Scalable makerspaces in the rural community for creating a sustainable ecosystem in developing countries

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Abstract

Underserved communities in developing India are facing significant barriers to implementing policies to develop an education system that prepares India's labour force for the 4th industrial revolution. Comparing three stages of the academic trends - past, current and future, there is a drop of interest and a disconnection with academics where an absence of context-based learning is one of the reasons. Our research focuses on the role of the maker ecosystem to the overall development of an individual's self-efficacy and mindset in rural/remote communities in developing countries like India by launching scaleable makerspaces. This study develops a model for the concept of community-driven makerspaces to learn new approaches to STEM. We observed that in general the students from rural schools accepted the teachers' position easier than urban students and they also demonstrated more cooperative learning without negative competitive motives. This helped students learn STEM concepts through group work. Findings here are based on a project involving 7500 participants (students, college students, teachers, parents) from 60 schools from 51 villages.

Introduction

Entrepreneurs have the power to transform communities by building startups that solve problems and create jobs. Current efforts in the development of entrepreneurs are primarily limited to helping and training university students and young adults in the startup process while many have not built the necessary skills and mindset to be an entrepreneur. What if school age students could be trained to develop these factors at an early age? How would it affect their academic performance, innovation skills, entrepreneurship attitudes and social engagement? Can such training be offered in under-served and rural communities?

EnCube Labs, a social enterprise with the goal of creating tomorrow's innovators and entrepreneurs through training them on creativity, making skills and critical thinking, aims to work with school students in underdeveloped and remote communities to initiate changes at individual and societal levels. With a plan to reach 1 million students in India over the next 10 years to create 100,000 entrepreneurs, EnCube Labs piloted different maker programs in the form of STEM activities at different academic levels. This goal created many opportunities for EnCube Labs to collaborate with government bodies, private sector schools, colleges and organizations to implement and run pilot projects to achieve the goal. To start with the experimenting, we gathered a team of mentors and resources at different schools directly in villages which can be scaled to develop STEM awareness with minimum costing. As a result, we created a system which builds a chain of young student mentors who can scale the STEM activities in their surroundings.

Early engagement, collaboration and then execution of different activities helped build healthy maker ecosystems in rural environments. Trust and belief are two major determinants of healthy working relationships with stakeholders in villages. Observations of increased membership and commitment showed enhanced alignment of the community's mindset with EnCube's methodology. Cost-effective interventions, with self-learning and co-learning approaches, triggers capability and learning attitude of kids.

A seed project was done collaborating with a local execution partner and was used to develop a scale model for 60 schools in 51 villages of an Indian district, with the creation of a rural maker community.

This paper focuses on a scalable model for 'community makerspaces in rural academics' started from a village named Idar (Gujarat, India) with an emphasis on awareness, collaboration, competency, culture, strategy and planning. To have the next generation of young entrepreneurs we need a team of makers/trainers/mentors with enhanced self-development skills.

Rural Dynamics

In academic institutions in villages, the student communities feel less confident to come forward, collaborate and learn new technology because of language barriers and the lack of resources, self-efficacy, and guidance. They remain untapped for opportunities. But on the other hand, our research shows that in villages/remote areas in India, we have a lot of innovators (maybe more than in urban areas) who have solved their encountered problems very differently, creatively and cost-effectively.

To fill this gap, spread awareness, create role-models, and provide resources and mentorship, we conducted a few interventions which we have covered in this paper [1].

Methodology

Scalable Makerspace

The idea of scalable makerspaces is to initiate a maker movement with low-cost activities where students [4] can be engaged and involved in context-based learning. Once they get positively addicted to making and experiential learning it can be scaled according to financial budget and learning requirement [3][4].

