SCIENCE TECHNOLOGY ENGINEERING MATHEMATICS (STEM) LAND: FOSTERING RESPONSIBILITY IN LEARNING IN RURAL SCHOOLS

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Is it possible for adolescents to take responsibility for their own learning? How does a free progress system where children make choices about what they want to learn and how (within a given framework) impact this sense of responsibility? Would the need for self-direction result in renewed engagement from children or would it lead to children feeling lost? Would such an environment result only in individualist learning or can interventions based of values support the creation of collaborative learning community with rich peer-to-peer and group learning? This paper offers a case study of a rural STEM center (called STEM land) that attempts to answer these questions with 7th to 9th graders. It examines some of the challenges and interventions that supported the creation of the culture of learning. It offers various examples of learning as a social activity, deep learning, art, reflective spaces as well as academic performance. It also offers an insight into how the essence of this learning culture could be replicated with much younger children from 3rd to 7th grades in a different school.

Context

We are a team of engineers who teach and are presenting our observations in rural STEM centers run in two outreach schools of Auroville – Udavi School and Isai Ambalam School. Both schools aspire towards holistic development of the child and the managements are progressive. The children attending come from villages surrounding Auroville.

Udavi School follows state board syllabus and we work with 47 children from 7th to 9th intensively for 6 hrs/week for all their Mathematics (Math) classes. Isai Ambalam School follows the central board syllabus and we work with 48 children from 3rd to 7th grades intensively for 6 hrs/week during the Environmental Sciences (EVS) and Math classes. In demographics, the occupation of parents in both schools is unskilled labor (35%), skilled labor (55%) and salaried workers (10%). The predominant community accessing Udavi School is MBC (Most Backward Caste) and accessing Isai Ambalam School is SC (Scheduled Caste). The primary focus of this paper is our work at Udavi School.

The villages around Auroville are very close knit in caste and family structures which also results in segregation of living spaces. The schools allow for spaces where children from different communities are together. Alcoholism and its related problems are predominant in the villages. Many children come from poor and dysfunctional families. About 40% of the children have access to an evening center where they get support for homework or exposure to activities.

The name STEM land is in reference to Papert (2002) Mathland as places where children would learn Math naturally.

Philosophies underlying stem land

The philosophy underlying the approach for STEM land is based on the principles of progressive and constructivist thinkers like Jerome Bruner in the United States, Sri Aurobindo and Mukanda in India and many others briefly described here. Constructivist Education Theory (Bruner, 1960) indicates that knowledge is not delivered into the learner (whether child or adult) but recreated by the learner on his or her own. Children actively construct their knowledge by connecting new knowledge to what they already know.

In India, Sri Aurobindo (Aurobindo, 1910) says that nothing can be taught, but the teacher can guide, support and encourage a child in the process of learning enabling them to evolve towards perfection. More recently, Mukunda (Mukunda, 2009) describes the three aspects of learning that are relevant to schools – conceptual knowledge, procedural knowledge and higher order reasoning. Conceptual knowledge (and change), she states, greatly benefit from constructivist approaches.

Taking a specific aspect of STEM for Maths, the National Curricular Framework (NCF 2005) (Pal et al, 2005) states that the 'useful' capabilities relating to numeracy, number operations, measurements, decimals and percentages are only a narrow goal of Maths education. The higher purpose of Mathematics, it says, is Mathematization: the understanding and application of mathematics in different situations with a focus on abstraction, patient problem solving and logical thinking. Meeting this goal requires a fundamental change in the approach used in schools. It requires classrooms to move away from simplistic 'sums' to more complex problem solving and contexts. It requires a shift in conversations in the classroom from the 'right answer' to considering and discovering approaches to problem solving. In a similar fashion NCF treats the development of scientific inquiry as more important than the knowledge of scientific facts.

The constructionism theory (Papert & Hare, 1991), adds to the constructivist theory the belief that children construct their own knowledge best by creating something outside their minds that is often shareable both physically as well as virtually. This highlights sharing as an interesting aspect of learning as is and the role of peers. While this appears at odds with radical constructivists (Cobb, 1994) it completes an essential aspect in the learning process of children for social interactions and the richness of the learning environment. Further research has worked on creating classroom environments that engage children in collaborative practice and is further elaborated specifically through inquiry (Goos, 2004).

Emphasis on the social aspects of learning is predominant in most alternative schools, and particularly emphasized in democratic classrooms and schools that bring democratic values to education. It can include self-determination within a community of equals, as well as such values as justice, respect and trust (Waghid, 2014; Apple & Beane, 2006).

Values form the essential basis of actions and are required for the improvement of the social aspects of learning and forming a learning community. However, ‘teaching values’ has often had its limitations. The exploration of inner capacities through leadership tools (Sharma, 2006) has the potential for transforming reactions of fear into conscious responses based on inner potential and to transform group dynamics to be more humane and respectful (Tim et al, 2003). LIAP (Leadership in Action Programs) are leadership programs are based on actual application to real life problems rather than a role designation. It is the development of leadership practices and behaviors through individual and group reflection with the goal of creating new behaviors and mindsets. The impact of LIAP is explored in this research.

Further beyond the skills, competencies and societal aspects education is the development of the child as a whole. ‘The progress of the child guided by the soul and not subjected to habits, conventions and preconceived ideas is illustrative of a system of free progress’ (The Mother, 1956).

At STEM land, our goal is to develop the values of responsibility, equality and the courage to create in children. The implications of following such a philosophy, its challenges and some results are presented in this paper.

Activities and interventions at STEM land

STEM land is a dynamic space that is constantly consciously responding to the learning needs of students, facilitators and youth. Here is a glimpse on how things work:

Circle time

When students come in for their Math classes there is a circle time. This allows everyone - students, facilitators, volunteers as well as youth who come in to learn electronics and programming to start the session together. Other than announcements anyone can share or bring up an issue in the circle and it often has updates on what individual students or groups have been working. An example of an announcement would be the creation of a reporting notebook to share if something was broken or needed purchasing. While very broad ground rules of respect yourself, respect others and respect materials were agreed on in STEM land further detailing of this happens as an issue or need for organization comes forward e.g. a child brought up that there should be an agreement that laptops need to be signed up before being checked out for use, or that no food should be eaten inside. Most of these agreements are reached quickly and followed by all, including facilitators.

It was through these discussions that the children arrived at the learning rules of learn something new, learn something old and learn something now. While new represents the various hands on activities, games, puzzles, etc the now represents what is there in their Math curriculum that they are expected to learn as part of the state board syllabus. The old represents gaps in learning that they identified as they were learning something new and now.

Multi-grade classroom

There are multi-grade classrooms for one or two sessions a week where there are around 40 students from higher and lower grades together. There is significant peer learning and sharing of what one has Values form the essential basis of actions and are required for the improvement of the social aspects of learning and forming a learning community. However, 'teaching values' has often had its limitations. The exploration of inner capacities through leadership tools (Sharma, 2006) has the potential for transforming reactions of fear into conscious responses based on inner potential and to transform group dynamics to be more humane and respectful (Tim et al, 2003). LIAP (Leadership in Action Programs) are leadership programs are based on actual application to real life problems rather than a role designation. It is the development of leadership practices and behaviors through individual and group reflection with the goal of creating new behaviors and mindsets. The impact of LIAP is explored in this research.

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Material accountability

The responsibility of taking care of the material at STEM land has been taken care of by children splitting the task of checking everything is in order. At one point a wooden ball from one of the games was lost. Unable to find another quite like it the students 3D printed the piece and painted it with nail polish to make it look like the original

LIAP (leadership in action programs)

One of the challenges was that not all children found themselves able to cope with the freedom given to them. A few felt that they needed continuous support from facilitators or peers and a few got carried away with this and frequently played games and did not meet their goals. We organized a leadership program that looked at aligning who I am (what I care about), the systems and patterns of the society and what I do. This was followed by triads which are reflective spaces where 3 children and a facilitator meet and share what they able to do over a fortnight.

Here are some reflections from the children shared at triads with facilitators:

Student 1: *"The game we were playing as a group during lunch hour is very physical One child was unwell and was being forced to play the game by the group with the threat of being excluded from further games. I decided not to participate in such a game as I stand for caring."*

Student 2: *"There is no specific organization of mouse in the box to keep it. It is being put back haphazardly and gets tangled and the mouse is going bad. I would like to organize the box".* She organized a system where she made partitions in the box and labeled each of the partitions so everyone knew where to put them.

Student 3 noticed many gender biases that we hold in our society and how it took her and her mother courage to allow her to be involved in a workshop from which she came home later than usual

We hope that the ability of children to notice culture, social patterns and reflecting on them will help them notice and address social issues that we face as a society as they grow up.

Observations of learning as a social activity

When learning becomes a social activity, it spreads effortlessly starting from one initiator and soon covering a large number of children. Here are some examples:

Rubik's cube, games and puzzles

In our hope to teach through inspiration we attempted to build a robot that could solve the Rubik's cube. Our progress was slow and tedious. The children asked us what we were trying to create and we showed them a video of a robot solving the cube. The children were extremely inspired watching the video and tried to solve the Rubik's cube by themselves. They could not solve it at first. Later, they solved the Rubik's cube using an instruction manual. This became a social activity with many children learning strategies and formulas from other children. Over 20 children we work with can now solve the Rubik's cube without looking at the instruction manual Among them, 10 students can solve it within 2 minutes and 1 student less than 1 minute. The way the activity grew made learning a social activity and was replicated in many other aspects of their work.

