Fab Lab 0.0 to Fab Lab 0.4 - Learning from running a lab in an Indian Village

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Abstract

Fab Lab in developing countries has different operational problems. Within the constraints of resources, they have to prove effectiveness and the impacts of utilization of Fab Lab for their community. Vigyan Ashram (VA) Fab Lab was started in Pabal, a small village in western India with the support of MIT and Fab Foundation in 2002 and has been operational since then. It was started in a small 150 sq.ft tin shed with few machines. This lab is used by rural youth mainly, school dropouts. As the utility of the Fab Lab was experienced by the community, the lab grew in size. It saw three phases of expansion in terms of physical space and machinery. This paper is presenting challenges faced in this evolution in terms of machinery, inventory, infrastructure, manpower and projects. It is also presenting different approaches tried by VA to overcome these challenges.

Keywords

Rural Fab Lab, Vigyan Ashram , digital fabrication, developing country

1 Background & Introduction

Vigyan Ashram (www.vigyanashram.com) is located in a drought prone village Pabal, which is approx.60 kms from nearest city, Pune in western India. Vigyan Ashram(VA) was established in 1983 and it is engaged in training rural youth on various rural technologies and helping them to start their enterprises. VA practices 'Learning while doing' philosophy of education. It is successfully using secondary schools for dissemination of technology among rural communities. The program, 'Introduction to Basic Technology (IBT)' is implemented in secondary schools from Class VIII-X. Various technologies viz. Agriculture, Animal Husbandry, Food technology; Health related laboratory techniques, different renewable and non-renewable sources of energy, engineering methods etc. are taught to the students as part of their curriculum. Artisans, farmers, innovators and entrepreneurs from the community are trained in new technologies and they in turn work as instructors to train the students. These instructors also provide technical services to the community as their own enterprise. The program got evolved in VA over 30 years and is running over 150 secondary schools but it uses mostly the traditional fabrication tools.

Dr. Kalbag, the founder of the *ashram*, was a firm believer that instead of giving ready made solutions to the poor community, we must give those means to find out their own solutions. Dr. Neil Gershenfeld (Center for Bits and Atoms, MIT) first visited VA on the 27th January 2002 and stressed the need to use advanced technology to find out solutions to some of the pressing developmental issues in the community. Through the interaction between Dr. Kalbag and Dr. Gershenfeld, the first Fab Lab outside MIT was established, hence called VA- Fab Lab as 'Fab Lab 0.0'.

The VA Fab Lab end-users are mainly rural youth with minimum qualification and computer literacy. Machines in the Fab Lab are often too sophisticated for them. There were challenges in terms of the quality of electricity, dusty atmosphere and high ambient temperatures which caused troubles in the appropriate functioning of the Fab Lab. In spite of all these odds, VA Fab Lab could sustain its momentum. This paper documents the learning and difficulties faced in each of the operational areas. The operational areas are divided into machines, man power, education, projects, camps and

community outreach, funding and support from the Fab network. It also documents alternative strategies found by VA. This learning may help new Fab Labs setup in rural areas of developing countries.

2 Fab Lab Machines

It is often said that the Fab Lab is not about the machine. It is about the makers and them making things! But tools for digital fabrication differentiate Fab Labs from maker spaces and tool rooms. There was initial hesitation at VA about using digital fabrication. Teachers and students were finding it convenient & faster to use traditional tools for making things. Use of computers for drawing design was taking considerable time due to lack of practise and skills. Further the originally installed Fab Lab machines were not found suitable for making projects involving metals, as required for example in making improved agricultural tools etc. Table 1 presents a machine wise analysis of the problems faced in the machine operations. Overall learning curve of VA fab lab was long to master digital fabrication. Now, VA fab lab is comfortable with these tools and has become an integral part of Vigyan Ashram programs.

