SCIENCE TECHNOLOGY ENGINEERING MATHEMATICS (STEM) LAND: DEEP LEARNING OF MATHEMATICAL CONCEPTS THROUGH EBD AND BY USING MATERIALS

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ABSTRACT:

This is an action research project in which we describe deep learning of Mathematical concepts in children through using materials and by Education by Design (EBD). For this paper we define deep learning as: a) ability to apply what they learn in different contexts, b) ability to retain the concepts they learn from term to term or across grades, c) ability to connect what they learn with what they deeply care about

The two methods described are a) use of physical materials to learn abstract concepts, b) creation of projects through Education By Design (EBD).

EBD is a process of creating projects for learning or to demonstrate learning of a concept. In this paper we will focus on real life problems. We also describe how these EBDs have altered the norms and functioning of the school.

CONTEXT

Education by Design (EBD): An EBD (Mobilia, 1998) "is a classroom dynamic that guides the thoughtful design of learning experiences for students. In an EBD classroom, students frequently work collaboratively to achieve desired results (for example solutions to real life problems) as they develop knowledge and understanding, critical skills, and vital habits of mind." In EBDs inquiry methods and self-evaluation are frequently employed.

STEM land comprises of a team of youth engineers who teach in rural STEM centers run in two outreach schools of Auroville – Udavi School and Isai Ambalam School. The engineers were born and brought up in and around Auroville and volunteer part time in both the schools. Both schools aspire towards the holistic development of the child and cater to children from villages surrounding Auroville.

This paper primarily focuses on the younger group of 68 children from 3rd to 7th grade at Isai Ambalam school (age group 8-13 years). Isai Ambalam School follows the central board syllabus and we work intensively with the children for 6 hrs/week during the Environmental Sciences (EVS)/Science and Mathematics classes. In demographics, the occupation of parents at the school is unskilled labor (35%), skilled labor (55%) and salaried workers (10%). The predominant community (45%) accessing the school is SC (Scheduled Caste) which are communities that are socially disadvantaged. Most parents of these children have not completed the 8th standard.

PHILOSOPHIES OF STEM LAND

At STEM land we follow the three principles of true teaching by Sri Aurobindo (Aurobindo, 1910). One, **Nothing can be taught** and the teacher is not an instructor or task-master, but a helper and a guide who shows the child how to acquire knowledge for him(/her)self. Second, **Mind needs to be consulted in its own development:** working with student initiated projects or student questions are good examples. Third, to **Work from near to far:** from the concrete to the abstract, from the known to the unknown. These principles are well aligned with a constructivist philosophy. The name STEM land is in reference to Mathland (Papert, 2002) as spaces where children would learn Mathematics through the provision of appropriate materials these include materials that children can access on their own, as well as tools to create their own projects. Our progression towards meeting these principles is described in this paper.

LITERATURE ON MATHEMATICS EDUCATION

The dislike and fear of Mathematics in children is well documented in literature (Daniel, 1969). The underachievement of children especially from rural and disadvantaged backgrounds is further documented in literature both nationally (Banerjee, 2016) and internationally (Howley and Gunn, 2003).

This is an action research project, as the research has been conducted by the teachers themselves. The purpose of this work is not to analyze children's limitations, but to describe what helped us become more effective in the hope that it will be useful for others. The paper also briefly notes how the functioning of the school itself has transformed through working on real life challenges using philosophies of EBDs.

Our aim is close to the NCF (National curriculum framework) 2005 (Pal Y, et al., 2005) that describes how Mathematics education should address the "higher goals" of broadening the child's mind to help Mathematize (or think Mathematically) and build critical skills like problem solving and logical thinking while addressing narrow goals of knowing skills in Mathematics. The NCF 2005 further states that "Learning should be made enjoyable and should relate to real life experiences. Learning should involve concepts and deeper understanding." In further references (Mayer, 2002) we find that the goal of instruction should emphasize objectives that include cognitive processes associated with "Understand, Apply, Analyze, Evaluate, and Create". These goals are similar to those of Education By Design.

In this paper we describe the interventions that led us towards real life EBDs that helped us learn more about how children learn deeply - retain, apply concepts and also connect with what they care about, and fundamentally alter some of the norms at the school.

LEARNING WITH TEACHING MATERIAL

High School Survey of Student Engagement (HSSSE) found that creation of learning materials could possibly engage children more filling the engagement gap (Yazzie-Mintz, 2009). Further research suggests that engaged students are better able to make an effort to comprehend complex ideas or master difficult skills throughout their education (Fredricks, et al., 2011).

