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Synthetic Biology:
The Principles of Engineering Life
Human Practices
Education & Public Engagement
Report

Abstract

Judging from experience, our team noted a lack of public engagement with the cutting-edge technological advancements. In Greece, both in **secondary** and **tertiary** education, the main goal is the propagation of the fundamental knowledge related to one's academic field, casting awkwardly aside the interaction with innovative scientific and research fields. Therefore, our team prioritised human practices activities with an **educational purpose**, reaching out to a plethora of communities, ages and backgrounds, all the while **observing and documenting** participants' reactions, opinions, comments and beliefs. We firstly educated ourselves, in order to then effectively engage in discussions, participate in public scientific events and organise presentations and workshops. Closing our cycle of activities, we approached specialists and gained insight and suggestions for introducing SynBio to the greek educational system. Our findings and proposals are documented on this elaborate report, while our approach on introducing SynBio to greek students was transformed into a **3-minute-video**, implementing a linguistic approach.

Timeline of Ed.+P.E. Actions

27.04.18

Athens Science Festival @Athens
Technopolis, Greece

03.05.18

“SynBio: Engineering Life” Presentation
@Arsakeion 2nd Lyceum (High School)

07.05.18

“SynBio: Engineering Life” Presentation
@Athens College Lyceum (High School)

17.05.18

“SynBio: Engineering Life” Presentation
@Ionideios Model Lyceum (High School)

05.07.18

“SynBio Workshop: The Principles of
Engineering Life” @NTUA, Athens, Greece

25-29.07.18

5th Synthetic and Systems Biology
Summer School @Siena, Italy

19.09.18

Discussion with **Professor Kosmas
Haralampidis** @Biology Faculty, NKUA,
Athens, Greece

29.09.18

Researcher’s Night @Hellenic Pasteur
Institute, Athens, Greece

15.10.18

Freshmen Welcome Ceremony - School of
Chemical Engineering @NTUA, Athens,
Greece

Athens Science Festival



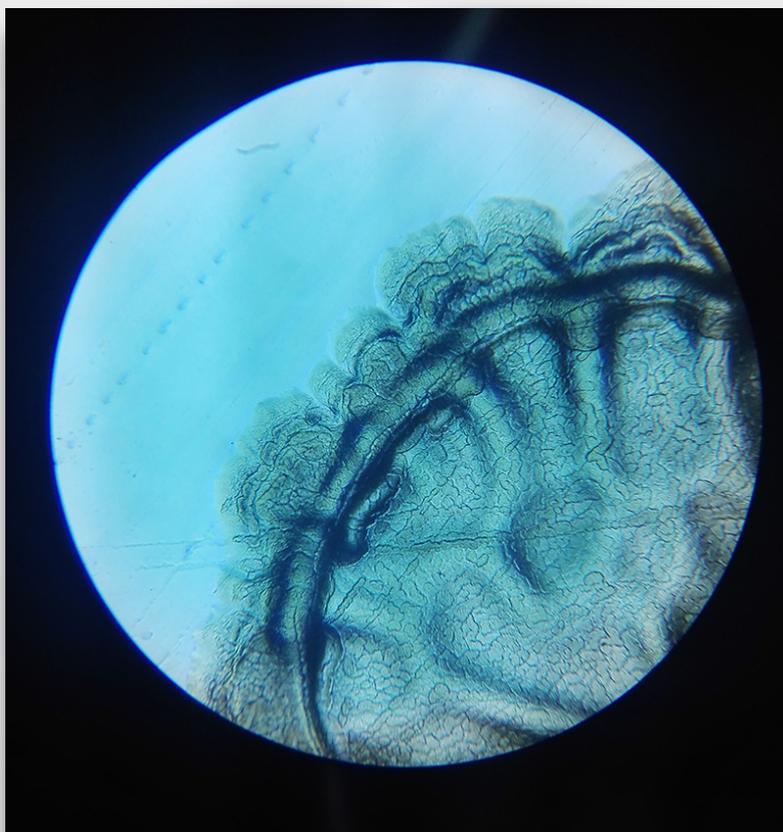
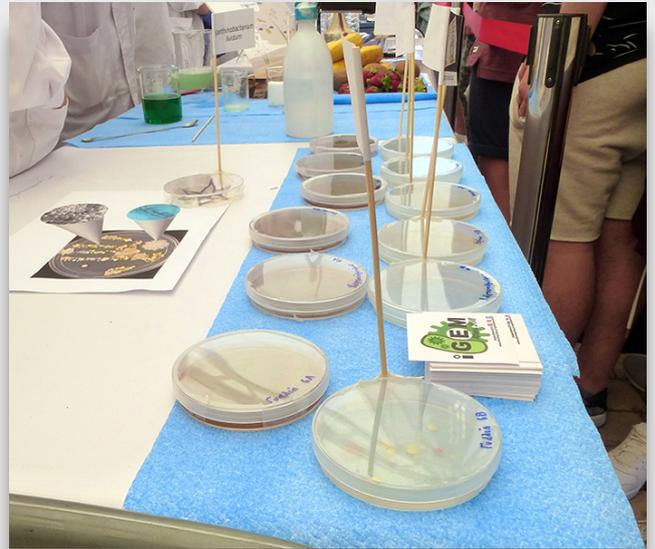
Our team participated in the annual Athens Science Festival on April 2018, an event organised by **Sci-Co (Science Communication)** that brings together students, teachers, professors and researchers, families, and everyone sharing one passion: science.