Playing and learning strategies in the games and puzzles in STEM land have similarly spread without one-on-one inputs from facilitators. The children have also started an activity of putting up their favorite games and puzzles as a part of challenges in the school fair adding an intellectual dimension to the school fair.

Sets game

One of the volunteers had an interesting game that helped children learn some of the fundamental ideas about sets. The setup of the game required a couple of hidden rules about two sets (e.g. one set of blue shapes and the other set of rectangles). Then we drew the Venn diagram and the children guessed a shape and its color in each section till they were able to figure out the secret rules. He gave this game to a small group of students, but within two or three days most children had mastered it and were then able to link it to concepts of intersection, complement within set theory.

Deep learning: ability to apply concepts learned

A couple of the letters in a display that blinked ‘STEM land’ using 7-segement displays made by students a year back were not functioning properly. Two children in the 7th grade expressed interest in fixing the display. A facilitator walked them through how powering a leg of the display lights up one of the 7 segments similar to an LED (Light Emitting Diode). They were fascinated by being able to understand and fix something and did so over a couple of classes. After fixing the board one of the two was interested in doing something more with the Arduino.

He wired up the 7 segments to a separate Arduino pins to control the segments individually and managed to write his first program in ‘C’ to display a 1 by the end of a class. He was provided an inputthat the code will soon get out of hand if he did not start organizing the code (in a language he was learning) into functions.

The next day, he came by during lunch and asked to be shown what these ‘functions’ were. When he was told that they similar to blocks in Scratch, his face immediately lit up and he said, “*Well I understand blocks.*”

He had an activity class after lunch and he sat down to implement what he had in mind. He ran into a couple of syntax errors, but then worked on his own for 45 minutes. In this time, he had made a single digit counter that incremented from 1 to 9 every second. He then asked for ideas on extending the functionality to make a clock out of the Arduino. After a conversation, he added a second 7-segment display to get the second digit of the clock he needed. He even managed to figure out the logic of the first digit continuing to run when the second was implemented to create a 99s counter.

We feel that taking a concept of a blinking LED, extending it to fix a 7-segment display, to controlling individual segments and putting it all together to make a 60 s clock with very little help from an adult is a good example of deep learning.

STEM to STEAM

The children made many projects to demonstrate their learning and used these as presentations for other children to learn concepts. Some of these were remarkably detailed and artistic. For her presentation one of the children created a project in coordinate geometry that allowed the user to enter points one-by-one and when the picture was complete it became a van (as shown in Figure 1). These projects add a very important element of creativity and art and bring in beauty and inspire the group as a whole to want to create not just projects, but beautiful projects.

Outcomes of 9th grade

At the end of the year we did a survey with the 9th graders to understand what they felt was their achievements of that year in school. 90% of the children were able to point to something specific they were proud of these included projects they had created, being able to solve the Rubik's cube, being able to work independently and in groups, ability to plan their work and track their progress. Many of these were higher order skills and competencies and meant that students believed that what can be learned is more than academic skill. We also found that the academic performance on an average had increased by 7 points from before.

Working with younger children

About a year after starting STEM land at Udavi school we were given an opportunity to create such a space for 3td -7th graders at Isai Ambalam.

As a school, Isai Ambalam faced many challenges and we engaged the children in small real life challenges. This allowed them to take responsibility of their school and surroundings. As an example, the school faced a water issue and the children started exploring and understanding water. They built an instrument to measure the water level of the bore-well and track water depth. They also created an overflow alarm system for the tank to avoid wastage of water due to overflow. The children also felt that the sense of scarcity could be transformed into a sense of abundance if there was a pond and over time they worked over breaks, lunches and eventually stayed over for a couple of days at the school to create a pond. The children of 3rd and 4th grade worked as a team and also learned estimation, areas, ratios in cement mixing, etc while creating the pond.

When the students inaugurated the pond by putting fishes in the pond even parents who had otherwise expressed unhappiness that their children were working with their hands in their breaks and sleepovers and coming home with dirty clothes were thrilled to see what their children had created.

We felt that even though our approach with younger children had been quite different we were still looking at inculcating values of responsibility, equality and courage to create alternatives in them.

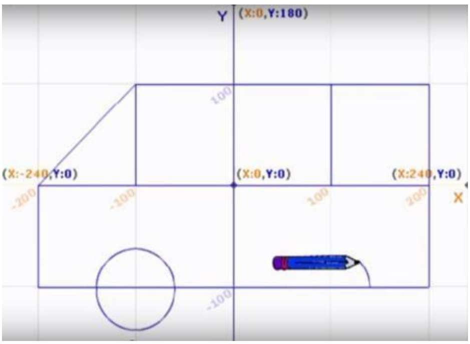

Figure 1: Co-ordinate geometry as an art form.

Figure 2: Pond at Isai Ambalam School.

Conclusions

Children can be responsible for their own learning. The challenges of being unable to handle freedom (and responsibility) can be addressed if the children have access to tools that allow them to work out of possibility rather than fear. This creates an environment based on values where children guide themselves with what is important for themselves, as well as, for society as a whole. Children can learn from each other in an environment which encourages peer interaction and the freedom to explore one's own ideas independently, or to work with peers on projects. When facilitators provide and encouraging and supportive environment without directing all the activities surprising discoveries and demonstrable progress can be made. The opportunity for individual and group reflection further supports children in becoming observers and owners of their own learning.

We have presented a case study in a rural STEM land with 7^{th} to 9^{th} graders where the above resulted not only in individual progress, but also created a collaborative learning community with rich peer-to- peer and group learning. Learning itself became a social activity.

The essence of such a learning environment is values and progress can be seen with even younger children with real life projects if the focus is on developing responsibility, equality and courage in children.

Acknowledgements

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Notes:

SCIENCE TECHNOLOGY ENGINEERING MATHEMATICS (STEM) LAND: FACTORS AND INTERVENTIONS INFLUENCING CHILDREN'S ATTITUDE TOWARDS MATHEMATICS

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Abstract: *The dislike and fear of Mathematics in children is well documented in literature (Daniel, 1969). Further, literature suggests that children's interest in Mathematics decreases from elementary to high school (Köller, Baumert and Schnabel, 2001). Many practising teachers also tend to believe this. However, a survey with the children in a rural STEM land indicated that their interest in mathematics had been retained or increased from when they were in 5th grade. In this paper, we look at*

1) Is there a co-relation of interest in Mathematics with how well children do in their curricular examinations?

2) We also describe the learning environment and interventions at STEM land and the response of children to these. The questions we focus on:

Will freedom to plan their work help?
Does opportunity to choose working individually or with peers change the learning environment?
Does access to games and puzzles give a broader perspective of Mathematics and will it lead playful learning?
How interested are children in using materials in Mathematics that make abstract ideas concrete?
How interested are children creating projects
Demonstrate mastery of concepts?

CONTEXT AND INTRODUCTION

This is an Action Research project by a team of engineers who wanted to study our interventions as we implemented them to find out whether these methods and materials would increase children's interest, or exam results, in two rural STEM centres run in two outreach schools of Auroville – Udavi School and Isai Ambalam School. Both schools aspire towards the holistic development of the child and the managements are progressive. The children attending come from villages surrounding Auroville.

Udavi School follows the Tamil Nadu state board syllabus and we work with 47 children from 7th to 9th intensively for 6 hours/week for all their Mathematics (Math) classes. A few children also come for an activity class in STEM. Other subjects are handled in their regular classrooms. Isai Ambalam School follows the central board syllabus (CBSE) where we work with 48 children from 3rd to 7th grades intensively for 6 hours/week during the Environmental Sciences (EVS) and Math classes. In demographics, the occupation of parents in both schools is unskilled labor (35%), skilled labor (55%) and salaried workers (10%). The predominant community accessing Udavi School is MBC (Most Backward Caste) and accessing Isai Ambalam School is SC (Scheduled Caste). This paper focuses on STEM land at Udavi School and on Mathematics.

At STEM land our goal is to develop the values of responsibility, equality and the courage-to-create in children. At STEM land in Udavi school the children learn to take responsibility for learning and address not only their curriculum, but also create projects that demonstrate their mastery on topics learned (Ranganathan, 2015) and also learn electronics, programming, etc. They do this through self-learning, peer- learning in multi-grade environments and through interactions with facilitators. Children have assessments once in a week on their chosen goals to help them with seeing their progress in addition to their regular examinations from the school. STEM land is also open to anyone to come and learn electronics, programming, Mathematics, puzzles and strategy games. The activities of STEM land that help create a collaborative learning environment are documented in detail elsewhere (Ranganathan, 2018). This paper focuses on specific interventions as listed in the abstract at Udavi.

Motivation of the paper: Change of interest in Mathematics

We asked the children "Rate your interest in Mathematics from the time you were in 5th grade to now". They rated this on a Likert Emberling scale of 1-10 with
1 indicating a strong decrease, 5 a retention and 10 a strong increase in interest.

