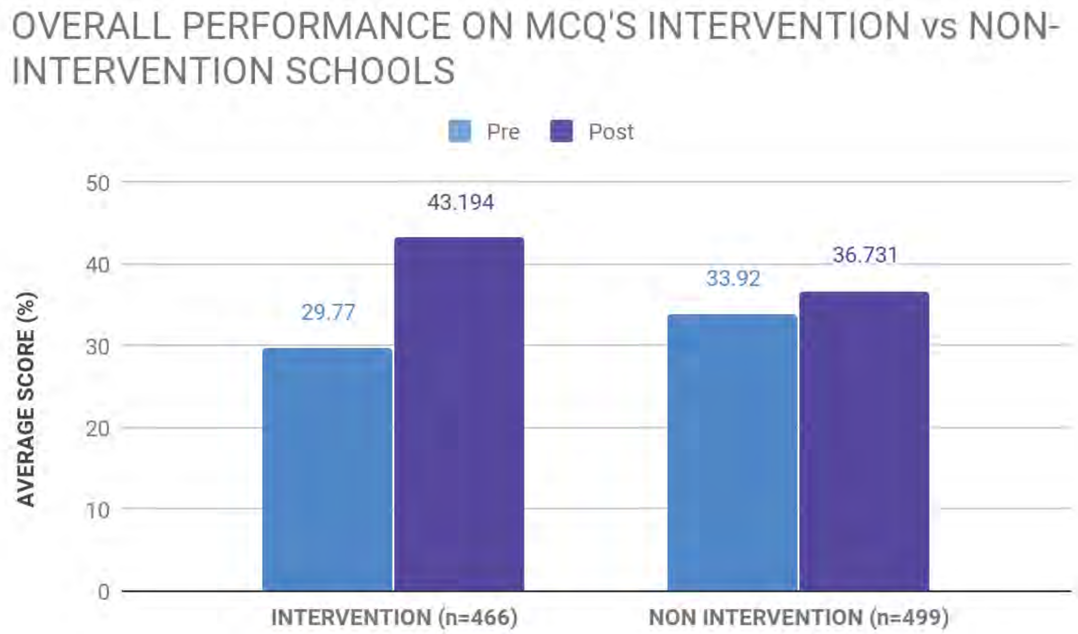


Figure 3.3. Overall performance of MCQ's (%) in intervention v/s non-intervention schools

It is also important to report here that when the scores were analysed gender-wise, results showed that the overall gain score of the girls in the intervention group was significantly higher than that of the corresponding cohort in the non-intervention group (p =.0002).

3.4.1.2 Variations across Schools

Looking at gain scores of individual schools, 8 intervention schools outperformed the non-intervention schools in terms of both absolute, and normalised gain scores as shown in figure 3.4 and figure 3.5. The gains from pre to post-test scores were statistically significant for 8 intervention schools except MIS03 and MIS07. For non-intervention schools the gains were significant in only 2 of the 9 schools i.e. MNIS06 and MNIS09. We ranked all the 19 schools (intervention and non-intervention) based on their

1) gain scores (absolute) in percentage in figure 3.4 ,and

2) normalised gain scores in figure 3.5.

It is perhaps important to note here that the MIS07 which shows a very low, almost negligible positive change, is a school in which CLIx was introduced only this year. Additionally, the teacher at that school could not attend the intensive teacher workshop conducted prior to the implementation.

Figure 3.4. Absolute gain scores - Intervention and non-intervention schools

Figure 3.5 below shows each school's rank based on their normalised gain scores. A similar pattern is visible when the ranking is done on the basis of normalised gain scores. (The normalised gain score method compensates for the bias against students that have high scores in the pre-test, since they have relatively less scope for 'improvement' in scores). Since many of the non-intervention schools had slightly higher scores to start with, the negative normalised gain scores of 6 of them indicate that the gains exhibited by the intervention schools is quite significant.

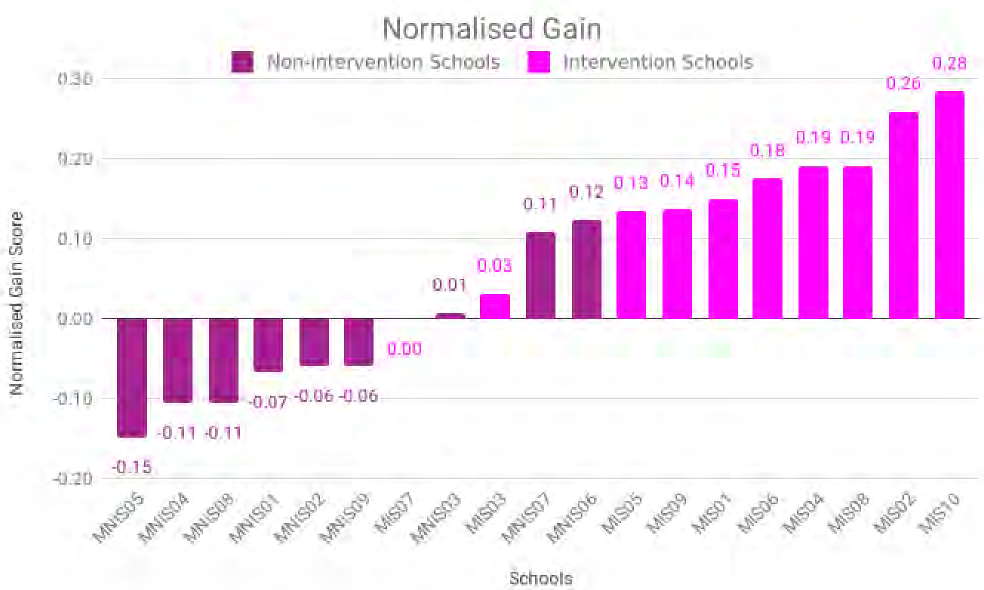


Figure 3.5. School ranks based on normalized gain scores

Schools were then categorised based on their scores on fidelity and extent of Implementation, and placed in table 3.3 below along with their normalised gain score ranks.

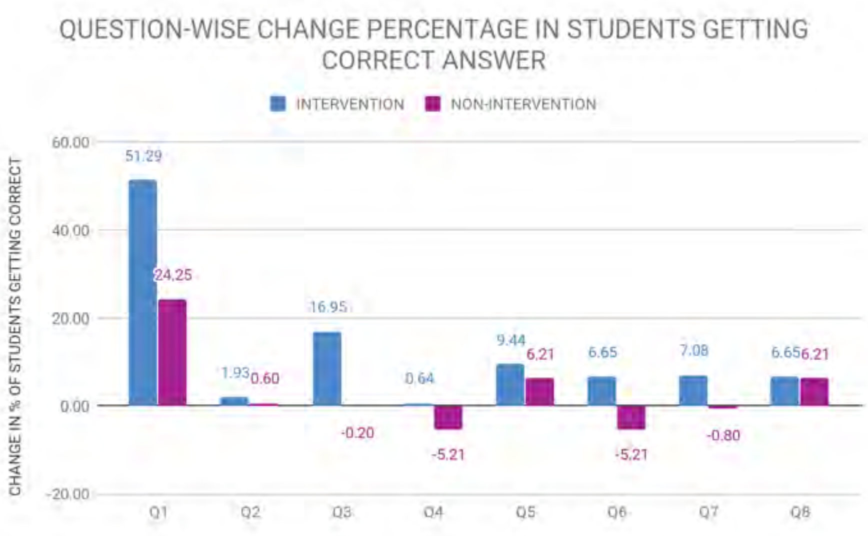
Table 3.3. Schools categorised based on their scores on fidelity and extent of implementation

EXTENT (LOW TO HIGH)	--- (LH)	MIS08 - *Rank 4* MIS09 - *Rank 7* (MH)	MIS04 - *Rank 3* MIS10 - *Rank 1* (HH)
	--- (LM)	MIS02 - *Rank 2* MIS06 - *Rank 5* (MM)	MIS01 - *Rank 6* (HM)
	MIS03 - *Rank 11* (LL)	MIS05 - *Rank 8* MIS07 - *Rank 13* (ML)	--- (HL)
	FIDELITY (LOW TO HIGH) →		

As seen in the table 3.3, schools where both fidelity and extent of Implementation scores range from Medium to High, seem to have the top 7 ranks[6] - demonstrating relatively higher learning gains. Also, the two HH (high Fidelity and high Extent of Implementation) schools, are at Rank 1 and 3 respectively. The data suggests that the type of implementation of the module in a school corresponds to students' learning gains.

3.4.1.3 Geometry understanding and geometric thinking

A question-wise comparison of the performance of the intervention and non-intervention schools (see figure 3.6) shows that for the intervention schools, the percentage of students selecting the correct answer increased (though to different extents, with p<.05), in each of the 7 MCQs related to geometry. In contrast, for the non-intervention group, the percentage of correct answers has increased in only 3 of the 7 questions, decreased in 3, and remained almost the same in one. The decrease in post-test performance for non-intervention schools may be due to an increase in the difficulty level of post-test questions. However, it also indicates that significant gains in intervention schools for increased difficulty items is a considerable gain.



6The school 'Rank' here refers to the rank based on normalised gain scores as given in figure 3.3

Figure 3.6. Change in percentage of students responding correctly from pre to post-test

One interesting fact to note here is that in contrast to the other questions, the difference between the intervention and non-intervention schools is negligible in Q8 - a logic-based question, which was not explicitly taught in either group. In a manner, this could be treated as an anchoring item, which suggests that the difference in gain between the two groups in the other items is likely to be an effect of the intervention.

In the following subsections, students' performance on selected questions will be discussed to examine the learning gains in the areas specified in RQ1.

3.4.1.3.1 Concept of shape

In the MCQ portion of the test, Q1 assessed the concept of shape.The pre and post-test items shown in figure 3.7 are considered equivalent. The main purpose of the item was to distinguish between students who could or could not recognize a turned square as a square. Figure 3.8 shows the comparative performance of the two groups on this item.

Q1 in pre-test **Q1 in post-test**

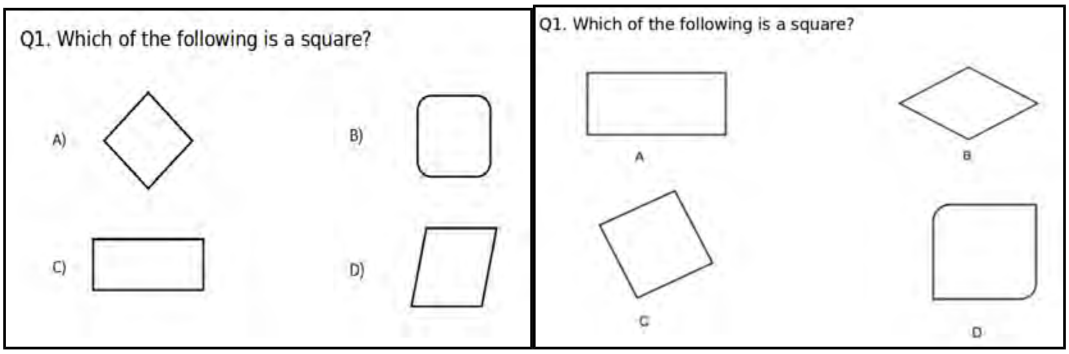


Figure 3.7. Q 1 in pre and post-test

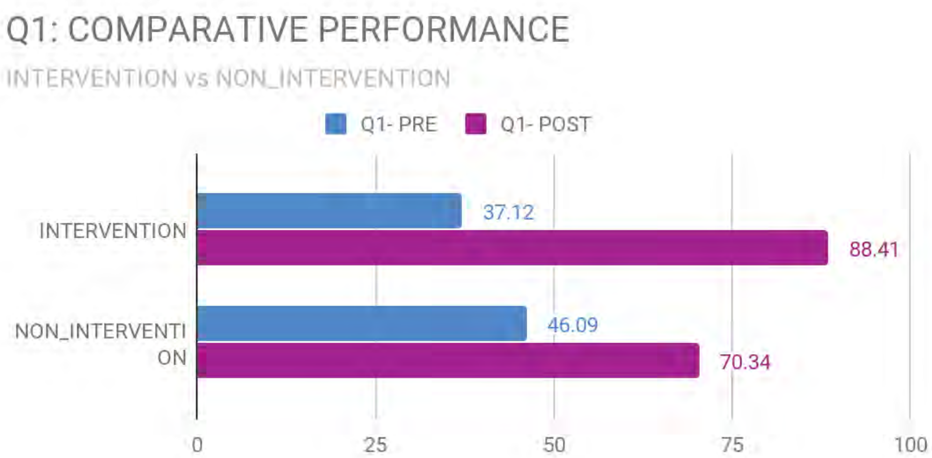


Figure 3.8. Comparative performance (%) of intervention vs non-intervention schools

The pre-test results showed that more than 60% of the students in intervention schools were thinking at a visual level. However, in the post-test the pattern was reversed, and a considerably higher percentage of students in the intervention schools answered the question correctly, indicating thinking at an analytic level. This suggests that a larger proportion of students moved to higher levels of thinking in the intervention group.