Students of all ages, from elementary school to university students, joined our discussions. Because of the variety of age groups and their respective biological background, our approach was more fundamental and our team focused on the **basics of Biology**. Among the discussions, the following were included:

Athens Science Festival

Experimental demonstrations:

- ▶ Bacteria of everyday life: Sampling from everyday objects and places (cell phone, bus, toilet sink, sunglasses), we presented different types of **bacterial and fungal colonies** that are present in our daily routine.



Bacillus Subtilis under the microscope

Athens Science Festival

- ▶ Fluorescent Bacteria: Taking the demonstration one step further, we transformed *E. coli* by adding a plasmid containing the **GFP (Green Fluorescent Protein)** encoding gene. Shining a blacklight on our petri dish, everyone was able to observe the fluorescence. At the same time, we engaged in discussions concerning the origin of GFP and how it is possible for a bacterium to attain the fluorescence ability.



Discussion on the basics of life: Engaging elementary and high school students we discussed about life, living organisms, cells, bacteria, viruses, the Central Dogma of Molecular Biology and, finally, the ability to intervene and tinker with the genome of a selected organism.

High School Presentations

Judging from our own high-school experience, we observed a lack of engagement with world-leading technological advancements, Synthetic Biology and Biotechnology included. Thus, we sought to include high school students in the discussions.

We presented in **three different high schools** over a two-week period in May 2018, in an audience of **10th and 11th graders**. Our presentation entitled “*Synthetic Biology: Engineering Life*”, span from an analogy between living cells and machines, to biotechnology and the principles of synthetic biology and, finally, to our own iGEM project. The presentation was concluded with a discussion on **bioethical** topics and general questions that the students had.

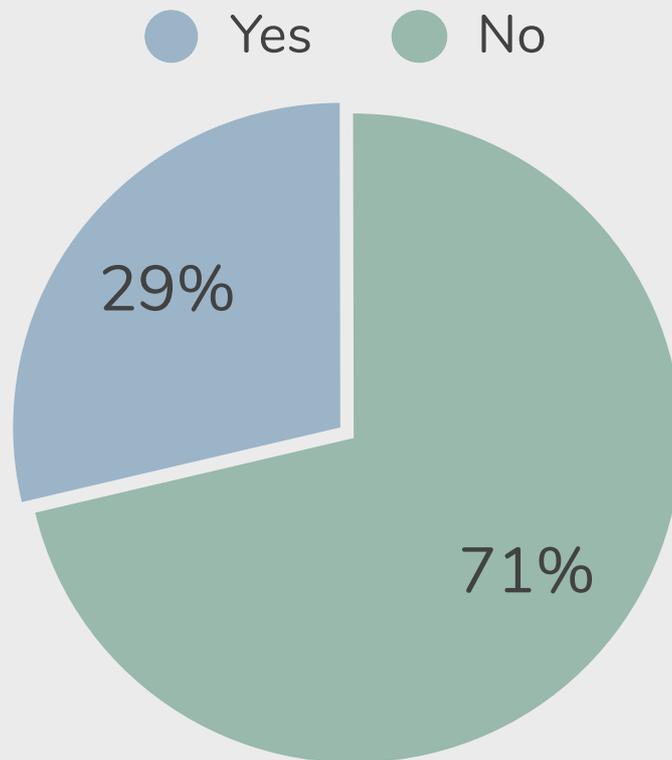
At the same time, a **questionnaire** was handed out with two sections (pre and post-presentation). This way, we wished to observe how our presentation had engaged the students, gave birth to new questions and planted the seed of interest towards Synthetic Biology.

Below, the questions of the questionnaire are presented, as well as the students’ answers.

High School Presentations

Questionnaire Section 1: Pre-presentation

- ▶ Are you aware of the term “Cell Factory”?



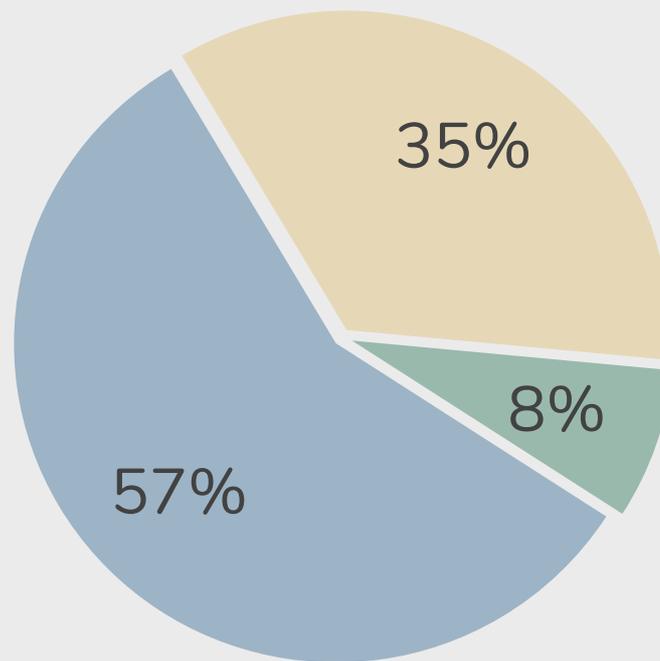
Comments: It is interesting to note that the term “cell factory” is not included in students’ textbooks. We could ascribe the students’ positive answers to two main factors: **personal interest** that had led them to discover the term; or a **misconception** with phrases found on text books, such as like “mitochondria are the energy factory of the cell.”

High School Presentations

Questionnaire Section 1: Pre-presentation

- ▶ Would you agree to consume a pharmaceutical drug that is produced by bacteria?