Table 1: Sequence of scalable makerspaces

Cost	Material	Make	Tech Skill	Smart Skill
$0 Zero Lab	Newspaper, Glue, Thread, Rubber Band	Paper Tower, Bridges, Origami	Complex geometry, Structure design, Product Sketching, Art	Learning from failures, Presentation, Teamwork
$100 Mini Lab	Hot Glue gun, Jigsaw, Styrofoam cutter, Basic Electronics, Motor	Static & Kinetic Models,	Basic Electronics, Simple Machines, Casting	Movie Making, Design Thinking
$3000 Maker Lab	3D Printer, Arduino, Sensors, Actuators, Hand tools	Intelligent control Systems & Robots	System design, Advanced electronics, Coding	System thinking: UI/ME/EE/ Coding

1. Zero Lab (No Cost) - Type 1 Intervention

To initiate a Zero Lab makerspace, the EnCube's partner institutions provides a common space to make things using material brought by students from their surroundings, which has little to no cost.[6] Example materials include newspapers[7], paper cups, and string.

At UniqYOU school in Idar, India, in one repair fest session called Break and Repair (Tod-Fod-Jod in Hindi), students brought mostly non-working products and opened them up to understand the science and technologies behind them supported by EnCube Mentors. As an outcome of this session, the fear of black boxes in the students' minds diminished significantly. This batch of students became mentors and conducted similar such sessions to teach their peer groups. This also started the students' journey with experiential approaches to developing practical applications[9].

Figure 1: Paper tower and Break & Repair session from Zero Lab Activity, where students teach students

Experiments for Zero Labs

We have developed a list of activities where students utilise various waste materials available in their surroundings for the practical approach of STEM education. It is the nature of a student to explore practical concepts more than theories, and this became a leverage point with the school students.

We started with the fun exercise of making a tower using newspaper. Students had to bring old newspaper from their homes and we provided tape and clips. With a 30 minute making activity, we enhanced their practical understanding of concepts such as centre of gravity, mass, mass distribution, different types of structures and bases, and degrees of freedom. This challenge could be enhanced by an additional constraint of supporting a half-litre water bottle on the top of the tower. Using zero lab activities, we can enhance the students' abilities of analysing their surroundings.

2. Z2M Mini Labs ($ 100) - Type 2 Intervention

After being introduced to STEM activities in Zero Labs, with experiential approaches, students demanded more technical exposure. This initiated our next phase of 'making'. We introduced a "Mini Lab" costing only $100, and challenges covering different topics of physics, maths, electronics, and design.

The Mini Lab introduced the concepts of electronics, design, and mentor support. This activity changed students' mindset and their approach to handling community problems. They learned to learn from their environment and were empowered to propagate this knowledge.

Figure 2: Robotic car assembly and basic of electronic session from Mini Lab

Intervention 1 (Nov 2018)

To start the journey of 'making' and test their curiosity and capability, we planned this Mini Lab Program in five schools from different villages and monitored how rural students adopt this methodology without any support from us. The program provided Mini Labs to each school. A limited curriculum in the form of the processes required to make objects from a specific maker kit was also provided. Each Mini Lab included a timed self-learning activity that could engage a batch of 30 students. As a resource, a mentor was provided on an availability basis for each lab to address technical challenges associated with the kits.

Example Mini Lab - Navigation Robot

This Mini Lab consisted of 4 geared DC motors, 4 wheels, one 9V power adapter, two DPDT switches, and tools (such as screwdrivers and a soldering iron)

The Lab covered the following Self Learning Challenges:

1. Assembling a robotic car with 4 motors, wheels, and chassis. (20 min)
2. Soldering and connecting wires to control motors. (20 min)
3. Connecting motors with a 12-volt power supply and moving motors while checking polarities. (45 min)
4. Connecting DPDT switches to control the direction of rotation of motors. (30 min)
5. Making connections in a way that their bots move in all directions. (45 min)

Based on completed projects the teams were evaluated by their demand for continued activity, self-learning and team capabilities, confidence, and teaching abilities.

Learning

After this experiment, we saw an enhancement of confidence based on self-exploration as they identified and discovered their capabilities. The trained group of students from the first batch became mentors for peers around them and started a chain of peer learning, thus helping in creating a local maker community and movement. YouTube and Google search played a very important role in this intervention.

With gained knowledge, the same group approached EnCube with more advanced technical and logistical demands. Their hunger for knowledge enabled them to push these forward by themselves. By providing exposure to the program to other schools via invitations and outreach, we received requests from other schools from surrounding villages to start similar programs.