3.4.1.3.2 Properties of plane shapes

Q3 of the written assessments in both the pre and post-test required students to analyse a set of shapes by selecting a property common to all. Figure 3.9 shows the pre- and post-test questions, and figure 3.10 shows the comparative results between the intervention and non-intervention schools.

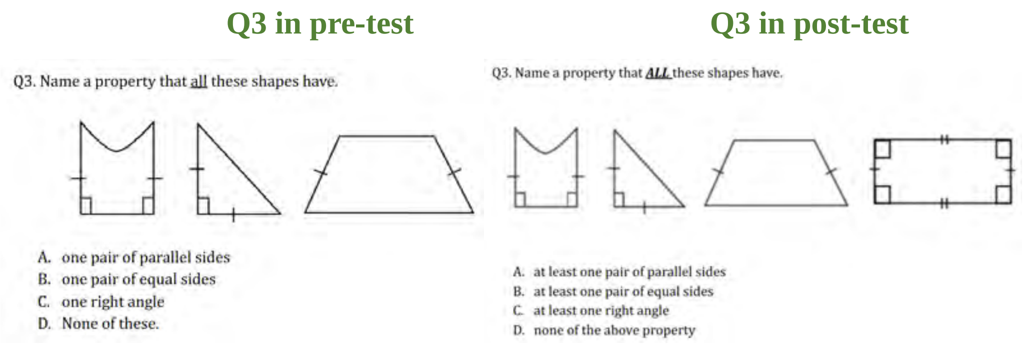


Figure 3.9. Q3 in pre- and post-test

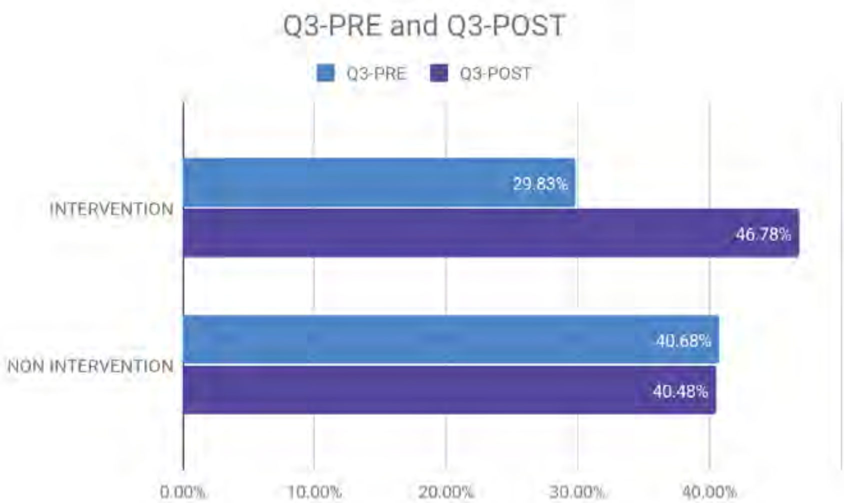


Figure 3.10. Comparative performance (%) of intervention vs non-intervention schools

The post-test results showed that the intervention schools performed better than the non-intervention schools, with 46.8% of the students answering correctly on the post-test. This was a sizeable gain, while there was almost no change in the performance of the non-intervention schools. The dip in performance of the non-intervention group could be due to adding the term ‘at least’ to the post-test question, which was addressed in the CLIx module. Student learning related to properties of shapes is discussed further in the section on students’ mathematical discourse.

3.4.1.3.3 Hierarchical class relationships

Understanding hierarchical class relationships amongst special classes of quadrilaterals involves the highest level of geometric reasoning, and was the most complex understanding targeted in the CLIx

Geometric Reasoning module. In the MCQ items, there were two that were specifically related to the understanding of class relationships amongst quadrilaterals – Q5 and Q7. For this report, results for Q7 will be analysed (see figure 3.11). This question asked students to identify all the figures that could be called 'rectangles' from a given set. Solving it correctly required the students to understand that a square is a rectangle because a square has all the properties needed for a quadrilateral to be a rectangle.

Q7 in pre-test **Q7 in post-test**

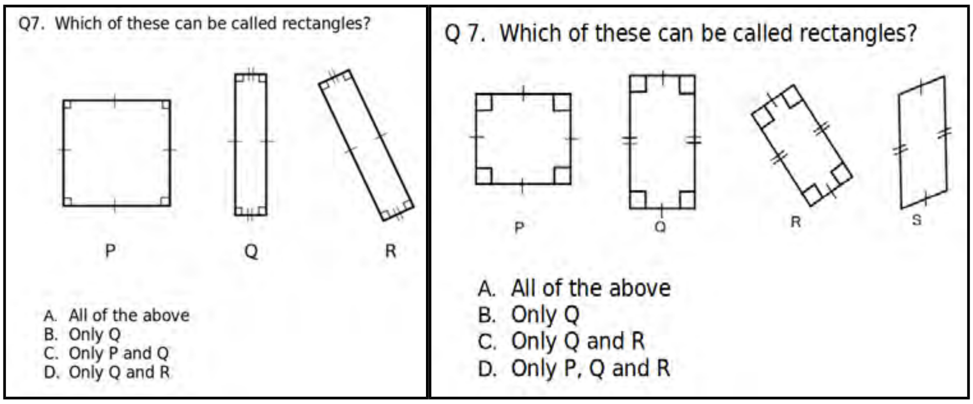


Figure 3.11. Q7 in pre- and post-test

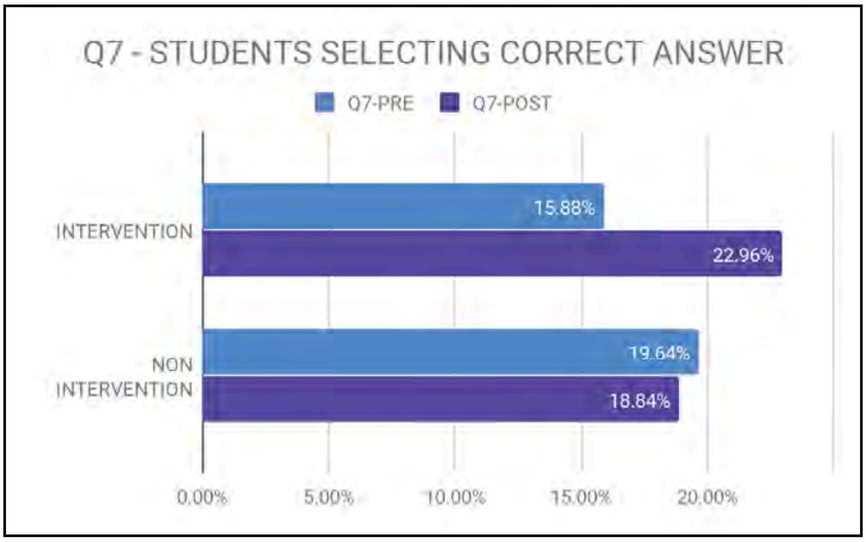


Figure 3.12. Comparative performance (%) for intervention vs non-intervention schools

Figure 3.12 shows that while the non-intervention schools experienced a minor dip in correct answer percentage from pre- to post-test, the intervention schools showed a gain – almost 23% got it right in the post as compared to about 16% in pre-test. Also, the intervention schools showed a larger reduction in the percentage of students selecting the common wrong option – thereby showing a greater reduction in the number of students who believe that a square is not a rectangle. One needs to note that although several intervention schools could not reach the lessons in the module addressing hierarchical class relationship due to time constraints, we observed discussion of this important idea during several class observations.

3.4.1.4 Changes in students' mathematical discourse

We have defined mathematical discourse as the way students communicate or exchange ideas, display facility with mathematical vocabulary and articulate reasoning – both during the 'math talk' in the classroom, and in their written responses. This section focuses on students' written responses for Q9 of the pre-test and the corresponding equivalent items Q9 and Q10 from the post-test of one intervention school that exhibited high 'Fidelity', high 'Extent of Implementation,' and the greatest gain score (both normalised and absolute). Since these items were open ended, they elicited the knowledge and vocabulary readily available to, and internalised by students (see figure 3.13). For this analysis 16 students' responses were randomly selected from a sample of 48 students from that school.

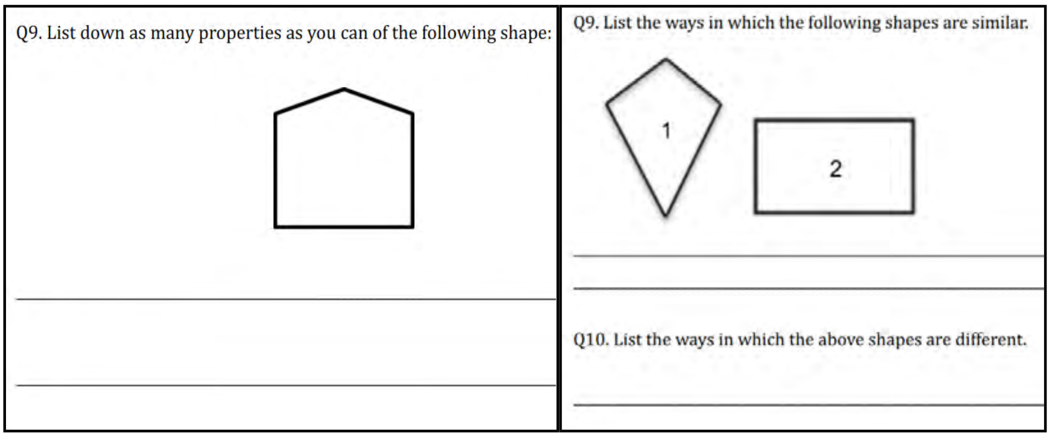


Figure 3.13. Q9 in pre and related Q 10 post-test

The pre-test question asked students to list as many properties as they could of the shape given, but the post-test contained two questions corresponding to this task – list the similarities and the differences between the given pair of shapes. Figure 3.14 shows that while almost one third of the students did not even attempt the question in the pre-test, just 6% left the questions unanswered in the post-test

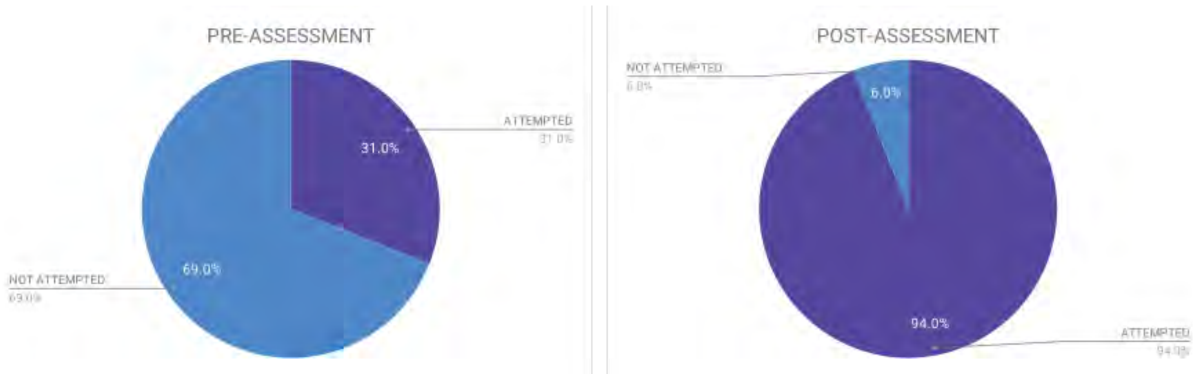


Figure 3.14. Comparison of students attempting the constructed response item in pre- and post-test in one intervention school

The properties and descriptions these 16 students used in their responses was analysed qualitatively. The results indicated that in the post-test, 7 of these 16 students mentioned the names of both the figures correctly while only 3 had mentioned the correct name of one figure in the pre-test. While 7 of them mentioned the diagonal properties in the post-test, no student had mentioned it in pre-test. 10 of the 16 students mentioned a correct side, angle, diagonal or other properties in the post-test compared to only 4 in the pre-test. An exemplar post-test response from a student - demonstrating use of precise vocabulary in her description, as well as a clear understanding of the question format, is shown in figure 3.15. The student is able to clearly articulate the properties of sides, number of corners and diagonals of both shapes as well as the difference about right angle, parallel sides and bisecting of diagonals.