● Yes ● Neutral ● No



Comments: The students were asked to raise their hands if they had answered “No” to this question. When asked the reason why they answered that way, among the replies we received were the following:

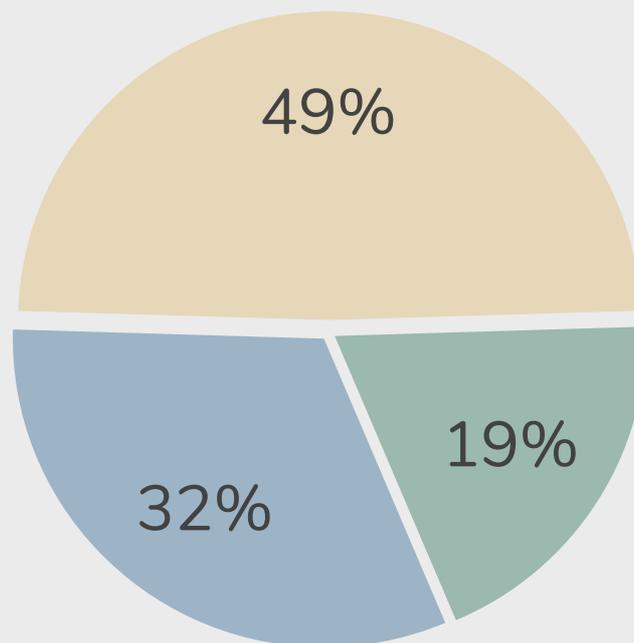
- ▶ Expressing repulsion: “It’s disgusting!”, “Eeew!”
- ▶ Expressing reluctance: “Is it safe?”, “I don’t think it is natural.”

High School Presentations

Questionnaire Section 1: Pre-presentation

- ▶ In your opinion, are Genetically Modified foods detrimental to the consumer's health?

● Yes ● Neutral ● No



A discussion took place on how different crops are today, relative to 200 years ago, pointing out that genetic modification can also come in terms of **selective cultivation** and **breeding**.

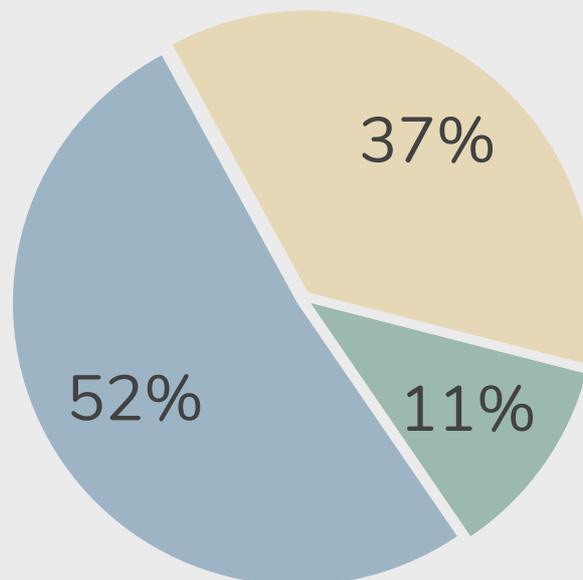
Comments: One would expect that most students would answer “No” to this question. However, a neutral and skeptical stance towards the matter is observed, indicating that the topic at hand is one that troubles students.

High School Presentations

Questionnaire Section 1: Pre-presentation

- ▶ In your opinion, could foods that are genetically modified to withstand high temperatures prove to be effective towards the elimination of famine and/or malnutrition?

● Yes ● Neutral ● No



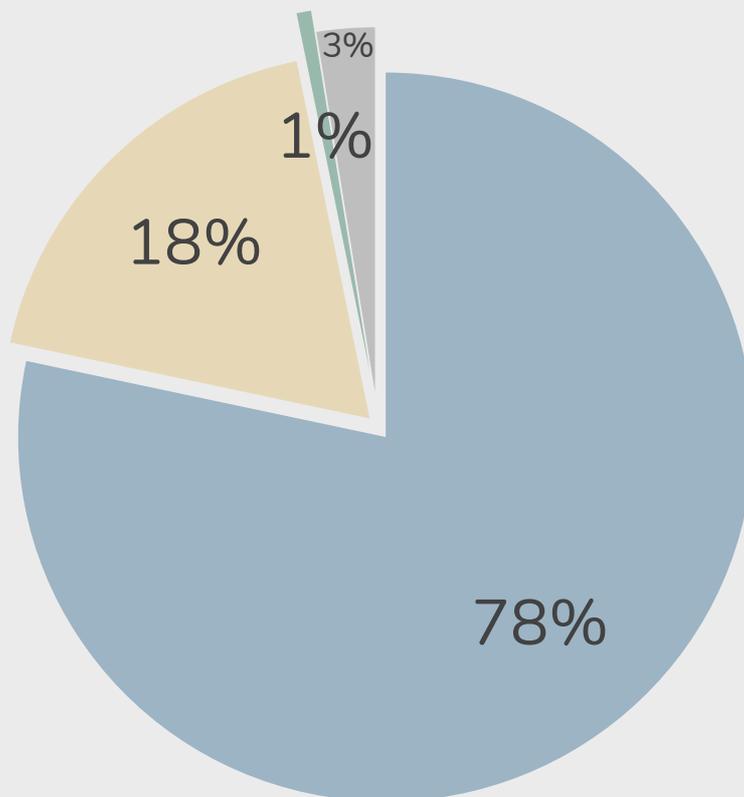
Comments: When confronting a more **practical** situation, and one with emotional gravity, students changed their stance on the matter, relative to the previous question. The answers above show that students believe that sometimes the “*end justifies the means.*”

High School Presentations

Questionnaire Section 2: Post-presentation

- ▶ After this presentation, what is your opinion towards Synthetic Biology?

