

# STEM Laboratory for Schools in Gandaki Province and Beyond

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## Abstract

The principal motive of this study is to design a master plan that promotes STEM education integration in the academic sector and strengthens the laboratory settings of the schools in Gandaki province and beyond. This study has summarized the essential components for developing a STEM lab, guidelines for the design, and a tentative cost estimate for a school-level STEM lab. Moreover, this study provides insights into STEM Club formation, its objective, and curriculum for training trainers in the STEM Lab. Evaluation parameters for over-all STEM performance have also been highlighted in this paper. Therefore, this study will be an essential document to guide the academic sector regarding STEM laboratory design, the implication of STEM club formation, and organizing training for teachers, which cumulatively become a driving force for STEM education in Nepal.

*Keywords:* Master Plan, Guidelines, STEM Lab, STEM Club

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## 1. Introduction

“STEM,” an acronym for science, technology, engineering, and mathematics, was initially proposed by the National Science Foundation (NSF) of the USA in the 1990s to emphasize the need of these four disciplines in the education community and society [1]. STEM education is a practical based method of teaching and learning in which focuses on learning by doing. Unlike traditional approach, this is a multidisciplinary approach which interlinks the science, technology, engineering and mathematics in the contexts that has connections with community, society, and nation: thereby preparing the workforce required to keep country competitive in global economy. The STEM lab is an integrated environment that supports hands-on learning. STEM lab plays a crucial role in arousing students’ interest in science, technology, engineering, and mathematics. Laboratories applications

play a central role in enabling effective, permanent, and enjoyable learning. The advocacy of STEM education will be beneficial to ameliorate the nation’s economy and individuals’ comprehensive abilities [2]. Currently, in Nepal, the traditional mono-disciplinary approach is more prevalent in the academic sector, due

to which there is a gap between theory and practice. According to the report on higher education published by UGC in 2021-out of 40921 students enrolled in higher education during the year 2019/20 only 23% were enrolled in STEM disciplines [3]; in order to improve this status interests in school students about STEM disciplines should be aroused from school interests integrated approach to teaching the STEM disciplines with a meticulously designed STEM lab is the need of today.

## 2. Methodology

The work commenced with the review of documents found on web and National Building Code of Nepal. With the information obtained from literature review and field visit of labs; requirements for a STEM lab were identified. Few meetings with experts were organized through which the experts provided their opinions and views on the topics like floor plan, guidelines, club formation, monitoring and evaluation, etc. Assimilating all the aspects of a STEM lab, a draft master plan was prepared, and discussions were carried out. Ultimately the final master plan was designed to incorporate all the comments and feedback. The flowchart demonstrates the methodologies during the work.

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Figure1: Methodological flowchart

### 3. Results and Discussion

#### 3.1 Guidelines for laboratory design

This guideline gives recommendations for setting up a new STEM lab from scratch.

#### A. Room Requirements

##### Size

The laboratory should be designed to accommodate 24 students, excluding teachers. The laboratory floor area should be 43 square feet for each student [4]. The minimum standard area should be 1032sq. feet.

##### Doors

Each room should have a main entrance and an emergency exit. The doors should have ventilation on their top. The width of the emergency exit should not be less than 3 feet and 6 inches.

##### Windows

The recommended area of the openings is one-fifth of the floor area for proper natural lighting and ventilation. Windows should be provided on at least two sides of the room for appropriate natural light and ventilation. The sill level should be at least 2 feet 6 inches above the floor level, and the lintel level can be extended up to the beam.

##### Electricity

Concealed conduit wiring hidden inside the wall slots with the help of plastering. A single emergency shut-off switch in each science lab/classroom that will break all the circuits should be provided. The emergency switch shall be highly visible and be readily accessible to the teacher but not easily reached by students.

##### Plumbing

Open plumbing system on the surface of the wall. CPVC pipes of half-inch diameter can be used to supply water to each sink and a pipe of one-inch diameter can supply water to the showerhead. There should be two separate gate valves for supplying water to the sinks and the showerhead.

##### Gas supply

Branches from mains to each burner with check valves to prevent the reverse flow.

#### A. Interior Requirements

##### Teachers Area

A raised platform should be made that can accommodate a teacher's desk and a chair. At the back, the writing board should be mounted on the wall. The recommended dimension of the teacher's desk is 5'X2'6" X2'6".