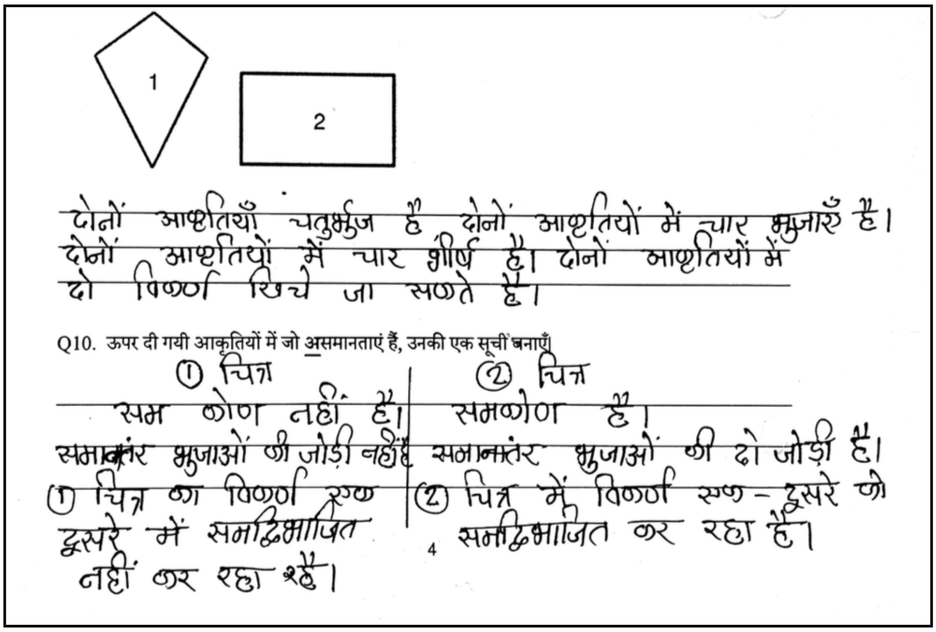


Figure 3.15. Example of a student’s response for Q10

From the tables and qualitative analysis, it seems evident that post the intervention, many more students in the intervention schools articulated better descriptive responses using appropriate geometric vocabulary.

3.4.2 Classroom observations

This section addresses RQ2, which examines the outcomes related to the student learning behaviour, and also RQ3, which looks at the outcomes related to the learning environment and desired pedagogical practices in the classroom, namely 1) a safe space for students to make mistakes and learn, and 2) peer discussion and ‘math talk’ amongst students

Data from observations conducted in intervention and non-intervention classrooms were analyzed to gain insights on these two research questions.

3.4.2.1 Comparative analysis: Intervention vs non-intervention classrooms

For this comparative analysis of classroom interactions, classroom observations from the 6 top-performing[7] schools from the intervention and the non-intervention schools were considered. For

7Based on ranking of schools on absolute gains the intervention group, 12[8] out of a total of 27[9] classroom observations were analysed. For the non-intervention schools, all the 11 observations were included (2 from each school, except in MNIS08 where only 1 observation could be done). To compare the observations across intervention and non-intervention schools, an average of the total number of instances observed in both type of schools was taken.

The general observations of intervention schools indicated that students were highly engaged in digital activities in the lab, especially the Police Quad game. Even when they sat in large groups or had infrastructure issues, students could read the clues and engage actively in discussion without having active control of the mouse. Some teachers were able to facilitate the digital tasks well, allowing students a reasonable amount of time to struggle and make mistakes. They were also alert and initiated whole group discussions when a number of students got stuck with similar issues. The consolidated 'Freewrite' data from the classroom observations provided information on the distribution of class time, as shown in figure 3.16.

As shown in the figure, intervention schools spent close to 60% of the observed time on classroom discussions, with the teacher facilitating meaningful 'math talk' between 2 or more students, or between the teacher and (one or more) students. This is markedly different from their counterparts where no intervention took place. In that context, almost 70% of time was spent in the 'Teacher Lecture (TL)' mode, with students simply listening passively and occasionally answering in chorus. The students in the intervention schools also spent more time on individual work. Mostly, this time was spent working on student workbook tasks, which were specifically designed to bring out students' existing ideas and help articulate their reasoning.

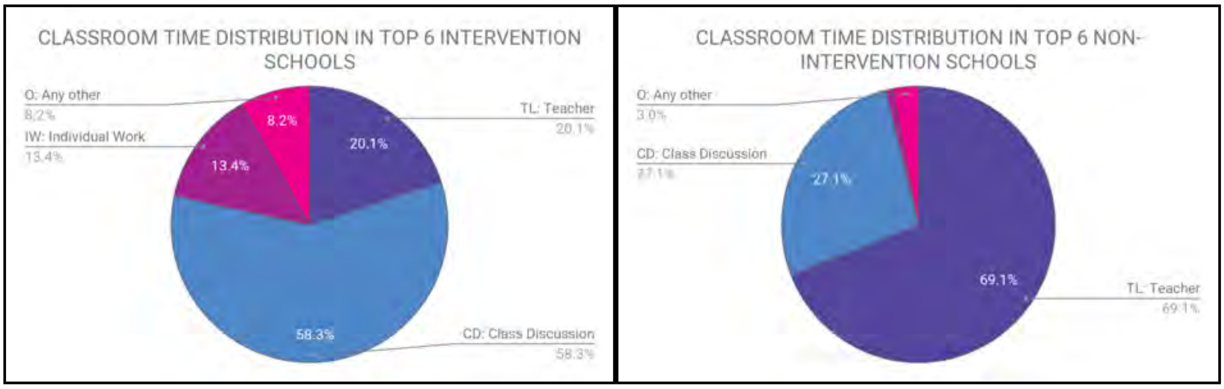


Figure 3.16. Comparison of class time distribution for different activities

Data from the 'Student Action Tally Tool' provided more detailed insights on what exactly was happening differently in the intervention classrooms as compared to the non-intervention ones. The table 3.4 below presents the consolidated student data from the tallies of the top 6 intervention and top 6 non-intervention schools.

[8] 2 observations from each of the 6 Intervention schools

[9] This number excludes the lab observations

Table 3.4. Student behavior data from top 6 intervention and top 6 non-intervention schools

Student (S) action		Average (total) number of instances observed	
		Intervention	Non-intervention
# Times any S[10] expresses DOUBT	Boys	4	0
	Girls	3	2
# Times any S asks a QUESTION	Boys	4	0
	Girls	4	0
# Times any S gives REASONING for OWN Response	Boys	30	5
	Girls	30	3
# Times S gives REASONING to support/challenge PEER/ T[11]	Boys	8	0
	Girls	9	0
# DISTINCT S who give SHORT ANSWERS/ RESPONSES	Boys	57	38
	Girls	54	41
# DISTINCT S who give EXTENDED RESPONSES/ ANSWERS (with Reasoning)	Boys	22	3
	Girls	25	2

As visible from this table, there are striking differences in some of the key learning-behaviour indicators for students. A few of these are discussed in brief:

- Student Engagement and Interaction: Girls gave short answers in the intervention classrooms approximately 1.2 times more those in the non-intervention ones. For boys, it was 1.5 times more in intervention classrooms. When considering students' extended responses with reasoning, the difference is even more pronounced – only 3 boys and 2 girls in the entire set of observations in the non-intervention school gave an extended response in class, as compared to 22 boys and 25 girls in the Intervention schools. This demonstrates a higher level of interaction and engagement on part of the students.
- Engaging in 'Math Talk': The comparative data on students giving extended responses with reasoning also shows a much higher number of instances of Math Talk in the intervention classrooms. Also, there were 60 times that a student was observed to provide reasoning along with his or her own answer, as compared to a total of just 8 times during the entire observation period in the non-intervention classrooms.

The tally tool also captured data on teacher actions during the lesson, and the consolidated data from the intervention and non-intervention classrooms is shown in table 3.5.

10S= Student
11T= Teacher

Table 3.5. Teachers' behavior data from the top 6 intervention and top 6 non-intervention schools

Teacher (T) actions		Average number of instances observed	
		Intervention	Non-intervention
# Times T asks S for REASONING/ EXPLANATION after response	For Correct	60	1
	For Incorrect	16	0
# Times T herself PROVIDES ANSWER or EXPLANATION to question		33	28
# Times T IGNORES S question or incorrect response		5	2
# Times T shows an UNFAVOURABLE REACTION to S question or incorrect response		2	2
# Times T BUILDS ON S INCORRECT (or partially correct) response to move lesson forward		17	2
# Times T PRAISES OR ACKNOWLEDGES VALUE of S question or incorrect response		4	0

The data shows a clearly discernible difference in the teachers' actions between the intervention and non-intervention classrooms. These are discussed in light of our specific research questions:

- Encouraging peer discussion and 'math talk' amongst students: In the intervention schools, the teachers were observed asking students for justification after a response 76 times, as compared to just one time in the non-intervention schools. An important observation is that intervention school teachers did this for both correct and incorrect responses. This evidences the change teachers were trying to bring into their practice by encouraging more student 'Math Talk'.
- Ensuring a safe space [12]for students to make mistakes and learn: The intervention teachers were also seen on 17 instances to move the lesson forward by building on incorrect responses, as compared to just 2 times in the non-intervention group. This shows that intervention school teachers recognized incorrect responses as good learning opportunities, a central tenet of the CLIx pedagogy, and tried to implement the same in their classrooms. This is also borne out by the fact that in the intervention classrooms, there were 17 instances where a student (8 boys, 9 girls) responded to or challenged a mathematical idea presented by another student or the teacher, while there was not a single such instance seen in the non-intervention classrooms.

Although the teachers in the intervention group asked students more frequently to articulate their reasoning, they often ended up answering their own question or providing the reasoning themselves, because many students were still reluctant to open up and speak in front of the class.

The observations of the intervention schools also indicated that apart from learning gains and a

12It is important to state that while the comparison presented here is from the classroom sessions, it was the CLIx lab sessions and the digital activities there that highlighted the 'safe space' aspect the most. We do not discuss that in detail here since the focus was on looking at the intervention and non-intervention classrooms in a comparative sense.

positive effect on the students' mathematical discourse, some non-cognitive and affective changes were also visible, though they were not systematically studied.

- Increased confidence, interest, and motivation to learn the subject – The students were seen to engage deeply in the mathematical tasks in the module, both digital activities and classroom discussions. In several schools teachers reported higher engagement & increased confidence levels – especially amongst girls, and in previously under-confident students, including students who were repeating class 9.
- Enhanced collaboration skills and teamwork, initiative and autonomy – The students were seen discussing, debating and collaborating actively - especially while playing the game Police Quad. The design element of having 2-3 students playing the game at one terminal helped generate more discussion and debate, at least in most cases.
- Enhanced skill and confidence in handling computers – Many of the students had never seen or used a computer prior to the study. They had not even gone through the CLIx module on digital literacy (i2c). But at the end of a month, in most of the intervention schools, students were not only operating the machines confidently, but also able to handle and troubleshoot minor issues independently.