● Positive ● Neutral ● Negative ● No answer



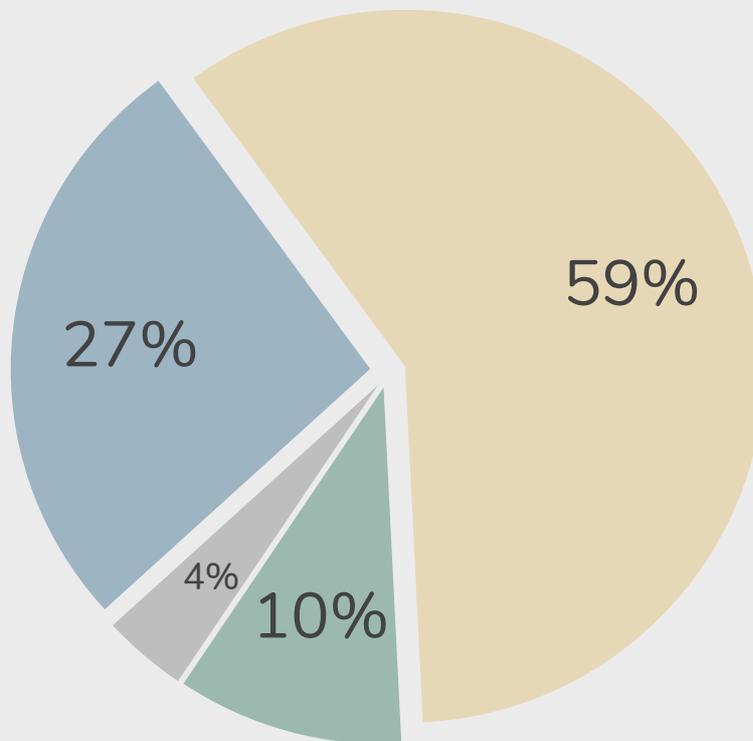
Comments: Because of the **introductory** character of this presentation, the statistical analysis can not be definitive. However, it is a good first impression of the positive impact synthetic biology can have on students, and it is our team's pleasure to observe such a positive response towards our presentation.

High School Presentations

Questionnaire Section 2: Post-presentation

- ▶ Based on the insight you gained from this presentation, do you think that genetic modification is ethical?

● Yes ● Neutral ● No ● No answer



Comments: An emotionally heavy question where one could yet again observe the neutral stance of the students, denoting the underlying skepticism and hesitation to reply decisively.

High School Presentations

Questionnaire Section 2: Post-presentation

- ▶ Briefly reflect on the preceding presentation and discussion.

“How much should everyday life applications of Synthetic Biology intervene with human nature?”

11th grade student

“Did bioethics influence advancements in biology?”

10th grade student

“Will there be experiments on living organisms or human clones? Using the tools of Synthetic Biology is it not possible that there will be mistakes? How do we know that these experiments will not have a negative impact on the organism instead of a positive one?”

10th grade student

High School Presentations

Questionnaire Section 2: Post-presentation

“Which is the impact on the one’s health if we do not know everything there is to know in Biology?”

11th grade student

“After all, is genetic modification “good”? If yes, why is there so much propaganda against it.”

10th grade student

“There are many conservative people that oppose to this kind of technological advancement”

10th grade student

“Is the consumer able to know which GM foods are healthy?”

11th grade student

High School Presentations

Observations

Some of the reactions, questions and comments we received surprised our team. Many of those fall under the **emotional engagement** category, as students tried to *process the new information in a sentimental way*, while other remarks fall under the **cognitive engagement** category, as they used *prior knowledge and their own logic* to analyse the facts.

One can generally note that the **lack of involvement** with the cutting-edge technological and scientific advancements and the **fundamental** knowledge students receive from school, do not suffice in terms of analysing and forming an opinion on scientific matters.

That was the case of the **GMOs** and the **bioethics** aspect: many students were unable to process the information, took a neutral yet skeptical and puzzled stance, and many resorted to emotionally charged statements. Words like “propaganda” or “conservative,” carry a sentimental gravity and are the student’s effort to **evaluate the new information** they were provided with.

High School Presentations

Observations

Nonetheless, one cannot simply discard the emotional way some students react to the information. On the contrary, it is a sign of engagement, of the effect one's presentations or actions can have on a student.