##### Student's desk and chairs

##### •Desk

Costume-made wooden desk on wheels, metal framed with waterproof, chemical resistant Phenolic resin laminate top; commonly known as Formica on the market. Each desk should not be designed for more than four students. Following recommendations can be followed:

Table Size: 6'X3'X2'6"

Edges: Round

Surface finish: Formica laminates (1-1.3mm thick)

##### •Chair

Costume-made wooden chair with a squared-shaped seat, metal legs, and two spindles (platform to rest legs) at a different height. A hole at the center of the chair is recommended so that it can be lifted, holding from there. Sharp edges should be avoided. Following recommendations can be followed:

Seat size: 14"X14"

Height: 2'

##### Storage cabinets

At least four numbers of storage cabinets should be provided to store the materials of Physics, Chemistry, Biology, and DIY. Following recommendations can be followed:

Size: 5'X1'6"

Height: Full floor height, i.e., from floor level to ceiling

Material: wood

Opening type: sliding or hinged type with recessed handles

Depth of a shelf: not more than 12 inches

Biology Storage cabinets may incorporate specimen display racks.

##### Display Cabinets

A display cabinet should be provided to display various items for demonstration.

##### Exhibition/Writing Boards

Three to four numbers of movable boards should be provided. They can either be used as exhibition boards or as student writing boards.

##### Flooring

Cement concrete flooring or polyvinyl flooring can be used. Use of floor carpets should be avoided.

##### Ceiling

In the case of RCC structure, a normal cement concrete painted with suitable color can be used, and in the case of truss structure, a false ceiling of plywood or Gypsum board can be used.

#### **Paints**

Paints that can be wiped clean will not readily absorb liquids and can prevent microbial growth are recommended. Emulsion vinyl paints and acrylic paints can be options [5].

#### **Electricity Fixtures**

At least six numbers of electrical outlets should be mounted on the walls. They should be near to the students working table.

#### **Sanitary Fixtures**

Single bowl sinks made of ceramic, steel, or polypropylene is recommended. There should be at least six numbers of sinks for the student. An additional sink may be provided to the teachers. These sinks should be near to the students working desks.

#### **Burners**

At least six Bunsen burners should be provided for the students. The burners should be placed in such a way that they are near to each student's working table. LPG can be used for supplying the gas to burners.

#### **Fume hoods**

Chemicals with significant inhalation hazards should only be opened inside fume hoods and experiments generating corrosive and toxic gases should only be performed inside fume hoods. A chemical fume hood with a ducted outlet or an exhaust fan for evacuating the gases accumulated in the hood should be used. There should be the provision of lighting inside the fume hood. A fume hood having storage cabins is recommended.

#### **Preparation Platform**

Preparation areas should have enough space for placing different practical equipment. Following recommendations can be followed.

Top width: 2'

Surface finish:

Rough Ceramic tiles (50-70mm thick)

Height: 2'7"

Storage cabinets can be made below the work surface for storing chemicals and equipment.

Figure 3: Sample floor plan-Model 2

### **Safety Requirements**

#### **Fire Safety**

There should be at least two fire extinguishers placed at two different locations inside the laboratory. Powder type ABC fire extinguisher is recommended.

Some woolen blankets should be stored so that they can be used for protecting persons during a fire and as fire inhibitors.

Sand should be stored in buckets for metal fire.

#### **First Aid**

Each laboratory should have a first aid kit consisting of essential medicines, antiseptic lotions, creams, bandages, sterilized cotton, Dettol, etc.

#### **Shower and Eye Washes**

Each laboratory should have a safety shower to protect persons from chemical splashes and burns and eye-wash to flush away the hazardous substances into the eyes.

They should be within 25 feet of each working area.

There should be the provision of a continuous water supply for at least fifteen minutes once activated.

#### **Waste Boxes**

Various categories of wastes should be collected in separate boxes.

### **D. Lab uniform and safety wears**

#### **Uniform**

Before entering the laboratory, each student should compulsorily wear an apron. Coats and jackets can be hung on the apron hanger placed near entrances.

#### **Safety Wears**

While handling hazardous substances, everyone should wear masks, safety glasses, gloves, helmets, and PPEs.

### **3.2 Sample floor plan**

This sample floor plans depict the necessary facility and furniture prepared using AutoCAD software. These floor plans are solely sample and this doesn't mean every design should be exactly similar. Here a laboratory room is divided into entrance/exit sides, storage/display sides, preparation areas, working areas, emergency treatment area, teachers' area and so on.