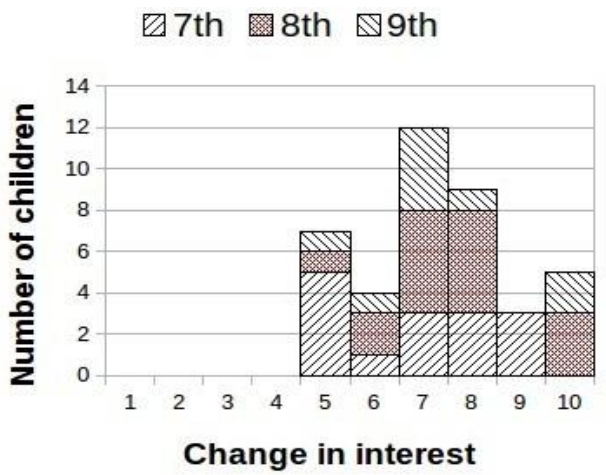

Figure 1: Change in interest in Mathematics from 5th grade for children in 7th, 8th and 9th grade.

The result of the survey was interesting for us, because it indicated an increase in interest when literature suggests otherwise(Köller, Baumert and Schnabel, 2001). In this paper we look at what could be special about the environment at STEM land that causes interest to increase.

PHILOSOPHIES UNDERLYING STEM LAND

The philosophy underlying the approach for STEM land is based on the principles of progressive and constructivist thinkers like Jerome Bruner in the United States, Sri Aurobindo and Mukunda in India and many others briefly described here.

Constructivist Education Theory (Bruner, 1960) indicates that knowledge is not delivered into the learner (whether child or adult) but recreated by the learner on his or her own. Children actively construct their knowledge by connecting new knowledge to what they already know.

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Taking a specific aspect of STEM of Maths, the National Curricular Framework (NCF 2005) (Pal, et al., 2005) states that the 'useful' capabilities relating to numeracy, number operations, measurements, decimals and percentages are only a narrow goal of Maths education. The higher purpose of Mathematics, it says, is Mathematization: the understanding and application of Mathematics in different situations with a focus on abstraction, patient problem solving and logical thinking. Meeting this goal requires a fundamental change in the approach used in schools. It requires classrooms to move away from simplistic 'sums' to more complex problem solving and contexts. It requires a shift in conversations in the classroom from the 'right answer' to considering and discovering approaches to problem solving. In a similar fashion NCF treats the development of scientific inquiry as more important than the knowledge of scientific facts.

LITERATURE ON ATTITUDES TOWARDS MATHEMATICS

The role of attitudes in learning Mathematics (Daniel, 1969) has been explored earlier. It has been found that there are many students have a fear of Mathematics, and dislike mathematical activities. Some students completely hate Mathematics, some fear making mistakes. Daniel also suggest that school should be a place where tasks are made more attractive and require educational programs to be more flexible and individualized.

Conceptualization of academic interest (Köller, Baumert and Schnabel, 2001). This paper says that although interest is usually considered important antecedent to successful academic learning empirical data suggests that this assumption is weak. While doing research in different schools and colleges in different countries the researcher found that interest in Mathematics continues to decrease from Grade 7 onward.

The psychological research and theory of (Silver, 2004) suggests that by having students learn through the experience of solving problems, they can learn both content and thinking strategies. When a problem doesn't have a single correct answer students work in collaborative groups to solve a problem which increases their peer learning. PBL (Problem Based Learning) increases self-directed learning which helps them to solve real life problems. Second, students must be able to set learning goals, identifying what they need to learn more about for the task they are engaged in. Third, they must be able to plan their learning and select appropriate learning strategies. The final goal of PBL is to help students become intrinsically motivated by their own interests, challenges, or sense of satisfaction.

CORRELATION WITH CURRICULAR EXAMINATIONS:

Here are the results and analysis of some of the surveys conducted with 45 children in STEM land. 7th Graders had experienced STEM Land for six months, 8th graders for one and half years and 9th graders for two and half years. Ten STEM land facilitators conducted the survey.

The survey of 14 questions was on their experience of various interventions of STEM land. The survey was conducted in a one-on-one interview with children (in English and Tamil as requested by the child). The researchers, who are also the teachers conducted this survey.

Linking with the original research of how children view mathematics (Daniel, 1969) we asked:

How is Mathematics different from other subjects?

In each class from 7th to 9th grade, there were about 15 to 16 students. In every class around 65% of the children said that Mathematics is difficult compared to other subjects. Among the children who found it difficult some found numbers and calculations confusing, others found it difficult to remember formulas. One child even said that Mathematics is the most difficult subject among all the subjects. 25% of the children said that they are able to notice that they use math in other subjects and said that it helps in life. Very few children said that there is no difference between Mathematics and other subjects. Only 8% of them said that they are interested in Mathematics and it is easy to understand. Some children even distinguished Mathematics as a subject from what they do at STEM land.

Correlation between interest and curricular examinations

Using the data on change of interest in Mathematics for each child from 7th to 9th grade and we calculated the Pearson Correlation Coefficient (PCC) with how well they did in their curricular examinations. We found that for 7th standard the PCC was -0.4329 which means the answer they gave for the interest level and the marks they have scored in exam was inversely related. For 8th standard the PCC was 0.222142 which is positive but very weak. For 9th standard the PCC was 0.171023 which was also weak. Similar to what we see in literature (Köller, 2001) we do not find a strong correlation between how children do well in examinations and their interest in Mathematics in the limited sample (47 children) in STEM land.

INTERVENTIONS AT STEM LAND AND OBSERVATIONS:

We focus on a few specific interventions and the response of children to these here.

Intervention: The freedom given to plan their work

At STEM land, we believe children are responsible for their learning and for their growth. A software was created at STEM land to support children create a plan and track their progress. Children create a plan of what they are going to learn each week. They are assessed each week on the goals they work towards and children can track their progress visually as a pie chart.

Response

We asked "*How satisfied do you generally feel at the end of a week? On a scale of 1- 10 with 10 being fully satisfied and 1 being not satisfied*". This question was asked to understand how students were responsible for their learning. Figure 2 shows that almost all the children are satisfied on working towards their goals.

We also asked what they did when goals were not met. Most said that they work harder and seek support from peers and facilitators. Some children said that they work at home to complete what they set out to do. Only a few mentioned that they felt sad and were not able to proceed to the next topic.

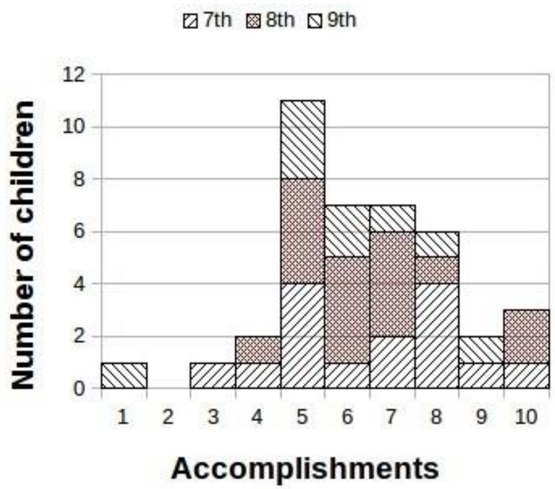

Figure 2: How accomplished children generally feel at the end of the week

Intervention: Access to games and puzzles that give a broader perspective of Mathematics and are

joyful

At STEM land we have an active environment of challenging ourselves with many puzzles and strategy games. The puzzles include physical disentanglement puzzles, rubiks cubes, etc. The games include strategy games such as Abalone, Othello, etc. These are as often checked out and used by children (even if it is for a short time) as laptops. There is a fairly large group of children who can solve the rubiks cube.

Response

We asked children "*How stressed or joyful do you feel at STEM land (1=stressed, 5=neutral and 10=joyful)?*". We found that most of the children felt joyful being at STEM land.

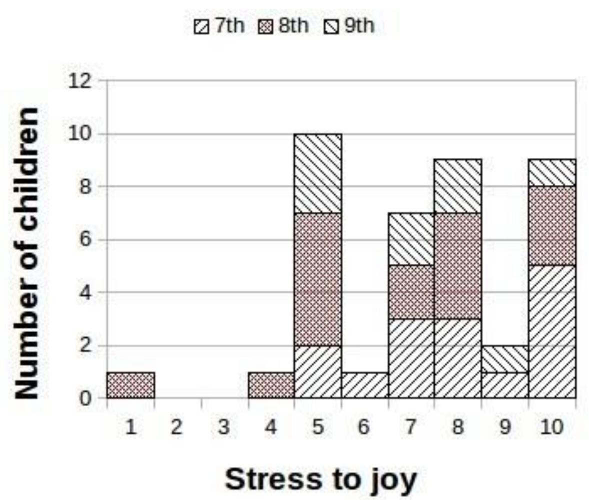

Figure 3: How Joyful children feel working at STEM land (1=stressed, 5=neutral and 10=joyful).

We also asked "*Where and how do you use math in your day-to-day life?*" Children furnished numerous examples about how they use mathematical concepts in real-life: some mentioned that they use it while shopping and to calculate monthly expenses for their house.

One child said that he uses Mathematics to change his perspective, when he had only

10 minutes to complete a task he changes this into 600 seconds and this helps him calm down and complete his work. He said this had increased his confidence level.

Intervention: Choice of working individually or with peers

At STEM land children have a choice of working individually or in groups. This allows for individual learning as well as peer-to-peer learning. In addition, in a week there are four to five multi-grade classes. Where younger children and elder children work together and collaborate in learning.

Response

The response to a question of "How often do you collaborate on a scale of 1 to 10 (1- rarely, 5-often, 10-always)" is shown below. This indicates that most of the children often collaborate with others, working in groups and sharing what they have learned.