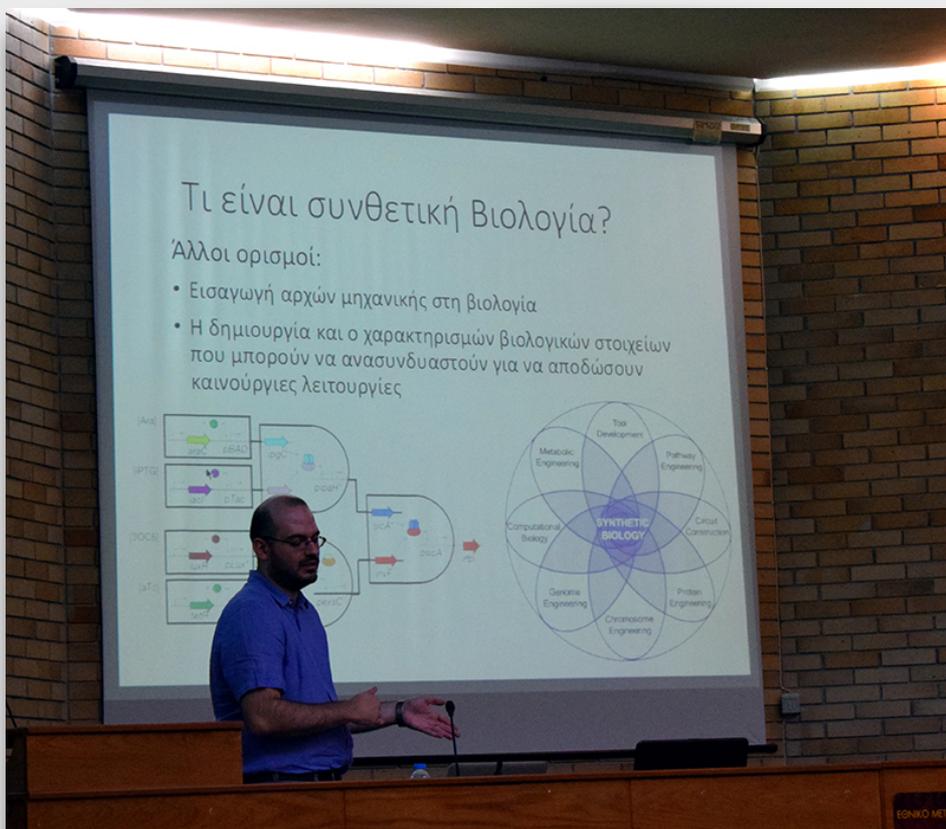
At the same time, many students, based on fundamental knowledge of biology, expressed their opinions and thoughts with rationality. They showed signs of wanting to **deepen their understanding**, solve questions they already had and learn more during the whole process.

Every question and remark, *emotional or cognitive*, is a sign of **involvement**. It is a sign that students, either with minimal prior knowledge or fully-informed on the subject, included the new information in their lives and **spent** -or will spend- **time processing** it. **Sparking the interest** was a main goal of these presentations. As far as there was **reaction** of any kind, one can be sure that the engagement was rewarding.

SynBio Workshop

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 (NTUA).

The workshop addressed university students of various backgrounds and specialties, as we sought to demonstrate that Synthetic Biology is an **interdisciplinary field**. The response to our call for participation was beyond any expectations and, in the end, 34 university students joined us on July 5th in NTUA.



Dr. Kostas Vavitsas on Synthetic Biology

SynBio Workshop

The workshop was divided in 4 main sections. In the first section, the **keynote speakers** section, Dr. Kostas Vavitsas of Queensland University in Australia and **Prof. Fragiskos Kolissis** of NTUA presented and discussed with the audience on the topics of Synthetic and Systems Biology.



*Prof. Fragkiskos Kolissis
on Systems Biology*

SynBio Workshop

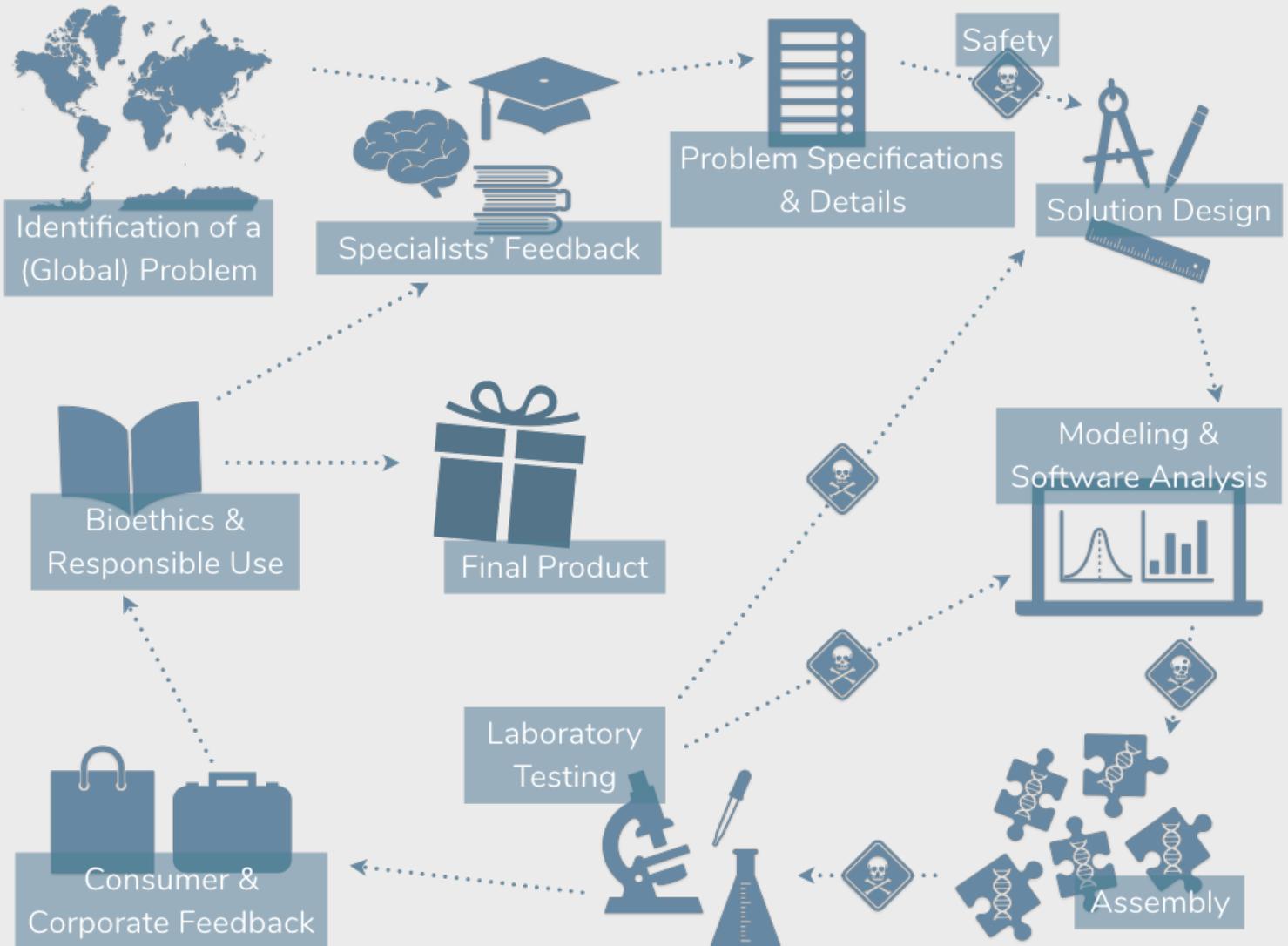
The second session was dedicated to greek iGEM teams. **iGEM Greece 2017**, iGEM Thessaloniki 2018 and our own team, iGEM Athens 2018 presented their projects and answered the audience's questions.



