



## **Biomimicry: An approach for Innovative STEM Projects in High School**

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### **Abstract**

*In Thailand, National Science and Technology Development Agency (NSTDA), the Science Society of Thailand under the Patronage of His Majesty the King, and the Institute for the Promotion of Teaching Science and Technology are the three leading organizations that contribute to the development of scientific education through encouraging high school students to do STEM projects. There have been more than 2,000 STEM projects supported by these organizations over 20 years. This article explores 2 topics, ideas behind Biomimicry and key factors that make the STEM projects successful.*

*Many innovative STEM projects from both international and national contests are inspired by the nature including structures and functions of living organisms which, through evolution, are both sophisticated and well optimized for surrounding environments. We define these types of projects as "Biomimicry". A few examples are millipede's movement mimicry, bio-based packaging plastics from fish scale, and water retention mimicry of the Bromeliaceae.*

*To investigate what makes successful STEM projects, I interviewed many STEM award winners, both project advisors and students. There are 5 major factors: the opportunity to closely observe the living organisms and their environments, relevant questions which bring about innovative ideas and designs, inspirable advisors who are open-minded and willing to spend sufficient time with students, deep scientific understanding, and last but not least perseverance to make the projects successful.*

**Keywords:** *Biomimicry, STEM projects, from nature to technology, inspiration, project approach, science education.*

### **1. Introduction**

The STEM project, which incorporates science, technology, engineering, and mathematics in conjunction with investigation, design and development skills, is designed to encourage creativity amongst students. This project does not only serve as a tool for expansion of knowledge, but also help develop essential skills for these students[1].

From an experimental perspective, in contrast to the current approaches to scientific learning of Thai students, in the past, the majority of them conducted projects without applying multidisciplinary methods or instruments. In summary, the 4 main types of research on which their research projects based are: a survey, experimental, theoretical, and developmental research projects or inventions.

Thus, over the past 20 years, we have been attempting to encourage high school students to conduct research projects with the assistance and support from schools and some Thai organizations. Over the course of these 2 decades, we have observed a number of notable research studies which follow a clearly growing trend towards integrated disciplinary application of science, technology, engineering, mathematics, and multiple processes, all of which are the criteria which lay the foundations for STEM projects.

Worthy of note, another key aspect of inducing creativity in students and the enabler behind the success of the STEM projects is biomimicry, an approach to innovation that mimics or imitates nature for new creations or processes for the purpose of solving complex human problems[2],[3].

This article, therefore, aims at motivating students to derive new ideas of developing their future STEM projects by employing the knowledge of biomimicry.

### **2. Program design and Methodology**

In this study, the award winning STEM projects from both local and international contests from the past 20 years were selected. Among those projects, only the ones which were inspired by nature were shortlisted. The questionnaires, then, were distributed to both teachers and students whose projects

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won the awards to establish as to how students derive the ideas of conducting their projects and what was attributed to the success of their projects.

### 3. Result and discussion

This study focuses on how students derive ideas to conduct their STEM projects and what contributes to the success of these projects. The following are the 5 contributing factors based on the interviews:

#### 3.1 The opportunity to observe the living organisms and their environments closely

Noticeably, students who play in or expose themselves to nature and have fun with observing and studying living organisms relatively tend to conceive new ideas from nature. This assumption holds true to Jarupon Sathirapongsuti, one of the student team members who received the first award from the National high school Science Project and the Best Interdisciplinary Project Prize from Sigma Xi, the Scientific Society, the Intel International Science and Engineering Fair (Intel ISEF2004) under the topic of “Walking with the Millipede”: A Mathematical Model of Millipede Gait and Locomotion. He observed that, during the rainy season, he saw a millipede crawling at his school. To his surprise, he noticed that the millipede could crawl on the slope and on a rough floor without falling.

These learning characteristics are shared by Suksan Itthipanyanan, Klongrat Suwanasri and Tanongsak Chinaroonchai, 3 of Thai students who received the award from the National High School Science Project and the Grand award from the Intel International Science and Engineering Fair (Intel ISEF2006) under the topic of “Dehiscence and Dispersal of the Popping Pod *Ruelia tuberosa* L.” According to their accounts, they really loved being outdoors and playing with friends. The idea of their STEM project originated from dry popping pods they picked up during their outdoor play. They observed that many pods would pop when they were rubbed with saliva or water.

Similarly, Sureeporn Triphetprapa, Kanjana Komkla and Thidarat Phiancha invented the water retention model by mimicking the structures of the Bromeliaceae[4]. The idea of this project emanated from their study of the Bromeliaceae’s leaf which has a U-shaped blade with its two marginal sides of the leaf thinner than the middle part, which enables water to flow into the catchment between the leaf sheaths. Their invention received the prize from H.R.H Prince Carl Philip of Sweden in the Stockholm Junior Water Prize 2016 in Stockholm.