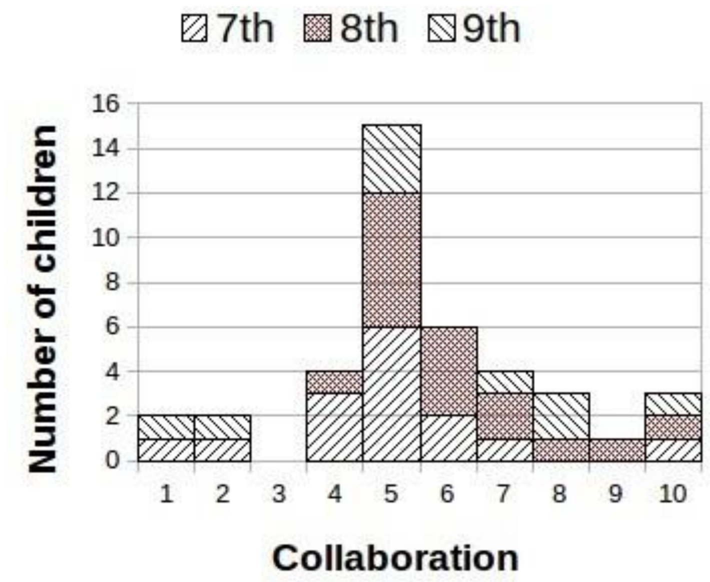

Figure 4: How often do I work with other children (1 – rarely, 5 – often, 10 – always).

When children were asked to list what they learned from peers they said they learned to solve problems that they don't know; Math concepts like square root, factorization; strategy games like Othello, Abalon; to solve the Rubiks cube; programming in Scratch, Geogebra and Alice; mind-storms (robotics), and electronics like makey makey, soldering. Some children also mentioned that they learned how to effectively use STEM land including using laptops, checking-in and out materials, filling plans for the week, taking up responsibilities for specific materials at STEM land and even not being afraid and asking for help when you don't know something.

Intervention: Access and use of materials in Mathematics to make abstract ideas concrete

In STEM land children have access to a wide variety of materials that make mathematical concepts concrete including Montessori, Jodo Gyan, etc.

Response

We asked children "*What is your interest in learning mathematical concepts using materials in STEM Land on a scale of 1 to 10. 1 being not interested, 5 being interested and 10 being very interested*". The average score was close to 8.5 and none of the children in all three grades went below a score of 5 on using materials.

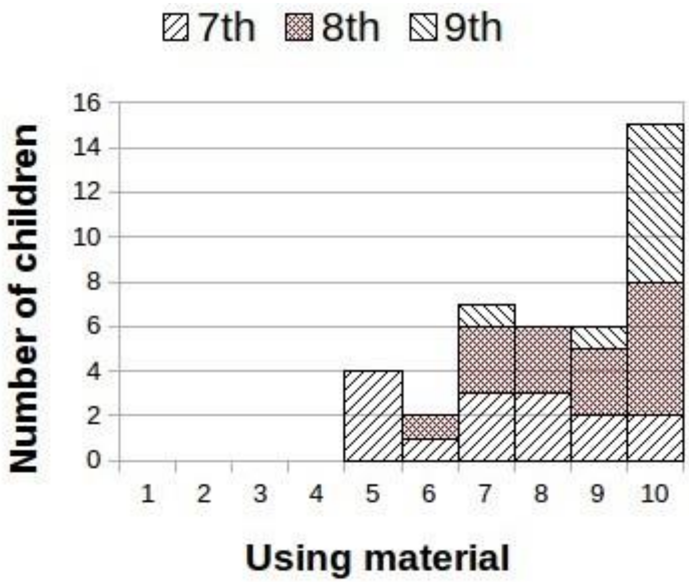

Figure 5: Interest is using materials to learn mathematical concepts.

Intervention: Creating projects that demonstrate their mastery of concepts

In STEM land children are encouraged to create projects while learning mathematical concepts. This is done by the facilitators themselves creating projects, allowing children to work across grades. Children take their own idea to create a project that they learned in their chapter. Projects can be both physical e.g. creating a sets game or in software e.g. creating a visualization of a concept or an interactive project or game.

Response

We asked children "*How interested are you in creating projects on a scale of 1 to 10 (1 not interested and10 very interested)*". Most children said they like learning through projects. Children mentioned that when they make projects they get clarity

on the concept. Some mentioned that they are able to solve problems easily after making a project. They are able to learn new things like programming while doing a project.

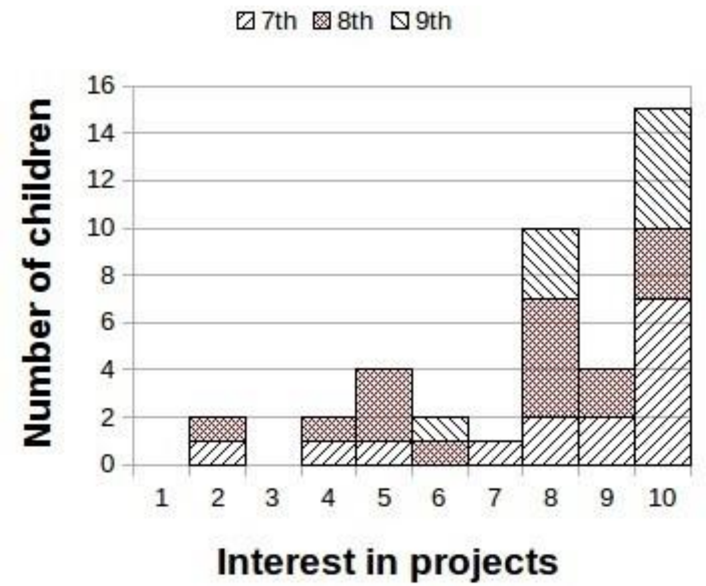

Figure 6: Interest in making projects (1-not interested, 5 – interested, 10- very interested).

Some children mentioned that while doing a project they face many problems and they are able to break down big problem into smaller problem. While working on a project children are able to think about how to proceed step by step. Having completed the project, if they forget the concept, they are able to revisit their project they themselves made to remember that concept.

CONCLUSIONS

Children have retained or increased their interest in

Mathematics when they come to STEM land.

Their interest is inversely or only weakly related to their ability to do well in curricular examinations. This implies that even those who do poorly find something of interest at STEM land.

We examine various interventions and their responses

the freedom to plan their work – gives them a sense creating a plan and accomplishment.

choice of working individually or with peers – allows them to work as they most effectively can.

access to games and puzzles that give a broader perspective of Mathematics and are joyful – makes it fun being in STEM land.

access and use of materials in Mathematics to make

abstract ideas concrete – helps make mathematics more

accessible.

creating projects that demonstrate their mastery of concepts – helps them express their creativity.

We continue to explore various interventions that alter children's attitude towards Mathematics.

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Notes:

Altered traits of alumni from a collaborative learning environment

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Abstract: A rural STEAM centre aims at developing responsibility in children, the courage to create projects and the competency to work together in this collaborative learning environment. Here children have freedom and responsibility to plan what they work on, develop mastery in Mathematics through projects in electronics and programming, work individually or with peers, etc. These factors appear to support develop a positive attitude towards Mathematics in children at the centre.

This paper is based on reflections of alumni two years after graduating from the centre. What factors do they still appreciate? We examine both the skills and attitudes they developed, retain and apply in their further education and life. What are the altered traits alumni retain when they transition from such centres to mainstream education?

Context and Introduction.

C3STREAM Land (C3 is *C*onscious for Self, *C*onscious for Others, *C*onscious for Environment, STREAM= STEAM+ R (Research), henceforth referred to as C3SL) are rural STEAM centres in Tamil Nadu in India. This paper follows the alumni of the centre at Udavi school, one of the outreach schools of Auroville. Auroville is a universal township that works towards human unity and engages with the villages around Auroville. Most of the children attending the school come from Edayanchavadi village.

Udavi school aspires towards the holistic development of the child and follows the Tamil Nadu state board syllabus. C3SL works with 80 children from 6th to 10th intensively for 5 hrs/week for all their Mathematics classes at Udavi.

The STREAM centres have been in operation in the school for the last 5 years. In demographics, the occupation of parents of the children is unskilled labour (35%), skilled labour (55%) and salaried workers (10%).

The aim of the C3SL centres is to develop the qualities of responsibility, equality and the courage to create alternatives. At C3SL centres the children learn to take responsibility of their learning and have freedom to plan and set their goals each week. They can choose to work individually, with peers across grades in multi-grade environments or with facilitators. They have access to Mathematics materials, strategy games, puzzles that help them engage with mathematics and play games. They have access to computers where they program in Scratch, Geogebra and Alice and also 3D modelling and printing. They also have access to electronics, Makey-Makey, robotics and other materials interacting with engineers who work in the industry. These help children not only address their curriculum, but also create projects that demonstrate their mastery on topics learned. The use of programming to develop mathematical thinking at C3SL has been documented before (Ranganathan, 2015, pp.339-346).

In India the lack of interest in education is attributed as the number one reason for children to drop out of high school (Government of India, 2018, pp.126). Among the subjects Mathematics is considered the most difficult subject requiring special attention not just in India, but across the world. While both literature (Köller, Baumert and Schnabel, 2001, pp.448-470) mainstream teacher experiences suggests that the interest in Mathematics deteriorates as children get to higher grades at C3SL there was an improvement in attitude towards Mathematics in children from 7th to 9th grade from when they were in 5th grade. We examined the factors based on the interventions mentioned above earlier (Ganesan, 2019, pp.894-898) when children were part of C3SL and had access to it.