3.5 Discussion

The study shows a significantly greater gain in students' geometric reasoning in the intervention schools when compared with students' gains in non-intervention schools. Cognitive gains like development of the concept of shape, properties of plane shapes, and hierarchical class relationships were reflected in the improvement in post-test MCQ items for schools in which there has been a reasonable extent of implementation and maintenance of fidelity. These schools also show that students' responded to open-ended questions, reflecting their facility with mathematical terms and discourse. However, beyond students' development of concepts, an important outcome of the study was that the module activities, as well as teachers' actions, supported behaviours for engagement in the mathematical processes of reasoning. The digital and hands-on activities of the module helped to elicit students' expression of ideas which otherwise remain hidden in the normal classroom setting where repeating known procedures and definitions is common practice. The processes of communicating mathematics through reasoning and justification were evidenced in classroom observations as students discussed concepts with peers or responded to teachers questions. Figure 3.17 shows one of the teachers leading a classroom discussion on properties of different classes of quadrilaterals.

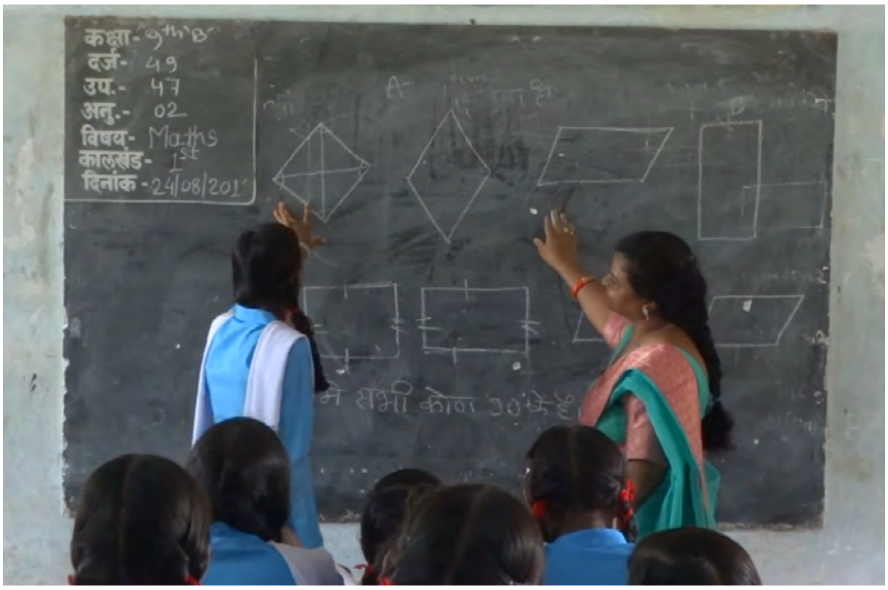


Figure 3.17.Snapshot of a classroom discussion

The students gained most when teachers were able to develop practices to support discussion in the classroom and were able to build on students ideas by giving counterexamples or encouraging them to reason. Although teacher learning was not the primary focus of the study, teachers did demonstrate increased content knowledge, ICT knowledge, and understanding of activities or practices to support students' reasoning. This was challenging for some teachers and took considerable time for them to develop the strong content knowledge required to implement practices related to pedagogical pillars, such as collaborative learning. Teachers learnt these strategies by using the modules with their students and by receiving feedback on their implementation from the math team. Although this mode of professional development requires human resources in classroom, thus presenting challenges for scaling, it is important to support teachers' efforts to explore alternative practices for teaching mathematics.

3.6 Limitations of the Study

Limitations due to technical issues, such as interruptions in power supply, created difficulty in scheduling time in the computer lab in the proper sequence. Additionally, computers with low RAM created problems when using software requiring high RAM such as Turtle LOGO, which led to deviation in recommended module flow. Non-technical issues, such as holidays, school celebrations, and school closures due to heavy rains also delayed the lesson sequence and led to challenges in completion of the module.

Classroom observations could not be conducted in equal numbers across all of the intervention schools. This occurred because each teacher or school differed in responsiveness and motivation toward module implementation. Additionally systemic issues like other school responsibilities or labs located far from schools prevented some schools from regular module implementation. Despite the team's best efforts, the 'dosage' of inputs for support and feedback was not equivalent across intervention school teachers as it depended on the amount of free time a teacher had to engage in discussion with the math team.

The free-write and the tally observation tools provided only data that researchers could attend to and record during the classroom observations, thus leaving the scope for missing data within the corpus of classroom observation data.

Lastly, there was potential for a difference in the amount of time students engaged in the module in intervention schools versus the students who studied using textbooks in non-intervention schools. Teachers in intervention schools implemented the module over 4 weeks whereas those in the non-intervention schools taught the information in approximately 2 ½ weeks. However, one needs to take into account that if intervention school teachers taught using the module every day, student batching (needed to accomodate students in smaller labs) may have reduced the amount of time individual students were engaged in the module. This would make time exposed to the information fairly equivalent between intervention and non-intervention school students. One could also argue that intervention school students, although exposed for the same total amount of time, were engaged in the module and the information over a longer period of time, e.g., every other day instead of every day, and thus they would have had more time to practice and reflect on their learning. Further analysis of the data could investigate the effects of spacing module engagement over a longer period of time on students' learning. Nonetheless, findings indicating that lower fidelity and extent of implementation produced poorer outcomes in some of the intervention schools suggest that these variables may affect learning outcomes as much as spacing of instruction.

3.7 The way forward

The data obtained and analysed in this study from students' pre-tests, post-tests, and class observations suggest that the combination of new pedagogy used by teachers as well as students' engagement in the modules resulted in positive differences in student's understanding. However, further analysis is required based on platform data to triangulate the nature and extent of students' engagement with the module. The students' interviews and focus group data are currently being analysed to identify parameters that reflect the nature of students' understanding before and after engagement in the module. The classroom data is also being further analysed to identify the challenges faced and learning experienced by teachers when adopting new practices and developing subject matter as well as pedagogical content knowledge

4.0 Basic Astronomy Module - Rajasthan

4.1 Background

Basic astronomy is a part of most high school curricula. It includes an introduction to the solar system and explanation of easily observable astronomical phenomena, such as the occurrence of phases of moon, eclipses and seasons. Research in science education shows that many students come to the classroom with alternate conceptions about the earth and astronomical phenomena (Vosniadou & Brewer, 1992, 1994; Padalkar & Ramadas, 2008). Representations such as visual images (photos, diagrams and digital animations), handling of concrete models, gestures, and bodily actions can play an important role in pedagogies to teach spatial thinking. Padalkar and Ramadas (2008, 2011) proposed a pedagogy which used a sequence of concrete models, gestures & actions and diagrams. We selected and appropriated some activities of the pedagogy proposed by Padalkar and Ramadas and combined with digital activities to design the CLIx Basic Astronomy module to teach astronomy to high-school students.

The Basic Astronomy module was chosen for this learning outcomes study because it contains digital activities that were designed in-house, it maps well with the astronomy material currently used in schools, and the science team (researchers) had expertise to support module implementation.

The research questions specific to this study were:

1. Does student engagement with the Basic Astronomy module decrease common misconceptions about astronomy?
2. Do students find the module interesting and relevant to their daily lives? Do they connect astronomy to their observations outside of school?
3. What kind of support do teachers need to implement the Basic Astronomy module with fidelity to the intended design?

In this sections that follow, we describe the participants, materials and tools, procedure, findings, and limitations of this study. Although the overall process of module development and implementation followed a design based research methodology, a quasi-experimental design was adopted for this particular study of module efficacy.

4.2 Methods

4.2.1 Participants

Initially, thirteen schools were selected in the Jaipur district, and school science teachers were brought together for a meeting where they were oriented about the Basic Astronomy Module and the study. Based on their interest and availability during the study period, seven teachers (4 females, 3 males) chose to participate in the study. The classes corresponding to the participating teachers then became the intervention group sample. A total of 169 students provided data for analysis in the intervention group, 69 boys and 100 girls.

Non-intervention schools were selected by matching the number of students with those in intervention schools, so that class strength was comparable. Additionally, the socio-economic background of students in the two groups was matched as closely as possible using DISE (District Information System for Education) data. Using these criteria, seven schools were selected for the non-intervention group. There were also 4 female teachers and 3 male teachers in this group. A total of 118 students provided data for analysis in the non-intervention group, of which 39 students were boys and 79 girls.

4.2.2 Materials and Tools

4.2.2.1 Basic Astronomy module

The Basic Astronomy module contains twelve lessons divided into three units (see figure 4.1). The third lesson of each unit is a digital lesson in which students directly interact with computers. The remainder of the lessons are to be conducted in the classroom by the teacher. See Appendix C.1 for objectives and key design aspects of the Basic Astronomy module.

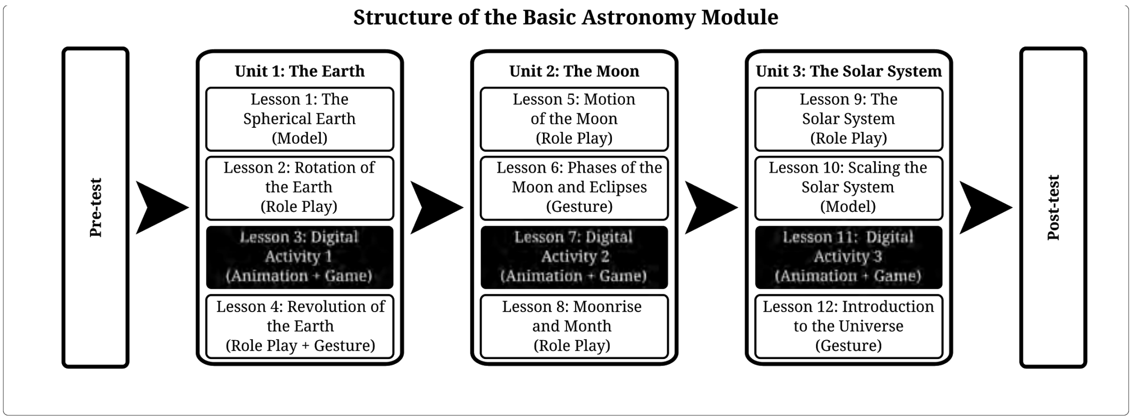


Figure 4.1. Structure of the Basic Astronomy module

Figure 4.2 and 4.3 shows students interacting with the digital activity in the module.

Figure 4.2 Students exploring the digital activity in Basic astronomy module

Figure 4.3: Teacher supporting the student to engage with Basic Astronomy Module

The number of activities focused on different kinds of spatial representations in each unit is shown in Table 4.1.

Table 4.1. Number of activities focused on different kinds of spatial representations

Unit No.	Concrete Models	Gestures	Role plays	Diagrams (given + asked to draw)	Photos	Videos
1	3	2	5	17 + 7	0	0
2	1	1	5	11+6	8	0
3	1	1	1	3+1	23	2
Total	5	4	11	61+14	31	2

An example of a concrete model used in the module is a geosynchron, a globe attached to a stand such that its axis is parallel to the actual axis of the earth (pointing towards Pole Star). An example of a gesture used in the module is the right-hand thumb rule, used to determine the direction of the rotation of the earth and to track the path of the sun in different seasons. An example of role play is mimicking the motion of the moon to understand why we see only one face of the moon like in Figure 4.4 (and motions of other celestial bodies to explain particular phenomena).

Figure 4.4. Teacher engaging students in role play activity for Basic Astronomy module

When designing digital content, Mayer's multimedia principles (2014) were used to guide our design. All digital lessons involve watching animations followed by a sequence of a digital game called AstRoamer. The pedagogical principles of collaborative learning, authentic learning, and learning from mistakes as discussed in section 1.4.2 were embedded in the module activities by asking students to answer alternately, relating timing of festival with phases of moon allowing trials in the game, and giving case specific feedback. More specific details related to the digital activities are shown in Table 4.2.

Table 4.2. Content of the digital lessons

Unit No.	Lesson No.	Part 1: Animation	No. of Animations	Part 2: Game	Astronomy Concept	No. of demos + No. of clues
1	3	Rotation of the earth	4	AstRoamer: What's the time	Rotation of the Earth and time of the day	1 + 7
2	7	Motion of the moon	3	AstRoamer: Moon Track	Phases of the moon	1 + 7
3	11	Solar System	4	AstRoamer: Planet Trek	Characteristics of planets	0 + 10

4.2.2.2 Pre and post-test

For this study, the module pre-test was revised from a previously administered version. The revised version consisted of 27 questions. Of the first 20 questions, 19 were multiple choice and one question required students to draw a diagram. These questions were based on content related to each unit of the module, assessing students' observations, as well as their conceptual and cultural knowledge. Five of the 27 questions asked about students' attitudes towards science and astronomy. The remaining two questions asked about students' beliefs regarding astronomy.