Table 1: Cost Estimate

Summary of Estimates		
SN	Expenses Head	Amount (NRs)
1	PCBM (Physics, Chemistry, Biology & Mathematics)	654,880
2	DIY (Do It Yourself)	396,975
3	Furniture	462,000
	<b>Total</b>	<b>1,513,855</b>



Figure 2: Sample floor plan-Model 1

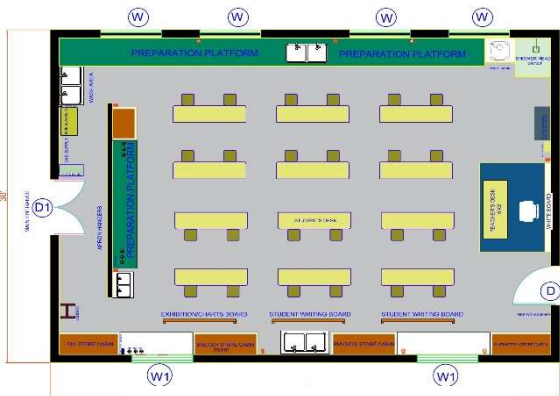


Figure 3: Sample floor plan-Model 2

### 3.3 Materials list

Materials required for conducting curriculum-based science practical and STEM activities are categorized based on science disciplines, availability, reusability, cost, etc. [6]. This section consists of the following list of materials: 1. Materials for conducting Physics, Chemistry and Biology experiments. 2. Mathematics materials 3. DIY/STEM materials 4. Materials for low budget 5. Locally available materials 6. Consumable and non-consumable materials. *Detail list of materials can be accessed at <https://bit.ly/3w8cX0w>*

### 3.4 Cost Estimate

The table below shows a tentative cost estimate for setting up a school-level STEM lab.

### 3.5 STEM Club

STEM club will be formed by the inclusions of students and teachers. The STEM club will help to organize the workshops and carry out the activities related to STEM disciplines in order to encourage learning by

doing. Consequently, the STEM club fosters technical skills, critical thinking, cooperation and collaboration among students which in long run will provide students the insights to solve the problems of community and nation as a whole.

Table 2: STEM club

STEM Club	
Objective	To promote learning of STEM disciplines in students to make them more marketable.
Club Structure	Three teachers (math, science, and computer) and five students (a student from every class 6-10)
Club Operation	Members visit the lab at least once a week and use STEM equipment to explore various projects. A workshop to be conducted once a month using STEM equipment

### 3.6 Teachers Training

The teacher is the prime influencer and decision-maker in the classroom; lack of training, or poor training, will make him/her face the challenge of having poor subject knowledge and poor professional and pedagogical skills to deliver the lesson, assess learning, and provide the learner with the appropriate knowledge and learning experience [7]. So, teachers' training is necessary to impart effective teaching and classroom management dexterities.

The following table provides succinct information about teachers' training.

Table 3: Teachers' training

Topic	STEM Lab
Target Participants	Teachers up to secondary level teaching in Gandaki Province
Training Rationale	Providing knowledge about STEM Lab design and implementation for integration into the current teaching profession
General Objective	To improve understanding of teachers for how to plan, implement and evaluate STEM Lab related teaching methodologies and bring motivation to enhance teachers' performance and hence students' achievement
Specific Objectives	<ul style="list-style-type: none"> <li>To develop skills and knowledge and implement</li> </ul>

	<p>the framework of STEM education</p> <ul style="list-style-type: none"> <li>• To learn how to develop and integrate STEM Lab activities into the academic curriculum</li> <li>• To understand different types of STEM Lab activities, their purpose with examples</li> <li>• To understand different teaching-learning methodologies for STEM education</li> <li>• To cultivate innovative and integrated pedagogy of STEM education in basic education</li> </ul>
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### 3.7 Monitoring and evaluation

<i>To be filled before entering the laboratory</i>					<i>To be filled after exiting the laboratory</i>			
Date	Entry time	Name of Student/s	Name of Teacher/s	Activity/Project work	Equipment Used	Challenges	Exit time	Comments /remarks

Figure 4: Sample logbook

For monitoring and evaluation, logbook preparation and evaluation forms are suggested. Monitoring includes the study of how many teachers/students have visited the lab, what they have performed, which discipline is more attractive to the students, how many hours the stem lab was used, and what type of support they need to run the lab smoothly and summarization of all activities that happened in the lab. Figure 4 shows a sample page of the logbook.

### 4. Conclusions

This comprehensive master plan covers all the aspects required for setting a complete STEM lab for schools, from the starting phase to the post-monitoring phases. Thus, this document serves as a guide on incorporating and combining multidiscipline to create a platform for learning, innovation, and cooperation, as there is limited curricular framework for STEM education initiatives in Nepal.

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