In this paper we look at the following research questions:

1) How alumni reflect now on the factors attributed to the improved attitude of children towards Mathematics when they were at C3SL. Specifically:
    - the responsibility and freedom given to plan their own work
    - creating projects physically and with programming on mathematics, electronics, robotics, etc.
    - choice to work alone or with peers
2) If alumni found their experience at C3SL useful and what skills they learnt that they have applied in higher education.
3) Given the diversity of what they experienced, other factors they valued at C3SL.
4) If the experience at C3SL resulted in *altered traits* in alumni in determining their choices in higher education and how they perceive they would like to learn.

Altered traits are defined as a new practice or attitude that endures beyond the environment that helped create it (Goleman & Davidson, 2017, pp.8)

Philosophies underlying C3SL

The philosophy underlying the approach for C3SL is based on the principles of progressive and constructivist thinkers like Jerome Bruner in the United States, Sri Aurobindo and Mukunda in India and many others briefly described here.

The theoretical framework of the work at C3SL is based on the three principles of true education by Sri Aurobindo (Aurobindo, 1921, pp.1-8):

- Nothing can be taught
- The mind needs to be consulted in its own growth
- From near to far

The first principle can be linked to the constructivist theory that knowledge cannot be forced into the mind of a child, nor can a child be moulded or hammered into the form desired by the adult. That the teacher can guide, support and encourage a child in the process of learning, enabling them to evolve towards perfection.

It further indicates that each human being is in their own path of discovery and progress. This is also recognized in the National Education Policy (Government of India, 2020, pp.12) which states that 'knowledge is a deep-seated treasure and education helps in its manifestation as the perfection which is already within an individual.' We would like to examine how the children have continued their journey and what role, if any, C3SL had in it.

The second principle indicates that the child needs to be consulted in his/her learning. This is done at C3SL as the children to plan what they want to work on (choosing a plan to work on) and how they want to work on it (self-work, peer-work, creating projects, etc). The children have this freedom and responsibility and we examine what the alumni felt about this.

The third principle is to work from near to far. To work from what is tangible and accessible to children to what is abstract to them. The children work on projects they care about, materials they can access and manipulate and move towards abstract ideas. They also create projects and programs at C3SL that take abstract ideas in Mathematics and convert them into visual projects that make them concrete.

Constructivist Education Theory (Bruner, 1960) is in line with the philosophy that knowledge is not delivered into the learner (whether child or adult) but recreated by the learner on his or her own. Children actively construct their knowledge by connecting new knowledge to what they already know.

Contemporary thought is also aligned with these ideas, Mukunda (Mukunda, 2009) describes the three aspects of learning that are relevant to schools – conceptual knowledge, procedural knowledge and higher order reasoning. Conceptual knowledge (and change), she states, greatly benefit from constructivist approaches. Procedural learning benefits from learning to program a computer to do the procedure. Higher order skills benefit from problem solving methodology.

While earlier curricular frameworks in India had already suggested shift from 'useful' capabilities to understanding and application the NEP 2020 states clearly:

> 'Pedagogy must evolve to make education more experiential, holistic, integrated, inquiry- driven, discovery-oriented, learner-centred, discussion-based, flexible, and, of course, enjoyable.'

In the context of the nation-wide conversations captured by the NEP the interventions being carried out at C3SL of creating experiential, learner-centred and enjoyable collaborative learning environment that challenges children to show their mastery by creating projects is relevant. Equally important is how these interventions are perceived - noticed, appreciated and retained by the children themselves over time.

Methodology of the research

Selection of Alumni

We use purposive sampling focusing on one batch of alumni of C3SL at Udavi School who had been at the centre in their 8th and 9th grades and were now in other schools in their 12th grade. This batch was selected because we were looking for a sample of students who have been away from C3SL for at least 2 years and had also experienced it for at least 2 years. The alumni are following the streams of humanities (arts), commerce and science with a predominant number in commerce.

This is a qualitative case study and the data collection consisted of

a. A group sharing of the nine (of thirteen) alumni on what they are doing and what they have retained and used from their experience at C3SL.
b. This was followed by a review of the intention of each of the 20 questions of the survey.
c. The children then filled out the survey individually.
d. Four children who could not attend the group sharing filled out the survey remotely without (a or b).
The primary data collection for this research was ‘c’ and ‘d’ and ‘a’ was the secondary
data collection used for cross verification.

The survey was created with the intention of having both a qualitative (Linkert scale) question linked to a descriptive one that would clarify the choice with details and reflections. The selected Alumni were in 12th grade and it was expected that they would be able to respond to these questions in simple English in writing. We felt that this would give them the time to reflect and respond rather than take interviews with us.
The survey had both broad questions like usefulness of C3SL in their life, or their memories of C3SL, as well as pointed questions on specific interventions of C3SL. We expected the descriptive questions to bring out the diversity of responses of how they engaged in with C3SL in line with the specific teachers experience of the children’s engagement at C3SL. We also included questions to verify if indeed their current environments were different from what they experienced at C3SL, how they coped with the change and what they preferred and more importantly why.

The conversation and the responses were analysed to understand what the children have found special, useful and what continues to be useful and impacts them about C3SL. The descriptive responses allowed us to check for factual consistency with their teachers and our records e.g. of what children they had created in C3SL. While we focus on the three interventions all the questions and responses of the survey is available online (C3SL, 2020) for review. The children know C3SL by its former name STEM Land and this is the name used in the raw data for children. We, however, continue to use C3SL to retain the flow of this paper.

Survey and Responses

We had noted factors or interventions that had improved the children's attitude towards Mathematics when they were at C3SL. We reviewed these with the alumni to see if they still found these interventions significant.

Intervention: The freedom given to plan their work

At C3SL, we believe children are responsible for their learning and for their growth. Children create a plan of what they are going to learn each week. They are assessed each week on the goals they work towards.

To understand whether children prefer to plan what they want to study or prefer that the teachers plan for them we asked two questions, '*Do you get the freedom to choose what you want to learn in the school you are in now?*' and if the response was negative '*Would you prefer to work with freedom of choosing what you want to learn or not?*'

Except two students all of them said that they don't have the freedom to choose what they want to learn in the schools they study now and all of the students said they prefer to work with freedom of choosing what they want to learn. One of the children specifically said that he wants to have his freedom to choose what he wants to study, but he can't because of society since the importance is given to marks rather than knowledge.

We have also asked children '*What are the difficulties you face switching from the system we follow in C3SL to other school environment?*' Children said that they perceived the system in C3SL as having the freedom to choose what they want to do, access to resources needed and being allowed to interact with everyone. This made C3SL a joyful environment. They felt not having such an environment limits learning as they are not allowed to use resources even though they are there, nor find support when needed. They have also said that they had to memorize everything, had to always study and don't have any other activities. One child remarked 'By choosing to learn I dedicate more in learning.' [By choosing to learn I am more dedicated in learning].

Intervention: Creating projects physically and with programming on mathematics, electronics, robotics, etc.

In C3SL children are encouraged to create projects to demonstrate their mastery of mathematical concepts. Children learn programming early through peer learning and with facilitators. Children come up with their own idea on projects based on what they learned in their chapter these could be physical projects e.g. building a game or in software e.g. creating a visualization of a concept or an interactive project or game.

We asked '*Did doing projects in Scratch, Geogebra and Alice help you in any way?*' All of them said doing projects using Scratch, Geogebra and Alice helped them to remember the concepts in Mathematics. All the children said that doing projects helped them in many ways such as to improve their speed in Mathematics and is easy to understand Mathematical concepts. One of the students said that doing a project in Scratch helped her to learn graph, and computer programming. One of the children said that Scratch helped him get a different perspective, Geogebra to learn geometry. They still remembered the projects they made and owned their work. In response to their current status all the children said that they don't get the resources, time and support from staff in the school they are currently attending for such activities. One of the children said that she feels more comfortable working with computers when compared to the other children in the school she is currently pursuing.

We asked them about projects not directly linked to academics that some of them worked on '*Were you able to learn mathematics concepts when you work on electronics, robotics and Big-shot? 1 – less, 5 – neutral, 10 – more.*' All the children were positive or neutral about this and in the descriptive responses four of them said they were able to learn mathematical concepts while working on electronics, robotics and Big-shot cameras.

Intervention: Choice of working individually or with peers

At C3SL children have a choice of working individually or in groups. This allows for individual learning as well as peer-to-peer learning. In addition, in a week there are some multi-grade classes which allows children to work across grades. At C3SL the children learn about themselves and how they like to learn in response to the question, *'How useful was peer learning?'* one of them indicated that they liked to work alone, another was neutral about it the rest preferred to work with peers.

Further we asked children '*Do you continue to learn with peers in the other schools?*' Most of the children have said within the classroom they can't continue peer learning as they don't have an environment where they can communicate with other students or share freely with teachers.

In response to '*Have you taught anything you learnt from STEM land to your friends in other schools?*' Almost all children indicated that they had taught something to others they mentioned using Ubuntu, programming in Scratch and Alice, html, practical geometry, solving the Rubik's cube. Further, in response to an earlier question on application of what they had learned children shared that they are helping their friends and classmates understand concepts through alternative methods and taught puzzles and Rubik's cube to others.

