A Self-Sustaining Model for Peer-to-Peer Engineering Education Among Children in Low Resource Environments

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***Abstract*—Engineering education among children has the potential to spark their interest in technical subjects, overcome gender imbalances within the field, and empower young people with the tools to make positive changes in their communities. However, it can be difficult to integrate into existing school curricula, especially when resources are constrained.**

Here I present a one-year case study conducted in Nepal where I formed a student-led electronics and programming club for children aged 10-16. The club model uses hands-on peer-to-peer teaching and open-source activity documentation. This approach allows the club to sustain itself and scale up without the need for ongoing teacher involvement. The documented club activities are low-cost, further lowering barriers for implementation. In total, over 100 hours of activities were conducted. Today, the students independently run 3 hours of activities each week, teaching their peers basic programming, electronics, and engineering design concepts.

This model for student-driven hands-on learning could also be used in higher education to increase student motivation and interest in course material. As student led initiatives, the activities would require minimal guidance from teaching staff after setup, while effectively complimenting typical lecture/lab course structures.

***Index Terms*—engineering education, Open Educational Resources, pre-college programs.**

I. Background

Between August 2017 and July 2018 I started an electronics and programming club at a Shree Mangal Dvip School (SMD) in Kathmandu, Nepal, which provides free education for children from remote Himalayan villages. There I partnered with a recent graduate, Tashi Choeden Lama, to form the club. In addition to his hands-on electronics repair experience, T.C. Lama's understanding of the school's routines and structure helped get the club started quickly.

During the first 6 months I developed, documented, and led new club activities every weekend with a group of ~50 students[1], aged 10 to 16, split into four sections. This approach was top-heavy, requiring full-time work. Reflecting on those first months led to the following 4 changes, aimed at improving the club's self-sufficiency.

1. The club operates on a clear year-to-year schedule.
2. Activities are documented in detail and made freely available for use and adaptation.
3. Activities are entirely student taught.
4. The structure has a built-in strategy for growth.

The four changes were implemented in the 5 months that remained before I left Nepal. Here I present the student-driven club model that resulted from the 11-month project. I refer to it as the Himalayan Makers Guild (HMG) club model, based on the club name chosen by the students. The club activities emphasize hands-on learning and the model is designed to be:

1. Self-sustaining: The club continually trains new students as leaders to maintain peer-to-peer teaching and the knowledge base among the club members.
2. Transferrable: Activities are documented such that a club can be established by someone with little or no previous knowledge. All teaching material is freely available use and adaption under the CC-BY-SA-4.0 license.
3. Inexpensive: The material cost for 11 activities, with groups of 20 students, is under $200 USD.

II. The Himalayan Makers Guild Club Model

A. Structure and Documentation

The HMG model consists of a Foundation Group (FG) and Project Groups (PGs). Each group's activities run for a 5-month period, with approximately one activity weekly lasting 1 to 2 hours. In the FG, new club members are introduced to foundational concepts in electronics and programming through 12 hands-on activities (see Table I). Each FG activity includes a lesson plan for the students leading the activity, as well as a single sheet hand-out for participants that highlights key points.

In PGs, students who have completed the FG activities apply their knowledge to solve a problem and learn about the engineering design process[2]. An overview document of the project provides guidance and resources for the student leaders of each PG to help them introduce the problem, understand potential solutions, schedule activities, and follow the engineering design process. The documentation for two projects has been created wherein the students create an obstacle avoiding car and a solar-powered light.

The use of 5-month periods in sync with the host-school's

Manuscript received November 1, 2018. This work was supported in part by the University of British Columbia Faculty of Applied Science.

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[1] All participation was voluntary. 60% of the participants were female, from a student population that was 50% female. However, only 50% of club members who took on leadership roles were female.

[2] https://www.teachengineering.org/k12engineering/designprocess

semesters gives the club a clear year-to-year schedule for their activities. Furthermore, each of the groups conduct the same activities during each period, but with new students. New members enter the FG, while other students transition sequentially through the two PGs. Reusing the same activities in each period allows the club to run continuously using the same documentation and sets a realistic bound for the knowledge that student leaders must be able to pass on to their peers.

TABLE I
FOUNDATION GROUP ACTIVITIES

No.	Description
1	Conductivity testing; introduction to breadboards
2	Rockslide analogy of electricity and building an LED circuit
3	Resistors in parallel and series, tested using a buzzer circuit
4	Introduction to Arduino, blinking an LED
5	Arduino with an RGB LED
6	Introduction to soldering, wire to wire
7	Ohm's Law and resistance; adapt LED circuit for 3V supply
8	DC motors and potentiometers
9	Arduino controlled servo motor
10	Servo motor locking box
11	Voltage divider nightlight, a light sensitive LED circuit
12	Improving the nightlight with a transistor (BJT)

Club growth and adaption is made possible by the students who have participated in all three groups and would like to continue to participate in the club. These students are invited to come up with their own projects to work on in small groups with guidance from existing student leaders. If these projects are successful they can be documented as future PGs that all club members can participate in.

