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SynBio Workshop:
The Principles of Engineering Life

Workshop Guide

Abstract

On July 2018, with the encouragement of **Dr. Kostas Vavitsas** and in collaboration with **iGEM Thessaloniki**, we hosted a *Synthetic Biology Workshop* in our university, the National Technical University of Athens. Our main goal was to immerse as many students as possible into the field of Synthetic Biology by introducing the basic **principles** and a **problem solving approach**. The workshop was divided into sessions including keynote speakers, iGEM teams presentations, introduction to synthetic biology, interactive hands-on workshop and presentations. The purpose of this guide is to become a **manual** for other iGEM teams in their quest to organise Human Practices activities with an actual impact on their communities.

Workshop Details

The workshop details are presented here briefly. More information on the SynBio Workshop can be found on our ***Human Practices Education & Public Engagement Report***.

- **Duration:** 8 hours
- **Participants:** (34) Undergraduate and graduate students of various academic backgrounds
- **Keynote Speakers:** (2) Dr. Kostas Vavitsas and Prof. Emeritus Fragkiskos Kolissis
- **Preparatory material:** Sent via e-mail 2 days before
- **Interactive session:** 2.5 hours, 7 teams of 4-6 members, followed by a brief presentation and discussion session
- **Mentors:** (11) iGEM Teams' members
- **Judges:** (4) Prof. Georgios Skretas, Dr. Pelli Foka, Dr. Timos Karamitros, Dr. Kostas Vavitsas
- **Promotion:** Social media, University's website, posters on campus
- **Questionnaires**

Feedback & Feedback Incorporation

At the end of the workshop, **questionnaires** were handed to the participants. In order to create this guide, incorporating the **feedback** we received was of great importance to our team.

Some participants mentioned that they valued how our team had approached students of various backgrounds, while others judged the facts that other participants lacked the necessary background to understand some terms. Of course, Synthetic Biology is an **interdisciplinary** field that has to be **accessible** to everyone who is interested in it. Thus, we believe that students of various backgrounds should be included but a better preparation should be made.

On that same topic, several participants mentioned the use of **scientifically advanced terminology** while others claimed they gained little additional information from the workshop. Moreover, some mentioned that the preparatory material was not enough, others that it was too much and others that it should be handed several days before. Last but not least, a common remark was the insufficient amount of time for the interactive session.

Proposed Outline

Taking into account the feedback we received, the following outline can be proposed for the workshop:

- **Duration:** 2-day event, 8 hours per day
- **Preparatory material:** To be handed 3-5 days before the workshop
- **Keynote Speakers:** 2 to 4
- **Interactive session:** A total of 6-8 hours, teams of 5 members, followed by a presentation and discussion session
- **Mentors:** iGEM Team members, PIs, Laboratory instructors, Professors
- **Judges:** A minimum of 4 specialists on the SynBio field that would provide advice and discuss with the students on the presentation session
- **Promotion:** Depending on the number of participants a team wants to receive. Social media, posters on campus, public announcements
- **Questionnaires:** Necessary for feedback
- Breaks for food during the Workshop

Proposed Outline

Day 1

- Keynote Speaker #1 **(30')**
- iGEM Teams Project Presentation **(60')**
- Introduction to Synthetic Biology
  - Problem solving approach **(30')**
- Keynote Speaker #2 **(30')**
- Introduction to Synthetic Biology **(60')**
  - SynBio Engineering Toolbox
  - BioBricks
  - Softwares used
- Interactive Session **(180')**

Day 2

- Keynote Speaker #3 **(30')**
- Interactive Session **(120')**
- Keynote Speaker #4 **(30')**
- Interactive Session **(90')**
- Presentations & Discussion Session **(120')**
- *Party!*

Preparatory Material

If one team wishes to address students of various academic backgrounds, it is important that the preparatory material includes fundamental knowledge of biology and good **definitions** of terms and mechanisms, apart from more advanced SynBio terms.