Usefulness of C3SL

We asked the children to rate and answer '*Was C3SL useful for you (on a scale of 1 to 10) and if so in what way? 1 – Not Useful, 5 – Useful and 10 – Very Useful.*'

Figure 1 indicates all students felt that C3SL was useful for them. In the descriptive response thirteen children indicated that C3SL helped them learn programming and Mathematics through Scratch, Alice, puzzles and games. One child reflected that he used to look for answers to the questions, but his experience at C3SL has helped him look instead at the methods of solving a question. One child said that it is useful for his higher studies specially in Mathematics and Physics. Another said it is useful for him to learn animations and electronics. Yet another said it is useful to learn new things. Each child brought forward a different facet of C3SL based on their own interest and what they explored at C3SL indicating that each found something he or she had explored based on the diversity and freedom given to them.

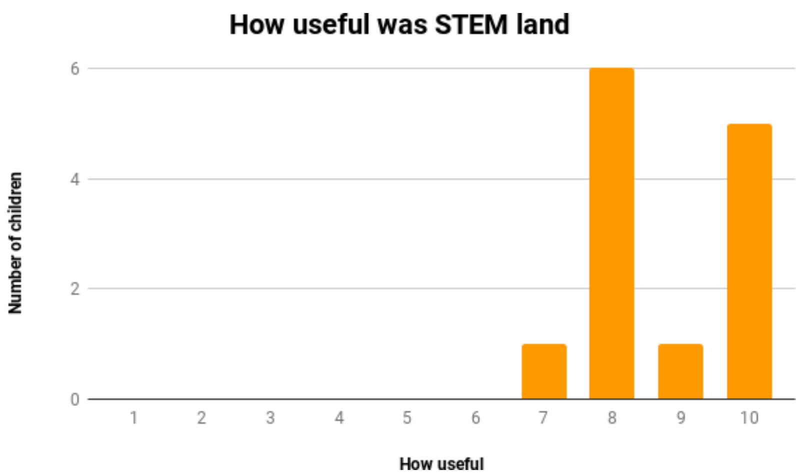

Figure 1: Rating of '*Was C3SL useful for you (on a scale of 1 to 10)?*'

What they retained and its application in higher education

We asked a question '*How much are you able to retain what you have learnt in C3SL? (1 - Not Retain, 5 – Retain, 10 – Retain Very Well)*'. Most children felt they were able to retain concepts they learned in Mathematics as well as what they learned in programming through Scratch, Geogebra, Alice, Goanimate as well as working on hardware such as Arduino, Mindstorms, Makey Makey which are programming related or Mathematics related.

To the question, '*How much (of this) are you able to apply in your higher studies?*' the children wrote that they felt that they found Mathematics related subjects such as Accounts, Economics as well as Computer Science related subjects Computer Application and Computer Science easy due to the similarity with what they learned in C3SL. Children also mentioned that they are helping their friends/classmates in understanding concepts through alternative methods in which they had expertise. One of the children mentioned that he learned lots of shortcuts in Mathematics and is able to apply them in his higher studies. In the conversation before the written survey one child even mentioned that she was among the only two girls in a class of fifteen in a Computer Science and she was topping the class.

We also asked a question '*What course are you pursuing?*'. Most of the children who have graduated from C3SL have opted for Mathematics related fields such as Commerce, Science, Computer Science and Biology with Mathematics. One student who took humanities (Arts) took up Computer Science as an elective.

'*How are you doing in Mathematics as compared with other subjects? 1-10.*' Out of thirteen students seven of them said they are doing well in Mathematics as compared to other subjects. Two students mentioned that Mathematics helped them to score more marks in other subjects like Accounts and Physics. The remaining students did not have Mathematics as a specific subject in their course. Others indicated that they did not have Mathematics but Computer Science they do well in.

Interventions noticed by children

We looked across the questions on aspects noticed by children about the environment created at C3SL and how they felt there. In a response to '*One thing you feel proud of being in C3SL*' a child wrote 'freedom, relationship, learning, understanding among student and staff'. In response to the transition to mainstream schooling a child wrote 'we enjoyed the environment in C3SL but now we are totally away from happiness.' On the response to the question *'Did playing games help you learn*

Mathematics?' the children had mixed responses to whether playing games helped in Mathematics as such, however, one child wrote, 'yes! that made time to relax my mind', similarly in response to '*How interested were you in solving the weekly puzzles? 1-10*' while most children said they were not interested again we had a different child write, 'I felt my mind get relaxed and very interested.' The diversity provided at C3SL for differing tastes of children allowed each child to find something they enjoyed illustrated in '*Share your memories of STEM land.*'

> 'I loved playing games and getting the freedom to choose what I want to learn. I very much enjoyed the (leadership) workshops. Because I learnt a lot about myself and my class mates.'

The children were sharing about the leadership/stewardship workshops we had offered children to make choices from their possibility (universal values they care about) rather than socialized fear. Another shared, 'I liked Stewardship that gone (was held) weekly once with our team staff. I enjoyed it and I am still following my stand and fear.'

The diversity of what touched the children in C3SL '*One thing you feel proud of being in C3SL*' four students said that learning programming and being able to create projects made them feel proud at STEM land. Two students mentioned that soldering and electronics kits made them feel proud of STEM land. Three students have said that they feel proud of being a STEM land student. They have also mentioned that STEM land gave the additional knowledge apart from text books and that they feel proud of the teaching method being part of a buddy system, having freedom to choose what they want to study, exposure to games and logical puzzles. One child captured the environment as 'freedom, relationship, learning, understanding among student(s) and staff(s)'.

Conclusions

Improvement of interest in Mathematics with grade is an important goal of Mathematics education across the world. The interest of children in Mathematics had improved in children at C3SL due to the interventions such as:

- the responsibility and freedom given to plan their own work
- creating projects physically and with programming on mathematics, electronics, robotics, etc.
- choice to work alone or with peers

while children were in C3SL. This research found that alumni even after two years after they graduated from C3SL and no longer experiencing such an environment perceived these interventions as formative to their understanding of how they like to learn, that it made it environment joyful and made them responsible.

All of them felt that they would like to continue plan their own work as they did at C3SL and choose how they want to engage with others. Even through most were not allowed to engage with peers within their classrooms now, they were supporting peers and had taught something they had mastered at C3SL to others beyond classrooms.

Each of them brought forward a different facet of C3SL they engaged with some in response to specific questions on projects, programming, electronics, games and puzzles and some as a response to generic questions about their experience e.g. leadership. A few of them specifically brought up the leadership and how it continues to play a role in their lives allow them to work from possibilities (universal values they care about) and transcending socialized fear.

We observed that the children had retained skills not only in Mathematics, but also in Programming, Electronics, etc. Further they had developed a positive attitude towards these and most had taken up Programming in their higher education even if they had chosen Arts as their discipline of choice across gender.

The children not only understood what they had learned, but also had clarity in the development of logical thinking, strategies and multiple methodologies of solving questions. They also shared that they found the learning environment joyful.

We see that interventions at C3SL had not only short-term effects on improving attitude of children towards Mathematics, but also longer-term impacts in their attitude towards how they understand themselves and how they learn. We term these as altered traits, indicating the impact of the few years they engaged in C3SL continues to have in their lives moving from one ‘among the crowd’ to ‘standing out of the crowd’.

We believe these interventions if introduced as part of Mathematics classrooms could support children taking responsibility for their learning as well as create supportive environments for their peers. This is relevant not only in the National Education Policy 2020 for India, but also for children across the world to use Mathematics and STREAM not only as skill development, but of developing responsibility both towards themselves and others.

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Notes:

Building Agency in Children through Mathematics: Applying Conscious Full Spectrum Response for Developing Skills, Competencies and Inner Capacities

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***Abstract**: Sustainable, equitable and enduring solutions to the complex problems of the world require not only technical solutions, but also shifts in structural and social norms of society grounded in responsibility and interconnectedness. How do we as teachers look at these aspects? In this action research we develop a perspective through the framework of a Conscious Full Spectrum Response (CFSR) model to develop not only academic and technical skills in Mathematics, but also competencies – using skills to shift systems and culture and inner capacities - self-awareness, self-regulation, responsibility and courage to create. These together build agency – the ability to act and transform based on what I deeply care about. We review case studies of the work of children both academic as well as real life projects with this framework.*

Context

C3STREAM Land (C3 is *C*onscious for Self, *C*onscious for Others, *C*onscious for Environment, STREAM= STEAM+ R (Research), henceforth referred to as C3SL) are rural STEAM centres in Tamil Nadu in India. STEM education can become "technology for the sake of technology" and miss out in addressing social, cultural and structural biases and disparities, it can also ignore the development of inner capacities of children. C3SL strives to address these as the deeper purpose of education.

Radical Transformational Leadership

Radical Transformational Leadership, the book, describes how we can generate equitable and enduring results using a unique response model based on extensive application world-wide in many sectors, themes and topics – the conscious full- spectrum response model. This model is designed for sourcing our inner capacities and wisdom to manifest change that embodies universal values of dignity, compassion and fairness, and simultaneously transform unworkable systems and norms in order to solve problems.

While each of us have an accountability of teaching Mathematics we are also trained through RTL workshops on the distinctions, design templates and tools. The distinctions allow each of us to work out of what I stand for (universal values I deeply care about) rather than out of socialized fear, the design templates allow for alignment of universal values, system and cultural shifts and actions when we design projects; the tools formalize processes that are cognitively coherent with the distinctions and templates.

Introduction to the Conscious Full Spectrum Response Model

The Conscious Full Spectrum Response model is used to generate results at scale and addresses complex problems across domains while allowing for alignment in:

a) Technical Solutions to solve immediate problems e.g. employment, education.
b) Shifting patterns and unworkable system and societal norms required for sustainability of the technical solutions e.g. policies, casteism, race, gender.
c) Underlying factors of what we deeply care about - why we want these shifts and how we act when we embody these universal values e.g. dignity, equity.