Maria from Team Athens on our Project

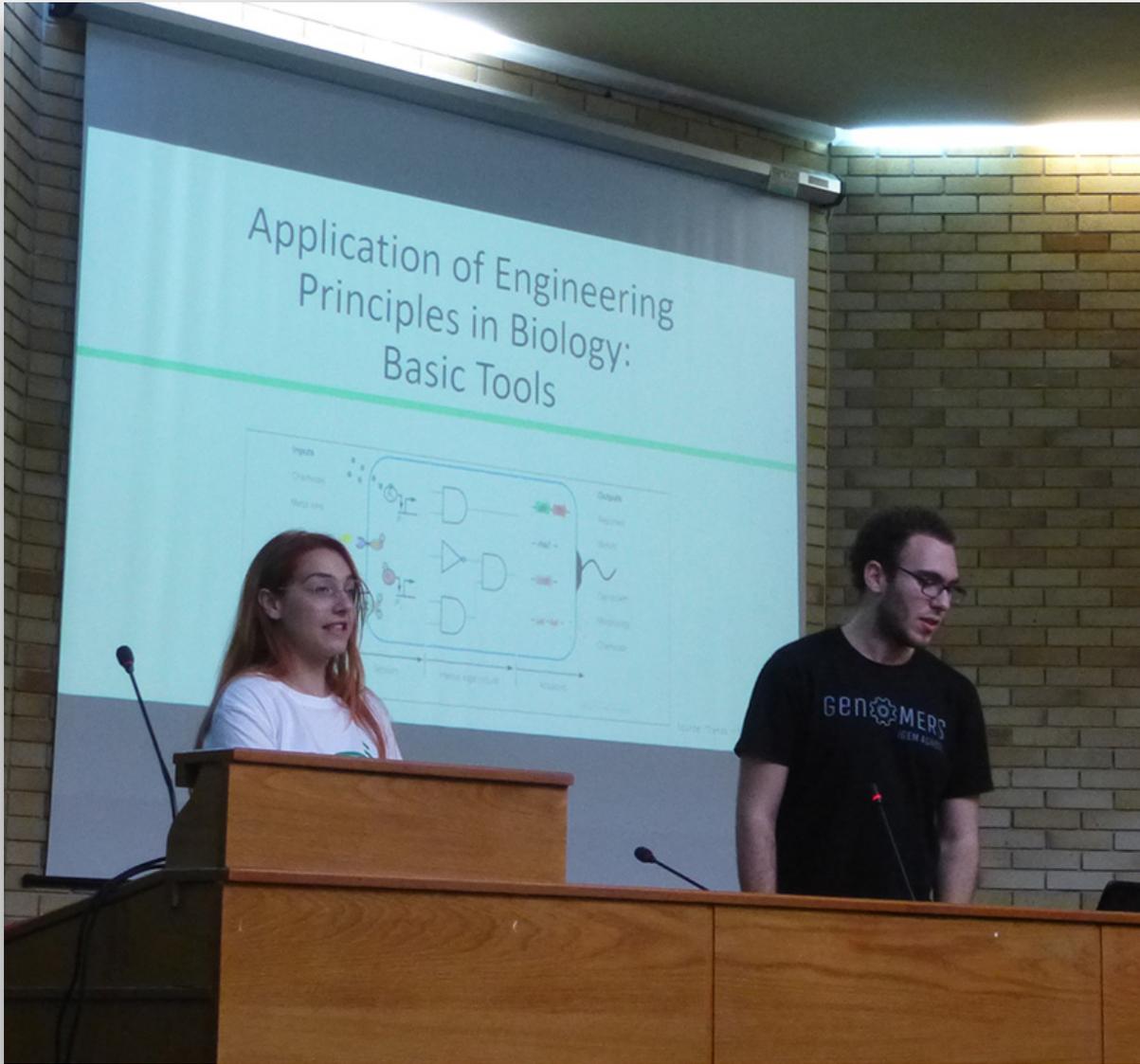
SynBio Workshop

On the third session we immersed on the **principles of synthetic biology**, as well as on the basic **tools and mechanisms of synthetic biology**.



