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.

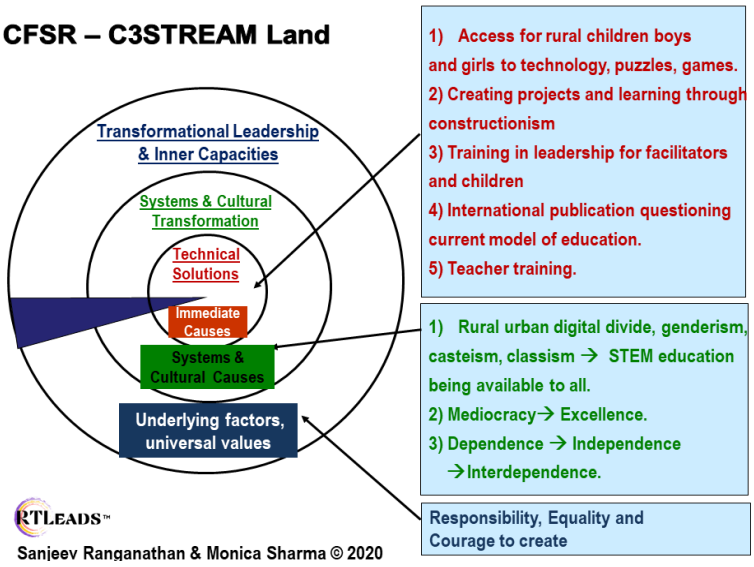


Figure 1: C3SL as an example of application of CFSR model.

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.

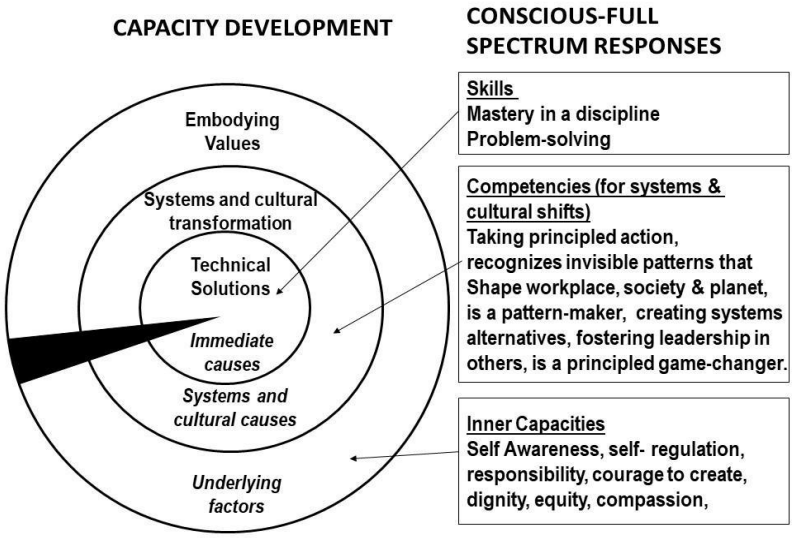


Figure 2: Capacity Development for Sustainable Results

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

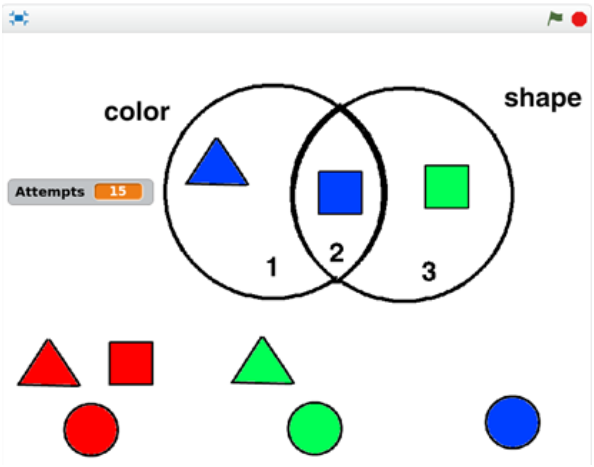
A few children from 10th grade had built a physical game with a chart and materials with Sets. This physical game inspired Diva, a 9th grader the built a game in Scratch (a visual programming language) on sets shown in Figure 3. Each circle represents a

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.



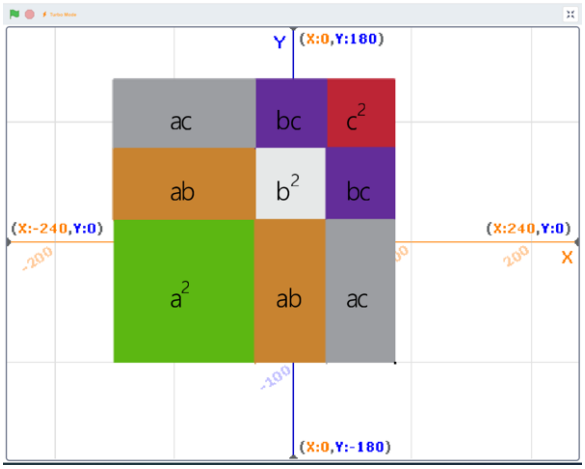


Figure 3 & 4: The two 2-sets game in scratch, algebraic identity in scratch

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∩B∩C, A∩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 well-wishers 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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References

Aurobindo, Sri. (1921). *The Human Mind, A system of National Education*, Tagore & Co. Madras (pp.1-8).

Government of India. Ministry of Education (2020) *National Education Policy* [pdf]. Retrieved from: https://www.education.gov.in/sites/upload_files/mhrd/files/NEP_Final_English_0.pdf

Iyyanarappan A., Anand B., Saminathan L., Kumar N., Ganesan P., Patchaiyappan P., Perumal R., Ranganathan S., Bharathi S., & Kothandaraman S. (2019). STEM Land (Science Technology Engineering Mathematics Land): Deep Learning of Mathematical Concepts Through EBD and by Using Materials, *Proceedings of Tenth International Mathematics Education and Society Conference* (pp.894-898).

Monica. S. (2017). *Radical Transformational Leadership: Strategic Action for Change*, North Atlantic Publishing, at Berkeley, California (pp.236).

Ranganathan S., Iyyanarappan A., Anand B., Kumar N., Patchaiyappan P., et. al. (2018) STEM (Science Technology Engineering Mathematics) Land: Fostering Responsibility for Learning in Rural Schools, *Proceedings of epiSTEME 7* (pp.294-302).

Ranganathan S., Anand B., Kothandaraman S. & Gunasekar V. (2015). Using Programming with Rural Children for Learning to Think Mathematically, *Proceedings of epiSTEME 6*. pp.339-346.