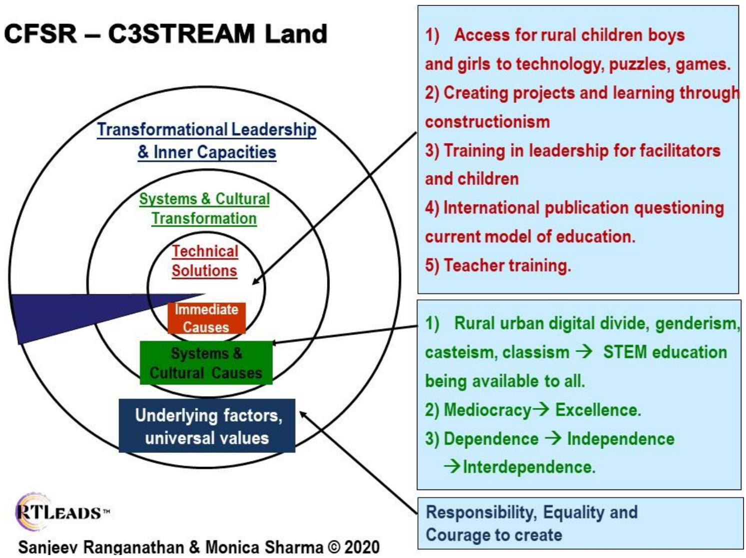


Figure 1: C3SL as an example of application of CFSR model.

We give an example of C3SL in Figure 1 mapped to the CFSR model and also set the context of this work. The outer circle of universal values of C3SL are responsibility, equality and the courage to create. We want to see these values in the children we work with, in ourselves and in what we do.

The middle circle addresses systemic and cultural causes here we work in rural schools we address not only the digital divide, but also use the work on STEAM to interrupt the common ISMs like genderism, class and casteism in rural India. We work equally with both boys and girls in STEAM education. We also move from mediocracy to excellence with the older children taking responsibility of learning to plan and set their goals for the week. They choose to do this individually, in pairs, in groups and in consultation with facilitators. They are also provided RTL training for children to move from dependence on teachers to independence to interdependence and creating a learning community.

In the inner circle of technical solutions the children have access to Mathematics materials, strategy games, puzzles that help them engage with Mathematics and play games. They have access to computers where they program in Scratch, Geogebra and Alice and also 3D modelling and printing. They also have access to electronics, Makey-Makey and other materials interacting with engineers who work in the industry. These help children not only address their curriculum, but also create projects that demonstrate their mastery on topics learned. With younger children we work on making Mathematics with real life (Education by Design) EBDs projects that they can do on themes they care about.

All these move the children from mediocracy to excellence. The details of the activities of C3SL (formerly known as STEM Land) are documented in detail elsewhere (Ranganathan et al., 2018, pp.294-302).

This research is conducted in two outreach schools of Auroville – Udavi School and Isai Ambalam School. The children attending come from villages surrounding Auroville. Udavi School follows the state board syllabus and we worked with 80 children from 6th to 10th grades intensively for 5 hrs/week for all their Mathematics classes. Isai Ambalam School follows the central board syllabus and we work with 71 children from 3rd to 8th grades intensively for 6 hrs/week as well as during Saturday activities and sleep overs for Mathematics as well as Environmental Sciences (EVS). In demographics, the primary occupation of parents in both schools is in unorganized labour e.g. masons, painters, agricultural labours and schemes providing rural employment. The predominant community accessing Udavi School is MBC (Most Backward Caste) and that accessing Isai Ambalam School is SC (Scheduled Caste).

Philosophies underlying C3SL

The philosophy underlying the approach for C3SL is based on the principles of progressive and constructivist thinkers like Jerome Bruner, Seymour Papert in the United States, Sri Aurobindo in India. The philosophy of Sri Aurobindo of the integral development of the child (Aurobindo, 1921, pp.1-8) emphasizes self-knowledge and assumes an important relevance in the recent National Education Policy (Government of India, 2020, pp.12) that is based on his work and states that "knowledge is a deep- seated treasure and education helps in its manifestation as the perfection which is already within an individual." The philosophy creates guiding principles as teachers and in how we engage with children. The three principles of true education by Sri Aurobindo are:

- Nothing can be taught
- The mind needs to be consulted in its own growth
- From near to far

The first principle can be linked to the constructivist theory that knowledge cannot be forced into the mind of a child. The role of a teacher is not to mould or hammer a child into the form desired by the adult. The teacher is a guide, or mentor that supports and encourages a child in the process of learning, enabling them to evolve towards perfection. Our engagement with children follows this principle.

The second principle indicates that the child needs to be consulted in his/her learning. This is done at C3SL as the elder children plan what they want to work on and how they want to organize themselves to do it with the broad ground rules of respecting themselves, others and the materials. With younger children this aspect was put in practice in the co-creation of challenges along with them.

The third principle is to work from near to far. To work from what is tangible and accessible to children to what is abstract to them. The children work on projects they care about in the environment they engage with and as they grow older move towards more abstract ideas. This paper will present projects both in the physical world and also in the abstract world.

Self-awareness and personal transformation are necessary, but not sufficient for social transformation. In this paper we take up a theoretical framework for social transformation that is aligned with values. This paper focuses on the application of the Conscious Full Spectrum Response capacity building framework that we use to review what we may be accomplishing through Mathematics and EVS.

Theoretical Framework of CFSR for capacity development

We use the framework of a CFSR (Conscious Full Spectrum Response) capacity development (Monica, 2017, pp.236) as shown in Figure 2.

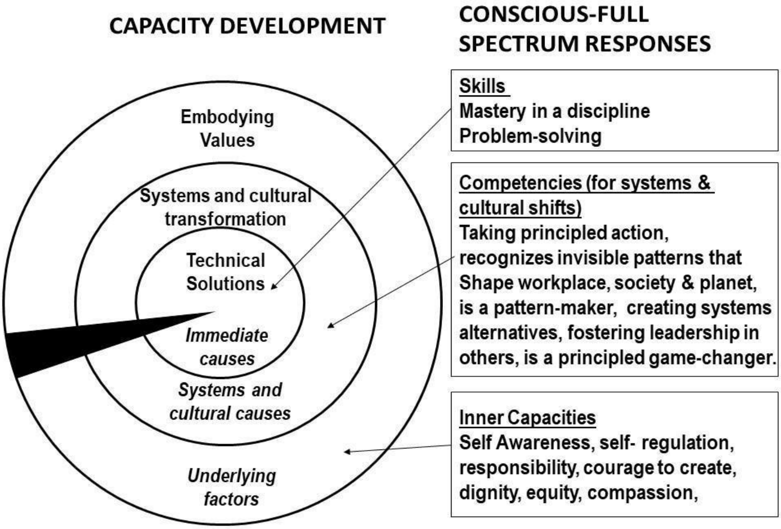


Figure 2: Capacity Development for Sustainable Results

A CSFR based capacity development simultaneously addresses:

1. Skills (inner circle) to generate technical solutions to address immediate causes. We look at mastery of the concepts as well as problem solving.
2. Competencies for systems cultural transformation (middle circle). We look at the ability of applying these skills in different contexts, pattern/system thinking, as well using skills to build healthy patterns in how children interact and learn.
3. Inner capacities to embody universal values (outer circle). We look what we noticed about children's responsibility, care and courage to create alternatives

Methodology

The topic/project and how the children went about creating them are described in each section. The skills are listed by analysis of the final product by the teachers. The competencies were observed by the teachers in the duration of the project and in conversations with the children. Inner capacities are not measured, but reflected. Opportunities were created for children to reflect on these and what were noted are derived through conversations on their reflections.

We will take a few case studies and deep dive into one of them to look at how these aspects are both supported and observed.

Case studies and observations

We first look at academic challenges and then at real world challenges. Can learning Set theory and algebraic identities be transformational?

Sets

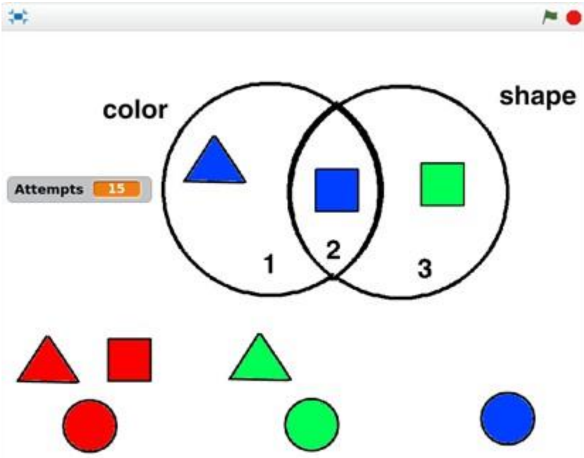
A few children from 10th grade had built a physical game with a chart and materials with Sets. This physical game inspired Diva, a 9th grader the built a game in Scratch (a visual programming language) on sets shown in Figure 3. Each circle represents a hidden rule of either shape or colour. The player needs to determine the rules by guessing where the pieces fit. Programming helps children learn concepts because they need to break it down into simple instructions while improving problem solving, logical reasoning. The use of programming to develop mathematical thinking at C3SL has been documented before (Ranganathan, 2015, pp.339-346). In this case, Diva realized that in order for the computer to understand which region of the Venn Diagram was being sensed by a new token (sprite) he needed to divide the Venn diagram into different regions (A-B, B-A, A∩B and U-AUB) helping him learn these better. He first made the game with a fixed rules and later generalized it for the computer to randomly pick the rules so it would be a challenge for him too. At C3SL we have sessions where children share their projects. Diva presented his project at one of these sessions. His presentation got the 8th graders, who were not expected to learn about sets, to learn about sets.

