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 learnt. Students have learnt both hands on activities such as soldering, robotics, programming, games and puzzles as well as academic aspects such as number systems, practical geometry from each other. It is not younger students who learn from elder ones and anyone who has spent enough time in mastering something shares it with others. Youth from the villages often come in and learn from children programming and hands on electronics. One of the challenges in multigrade classroom is space and effective circle time as well as limited resources such as laptops. But, such challenges are usually got around by working in groups.

Project presentations

Further into a term once a week there are project presentations where students share the projects they created in Scratch 2 (Resnick et al, 2009), Alice 3, etc. This inspires other students to create similar projects or build on what is presented. It was hard to manage time for project presentations and it brought in a system for the presentation to be completed in 5 minutes with 5 minutes for interaction. This has helped children improve their presentation and organization skills as well as manage time. It also gives a need to be accurate and rigorous in what they present and aids in their own understanding and retention of ideas and concepts (Ranganathan et al, 2015).

Additionally, as children are all working on different areas it gives a chance to be exposed to new concepts or reminded of them.

Weekly puzzles

We introduce activities e.g. the weekly puzzle that creates conversations about mathematical challenges. There are no prizes for solving puzzles and both those who attempted and those who completed are acknowledged. It has been noticed that though children engage in conversations with each other over puzzles no child has copied the solution from another to claim as their own.

Plans and tracking

Children do not all work on the same concept, chapter or project. They plan their goals every week and also track their work both at STEM land and at home. Children also document how they felt after their weekly assessments and what they will do different the next week. These are reflective practices that we have put in place for children to learn to plan and track their progress. The first year this was done using spreadsheets, however, it took children a lot of time to type, there were also errors with managing the formatting in the spread sheet and it was cumbersome to track each day. In the second year, a software helped them track this information in a database with quick entry for their academic goals. The plans for all the children for a week are displayed to support collaborative and peer learning.

Assessments

There are weekly assessments that have 3 stages – novice, intermediate, expert that supports students understand their skill level. The students can close their notebooks and have conversations about the content. This encourages abstraction and conversations about the topics through collaboration.

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.

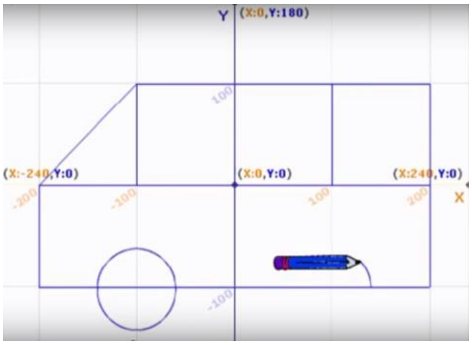

Figure 1: Co-ordinate geometry as an art form.

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.

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References

Apple, M.W. and Beane, J.A. (2006). Democratic Schools: Lessons from the chalk face. Bhopal, India: Eklavya Publication.

Aurobindo, Sri (1910). The Human Mind, *Karmayogin*. Calcutta: Sri Aurobindo Ashram.

Aurobindo, Sri, & Mother, The. (1956). Sri Aurobindo and the Mother on education. Pondicherry: Sri Aurobindo Ashram.

Bruner, J.S. (1960). The Process of Education, Harvard: Harvard University Press

Goos, Merrilyn (2004) Learning Mathematics in a Classroom Community of Inquiry. *Journal for Research in Mathematics Education, 35*(4), 258-291.

Mukunda, K.V. (2009) What Did You Ask at School Today, UK: Harper Collins.

Papert, S. (1986). Constructionism: A new Opportunity for Elementary Science Education, M.I.T, *Media Laboratory, Epistemology and Learning Group (NSF Grant Proposal)*.

Papert, S. & Harel, I. (1991) Constructionism. Norwood NJ: Ablex Publishing Corporation.

Pal,Y., Ramamurti, A., Shirali, S. A., Dhankar, R., Acharya,P.,Swaminathan, M. et al, (2005). National Curricular Framework, National Council of Educational Research and Training [pdf]. Retrieved from http://www.ncert.nic.in/rightside/links/nc_framework.html

Ranganathan S., Anand B., Kothandaraman S. & Gunasekar V. (Dec 2015) Using programming with rural children For Learning to think mathematically, In S. Chandrasekharan, S. Murthy, G. Banerjee and A. Murlidhar (Eds.), *Proc. of epiSTEME 6*, (339-346). Cinnamonteal: India.

Resnick, M., Maloney, J., Hernández, A. M., Rusk, N., Eastmond, E., Brennan, K., et al, (Nov 2009). Scratch: Programming for All. *Communications of the ACM, 51*(11), 60-67.

Sharma, M. (2006). Conscious Leadership at the Crossroads of Change, *Shift: At the frontiers of consciousness*, *12*, 16-21.

Waghid, Y. (2014). Pedagogy Out of Bounds: Untamed Variations of Democratic Education. *ISBN 9462096163.*

Waters, T.,Marzano, R. J.,and McNulty, B. (2003) Balanced Leadership: What 30 Years of Research Tells Us about the Effect of Leadership on Student Achievement. A Working Paper.