Machine (year of installation)	**Applications**	**Frequency of use**	**Technical Problems faced & solutions found**	**Outcomes**
Vinyl Cutter (2002)	Screen Printing, Name Plates, flexi-circuits for wearable electronics.	Good	Not major issues other than software re-installation.	Two of VA alumni started their micro enterprises. They have purchased machine and providing letter cutting service.
Laser Cutter (2006 & 2016)	Acrylic / thin plywood for casings, sign boards	Good	- Severe problems due to bad quality of electric supply, needed replacement of controller and laser tube. Normal earthing did not work due to dry & rocky soil so chemical earthing was used. - Cost of acrylic and MDF sheets was overcome by using packaging cardboard for practice.	Most loved machine! Many projects and all electronics casings made on this machine. VA wrote a manual on 'How to do earthing?' for laser cutting machine based on this experience. Got additional CO_2 laser machine from corporate donor.
Plasma Cutting (2007 & 2016)	For making Agri tools using metal.	Not used	The machine never worked since beginning. There were issues with critical parts. Other issues related to electricity and voltage led to its failure.	There are lots of applications in agri tools and solar using sheet metal plates. Therefore in consultation & support from local metal fabrication industry, VA has recently purchased new plasma cutting machine.

CNC Milling M/C	PCB making, Moulding & Casting	Average	- End mills are expensive. Therefore unless essential (e.g. fab Academy), VA students used traditional PCB making methods. - Availability of SMD components was problems in the past. Making through hole PCB was difficult on CNC milling. Therefore traditional PCB making methods were used.	- The use is limited to Fab Academy projects and in the Fab Camps. - Moulding and casting is mainly used for training.
3D Printer (2014, 2015, 2016)	Science project, Jewellery design, casings, prosthetic project.	Good	- VA tried to make our own 3D Printer using D-I-Y kit. But it did not work. - Then VA purchased PLA 3D printer from local start-up. It had several maintenance issues, the company closed down. VA fab lab could not use it any more. - VA have purchased ABS printer from another start-ups. It is performing satisfactorily. - All this experimentation was funded from the awards received by VA.	Now 3D printer is working fine. VA team are working on making open sourced prosthetic hand in our lab. Recently, VA have got 3D printer from corporate foundation for secondary school.

Table 1: A machine wise analysis of the problems faced by the various machines installed in VA Fab Lab.

3 Fab Lab Staff

Vigyan Ashram (VA) is a voluntary organisation. There are challenges in attracting qualified persons due to limitation in salary, limited resources and remote location. Therefore VA employed technically qualified fresher's from surrounding areas and trained them on the job. They were encouraged to learn digital fabrication. Bright and committed members are sponsored to Fab Academy course. Sometimes, the trained person leaves the job for better opportunity. It has impact on VA lab operations due to such changes. But over a period, VA has many trained users of the lab. Now many of ex-VA staff and students have joined other Fab Labs. As such the efforts in training of youth are benefiting the Fab movement in India.

Volunteers / Interns: VA being a social organisation attracts many youth from India & abroad for volunteering. They have worked with VA Fab Lab in durations of 1-6 months. VA used their expertise to streamline some of the processes of the VA Fab Lab. Every year, about 4-5 volunteers contributed to the VA Fab Lab. These volunteers helped VA to complete projects, develop curriculum, conduct Fab camps and solve maintenance issues of the equipment's. Beside volunteers, students from MIT/Fab Foundation introduced new tools and techniques. Realizing contribution of volunteers, VA has developed modest residential facility for volunteers. There were few volunteers who took sabbatical from their corporate job and worked in VA Fab Lab for a few months. In short volunteers are important strategic contributors in the VA Fab Lab operations.

4 Education

Education is the most important activity of VA Fab Lab. Students of VA are the primary users of the lab. They are youth in the age group of 14-20 years and have studied up to secondary school level. VA uses pedagogy of involving student in 'Socially useful productive work'. The work activity is selected in such a

way as to introduce curricular concept to students. Students provide various services to the community as a part of their learning. Services include agriculture, fabrication, electrical fitting, food processing, repair and maintenance, construction, etc. Digital fabrication tools become addition to this bouquet of services.