C3SL also organizes courses to learn programming to that gets children to make smaller projects and learn through interactions with peers and facilitators. After one such course the following project was created.

Algebraic identities

A few children from 8th grade created projects on algebraic identities. For example, Jan made a program that drew $(a + b + c)^2$ as three squares i.e. a^2, b^2, c^2, and $2ab$, $2bc$, $2ca$ as areas of rectangles. Images such as these were also available in the text book, were static, but when children created them in scratch they were able modify their programs to use variable lengths for a, b, c

and see for themselves that even with the different lengths the identity still held.



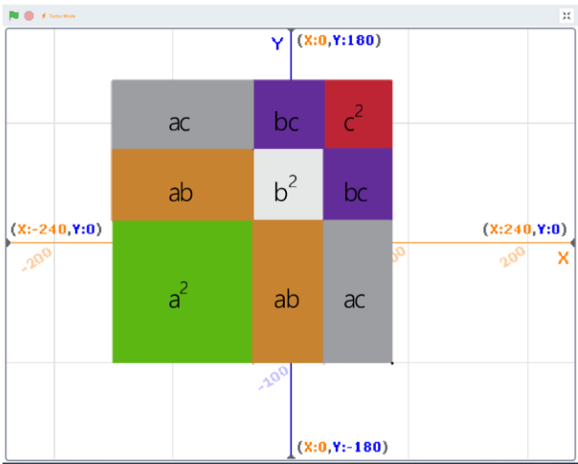


Figure 3 & 4: The two 2-sets game in scratch, algebraic identity in scratch

Observed skills, competencies and inner Capacities

In the two virtual activities above through the CFSR framework for capacity development we see:

Skills: In academic skills they learned the different sections of overlap of Venn diagrams with 3 sets ($A \cap B \cap C$, $A \cap B - C$, etc), understanding that rules (descriptive form) can be used to define sets, deriving derive descriptive form from elements, algebraic identities. In programming, they learned interactive queries (sensing), drawing different shapes (pen), functions in scratch, variables, for loops, if, repeat.

Competencies: Ability to create projects to share their ideas, break down a problem into smaller components, move from specific implementation to generalization, shifting from dependency on teacher to independently working on projects to interdependent learning from peers and supporting peers learn through sharing projects.

Inner Capacities: Care – sharing knowledge & Courage to create.

Needful things Co-operative (Shop) Project

We will now take an example of a real-life challenge and describe the methodology we follow in the guiding process as well as reviewing through CFSR model in practice.

In Isai Ambalam School the 7th and 8th graders had difficulty understanding profit and loss. Such skills (inner circle) could have been addressed by theoretical problems and even a mock market within the grade.

With most topics as teachers, we attempt to create opportunities for children to explore and understand the world around them and asked them to research what and where they buy the things they commonly use.

On looking at the prices of stationary in the shops they found that the price for the same product varied and the local shops in the village which were charging too much. The children began to wonder what is the ‘real’ price of a product. The children also noticed that it was not always easy for the young children to have access to shops for small items they needed like pencils, erasers, scales, notebooks that their parents were not always able to provide at the required time. Sometimes such explorations only support understanding, but the children felt a need to act and create a system that addressed this dependence on parents for time for purchases move towards independence of children and interdependence within the school. They decided to open a small makeshift store within their classroom at breaktime. This is the middle circle of looking at patterns and wanting to shift them.

Before starting the shop for a couple of weeks teachers organized group discussions on various topics e.g. what are the needs of children, items that could practically be stored, investment required. The children surveyed and found preferred items that they would need to have in stock at the store. Practically, none of them had a background to fund the amount required. In conversation with their teachers the children felt that since it was a collective initiative it should not have distributed funding. They broke the amount down into 40 investors including the children themselves, volunteers and wellwishers of the school. For this they created a small kit for investors highlighting what they were attempting to do, the benefits it will give children, a period for which the funds would be locked and a small return that the investor could get.

Once the finances were raised and the items were purchased by the teachers in bulk from wholesale shops. The next set of discussions the teachers had with the children were on how things will be priced to meet all expenses including travel expenses, how it would be advertised, location of the shop, timings, roles and responsibilities.

Planning and Accountabilities: Children came up with several criteria for their shop including for investors, accounts, team work, being fair, following 5S system (Sort, Set in order, Shine, Standardise, Sustain) in their shop. They also came up with marketing strategies - cheap and best and rules of their shop - No borrowing, Fixed price and No bargaining.

Children divided their accountabilities among themselves – an accountant who collects all the cash and gives a bill, two helpers to sort the stationaries and arrange them in the appropriate place, a shopkeeper who gives the items a customer needs and one person to check the stocks at the end of the day. They exchanged their roles while maintaining the rigor of practice including those that included keeping the place clean. When keeping the shop space clean where they interrupted genderism when cleaners at the school initially objected to a boy doing a ‘girl’s job’ the children stood for equality.

Addressing real life challenges also allowed them to demonstrate a variety of skills that academic classroom didn't and that we had not perceived in them in an academic classroom. The children ran the shop till the end of the schooling year and also realized that there are many other costs like electricity, rent, labour that they had waives for them to be able to make the products available significantly cheaper at the school.

Skills: Children learned to keep stock, write receipts, handle accounts and pricing, understand profit and loss, proportions, ratios and scaling, e.g. an individual item from a packet. Conversion from inches to milli meters, different angles, measurements, marketing strategies (by advertisements and attractive offers).

Competencies: The children noticed the patterns of how shops sell and noticed gaps in both the quality and pricing in local shops. They demonstrated the competencies to enrol others raise the investment for their initiative, to work as a team, allocate accountabilities among themselves and interrupt genderism. They moved from dependence on parents to have to find time to purchase stationary to interdependence and were able to handle real-life issues which helped us notice our own biases in children's capacity that was based on academic interactions.

Inner Capacity: We found that the children took responsibility and stood for well-being and care for children, demonstrated the courage to create an alternative. Further they found something each of them excelled at and felt more confident about themselves.

Pond Repair

The second case study is in Isai Ambalam School with real life projects. Taking responsibility for their school and surroundings, such as the water issue. The children had created a pond (Iyyanarappan et al., 2019, pp.894-898). However, within a year the pond developed cracks due to roots from trees nearby. The children felt that they did not want all the work that they have done to go in vain so children wanted to create a stronger structure that would last.

Figure 5 & 6: Building mesh structure

The children supported by the facilitators built a frame in the shape of the pond and through this they learnt to bend metal rods (6mm and 12mm) at specific angles such as 90º, 45º etc. They also learnt unit conversion from inches to cm for buying the appropriate rods and to cut them in right dimensions. Once the frame was done, they mixed Reinforced Cement Concrete (ratio 1:2:3; cement: granite gypsum: sand) and poured into the structure filling all the rods and finally got some adult help to smoothen it.

Through this process they learnt angles and frames as well as ratios and proportions with more than two quantities. We observed children who are less engaged in academic classes are enthusiastic in building with their hands. In this example we have looked at building technology as a way for children to learn.

Skills: Children learnt conversion from inches to milli meters while building the mesh structure of the pond, angles such as 90º, 45º while bending the rods, they learned to measure length, calculated the circumference and how they wanted to mesh the pond. They learned to mix in the right proportions for the RCC mix and of course the practical skills of creating structure meshes and preparing the reinforced cement.

Competencies: The children took responsibility for what they have built, noticed the gap in what had been missed, worked as teams and shared learning and knowledge with each other, faced real-life problems and got the support they needed by enrolling partners.

*Inner Capacities***:** Responsibility, self-awareness about what they cared about in the environment they wanted, Care – sharing knowledge, Courage - ability to create projects.

C3SL initiatives to support collaborative learning

As mentioned at C3SL we have sessions for children to share projects and conduct programming courses for children. We also work on initiatives across the schools we work with e.g. a Rubik's cube tournament. The goal of the tournament was not so much to find the fastest solver, but to encourage people to learn to solve the cube. This included sessions at the tournament to learn the cube and teachers at the schools who were inspired by the children also learned to solve it from the children. This interrupted ageism where even teachers not part of C3SL were willing to learn from children.

We created open challenges for children to create videos for children to teach what they had learned visually with materials or drawings e.g. integers. Children looked at different ways of demonstrating with materials integer addition, subtraction, multiplication and division. We used these videos across grades to encourage children to learn from each other.

Conclusions

In this paper we discuss the Conscious Full Spectrum Response model both in terms of a design template as well for capacity development that is needed for enduring and sustainable changes in the world in line with universal values. We give examples of the use of this model as a template of design for C3SL as well as how we used it observe what we are accomplishing with children beyond academic and technical skills.

Such cognitively coherent framework allowed us to step beyond the comfort of our primary accountability as Mathematics teachers and assume the responsibility of global citizens and community leaders. It requires us to work on technical skills needed to solve immediate problems, competencies of using skills to shift culture and systems by noticing systems and patterns and learning how to work together towards interrupting disempowering ISMs, while being aligned with universal values such as responsibility, equality and courage to create.

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