The revised pre-test was piloted in Hindi with grade 9 students (5 girls and 6 boys) from a Hindi medium school in a sub-urban area of Mumbai. The 9 students had similar socio-economic backgrounds too the target students in Jaipur district of Rajasthan. Minor changes in the formats and phrasing of the questions were made following the pilot study (See Appendix C.2). The pre and post-test were not identical but were equivalent; the post-test contained 5 extra questions on the content which was not taught in earlier grades but was covered in the grade 9 textbook and in the module (See Appendix C.3). Time allotted to students to attempt both the pre and post-test was 40 minutes.

4.2.2.3 Student workbooks

Several questions in the module required students to respond by drawing a diagram. Each student received a copy of a student workbook for this purpose. Teachers were told to encourage students to draw what they understood rather than copying diagrams from the board.

4.2.2.4 Teachers materials

A handbook was developed for teachers to further their understanding of the content and pedagogy necessary for successful module implementation. In addition, a survey was designed for teachers (Appendix F). Teachers were also encouraged to attempt the student pre-test so they were familiar with the questions. This provided teachers an opportunity to realize their own misconceptions prior to module implementation with their students.

4.2.2.5 Classroom observation tool

The classroom observation tool was a series of running notes (with time recorded) throughout the entire class period. The notes recorded as much as possible about the classroom transactions, but special attention was focused on the following teacher and student behaviors: 1) Number of questions asked and their type (Rhetorical / Yes/No/ Open ended); 2) Use of diagrams; 3) Use of gestures; 4) Use of role play; 5) Use of concrete models; 6) Use of analogies to explain something; 7) Instances of collaboration between students; 8) Instances in which teacher gave examples relevant to students' lives (authentic learning); and 9) Instances in which teachers used students' mistake as an opportunity to learn from them (learning from mistakes).A summary of the notes was documented after every observation. Figure 4.5 shows a teacher using diagrams on board to teach Astronomy.

Figure 4.5: A teacher teaching astronomy using diagrams

4.2.3 Procedure

For intervention schools, the study procedure included conducting a teachers' workshop, administering the pre-test, observing classrooms during implementation, and administering the post-test. The procedure was similar for non-intervention schools except that teachers did not attend a workshop, and they taught the astronomy material using their regular textbook. The procedure for both groups is summarized in table 4.3.

Table 4.3. Study activities in intervention and non-intervention schools

<table>
<tr><th colspan="2">Intervention schools</th><th>Non-intervention schools</th></tr>
<tr><td colspan="2">Teachers attended the first face to face workshop</td><td>NA</td></tr>
<tr><td colspan="2">Pre-test (on 21 August 2018)</td><td>Pre-test</td></tr>
<tr><td>Teachers taught half of the Basic Astronomy module (6 lessons)</td><td rowspan="3">* Total number of working days between pre and post-test (excluding the days of workshop) were 11 or 12 (typically included 12 lessons).
* 5 or 6 (average 5.5)classes were observed by science team member
* Observed classes and teacher interviews were audio recorded</td><td rowspan="3">* Teachers taught and students learned the information through their regular method (without ICT).
* Two classes were observed by CLIx team member</td></tr>
<tr><td>Second face to face workshop for teachers was scheduled on 7th working day.</td></tr>
<tr><td>Teachers taught remaining half of the module (6 lessons)</td></tr>
<tr><td colspan="2">Post-test</td><td>Post-test</td></tr>
</table>

4.2.3.1 Teachers' workshops and support

Teachers from intervention schools received a printed copy of the teachers handbook for the module three weeks prior to implementation, along with a printed copy of the module. They attended two workshops--one prior to the beginning of the study and another in the middle of the study period. Researchers also engaged in discussions with teachers before and after observation sessions and on phone.

The two workshops allowed opportunity for teachers to engage with content, ask doubts, express opinions, and develop a deeper understanding of the purpose of the module. The second workshop was held 7 days following the first workshop, after teachers had tried out the first unit. Six teachers attended this workshop. The results of the pre-test were shared with the teachers (without mentioning school names) to discuss the common misconceptions present among the students. This was followed by teachers' engagement in an activity from the second unit of the module.

The teachers were given continued support for both content and pedagogy during module implementation. After a class observation, researchers often praised teachers for achievements such as meaningfully engaging students in an activity. Researchers also pointed out if teachers made mistakes related to content, if they skipped activities, and if/how the class or a particular activity could be improved. Some teachers began to search for extra information on the Internet or from YouTube videos and then asked researchers questions about it.

4.2.3.2 Pre-test and post-test

Students in the intervention schools completed the pre-test before the implementation of the module in their classes. One CLIx team member was present in each school during pre-testing. Teachers were present at least for some time. Students were assured that this was not an exam, but rather an activity to understand what they know. Students were told to draw stick figures for the diagram question in the test. They were able to complete the tests in 40 minutes. The post-test was administered at the conclusion of the study. In the non-intervention schools, the pre and post-tests were administered at the beginning and end of their astronomy chapter.

4.2.3.3 Classroom observations

The module included 12 lessons by design. In the intervention schools, 5-6 class sessions were observed in each school by a member of the science team. Two class sessions from each non-intervention school were also observed. During the class observations, an audio recorder or a mobile phone was kept on a table near the teacher to record the sessions. Important activities were video recorded or photographed using a mobile phone.

The intervention school teachers did not start to implement the module until the researchers visited the school for the first observation, and initially they did not teach the module unless the researcher was present. All intervention school teachers asked the researchers to take the first class to demonstrate how the module should be implemented in the classroom. The researchers directly engaged with the class during the initial module session. The second class was taught by a researcher and teacher together; the lead role varied from teacher to teacher. By the third class, most of the teachers were taking the classes independently, although some of them continued to discuss content or pedagogy with the researchers during the class when necessary.

4.3 Findings

4.3.1 Pre and post-test - quantitative analysis

All scores in the pre and post-tests were converted into percentages for comparison since the maximum possible scores were different. The question that required the diagram response was not included in this analysis. An independent t-test indicated that the difference between pre-test scores for the intervention schools and non-intervention schools was not statistically significant ($p=.88$). This indicated that the intervention and the non-intervention groups were equivalent in their understanding of basic astronomy concepts prior to the intervention.

A dependent t-test conducted to analyse the difference between students' pre and post-test scores showed that the scores of the students from intervention school improved significantly after the intervention ($p<.001$), whereas pre-post scores from those in the non-intervention group did not improve significantly ($p=.10$). In addition, there was a significant difference between post-test scores of intervention and non-intervention groups, as well as a significant difference in improvement (pre- to post-test gain) between intervention and non-intervention groups ($p<.001$). Note however, that in the intervention group, the post-test score is slightly less than 47% so there was scope for improvement. Figure 4.6 illustrates the mean pre and post-test scores for students in the intervention and non-intervention schools.

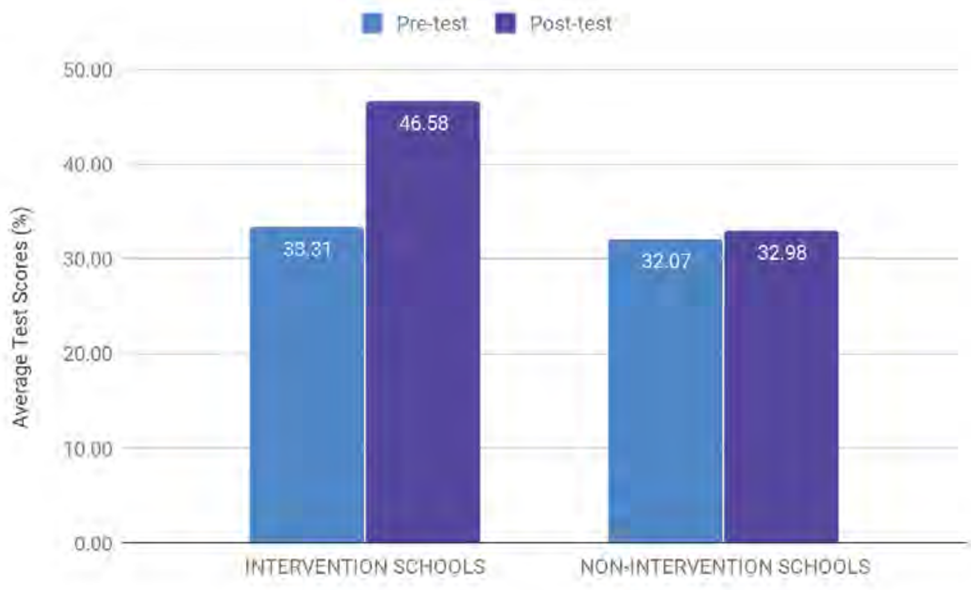


Figure 4.6. Comparison (%) between intervention and non-intervention scores

For the intervention group, the average percentage of the pre and post-tests for each school is provided in table 4.4 and that for the non-intervention group is provided in table 4.5. As seen in both tables, the average percentage of both groups for the pre-test was very low, 33.31% and 32.07%. This suggests that students had very little knowledge in the subject of astronomy at the beginning of the study.

Table 4.4. Means and significance of pre-post gain for intervention schools

Name of the school	Average % score on pre-test (S.D)	Average % score on post-test (S.D)	Effect size (* difference significant at 1% level of confidence)
School SIS01	27.50 (8.45)	36.67 (12.29)	0.82*
School SIS02	42.79 (11.36)	74.00 (6.17)	1.73*
School SIS03	30.74 (12.01)	38.12 (11.95)	0.60*
School SIS04	33.75 (11.11)	40.43 (10.80)	0.59
School SIS05	32.5 (11.73)	46.91 (12.60)	1.04*
School SIS06	27.92 (14.21)	37.17 (11.03)	0.70*
School SIS07	33.89 (13.41)	38.22 (10.22)	0.38
All school together	33.31 (12.71)	46.58 (17.63)	0.79*

Table 4.5. Means and practical significance of pre-post gain for non-intervention schools

Name of the school	Average % score on pre-test (S.D.)	Average % score on post-test (S.D.)	Effect size (* difference significant at 1% level of confidence)
School SNIS01	30.65 (7.28)	29.91 (8.17)	-0.10
School SNIS02	32.33 (10.67)	33.33 (9.52)	0.14
School SNIS03	33.21 (9.32)	34 (7.65)	0.10
School SNIS04	32.24 (11.69)	36 (10.47)	0.34
School SNIS05	33.33 (9.85)	30.33 (7.13)	-0.36
School SNIS06	24.67 (5.50)	35.73 (9.25)	1.20*
School SNIS07	39.33 (11.00)	29.87 (11.10)	-0.81
All school together	32.07	32.98	0.09

Figure 4.7 shows the gains of the intervention and non-intervention schools in ascending order. It clearly shows the absolute gain scores (post-test minus pre-test) of most non-intervention schools are less than that of intervention schools with exception of one non-intervention school, SNIS-06.