VA has developed a program to introduce them to the fab lab environment. Following programs are conducted for new students:-

1. Fab camp – To introduce machine operations in 3 days sessions. It involves introducing drawing software, operation of machines, printing of job & documentation. There is also small introduction to Arduino and micro-controllers. The details of the camps are on :

   https://vigyanashram.wordpress.com/2016/07/17/fablab-workshop-schedules-curriculumduration/
2. Think like an innovator – A manual to select project ideas and work on them. It is available on http://www.navazkarim.com/works/think-like-an-innovator/
3. FabEd – For secondary school children, VA has started a FabEd program. It is designed to link fab lab activity with curricular areas. The process of conducting FabEd activities can be found in the following link: https://drive.google.com/file/d/0B_Jk2xLqAXjcVmNydHRSc0EtVnRGOWNqSzdJLURLSHQ4MW1R/view?usp=sharing
4. VA is working with 122+ rural secondary schools and implementing 'Introduction to basic Technology (IBT)' program. In IBT program, students learn while doing for 20% of the school time. These schools have conventional fabrication & electrical tools. They also have computers. These schools are encouraged to work on design software and use VA fab lab for creating from their files. Projects on automation & microprocessors were introduced last year. This year, VA has planned to introduced electronics and 3D printing by conducting 40 camps for secondary school children targeting 300 students.
5. How to start Fab Lab : VA has designed and conducted 3 day workshop for organizations willing to start Fab Lab. It was successful and many new labs are opening up because of the training.
6. The new programs are announced and communicate through social media. Schedule of Fab events are on : http://www.vigyanashram.doattend.com/
7. On an average, VA fab lab is used by approx. 100 + youth every year.

5 Fab Projects

Fab lab environment helps to generate new ideas from VA students. Many projects ideas were born at VA Fab lab and developed into prototypes. There ideas have great potential. A few ideas, VA could not take it to the logical conclusion. Students, however, learned very well through these projects. It was very good academic exercise. But harnessing the good ideas to its full potential remains the main challenge of VA Fab Lab. Some of the good projects on which VA has worked but remain unfinished are listed in Table 2. These examples show the variety of projects that were handled by VA Fab lab. VA has invested time and resources on the projects. They could have benefited Fab lab and society. Such unfinished project remains main worry of VA fab lab.

On the other hand, VA has been successful in completing many other projects. Members have used traditional fabrication tools like arc welding, CO_2 welding, lathe machine, electrical motor rewinding unit, etc., along with tools for digital fabrication. VA has a food processing unit, poly-house, dairy, goat farm, poultry, traditional fabrication shop etc., on our campus. In true sense, VA can make almost anything on the VA campus. The completed or near-completion projects are listed in Table 3.

Documentation & report of all projects are shared on the blog www.vigyanashram.wordpress.com

Name	**Progress Made**	**Difficulty Found**	**Status**
Milk testing Device. (2002)	VA got initial circuit & program from MIT. It was reproduced in the lab. It was able to detect difference in the quality of milk samples.	VA team could not carry out the calibration of the circuits between good milk and spoilt milk. VA could not get technical report to make the efforts successful.	Projects still remains relevant.
Admin Device for Teachers (2005) To help teachers to maintain students records.	A device was made in the fab lab to record attendance of students.	Only one device was made. It worked and was tested in Pabal. Some more refinement was needed. But the person in-charge left the job.	There is no more need of the handheld device due to availability of Smart phone and apps.
Low cost weather station(2006). Unlike commercially available weather station this device measures only customized parameters necessary for pest management.	This was made with the help of volunteers from *Engineers Without Borders*.	One device was made. Refinement was not done. After first prototype, new person was not able to take it forward.	Still relevant and required.
Leaf Wetness duration sensor (LWSS). This need was expressed by grape growers. They want to know duration of dew wetness on the leaf to control pest attack.	Prototype was made and tested in the lab. There were issues in the consistency of the readings and sensor.	Two engineers worked on it for almost a year but could not take it to the field.	Project is still needed. It requires competence and patience in taking solution to the field.
Bull Controller - To control bulls in bullock race.	Idea is to make remote control reins to control bull. The circuit was made and it worked as prototype.	Did not get high torque motors to pull bulls reins. Therefore not tested in the field. The person doing the project lost interest and it remains incomplete.	Task remains incomplete.