#### 3.2 Relevant questions which bring about innovative ideas and designs

As to Jarupon and his team, initially, they were curious to know why a millipede meanders the way it does and how we could develop a mathematical model in response to the millipede’s movement. Their curiosity led to the innovative idea of inventing a multiple legged robot which can walk on a slope and on a rough floor, mimicking the movement of a millipede.

For Suksan and her team who conducted the STEM project on Dehiscence and Dispersal of the Popping Pod. They created the innovative stiff paper-based device for measuring the circular trajectory of the dispersing popping pod and the stiff squared paper for calculating the angles of the dispersing popping pod.

Likewise, with their enquiring minds, Pornwasu Pongtheerawan and her team developed environmentally friendly material for their STEM project. They wondered how we could develop bio-plastic at a low cost to be used for food packaging. Therefore, they were interested in developing bio based plastic packaging made from fish scales by extracting biopolymers from the scales. The team was able to create effective, low-cost, eco-plastic food packaging for potential use and could help reduce reliance on petroleum-based products. Their project received the National High School Science Project, Grand award from the Intel International Science and Engineering Fair (Intel ISEF2011).

#### 3.3 Advisors of the STEM project are open-minded to get the new idea from students

Advisor is the important factor to successfulness of the STEM project in Thailand. Inspirable advisors who are open-minded and willing to spend sufficient time with students can contribute a lot to the successful STEM projects.

We have found that the innovative STEM projects should come from the initiative of students not come from the order or command from teacher. So the teacher who will be the advisor should have



qualification to be someone who inspires and motivates students to continue their curiosity and enthusiasm.

Nipon Srinaruemon, the advisor of STEM project who received the award "Nation Excellent teacher" remarked that teachers play a significant role in creating the encouraging learning atmosphere for conducting the STEM projects and in motivating students to pose as many questions as they can. Subsequently, those questions will be grouped and only one of them will be selected for discussion and to be the basis for conducting the project.

In the same fashion, Pornjak Untim, the STEM awarded teacher, suggested that teachers should be open-minded and supportive throughout even if they and their students hold opposing views.

Interestingly, all outstanding STEM teachers share the same characteristics. This is evident in their devotion and dedication to their students' projects and as well as their guidance and encouragement when students encounter learning obstacles.

### **3.4 Deep scientific understanding**

All STEM projects have been conducted based on profound knowledge of multiple disciplines. The national and international STEM awards attest to the success of these projects, all of which require deep scientific understanding of concepts and contents from individual students. As to the concepts, students need to realize that not a single concept has a deep meaning in itself but they need to be able to make multiple connections among different factors. Most importantly, the success of a project lies in the the students' initiatives to expand their new knowledge or create new inventions.

Additionally, almost all of the STEM projects employ integrated disciplinary experiments. For instance, the "Walking Millipede" project integrated: animal physiology and zoology in biology; wave, force, and movement in physics; a mathematical model in mathematics; concept design of robotics and automation in engineering and technology.

### **3.5 Perseverance to make the projects successful**

It is clearly evident that perseverance is one of the contributing qualities of the victorious students in the STEM projects. One of those students is Wasan Nantasanti, a student who conducted the STEM project under the topic of "Light Firefly Mimicry". He made a great deal effort and spent most of his time studying the behaviour of the mating fireflies. Subsequently, he invented a tool utilising LED technology which mimics the fireflies' rhythms of light flashing which can attract the opposite sex for mating.

## **4. Conclusion**

Undeniably, encouragement from teachers is proved pivotal in students' motivation for engaging in the STEM projects in which students are not only allowed to expand their knowledge to a greater extent but also equipped with essential life skills in addition to content knowledge gained in school. Evidently, students' knowledge of biomimicry is another contributing factor which is also considered an interesting and creative approach to scientific learning which leads to multiple innovations by students in the STEM projects. Therefore, allowing students to explore nature and to closely observe living organisms and their environments is of paramount importance since they can derive new and creative ideas from what surrounds them in nature. Ultimately, to succeed in the STEM projects which require mutual cooperation from teachers and students, as teachers or advisors, stimulating students to pose interesting and relevant questions is deemed requisite as it can result in novel and innovative ideas and designs by students. Likewise, they need to be open-minded and devoted to students' projects to ensure that students' learning obstacles are addressed. As for the students, they need to be equipped with deep scientific understanding and to put tenacious efforts into accomplishing their learning goals.

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