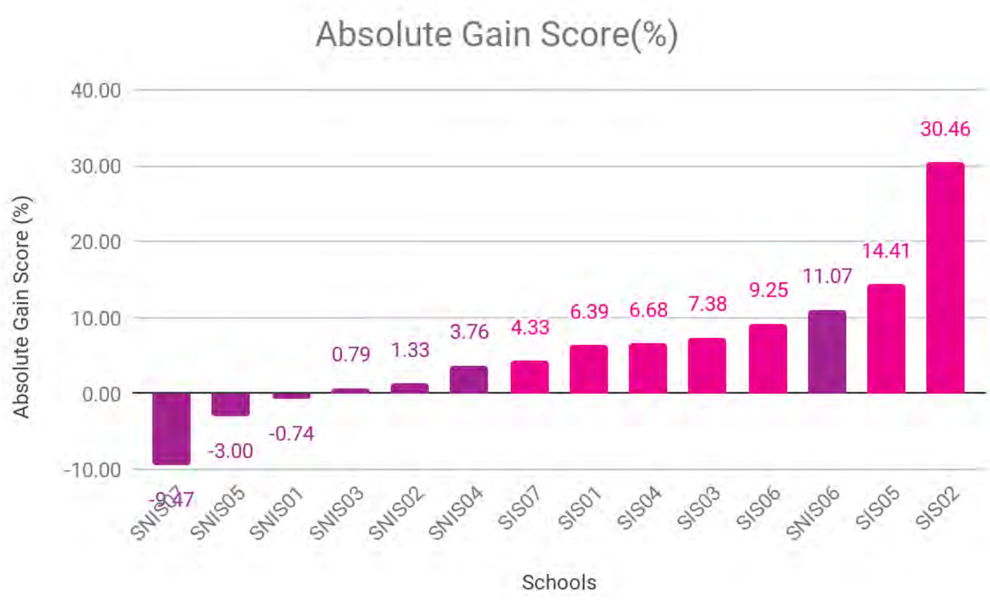


Figure 4.7. Absolute gain scores of science intervention (SIN) schools and science non-intervention (SNIS) schools arranged in ascending order

4.3.2 Pre- and post-test - qualitative analysis

This subsection delves more deeply into students' responses to astronomy content questions, attitudinal questions, and belief questions. We hypothesized that the Basic Astronomy module would lead to positive changes in all three areas.

4.3.2.1 Astronomy concepts

Change in the percentage of students who gave correct responses in intervention and non-intervention groups is plotted in figures 4.8. Students' average scores improved on 13 test items in the intervention group, and average scores improved for 11 test items in the non-intervention group.

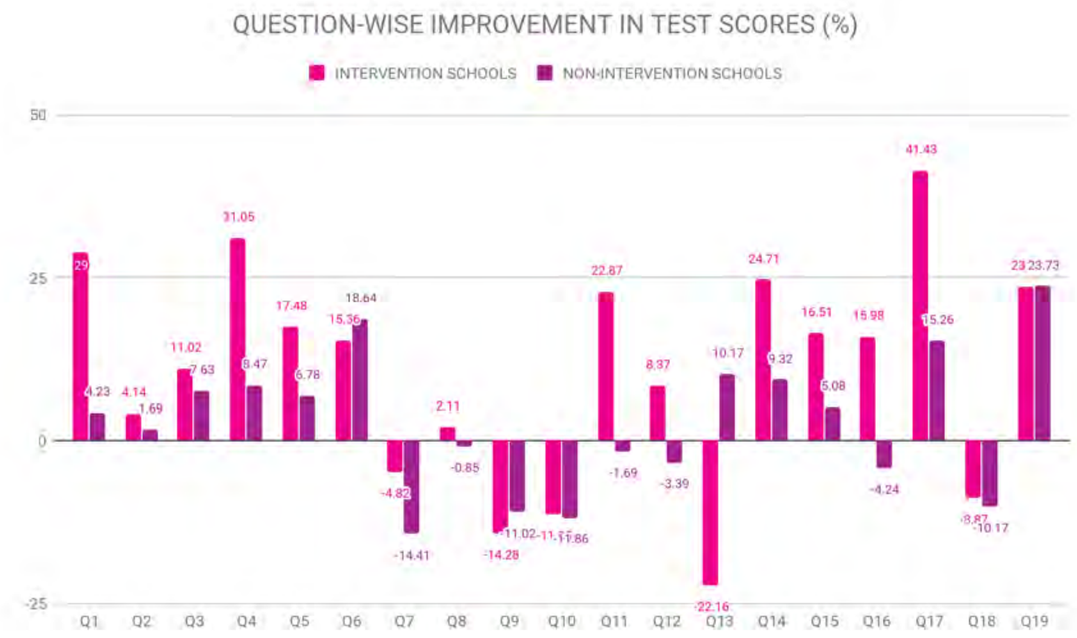


Figure 4.8. Question wise improvement in the intervention group vs non-intervention group

Analysis of improvement question by question unearthed some of the most common misconceptions that surfaced in the pre-test among the intervention group, revealing how they changed after intervention (See Appendix C.4 for the change in percentage of correct answers and popular correct answers). On seven questions, less than 20% percent of students gave correct answers initially, but this result improved significantly after the intervention. Three other questions showed major improvement by the post-test, although the percentage of students who gave correct answers was not too low to begin with. It should be noted that out of 10 questions on which students improved significantly, 6 questions required visuospatial reasoning or spatial understanding. The concepts evaluated in these questions were taught using role-play, diagrams and digital activities.

There were also questions for which student improvement was not significant. Most students did not know that Saturn (and Mars in post-test) can be seen by naked eyes (28% gave correct answer in the pre-test) and there was not much improvement in the post-test (38%). Similarly, in the pre-test only 24% of the students knew that the asteroid belt is situated between Mars and Jupiter and this percentage did not improve much in post-test (32%).

Finally, students regressed on 5 questions, meaning that a higher percentage of students answered the question correctly in the pre-test than in the post-test. In the pre-test, more than 50% of the students gave correct answers to four of these questions and 39% of the students gave the correct answer for one question. Thus, a good number of students already knew the correct answer for questions on which students regressed. Two of these questions were about observations like the direction of moonrise and moonset, and about a gibbous moon as a phase.The possible reason for regression on these questions might be that the module did not include explicit instructions on these particular observations, which was one of the major shortcoming of the module. Also, from our earlier experience we know that incorporating observations is difficult and activities based on them tend to fail in implementation.

The other two questions for which students performed poorly in the the post-test were related to indigenous knowledge. Most importantly, the digital activities in the module included questions that were related to the post-test questions, so students had been exposed to this information. The last question on which students regressed after engaging with the Basic Astronomy module was information based. The questions on which each of the groups regressed are plotted in a Venn diagram in figure 4.9).

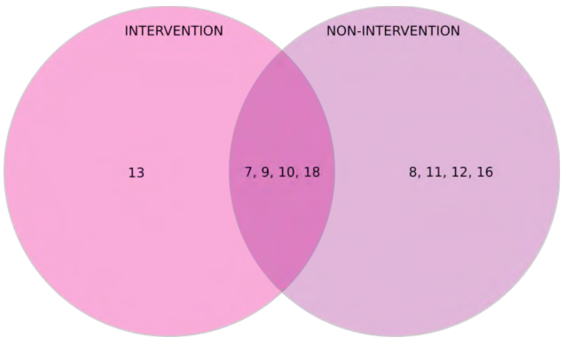


Figure 4.9. Questions on which students regressed in intervention group (set Int), non-intervention group (set N-Int) and in both groups (Int ∩ N-Int).

Out of 6 questions related to the moon, both intervention and non-intervention groups regressed on 2 questions--both were related to observations. Overall, students regressed on 4 out of 6 questions related to moon which shows that this was one of the more difficult areas. We surmised that students did not get enough input even through the module.

4.3.2.2 Attitudes toward astronomy

Out of five questions related to students’ attitude towards general science and astronomy, four questions were answered on a Likert scale with response options ranging from 1 to 4 (See Appendix C.5) while one was answered by checking boxes for each option chosen (See Appendix

C.6). A single score was calculated by adding the value of students' responses to the questions on the Likert scale to the number of check-boxes they ticked for astronomy topics that interested them. The maximum possible score for attitudinal questions was 28.

For the intervention group, the average score for attitudinal questions in pre-test was 18.45 (SD = 5.09). Thus, students showed good attitudes towards science and astronomy in the pre-test, which increased to 19.47 (SD = 4.61) in the post-test. Analysis using a t-test showed that the mean difference in pre- to post-test scores was statistically significant (p = .02), although the effect size of .21 is considered to be low.

For the non-intervention group, the average pre-test score for the attitudinal questions was 17.79 (SD = 4.13) which was not statistically different from that of the intervention group's average pre-test score (p = .23). However, the average score dropped significantly to 16.63 (SD = 4.06) for the non-intervention group in the post-test (p=.002) and the difference between the intervention and non-intervention group's post-test score was also significant (p<.001). These results suggest that the Basic Astronomy module helped to improve students' interest and attitudes towards science and astronomy whereas the regular teaching in the non-intervention schools decreased students' interest and attitudes towards science and astronomy. The average scores on attitudinal questions of the intervention and the non-intervention group on pre and post-tests are plotted in figure 4.10.

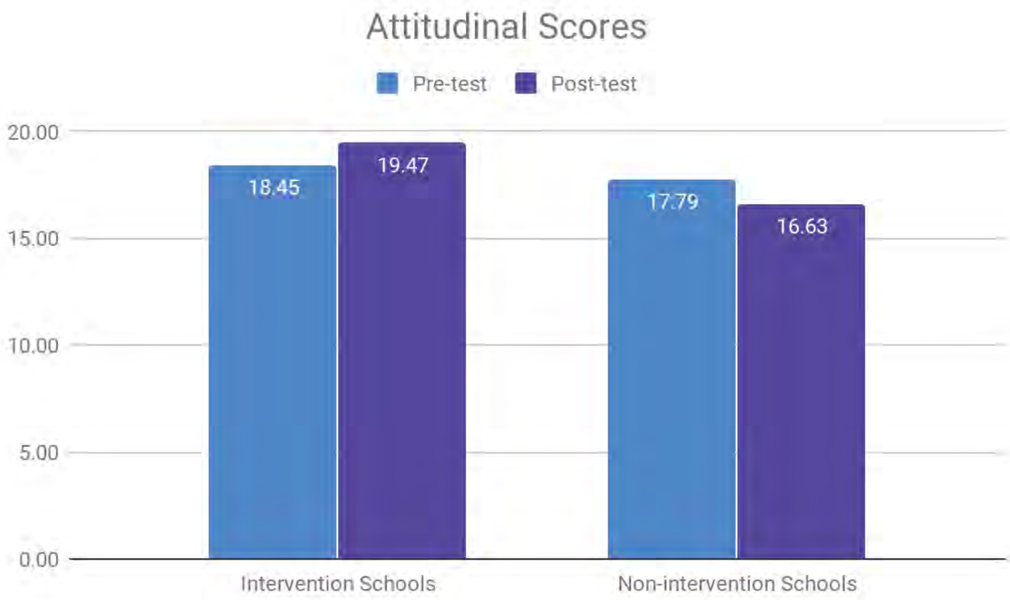


Figure 4.10 Average scores on attitudinal questions of the intervention and the non-intervention group on pre and post-tests

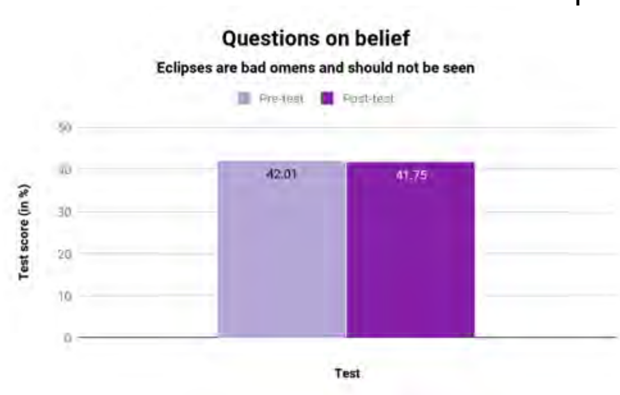
4.3.2.3 Beliefs

The module connects indigenous knowledge to observational astronomy wherever possible so that textbook knowledge does not remain disconnected to students cultural lives. Many of the terms which are used in indigenous astronomy are common in astrology as well. By explaining these terms we hoped that the mysterious aura around them will be reduced and students will be able to think rationally about them. The module contained several explicit questions and discussions around this.

Analysis of students' responses to pre and post-test questions showed that the module was not successful in changing the students deeply held belief that planets can influence our life in a supernatural way. The same thing can be seen in another question in 'Kha' category, where we asked about eclipses and shooting stars and superstitions related to them. Students' responses to that question also showed that their beliefs did not change.

Figure 4.11 shows the change in percentage of students who believed in astronomy related superstitions and figure 4.8 shows the change in percentage of students who believed in astrology.