Table 2: Unfinished projects at VA Fab Lab

Name	Applications	Status
LED lights for lighting (2003)	This was one of the first circuits made in the VA fablab. LED circuit was used to teach beginners on electrical concepts. Many students designed innovative lamp holders for their light unit.	VA published manuals and trained 40 youth in making such units. All together, VA & its students have sold approx.5000+ light units. A company M/S BOPEEI (http://www.bopeei.in/) is formed to make and sale the lights. VA won 'Development Marketplace' award 2012 by World Bank to train 300 village level entrepreneurs.
Pedal Power Generator (2006)	To charge batteries. Made a generator in the lab. It was later improved & commercialized and manufactured by BOPEEI.	VA won 'Development Marketplace' award 2007 by World Bank and supplied generators to 42 tribal residential schools.
Egg Incubator (2011)	To hatch eggs on small scale (100-500-1000) using grid /solar/wood as fuel. To maintain Temperature 37^{0}C and humidity 87% in the chamber.	Rotation of the tray and controller circuit was made in the lab. Now it is manufactured by firm M/S Future Innovative Solutions. They have sold 10 units so far.
Personal sanitary napkin Incinerator	To dispose of used sanitary napkin. It is for domestic use and can incinerate 1-2 pads at a time. VA also made a solar incinerator using Fresnel lens.	Made 10 units. The parts are cut using plasma cutter.
Automation system for hydroponic, poly-house and biome dome.	Automation system to maintain temperature, humidity, soil moisture. It is mainly used to make fodder with less water.	System made in the Fab lab is installed at poly-house, biome dome and hydroponic system at VA. It is also under testing at farmer's poly-house.
Smaller projects in use at Vigyan ashram	i. Talking Ganesha Question/Answer system ii. Water tank controller iii. Automatic street lights iv. Various educational toys	Used in VA campus. Designs are shared on the blog.

Table 3: Completed or near-completion projects at VA Fab Lab.

6 Peoples Involvement

Farming is the main occupation of the community around Vigyan Ashram. They are regular visitors to ashram. Through open house exhibition and demonstration, community become aware about the potential of Fab lab. Now, they come with their problems and ideas to VA. These are their needs and they are willing to pay for solutions from the lab. This helps VA, to work on real life problems. Following are few examples of projects done on demand from community :--

HTP spray pump attachment to a two wheeler.	For spraying pesticides in small farms.
High rise fruit cutter / Fruits on thorny bushes	Simple clutch and cutter attachment that can we fitted on any rod or bamboo.
Mahua collector	To collect flowers falling on the ground and getting spoilt in the soil.
Terrace dryer - low cost dryer	It uses basic drying principle and customised to local vegetables & climate.

Table 4: Service to the local community provided by VA Fab Lab

7 Fab Network & Fab Conferences

In last 13 years of Fab operations, there were many moments of disappointments and frustrations. Sometimes, nothing seems to work at VA Fab lab. The problems range from electricity to machines & computer software. Strength of network helps in overcoming such anxious moments. Visit of MIT students from Fab Foundation helped to overcome technical difficulties. Most importantly, VA team learned a lot from attending Fab Conferences. These conferences and workshops helped VA team to learn from other labs and implement the ideas at VA. Attending Fab conferences abroad by village based institute are not considered priority by many donors and foundations in countries like India. Therefore attending Fab conference remains a challenge and it has become possible so far due to support of Fab foundation. It can be concluded that investment in attending fab conferences by fab foundation greatly contributed to human resource development at VA.