We noticed the difficulty that children were having with learning in a didactic setting and introduced materials. In specific, we tracked the use of Ganit Rack to automatize addition and subtraction up to 20, Vaughn to master the multiplication tables. In both cases, we were able to see an improvement in the interest of children to engage, and ability work independently or with peers without direct engagement with teachers. With the Ganit rack 8 out of 12 children from the 3rd grade class wanted more problems from the teacher and later solved their own problems. They started seeing patterns of 5 they had not noticed before. We worked with 16 children (4^{th} and 5^{th} grade) who had not been able to master multiplication tables and they appeared to be able to master these with the use of Vaughn Cube. On re-assessment, after 6 months, the children asked for a quick refresh (1 day) after which 14 children had retained the tables. Few of the children were able to answer in the context of the Vaughn cube but had to be supported to correlate this method with their multiplication tables and its application. Deep learning was only partially met in retention supported (with scaffolding).

MAKING LEARNING MATERIALS

We looked at children making their own learning materials rather than using ready made ones. In specific we looked at three, making their own 1m scale from wood and 1m^2 square from chart to understand length and area and creating materials for comparing triangle and square areas with ratios. A 6th grade girl said that she was thrilled to use the hacksaw and cut the wood for the first time. The concepts of conversion from 100 cm to 1m and 1000 cm^2 fit into a 1m^2 were understood and retained over time. When creating scaled rectangle and triangles they noted that a (right) triangle is half the area of the rectangle with the same base and height and the areas scaled as squares of the sides. 18 of 22 children said learning with materials (creating and making) helped them understand and retain concepts better. We noted that on being asked where they could apply mathematics in their daily life the responses of children were in most cases still limited to purchasing from shops. We needed to do more to connect what they did with what they cared about.

REAL LIFE EDUCATION BY DESIGN (EBD)

When faced with acute water shortage at school children began to want to what happened to it. They started to learn about ground water, its depth and discuss in groups the reasons behind the shortage of water, came up with hypotheses and looked for ways to confirm them. They designed an instrument to measure the depth of water. This required some electronics and real life measurements and they started connecting what they learn in school with real life. They studied the water cycle (science) and different kinds of soil to understand ground water and created bunds across the school to increase water recharge.

They also built a pond to have a sense on abundance even in times of difficulty. They found that they needed to learn to work as teams to be successful at such projects and the need for more time to accomplish them. They students asked to come to school on Saturdays for projects and started staying at the school once a week. The school was primarily meant as a day school and lighting at night was limited, children built torches and set up light fixtures. They found that the when the bore well runs sometimes water fills and overflows, they created a sensor for overflow detection. They also looked at recycling the kitchen waste water and created a kitchen garden. The children look at the issues in school as an opportunity to be creative and solve them and take up field work such as painting, digging, masonry, plumbing, planting along with the teachers.

Measurements whether of wires and cables or for the pond they built were made with intent. Conversations on ratios of sand with cement became normal. English was written to describe their observations meticulously. The younger children who were not able to write in English wrote in Tamil first and then translated it into English and learned to present bilingually. The learning was thus integrated over many subjects.

In a survey of 22 children in Isai Ambalam school who were asked where they learn more (1 – class, 5 – both, 10 –EBDs) the average was 6.6. After 6 months of completing an EBD when asked about what they remember children were able to remember materials used for building the pond, many were able to connect mathematics they learned – ‘measurements, ratios, multiplication, division, addition, subtraction'. They were also able to describe skills like ‘process of painting in one direction to get a good finish’, 'how to make a raised bed’, ‘how to grow plants without using chemicals'. The response of how accomplished they feel after EBDs averaged at 8.4 on a scale of 1 to 10.

With stay overs and Sat school the didactic set up of the school has been significantly altered. This increased interactions between children the teachers on Saturday and in the evenings. Even through there was resistance especially for girls to stay over, this has more or less become a norm at the school. Due to the increased inputs from the children many unused area of the school have come to life. An overall improved perception of the school has led to an increase in enrolment of 40% of children with more diversity and a better mix of communities. The survey of the new parents pointed towards them noticing improved confidence and communication skills in the current children.

CONCLUSIONS

We found that while children tend to be more engaged in learning when they use materials, yet the learning is not necessarily deep. However, real life EBDs allow children to take up something they care about, apply their learning, and retain it longer leading to deep learning. Creating their own learning materials seems an intermediate between the two. Engagement with real life EBDs transformed the school from a more didactic arrangement to student-centred living learning environment. The children's ability to work in teams and their communication skills have increased evidence of deep learning and have been acknowledged and appreciated by the communities served by the school.

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