The SynBio Engineering Cycle: From the Identification of the Problem to the Final Solution/ Product

SynBio Workshop



Yvonne from Team Thessaloniki and Yannis from Team Athens on the basic tools of Synthetic Biology

The main point of this session was to give insight on the way of thinking and the **problem solving approach** that is commonly adopted when dealing with a SynBio project.

SynBio Workshop

In the final session, students were divided into 7 teams of 4-6 members, selected a problem and attempted to tackle it using the toolbox of synthetic biology. The teams were provided the following 4 problems that they could choose from, including relevant information that would help them approach the issue:

- ▶ **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



Teams'
brainstorming
session

SynBio Workshop



Teams' brainstorming session

The teams were given a total time of **2:30 hours** to process the problem, come up with prospective solutions using the tools of Synthetic Biology and sum them up in a **5-minute presentation**.

Of course, the time given was not sufficient to fully grasp the essence of a problem, research all the aspects and propose a well-defined solution. However, this was done intentionally, as our team's main goal was to **introduce** the principles of synthetic biology and trigger students into **engaging with SynBio**.

SynBio Workshop

Our team members as well as iGEM Thessaloniki's members had a mentoring role in the aforementioned session, assisting the teams, discussing with them and offering their feedback.



Maria from Team Athens discussing with a team

The teams' presentations exceeded everyone's expectations. Some of the teams chose to tackle problems of their own interest, 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.

SynBio Workshop

During the presentations, four specialists in the field of Biotechnology and Synthetic Biology joined us in order to provide the teams with feedback. Among them was Dr. Kostas Vavitsas, **Prof. Georgios Skretas** of the *National Hellenic Research Foundation*, and **Dr. Pelli Foka** and **Dr. Timos Karamitros** of the *Hellenic Pasteur Institute*. Along with the four specialists-judges, the mentors and the audience engaged in a discussion regarding the teams' proposals and the tools of Synthetic Biology.



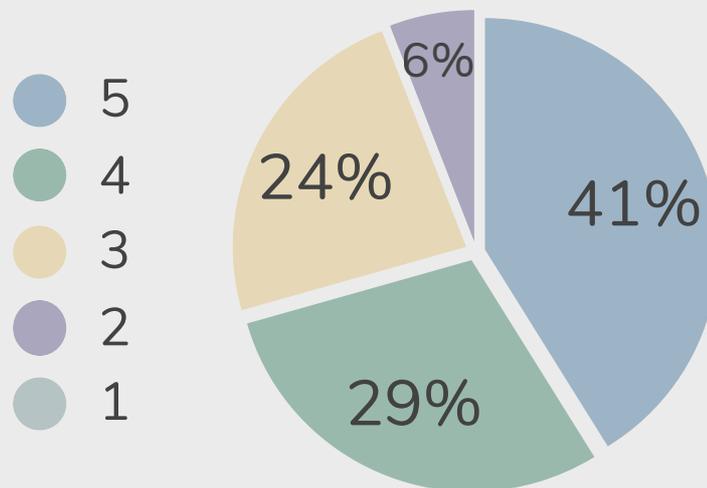
Team presentations session

SynBio Workshop

In order to wrap up the workshop, a questionnaire was handed to the participants. Among the questions, the ones that are of particular interest to this report are the following:

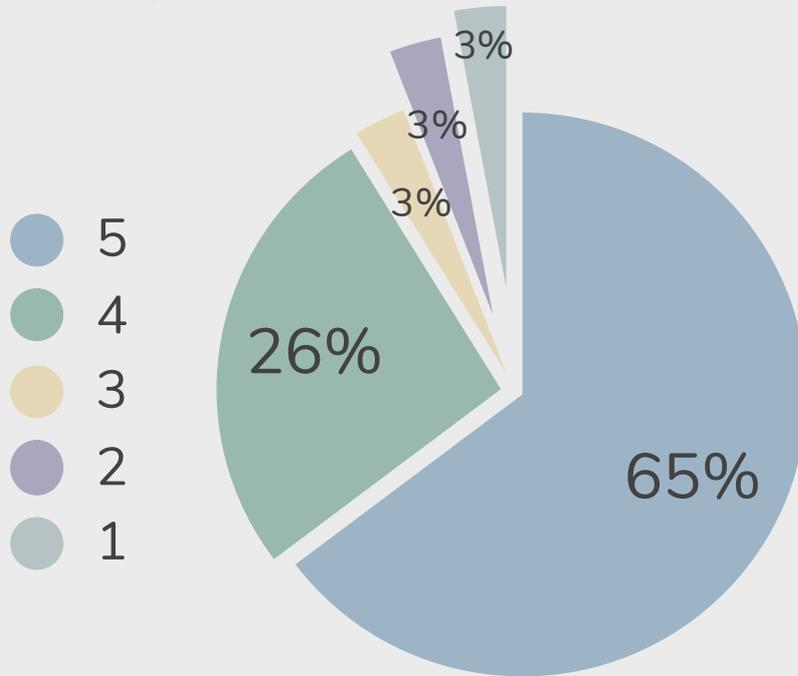
Note: **1-5 scale** - 1: no/little, 3: neutral, 5: yes/very

- ▶ Is your field of study relevant to the workshop's theme?