In our own preparatory material, the following were included:

- Basic principles of cell biology: The **Central Dogma of Molecular Biology, metabolic pathways**
- Biotechnology & Genetic Engineering: Definitions of the terms, as well as definitions of: **restrictive enzymes, plasmids**
- Synthetic biology: **Genetic circuits,** selected video sources on the mechanisms (**riboswitches, aptamers, toggle switch and repressilator, quorum sensing, CRISPR-Cas9 genome editing**)

Note: Our team believes that the **visual aids** are an effective way of presenting a topic, more effective than a written document. However, we do understand that time has to be dedicated to this activity. On the next page, you can find some of our favourite videos!

Preparatory Material

- Synthetic Biology - Drew Endy @ TEDxStanford
- Synthetic Biology: Programming Living Bacteria - Christopher Voigt
- Mechanism of the Toehold Switch
- Synthetic Biology: Engineering bacteria with CRISPR - David Bikard
- How bacteria "talk" - Bonnie Bassler @ TED

Several topics that could be added to this preparatory material are the following:

- Basic principles of cell biology: **Protein structure**, **post-translational modifications, cell signalling**
- Model organisms: **E.coli, Saccharomyces cerevisiae** and how they can be used in synthetic biology
- BioBricks: Introduction and examples
- Bioinformatics software

Presentations

Introducing the Problem-Solving Approach

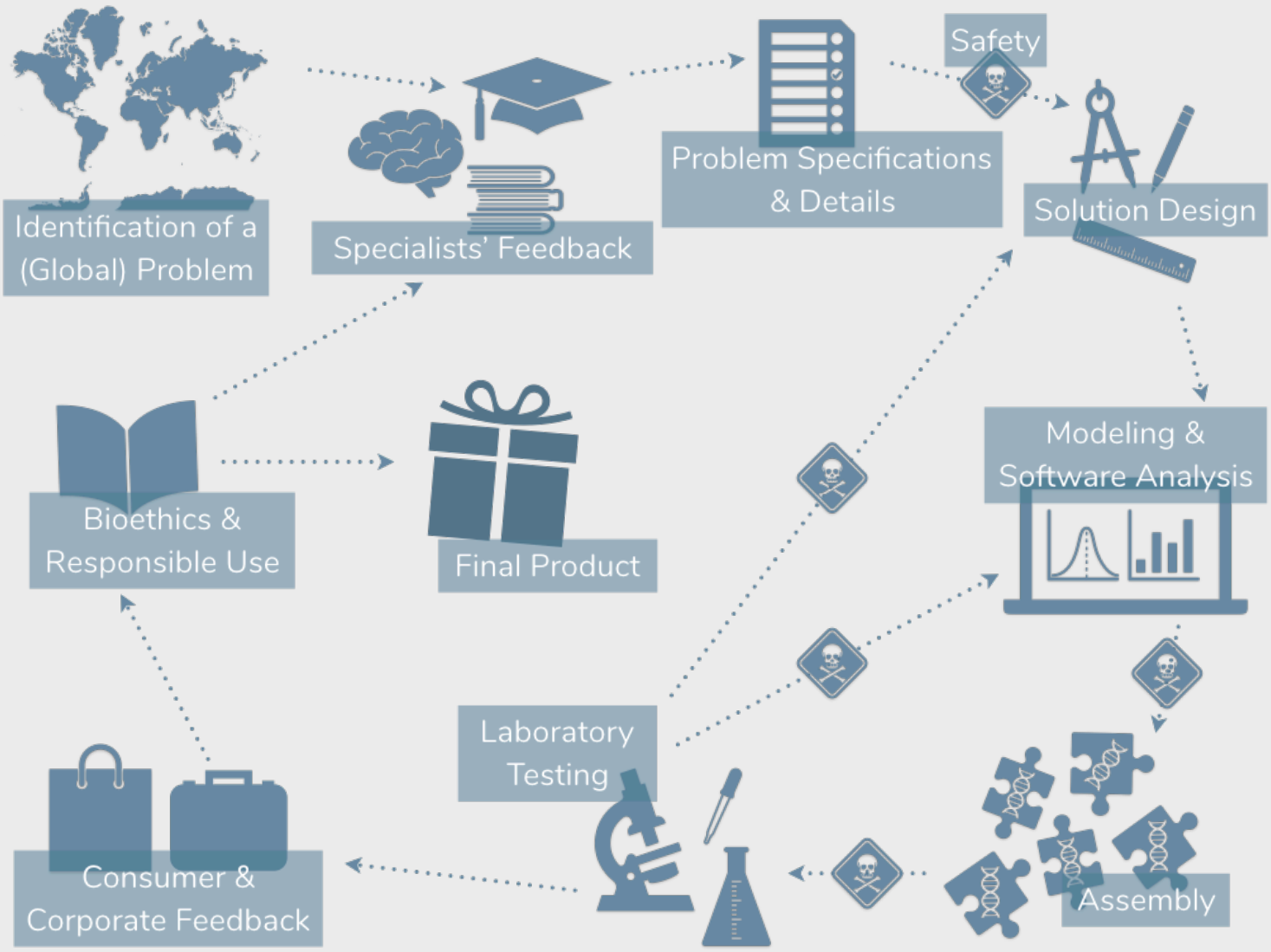
Communicating the way synthetic biology deals with the issues at hand is one of the most difficult tasks. The **top-down** or **middle-out** approaches that are commonly incorporated in a synthetic biology project, are quite demanding to explain in an audience that is not familiar with the topic.