8 Funding

VA is working with the support of foundation and individual donors. VA mainly caters to student from socially and economically disadvantaged community. Foundations are mainly interested in funding skill training which will give youth immediate livelihood. Long term and capacity building initiative like Fab Lab goes into lower priority activities. Fortunately, VA got initial support from MIT for machines. Department of Science and Technology (Govt. of India) supported salary of one Fab Lab engineer & a small financial support for recurring cost. Other than this, VA-Fab Lab has not got any significant financial support from 2002-2014.

VA-Fab Lab operation is funded by combination of following –

i) Government (Dept of science & Technology) : 20 % of total cost of operation, mainly for salary of Fab Engineer

ii) Fees of students: 40 % to cover mainly cost of project materials.

iii) Private donors and foundation : 10 % for machine up-gradation

iv) Projects against orders :10% (fees paid by the customers)

v) Fab Foundation : 20% (scholarship for Fab Academy students and Fab conference)

With the success of the Fab projects and awareness about the Fab Lab increased, VA started getting support from foundation to upgrade its machines and replenish its inventory. In 2015, VA got Laser cutting machine from corporate foundation and others.

In 2012, Government of Maharashtra sponsored establishing Mini Fab Lab in Pune. At present, Govt of India and State Government of Maharashtra are planning to establish tinkering labs, innovation centres at block & district levels. VA fab lab is regularly visited by authorities for consultation.

9 Way Ahead: Fab Lab for Appropriate Technologies

In last 13 years of operation, VA Fab Lab is becoming focussed on Appropriate Technologies (AT) for rural and under developed regions. Mr. Schumacher (1973) wrote a book 'small is beautiful'. His ideas give rise to concept of AT. AT technology solutions ask for:-

1. People's involvement in finding solution to their problems.
2. Solution which is environmentally friendly and uses local resources.

AT movement was at its peak in 1980. It has lost its momentum due to the following:-

1. AT solution was seen as inferior technology solution.
2. AT solution requires local skills and workmanship to make it locally.
3. AT solutions were difficult to replicate and hence its impact remains limited.

Fab Lab is for people to find solutions to their own needs with local resources. From the experience of Fab Lab at VA, it can be said that Fab lab can provide answer for the shortcoming of AT movement of 1980's.

1. Digital fabrication and computer cutting machine will reduce dependence on the local skills for reproducing the product.
2. Sharing of designs and files become easy in the fab lab network.
3. Fab network will make it is easier to work with the other labs with similar interest and problems.
4. Fab Lab are using advance technologies and gives aspirational value to the user.

At present, Vigyan ashram is concentrating on AT projects in the following areas-

1. Precision agriculture
2. Prosthetic solutions
3. Clean Energy solutions

Design Innovation Center (DIC) : VA has started DIC to overcome the problems of incomplete project ideas. DIC started a course on design for graduate students. They will work in the Fab Lab for six month and learn design concepts by working on real life projects. The project will be evaluated on the criteria of user experience and field testing. They will get academic credit from Savitribai Phule Pune university (SPPU). This initiative started in March 2016 and now has ten engineering students working on their projects. SPPU is planning to setup three more Fab Labs on the model of VA.

10 Conclusion:

In 2002, Journey of VA fab Lab started in small tin-roof room of 150 sq.ft. In 2005, Fab Lab was shifted to slightly bigger room of 800 sq.ft. In 2011, Fab Lab was shifted to well-constructed workplace of 1000 sq.ft. In 2016, VA fab Lab shifted to 2000 sq.ft place. The journey is described as Fab Lab 0.0 to Fab Lab 0.4.

The journey was full of challenges and fulfilment. Lots of questions are asked about sustainability of the Fab Lab. Anything which is useful and needed by the society, sustains itself. VA Fab Lab survived and grew up in last 13 years. It became possible due to support of various stakeholder and Fab network.

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