Intervention 2 (April 2019)

In rural areas, students do not get opportunities easily to explore technical objects by which they experiment with their own ideas and learn from their failure. Awareness plays a key role in spreading maker movement in rural areas with the help of two main bodies - EnCube's methodology and an execution partner like a foundation or a school. This is the key factor for scalability. *EnCube and Good Human Being Foundation* sparked a movement in 60 schools in 51 villages through *Intervention 1.*

In order to achieve this scale, the following steps were taken.

- Connections were established with various stakeholders to create awareness and teams for the Mini Lab activities.
- Core execution partner team members went to each village and identified students and teachers, capable to become mentors and propagate Mini Lab activities in their respective schools. Each village had a coach picked from this identified group.
- To facilitate this propagation, clustered workshops were conducted for the identified group and a competition was announced across the entire community.
- Mentors were provided the same kit as the one provided in *Intervention 1* for each school.
- A Maker Lab was established in each school and was available for any student to learn to make a navigation bot.
- Eligibility for groups to participate in the zonal competition event was specified as being able to mentor a minimum of 50 students in their community using robotics from the Mini Lab.
- The competing team received all resources free of cost from the corporate social responsibility and sponsorship funds provided by various supporting organisations.

24 teams were selected from the 60 schools and the challenge problem was slightly modified by including additional components (DC motor and DPDT switch) and requiring that the finished product be capable of lifting a 6-inch wooden cube. We observed that the maker mindset in these communities was beginning to take form.

Intervention 3 (May 2019)

To improve making abilities and skills, an electronics kit was introduced in the Mini Lab, to further enhance STEM capabilities.

Two mentors from the execution partner core team were identified and trained by EnCube as senior mentors to train the 24 student teams. Each team was trained using the included electronics to make a system that extended their basic controlled electric car bot into an automation robot. The mentors did not have any previous technical background in making, but they had clarity about the mindset of students and their desire to learn.

The training of the mentors was conducted at EnCube Fab Lab in Gandhinagar which is 120 KM away from these villages, reducing the requirement for all students to travel far. A total of 24 kits with an Arduino controller and sensors was provided to the teams so that they would learn the basics of microcontrollers and start to experiment with the technology.

The kit had enough components to cover the construction of a Bluetooth controlled bot, an IR based line follower and an obstacle avoider. These tools were provided to inspire further creativity in the students.

Following this project, a new 2-day Zero-to-Maker workshop was designed to allow students to undergo a full learning experience in general electronics and 3D printing within the existing Z2M Mini Lab curriculum.

This intervention further enhanced capabilities of students to present, make, understand, analyze, and communicate. This exposure to new tools and components not only made it more challenging and interesting to the students but also improved self-efficacy and confidence.[10]

3. Z2M Maker Lab in a box ($ 3000)

The Maker Lab in a box includes electronics, hand/power tools, a 3D Printer, and consumables using which participants can start making working prototypes and start solving real life problems.

Once students participated in the two levels of making using Zero Lab and Mini Lab, the Z2M Maker Lab kit was introduced to enhance their capabilities of emphasising, visualization, and implementation. This box not only provides resources, but it also helps them to give shape to their creations through making prototypes.

Figure 3: Zero2Maker Lab in a box by Prof. Rajesh Nair at Asia School of Business, Malaysia

Example*:*

Z2M Maker Lab, at Kedah, Malaysia was designed for 10 schools which support training and education for developing skills for the 4th industrial revolution by introducing ideation, mechanical, electronic and software design [8].

Figure 4: Zero2Maker workshop with participants with their projects from 7 different schools of Kedah, Malaysia

Maker Competency

We all have a maker inside us. With our experience, we now consider all stakeholders such as staff members, teachers, students, mentors as Makers. For the different Maker Lab levels we are defining the skills required to start local community-based maker spaces with minimum resources and identify team members to run them.

While running this first project, we were able to measure the impact of the maker labs through the following parameters using observations and surveys:

1) Hunger for learning
2) Problem identification
3) Self-learning ability
4) Team approaches
5) Communication

6) Presentation skills
7) Strategic planning
8) Analytical ability
9) Decision making

The project associated with these interventions allowed mentors to create more mentors, organisers to organise more activities and makers to become mentors for the next batch of activities through a recurring pattern. The initial models were scaled effectively and created a maker ecosystem for entrepreneurship in a rural Gujarati community. The same project can be expanded for different ages, communities and corporations to change the self-efficacy of individuals.