Intervention schools	Non-intervention schools



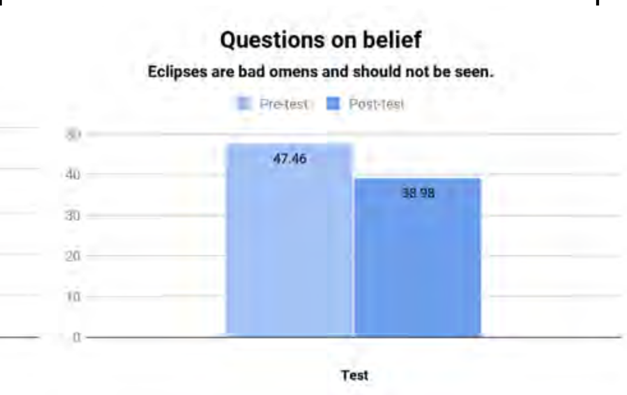
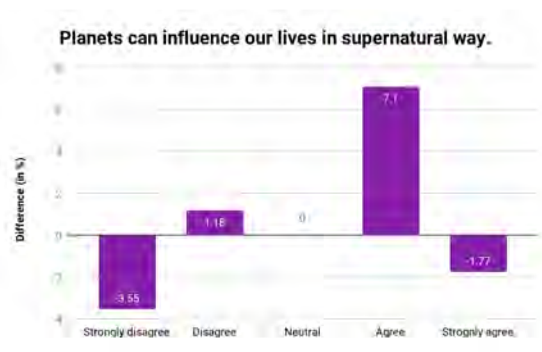


Figure 4.11. Percentage of students who held astronomy related superstitions (pre-test: Eclipses are bad omens and should not be seen; post-test: If you make a wish while watching a shooting star it comes true).

Intervention schools



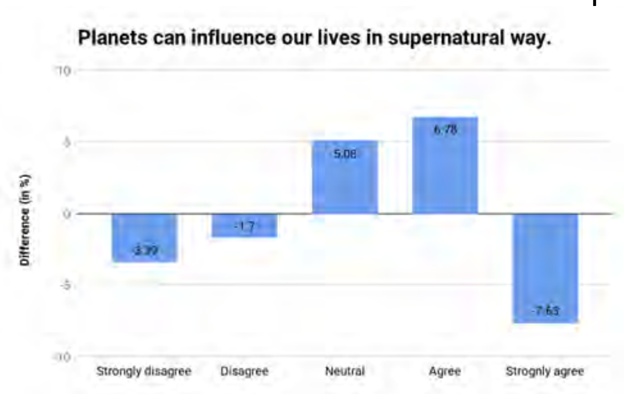


Figure 4.12. Change in percentage of students who believed that 'planets can influence our lives in supernatural way' from pre-test to post-test

4.4 Discussion

Our data analysis showed that student engagement in the Basic Astronomy module resulted in significant improvements in students' understanding of astronomy, when compared to students who learned the material in the usual way, which did not lead to significant improvement. Students from intervention schools showed improvement in questions that required visuospatial reasoning or spatial understanding in particular, and those were skills for which the related concepts were taught using role-play, diagrams and digital activities. However, even after the intervention, the average post-test scores remained less than 47% which shows only some success of the module in the field. It is premature to attribute this extent of student learning solely to the module since there were other factors such as lack of teachers' content knowledge and unfamiliarity with the pedagogy required by the module.

The post-test results showed that students' interests and attitudes towards science improved after engaging with the Basic Astronomy module, as opposed to their peers in non-intervention schools who indicated decreased interest and attitudes towards science on the post-test. However, students' beliefs related to astrology and astronomy-related superstitions did not change after engaging with the module. One possible reason for this result could be that the teachers themselves believed in astrology and hence did not challenge those ideas if students mentioned them in class. We observed several examples in which teachers suggested the astrological significance of astronomy. Moreover, these beliefs often tend to be part of an overarching belief system that includes existence of supernatural entities such as god, soul, heaven, afterlife and so on. Knowledge in one subject such as astronomy is not sufficient to change this entire system. However, we remain optimistic that many such pieces of knowledge (about evolution, diseases, conservation of matter and energy and so on) will help learners to eventually question their entire belief system at some point, and hence, change may occur at a later time.

Although the major focus of this study was on student outcomes, it must be noted that teachers also underwent significant change during the experience. During the first workshop, discussions with teachers from the intervention schools unearthed some of their own misconceptions about content as well as pedagogy. They struggled with the thought of teaching astronomy content to their students. On the one hand, they voiced that the content was elementary, but on the other hand, they also felt that the explanations for phenomena were too detailed for students to understand. This led to transformative discussions about the purpose of learning science, that it is to reason about phenomena rather than to memorize facts about it. When teachers began to engage in some of the module activities, for example, the role play that explains why we see only one face of the moon, they experienced some 'aha' moments, and then articulated that they would try out the module because they thought the activities might be useful for their students' learning.

By the second workshop, the teachers who were skeptical at the beginning expressed that much of their skepticism was unfounded and that this new pedagogy could give unexpected results. For example, one female teacher said (emphasis added):

> *I did not expect that students will respond positively [to change in the pedagogy]... but they respond so well… they showed so much interest.. And the most interesting part is that I*

learnt this [that different pedagogies can be used].

During module implementation, teachers also acknowledged the importance of preparation before class. Much of the content and pedagogy was new to them, and they realized the need to spend extra time preparing to teach. The teachers asked for the printed version of the student module to use for preparation.

Similarly, preparing teachers to implement the module was an intensive process for the research team as well. Two workshops, 5-6 school visits during implementation, and phone calls to encourage, solve queries, and ensure implementation were necessary. Personal bonds developed between researchers and teachers seemed to motivate teachers and gave them confidence to try out new pedagogies. Additional factors that affected module implementation were support by the school principal, smaller class sizes so that classroom and digital activities could be conducted effectively, and a working computer lab with enough number of computers.

4.5 Limitations of the study and future directions

Two of the main limitations of this study were teachers' insufficient content knowledge and their lack of time. Initially, teachers were not aware that they had misconceptions. They realized it just before the implementation began and hence they were under confident in the classroom. As a result, their entire attention was focused on producing correct explanations. Most of them were using the CLIx-recommended pedagogy for the first time. They were also unable to understand the overarching principles (importance of collaboration and context in learning, how students' mistakes can be exploited to engage them in discussion and role of inquiry, visuospatial thinking and multiple external representations in learning science) behind the pedagogy. Hence most teachers had limited success in meaningfully engaging students in activities and guiding students to construct the mental models and finding their own explanations.

Also some of the teachers could not spend sufficient time in preparation and even for the implementation. Many teachers did not implement the module unless the researcher was present for the observations, and then they covered large portions of the module in one session to catch up (sometimes in an extended period). Most of the digital activities were facilitated by CLIx team, so the material taught in the class might have been a bit disconnected from the digital activities.

One of the main limitations of the module is that it does not include any systematic observations. Earlier research has shown that although students are aware of common place phenomena such as phases of moon and seasons, their accurate and quantitative observations are lacking and contrary to common belief, as it is not easy to make these observations (Padalker, 2010; Trundle, Atwood, & Christopher, 2006). The Basic Astronomy module should contain activities that include systematic observations of shadows, stars and the moon. However, during module development, those activities were omitted for two reasons: first, observations are time consuming and the module was already large in terms of its content covered and time required. Second, observations (especially those of the night sky) are difficult to ensure. It is very often cloudy, and certain phases of the moon are not visible until late at night. Moreover, students often forget to observe, and if they do observe, they forget to note it or make mistakes while noting it. Therefore, if we included anything which was dependent on observations, the ease of implementation would have gone down. We did show ‘SkyEye’ app and Stellarium to teachers during the workshop but teachers did not use them during the period of implementation.

Finally, we would like to see the long-term effects of the module on both students and teachers. It would be interesting to know whether students’ retained their new knowledge for any length of time and also whether the teachers use at least some elements of the modules in the next year. It would be wonderful if some of the teachers develop interest in astronomy and some of the students pursue astronomy, or at least science in their later life.

5.0 Findings across the studies

5.1 Learning outcomes identified across sub-studies

This study includes the observation and analysis of students learning from 44 schools (22 intervention and 22 non-intervention) in three different locations in India (Aizawl, Raipur and Jaipur). All schools selected for the study were government schools catering to underserved student populations, some being located in rural areas. The study reflects the potential that CLIx modules have for supporting student learning outcomes of listening and speaking skills in English, understanding about geometrical shapes, and basic astronomy.

All sub-studies indicated that the use of modules contributed to students' learning positively in the intervention schools. In 17 out of 22 intervention schools, students showed a statistically significant gain in scores between the pre and post-test. This indicated that the use of modules and the associated pedagogy supported student learning. These results were obtained even when implementation occured in difficult circumstances--negotiations of teacher time, negotiations for CLIx time in the school time table, limited knowledge of teachers with regard to content, pedagogy and technical skills, technical glitches, physical transfer of students from classroom to lab, management of batches, and lack of lab space to interact with the modules.

Students in some of the non-intervention schools also showed significant gains from pre to post-test when the module subjects were taught in the usual way. Six out of 22 non-intervention schools showed a significant increase in students scores from pre to post-test. However, when independent samples t-tests were conducted to compare students' pre to post-test gains between intervention and non-intervention schools, the results showed that learning gains were significantly greater in intervention schools for listening skills in English as well as understanding of Geometry and Astronomy concepts. These analyses compared the 'absolute gain,' or the difference between starting points and endpoints for students in both schools. In most cases, the non-intervention schools began with higher pre-test scores, which may have given those students an advantage toward greater learning because a higher initial competency can make it easier for students to to learn more. Despite this possible advantage, students in the CLIx intervention schools showed significant learning gains, and those gains were significantly greater than their non-intervention school peers.

The significant learning gains of intervention school students did not mean that their post-test scores were high however. Even after four weeks of intensive intervention, students' average post-test scores only ranged from 43% to 61% indicating that more time and effort is needed for students to fully grasp the concepts and move performance scores into a more acceptable range. It is important to note that the pre-test, observations, and teachers' reports all indicated that many of the students in our intervention group sample did not understand the prerequisite concepts that they should have learnt in earlier grades. They showed low levels of knowledge for topics like properties of lines, angles, and parallel lines in maths, and models of the earth's rotation or revolution in science. It takes considerable time and effort to bring about significant change in knowledge when students have to learn basic prerequisite concepts in order to engage with more advanced tasks. The CLIx modules addressed these basic concepts, but the low post-test scores at the end of the intervention suggest that students still need more opportunities to engage with the modules' active learning and digital tasks to develop a robust understanding.

The overall results indicate that the learning gains were not limited to only cognitive gains. Classroom observations from the English and mathematics studies show that students engaged in behaviours that contributed positively to their learning, like being autonomous, learning collaboratively, asking questions and doubts and trying again when they made mistakes rather than being disheartened or giving up. Students engaged in module tasks that provided the opportunities as well as a safe space to try out their new knowledge or skills. They engaged in tasks like listening to and producing language in the English modules, or justifying their reasons for choices in the Police Quad game within the math module, or visualizing themselves with respect to their location on earth in the astronomy activities. The context of these tasks allowed students to use their knowledge from daily life is an authentic way to further their learning.

5.2 CLIx module design

The three modules in this study--English, Maths and Science--are similar in that they are all supported on the CLIx platform. The platform supports students' login, individually or as part of a group, content delivery, and numerous types of learning activities. The pedagogical pillars are also integral to module design: All modules have tasks that give feedback to students when they make mistakes, encouraging them to try again by allowing multiple chances to improve on a particular task, thus creating a safe space for learning. Modules provide ample opportunities for student collaboration or discussion, inviting them to work together to solve problems, plan strategies, or critique each other's work.

The modules were also designed to build on students' everyday life experience to provide opportunities for authentic learning. The English module focuses on communication skills of students who are learning English as a second language and supports skill development--more specifically speaking and listening--as students create and listen to expressions related to daily life activities. The science astronomy module supports conceptual understanding of basic astronomy concepts, and builds on students' observations of daily phenomena and indigenous knowledge related to different festivals celebrated in relation to lunar and solar phenomena. The mathematics module supports deductive reasoning from given information and identifying the information needed to solve particular problems. This type of thinking is required not only in mathematical procedures but in everyday contexts as well.