For this reason, and based on our own iGEM experience, our team developed two main tools in order to introduce the engineering mindset aspect of synthetic biology, the ***SynBio Engineering Cycle*** and the ***SynBio Checklist***.

The *SynBio Engineering Cycle* depicts all the stages that a project passes through, from the inception of a possible solution to a final product, as well as how those stages interact through **feedback loops**. This cycle also depicts the interdisciplinary features of synthetic biology, as various specialists have to cooperate in order for a project to be successful.

Presentations

Introducing the Problem-Solving Approach



As shown above, Safety is an integral part of every project design and implementation. At the same time, taking into account society by receiving feedback and by facing bioethical dilemmas, are also a significant aspect of a responsible project.

Presentations

Introducing the Problem-Solving Approach

The SynBio Checklist focuses on the main specifications that should be taken into account when designing a biological system and proposing a solution.

1. Identifying the problem	
1.	What is the problem you want to tackle?
2.	What is the reason of this problem?
3.	What are its consequences?
4.	Are there any recorded incidents concerning relevant to this problem?
5.	Are there any solutions for this problem? If yes, briefly mention them.

Let's take the **iGEM Athens 2018** project as an example, to briefly answer the questions above:

1. (MERS-CoV) Diagnosis is challenging
2. MERS-CoV has common symptoms, making it difficult to diagnose, while having a mortality rate of 35%
3. Patients who are not diagnosed on time may pass away, and/or its spreading can be uncontrollable
4. Major epidemics: Saudi Arabia, South Korea
5. Diagnosis via rRT-PCR

2. Specifications of the Problem	
1.	Biological characteristics (if applicable)
2.	Chemical characteristics (if applicable)

1. MERS-CoV has conserved and unique-to-the-virus regions, that make it a prospective target of molecular diagnosis. High concentrations of the viral load can be found on the patient's pharynx.

3. SynBio Mechanism	
1.	How does the mechanism address the problem?
2.	How does the mechanism work? Which is the **Input**? Which is the **Output**?