The teaching material for all three groups is freely available use and adaption under the CC-BY-SA-4.0 license. Each activity includes a time and cost break-down. The activity material costs were minimized to make them as accessible as possible. The cost of running 11 of the 12 FG activities with a group of up to 20 participants is less than $200 USD (see Table II) when ordering parts directly from China through websites such as AliExpress, Banggood, or DX. This sum excludes the 6th activity which requires 10 soldering stations costing a total of $205 USD[3].

B. Leadership

Each group of 10 to 15 students includes 2 to 4 student leaders who are responsible for guiding the activities. In the FG, 2 of the 4 leaders are new to the club, while 2 have already completed the FG activities and can do more to support the new leaders. Immediately training new leaders from the new student group helps familiarize students with the responsibility and maintain the number of student leaders in the club. Similarly, 2 of the 4 leaders for PGs are selected from among the existing club members, while 2 leaders who have already completed the project support them.

One experienced student leader in the club, the Club Head, is responsible for meeting with the student leaders prior to each activity to help them prepare. Together the student leaders and Club Head work through the documentation and practice teaching the activity. While the documentation for the FG is very specific and prescriptive, the PG documentation provides more general directions allowing the Club Head and leaders to decide on the details of each activity. The Club Head is also responsible for organization and administration of the club including scheduling, recruitment, and resources, for which they can depend on the support of the other student leaders. The role of Club Head is a large time investment and may be best facilitated by an internship-style appointment.

TABLE II
FOUNDATION GROUP PARTS COSTS

Part Name	Quantity	Total Cost[a]
Breadboard, 400 point	10	$10.80
Jumper Wire, Assorted	120[b]	$1.60
Resistor, Assorted, 1/4W	2100[b]	$9.00
5V/3.3V Breadboard Power Supply	10	$5.43
Rechargeable 9V Battery for Power Supply	10	$50.00
9V Battery Snap Connector, Barrel	10	$1.19
9V Battery Charger	10	$14.80
LED, Assorted colours, 5mm or 3mm	200[b]	$3.03
Arduino UNO Microcontroller + USB Cable	10	$48.00
Button, Momentary, SPST	100[b]	$1.60
Buzzer, 5V DC	10	$1.37
Servo Motor, 5V DC, 9g	10	$12.90
Light Dependant Resistor (LDR, LSR)	20	$0.70
RGB LED, Common Cathode, 5mm	100[b]	$2.99
DC Motor, 5V	20	$12.65
Potentiometer, 10 kiloohm	20[b]	$5.50
Transistor, BJT, NPN	20[b]	$1.40
Total Cost		$182.96

The cost for 10 sets of parts, suitable for up to 20 participants, excluding soldering stations used only in the 6th activity (an additional $205 USD cost).

[a]Prices are in USD from AliExpress, July 2017.

[b]These parts are likely to be broken during activities.

Leaders are selected based on their interest in the role, as well as the commitment they've shown the club through their attendance and participation, as judged by the existing student leaders and Club Head. A new Club Head is selected each year from among the experienced members of the club. During recruitment at the beginning of each period, the Club Head and student leaders decide which leaders will be responsible for each of the three groups.

Although the club is student-driven, it is important to have external support. If the club is based at a school, direct communication between the leaders and a designated staff member will help address administrative issues such as space and scheduling, as well as provide them with a mentor they can talk to about the technical content of the activities.

III. RESULTS AND DISCUSSION

Over 100 hours of hands-on activities were conducted throughout the development of the HMG club model. Today, ~50 students continue to participate in weekly club activities at SMD school. Since May 2018 the first cohort of students using the model have successfully completed the Foundation group and two Project Groups (see Fig. 1 and Fig. 2.), with each group meeting for 1 hour per week. T. C. Lama has acted as the Club Head. Funding has been secured to test the club model at the school for the next two years and validate the transition of club leadership between each 5-month period.

This model for student-driven hands-on learning also has potential for use in higher education. Activities analogous to

[3]For details on solder station setup, see http://www.harrypigot.com/nepal/solderingsetup/

those used in the Foundation Group for students aged 10-16 could be developed to present topics related to university-level course work. After initial documentation and setup, the activities could continue as student led initiatives, requiring minimal input from teaching staff. This would work particularly well in an open learning environment, such as a campus makerspace.

Fig. 1. Students from the obstacle avoiding car Project Group present their completed prototype, October 2018. Photo by T. C. Lama.

Fig. 2. Students from the solar-powered light Project Group present their completed prototype, October 2018. Photo by T. C. Lama.