The structure and implementation of lessons from the modules differed across the three subjects, as the respective modules are intended to support different learning outcomes. While the English module is completely digital-based and therefore implementation is limited to teacher facilitation within school computer labs, the maths and science modules require teachers to coordinate teaching of the content across two spaces--the computer lab and the classroom. Despite these structural differences, discussion remained an important aspect of module implementation. For some teachers in this study however, the infrastructure constrained the type of interactions that were possible in the computer lab space. It was difficult to do any discussion in many computer labs as there was no board to write on along with other space constraints. In those cases, however, the computer lab often became the space where students took charge of their own learning. The strength of classrooms, or number of students, also became a constraining factor in using the modules because it was not always possible to ensure equal lab time for all students. In these cases the classroom discussions became even more important to resolve issues in student understanding through discussion.

For each of the modules, analysis of data revealed possible areas in which module design could be strengthened. The results from the English speaking test showed that students in the intervention schools scored significantly lower than their counterparts in non-intervention schools, specifically in the areas of accuracy and adequacy of verbal responses to questions. In the current module, students are provided the opportunity to record and listen to their speaking as a means to improvement, but this practice is not required before moving on to the next activity. Because practice is integral to acquisition of speaking skills, future iterations of the module might include ways to motivate students' practice of speaking skills.

Analysis of post-tests from the maths study showed that the concept of unequal lines being parallel was difficult, as students from both intervention as well as non-intervention schools made mistakes, even after teachers in intervention schools had discussed this extensively and after students had seen examples in the module. Students' thinking around this common error needs to be analysed further, and perhaps the concept could be explained explicitly in the module through some tasks.

Preliminary analysis of the math post-test descriptive responses indicate that students were able to use the vocabulary and terms related to geometry to describe and compare shapes. However, a summary of concepts and strategies used by students at each level of the game would further support consolidation of what was learnt in the module. This could be used in classroom discussions to emphasise multiple approaches for problem solving. A summary of types of common errors made by students when playing the Police Quad game may help the teachers in having more focused discussion and a sense of how students are learning through the game.

Results from the astronomy post-test showed that students did not correctly answer questions related to observations of astronomy phenomena. Future iterations of the module could consider ways to incorporate some type of observation experience into the module learning activities. Additional teacher resources may help to develop teachers' content knowledge related to astronomy.

5.3 Fidelity of module implementation

The math team's data analysis suggests that fidelity of module implementation may be one of the most important factors contributing toward students' learning outcomes, and data from all of the classroom observations revealed that this essential element varied widely between teachers. The primary input to ensure fidelity was a workshop conducted with intervention school teachers by the subject teams. The purpose of the workshop was to familiarize teachers with the module that would be used in the study and make sure they understood the purpose of each of the module tasks.

Although there were common themes across the three subjects, there was variation in the duration, mode and workshop design for each subject. In all workshops, the presenters made a concerted effort to discuss the pedagogy to be used with the modules, especially related to the three pedagogical principles of supporting learning from mistakes, collaboration, and authentic learning. The variations in workshop design were driven by the nature of the modules. Because the English module was entirely digital-based and focused on the practices of speaking and listening, the English teacher preparation prior to the study gave particular attention to reviewing the function and facilitation of each module activity. The English team held a one-half day workshop that included role play and vignettes to discuss teacher actions that could support students' engagement in module tasks. As classroom observations were conducted, feedback to teachers revolved around making sure that students completed the various tasks as explicated in the module.

The teacher preparation prior to implementation of the maths module engaged them in exploring the Geometric Reasoning module, along with discussion regarding pedagogies needed for each lesson. The two-day workshop revolved around facilitating student discussion and making their thinking visible. The limitations of teachers' content knowledge and pedagogical content knowledge became evident during the workshop discussions about module tasks. The tasks in the module were able to elicit and challenge students' conceptions but teachers found it challenging to build on them. Following classroom observations, teacher feedback revolved around expanding their knowledge and suggesting strategies for building on students' responses.

The teacher preparation for the Astronomy module implementation revolved around use of novel pedagogies to improve visuospatial thinking. This was new and uncomfortable for the teachers, and engaging them in behaviors such as gestures and role play as learners during the training attempted to lessen some of the discomfort. The science team held two one-day workshops separated by a one week interval so teachers could reflect on their classroom experiences and then discuss them with peers. As the training progressed, it became evident that strengthening teachers' astronomy content knowledge was also an important part of their preparation. This process began during the first training and continued throughout the length of the module implementation.

The subject teams interaction with teachers during classroom implementation varied by subject as well. The math team conducted only after-class discussions with the teachers to encourage fidelity of implementation, whereas the science team used demonstrations in the classrooms to show teachers how a particular pedagogy could be adopted. However, in all the sub-studies we find that some teachers were able to grasp the underlying principles of modules and were able to adapt their pedagogy to support student engagement, while others found it hard to do that. Thus, fidelity of implementation became a function of teachers' receptivity, understanding of the subject matter, pedagogical content knowledge related to anticipating and responding to students' ideas, and their beliefs about using certain pedagogies and digital activities for teaching. Although this report does not discuss these issues in detail, further analysis could explore reasons for the variance noted between teachers' fidelity of implementation in this study.

Another important aspect related to fidelity of the implementation is the frequency and extent of module use by the students. In this report, the module implementation has been discussed only on the basis of classroom or lab observations. However, platform data can elucidate how often and how long students interacted with the modules in intervention schools, and would be helpful for those days when the research team did not conduct classroom observations. Platform data has been procured by all teams and further analysis will help in getting more information about the fidelity of implementation and its correlation with the gains in students' scores.

The earlier noted changes in student performance and behaviour were associated with engagement in the CLIx modules, but the greatest changes occurred when student engagement was further supported via specific pedagogies adopted by teachers in the classroom or computer lab. The math findings showed that schools in which the teacher adhered more closely to intended module implementation resulted in better performance by the students. This underscores the point that implementation should not be considered as just using CLIx modules but that fidelity of implementation is important-- that teachers and the school infrastructure support the pedagogy that has been envisioned for use of module. Quality of teacher facilitation is thus an important aspect that is needed along with the modules to ensure fidelity in implementation.

5.4 Roles that supported the attainment of learning outcomes

The improved learning outcomes for the intervention schools can be attributed to roles played by different stakeholders such as the students, teachers, researchers, principals, technology, and even available infrastructure in the schools.

5.4.1 Role of students

In each of the studies, the students as learners engaged in various tasks. In contrast to traditional teaching where they have to respond to questions based on memorisation of content, the students' engagement in CLIx modules was radically different--these modules required them to think, express their own ideas, and use agency in generating ideas or responding to questions in the module. As shown in the classroom observations, students' adoption of this role as creator of knowledge was initially challenging, and thus more students called out to teachers for help in the beginning of the study. Gradually, they got used to steering their own learning while engaging in the module.

The nature of support required by the students also changed from assistance with technology and formulation of answers to asking teachers about the doubts and difference of opinions within their group. In some schools, a few students became experts in starting the lab sessions and helping other students with login and navigation of the module. The observations indicate that the students engaged deeply and enjoyed learning from them. However, platform data will also provide additional insight into the extent and nature of engagement in the module. Qualitative analysis of classroom or lab engagement may also help to identify what ideas or behaviours were carried over from the digital engagement as well as hands on activities recommended in the module to the whole-class classroom interaction.

5.4.2 Role of the teacher

As mentioned above, teachers played a significant role in ensuring that the classroom implementation of the modules was ideal and sustained. They ensured lab readiness, adjusted their schedule, and worked intensely with students so modules could be implemented smoothly. The teaches diligently implemented changes from feedback provided at workshops and after every observation, and they shared experiences with other teachers through the mobile-based Whatsapp/Telegram group.

Initially the teams faced various forms of resistance regarding the use of modules; teachers thought they were extraneous to the syllabus and did not contribute to students' learning (a common complaint about the CLIx modules in general). However, through deep engagement with the modules during this study, many teachers realised that the learning facilitated by the modules contributed positively to students' skills and understanding, and thus would eventually benefit students. This made them engage with the modules more readily after they saw students engagement and these effects. Teachers also exhibited increased engagement in mobile-based chat groups during the period of the study, sharing events and students' work in the classroom with other teachers and researchers. Their engagement also lead to meaningful discussions about the role of modules tasks in modules for developing students' understanding.

Although the study was not initially intended to be about the teachers' learning, the role they played in module implementation, highlighted its significance. After participating in this study, teachers felt confident in handling the lab and even trying out other digital tools, thus indicating an increase in knowledge and a positive attitude towards use of technology for teaching. The responsive teachers enhanced their pedagogical content knowledge (PCK) through trying out new pedagogies and actively responding to student ideas. A few sought out support proactively, and engaged in deep discussions related to content and pedagogical understanding of content, and started making more frequent use of the internet to find useful resources etc. Some teachers even recognized the value of going beyond the textbooks and the pedagogical pillars supported by the module. It resulted in increased motivation and effort to try out tasks outside the textbook (ICT-based and otherwise, and interactive pedagogies). A few of the teachers acknowledged the need for 'deep understanding' by going beyond the textbook.

Teachers in the intervention schools were interviewed towards the end of the study to get their opinions and views about how participation in the study helped in supporting student learning and their own professional development. Analysis of these interviews for all studies will give insight into the varied aspects that were impacted in the study in the intervention schools.

5.4.3 Role of principals and administrators

Across all studies, the principals' support contributed positively to teachers' implementation of the modules. However, there were some cases in which principals showed no active support for implementation, but strong, motivated teachers were able to lead the implementation efforts. The principals’ support was crucial in changing the time table, allocating more periods for CLIx engagement and allowing flexibility to the teachers and researchers to take batches to the computer lab exclusively for a particular subject. In some schools, teachers were unable to engage properly with teaching using the module as they were directed by the principals to focus on finishing the syllabus first.

5.4.4 Role of researchers

Researchers played the dual role of collecting the data as well as supporting teachers. The research teams helped teachers understand the nuances of the module and its implementation in various ways – through discussions, demonstrations, planning, and sharing ideas. Although the replicability of this aspect of intervention is difficult, it points to the need of having support at the site of practice when trying out innovative pedagogy and materials. It also points to the need for spaces to discuss the events of teaching, as it helps in theory building through the lived experience of teachers. The role played by researchers in this study needs to be taken up by the principals, peer teachers, and teacher educators in the school contexts as well as in the mobile-based community to support teachers in adopting innovative pedagogy and use of ICT based materials.

5.4.5 Role of technology

Technology, in the form of ICT based modules, along with the pedagogy embedded in them shaped the interactions that students had with the content, among students, and even between teachers and students. The technological interface provided by CLIx placed students at the centre of their own learning, creating opportunities for them to make meaning and express those meanings through peer discussions and on the CLIx platform. The recording of students expressions made the students’ thinking visible to the teacher, making it their prerogative to engage with students’ ideas and understanding, which otherwise remain hidden in normal classrooms. Thus, opportunities provided by this technological interface did pave the way for disruptions in traditional classroom interactions by acknowledging students’ ideas in discussions.

5.5 Role of ICT in supporting student learning

The study contributes to our understanding of how materials and modules using ICT can be designed to support learning outcomes like skills, conceptual understanding of subject matter, and even attitudes towards a subject. The study highlights the aspects of design that visualises the role of the students and teachers in a more constructive manner, allowing them the opportunity to express their ideas and discuss with peers in authentic environments. ICT is integrated into the entire English modules to engage students, whereas the blended nature of the math and science modules allow students opportunities to engage in both hands-on as well as digital tasks.

Taken together, the study results suggest that when implemented using student-centered pedagogy, the CLIx modules can help to improve students' learning behaviors as well as their performance. Although there is room for improvement in performance as indicated by the post-test scores, there were significant gains in students’ performance in the intervention schools as compared to non-intervention schools. The use of modules had impact beyond students' learning by providing opportunities for teachers' learning and use of alternative student-centered practices. Thus there is scope for wider impact by disruption in traditional teaching-learning practices to support student-centered pedagogy using CLIx modules as exemplars.

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Appendix list

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Gestures
Communicative
Classroom
Reasoning
Gestures
Classroom talk
Reasoning