Our team chose the toehold Switch mechanism for addressing MERS-CoV diagnosis:

1. Molecular detection of specific MERS-CoV genome regions.
2. Production of a reporter protein that catalyzes the breaking of a glucose dimer when the viral RNA binds to the toehold switch. **Input**: viral RNA. **Output:** glucose

3.	Can there be any computational analysis or modeling incorporated into the project? Describe your thoughts.
4.	Starting from the **Input** of your system and ending at its **Output**, describe the mechanism with a **Flow** Diagram. What are the in-between stages? Are there any feedback loops or stage interactions in your system?
5.	Why is the suggested solution a Synthetic Biology approach?

3. The design of the toehold switches needs the development of a computational tool that predicts the sequences with the best toehold activity.
5. The toehold switch is a classic example of a genetic circuit.

4. Suggesting a Solution	
1.	What your final product/ method? How is the SynBio mechanism incorporated? How can this product/ method be widely distributed?
2.	What are the **safety** criteria to be taken into account?
3.	What are the **economic** criteria to be taken into account?
4.	What are the **environmental** criteria to be taken into account?
5.	What are the questions that arose during the design of your solutions? Were there any bioethical dilemmas?
6.	Compare this SynBio solution to the existing ones.

In this section, we are getting into more information and details that are not of interest to this guide. For an analogy to our project, please refer to our wiki!

5. Overall Problem Solving Approach
In a flow chart describe the flow of your thoughts when dealing with this problem and solution. How did you break a problem into **smaller problems**? Why did you choose to focus on one of the characteristics of the problem. How did you choose your SynBio mechanism over other mechanisms?

Overall, we believe that this checklist aids the workshop participants to organise their thoughts and effectively approach a problem utilising the toolbox of synthetic biology. This way, vague questions can be avoided, while also aiding the mentors give **targeted feedback** on questions. At the same time, it helps them construct the **outline and flow** of their presentations.

Presentations

Introducing Synthetic Biology

On this session, a description of the SynBio **mechanisms** and the **BioBrick parts** can take place, giving emphasis on *solving participants' questions*. Our team observed that the students were reluctant to ask questions, which is of major importance when dealing with new terms.

Also, what our team did not include in the workshop but believe is important, are several software tools that can be used in synthetic biology. Either by mentioning them briefly or by making a small demonstration, the fact that computational tools and models are an integral part of synthetic biology will be made crystal clear.

Interactive Session

In order to help the teams choose an issue and suggest a solution on it, we provided them with a pool of topics, from a variety of thematic categories, with information and special characteristics regarding those topics:

- **Diagnostics:** Design of a biosensor for Cow Milk Allergy Diagnosis
- **Environment:** Reforestation and Soil Remediation following forest fires
- **Therapeutics:** Accelerating External Wound Healing
- **Nutrition & Quality of Life:** Reduction of Hangover Symptoms

Many other topics can be included, or even let the teams chose by themselves. Some of the teams we hosted surprised us with their choice of topics, for example the development of an **"*Anti-Doping test for athletes*"** or the creation of a product that would **"*detect whether pesticides were used on fruit and vegetables.*"** At the same time, other teams amazed us with the approach of the problem, their ideas and their suggested solutions.

Mentoring is also very important, so we focused on discussing with the teams and providing them with feedback on their solutions.

Receiving Feedback

Of course, the procedure described above on organising a workshop is not perfect. Thus, we deem important the completion of **questionnaires** that demonstrate what the participant's have gained from this experience and what the organising team can learn as well.

For example, the feedback we received revealed a deep interest towards synthetic biology among the participants. Some of them have already started the procedures of creating their own iGEM teams! And at the same time, the positive and negative comments we received, presented at the beginning of this guide, **was the same reason we decided to write this "How to SynBio Workshop" manual.**

Our suggestion is to have a **two-section** questionnaire handed out that imprints the pre- and post- workshop knowledge. This makes it easier to extract comparative results regarding what the participant's have acquired during the procedure. Also, a **comments** section is very important, were students can document their overall experience, suggest alterations or praise your good work!

Acknowledgements & References

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References

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Team Wiki