Results & Future Improvements

This program was designed to start a chain of mentors who make mentors. As a part of this initiative, we have student participants who taught kids from their own villages, where they improved their presentation skills, confidence, communication skills, and decision making abilities [12].

Reports by teachers/mentors say that almost all students were able to overcome their fear over technology, robots and blackboxes, 77% of teachers said that students have started analyzing their surroundings more effectively and asking more logical and productive questions in their routine academics [11]. These results give us more flexibility to develop learning modules based on STEM where students can explore technology and build on the basis of their own observations and problem statements.

The students created WhatsApp group to exchange ideas and help each other with their questions. Other than the enhancement in the initial outcome indicators we received one interesting outcome where participants and teachers said that WhatsApp (a digital tool) played a significant role in sharing information and content and resulted in stronger performance in this robotic competition. 77 out of 86 participants said it helped them in social and technical interactions. Based on this observation, we are now developing new methodologies where students can use this digital medium effectively for the next phase of self-learning challenge [12].

The survey also showed that each student taught on average 31.3 other students in their school or village. Some of the counts may be duplicate since they may have been taught each other. This shows that the spread of the ecosystem is happening faster than originally estimated [12].

Support from family is critical to the sustainability of this learning cycle. In the survey 88 out of 86 said they received encouragement from their parents and 75 said that their parents and local mentors helped them in making their robots [12]. The mentors were local electricians/ carpenters/ elders who did not even go to high school but still were a big part of their making journey through this intervention. Based on this finding, we have started developing interventions where we can engage local makers who can build a strong base for sustainability of the local maker ecosystem.

Conclusion

The study was started to measure the impact of the maker experience in students from underserved rural/remote communities. The intervention with different levels of maker resources, such as, Zero Lab, Mini Lab and Maker Lab in a Box were designed and implemented in rural schools and village communities.

The measurement of confidence among participants showed a significant improvement. Involvement of family and local mentors strengthened the students' experience. Similar interventions are inexpensive and showed a ripple effect where the group of makers influences and attract new candidates from the community, making this approach an effective way to transform individuals and communities from the bottom up.

References

[1] University of Texas at Arlington Libraries, "Maker Competencies and the Undergraduate Curriculum". LG-97-17-0010-17 - University of Texas at Arlington. [Online] https://www.imls.gov/sites/default/files/grants/lg-97-17-0010-17/proposals/lg-97-17-0010-17-full-proposal-documents.pdf Accessed 16/08/2019

[2] Martin L. Culpepper, "Types of Academic Makerspaces, Their Import to the Education Mission, and The Characteristics of their Culture and community", International Symposium for Academic Makerspaces, 2016, Paper No. 01

[3] Julian, "Innovation and Entrepreneurship for Youth and Community Development: Prof. Rajesh Nair Panellist at United Nations" News Service NemFlash, October 15, 2018.

[4] Kiran Kaur Sidhu, "THE ENTREPRENEURSHIP JOURNEY BEGINS AT 10, NOT 25", DNA, March 15, 2019.

[5] YouTube website. https://www.youtube.com/watch?v=UM5i5CCubag Accessed 16/08/2019

[6] EnCube Labs web site. http://encube.co/wp-content/uploads/2019/07/Zero2Maker-National-program.pdf Accessed 16/08/2019

[7] EnCube Labs web site. http://encube.co/wp-content/uploads/2019/07/Zero-Lab-Paper-Tower-Activity.pdf Accessed 16/08/2019

[8] YouTube web site. https://www.youtube.com/watch?v=GOwkbiNiMaw Accessed 16/08/2019

[9] YouTube web site. https://www.youtube.com/watch?v=d-eIeKkKz4I Accessed 16/08/2019

[10] YouTube web site. https://www.youtube.com/watch?v=Oprmz2uJM6k Accessed 16/08/2019

[11] EnCube Lab data web site. http://www.encube.co/research/survey-data-RPL2019-teacher.pdf Accessed 16/08/2019

[12] EnCube Labs data web site. http://www.encube.co/research/survey-data-RPL2019-student.pdf. Accessed 16/08/2019