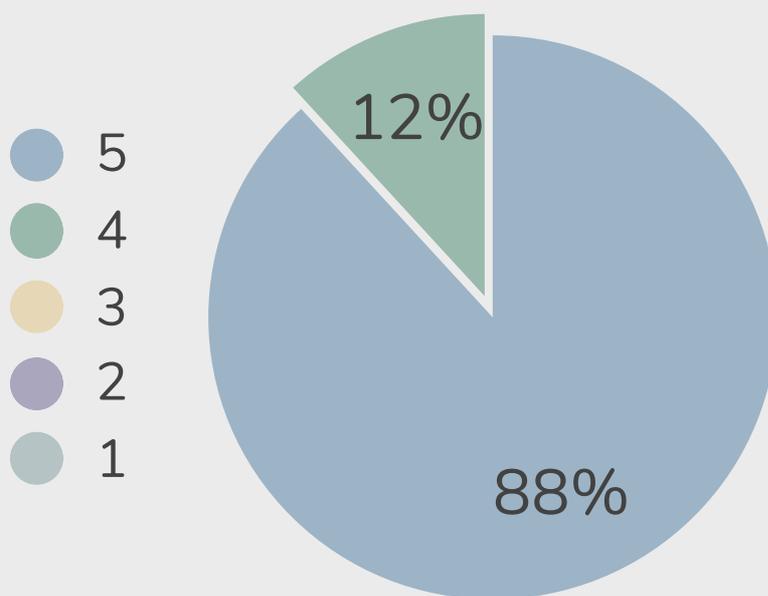


SynBio Workshop

- ▶ The content of the workshop widened your knowledge on synthetic biology.

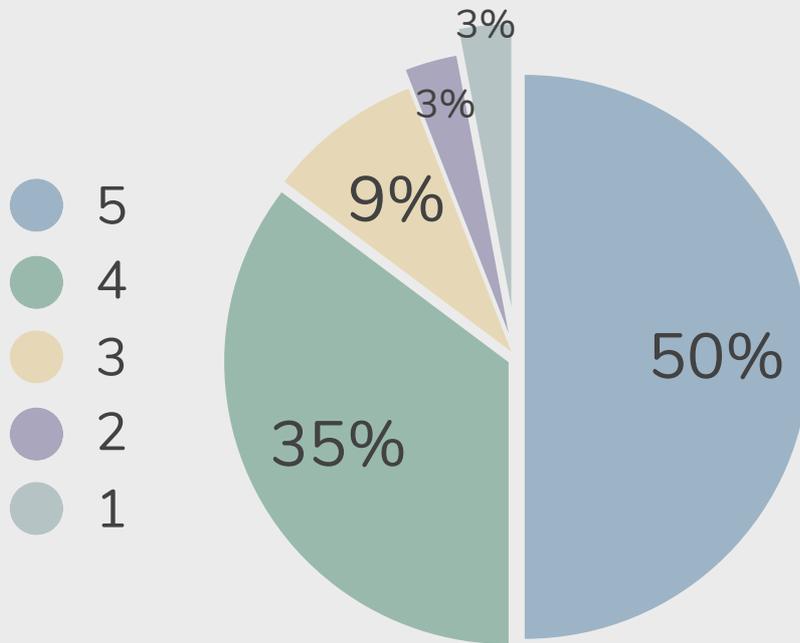


- ▶ Do you believe that synthetic biology can offer essential solutions to major issues?

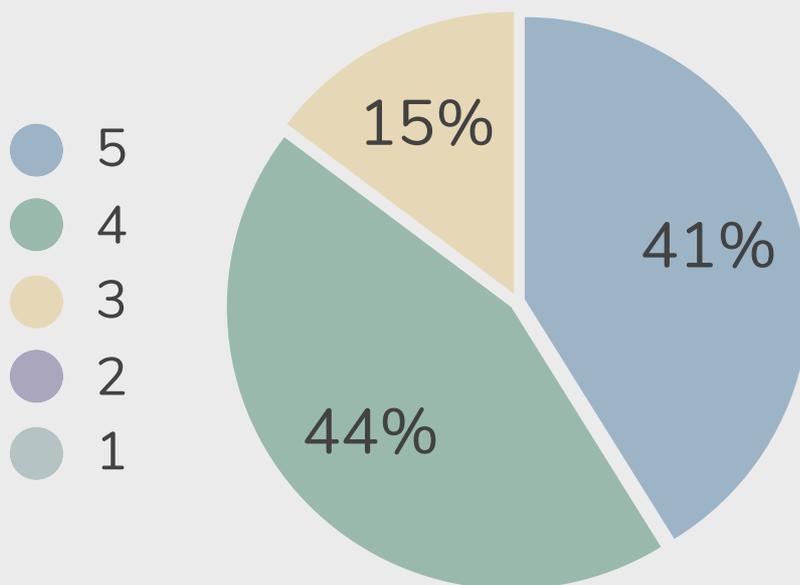


SynBio Workshop

- ▶ The preparatory material you were handed was sufficient and comprehensible.



- ▶ The keynote speakers' and the teams' presentations were comprehensible and interesting.



SynBio Workshop

The comments we received were mostly heartwarming. students found real interest in our projects and in Synthetic Biology, specifically.

I was surprised by “the fact that Synthetic Biology deals with a large number of issues and that the successful confrontation is real and not science fiction.”

Electrical Engineering Student

I was surprised by “the endless possibilities of the field. Also, by the whole thought process behind the implementation of an idea.”

Molecular Biology and Genetics Student

“I liked the keynote speakers’ session because I understood the possibilities of the Synthetic Biology field”

Chemical Engineering Student

SynBio Workshop

I was surprised by “the creativity and passion of the iGEM Teams, with which they promote the field of **Synthetic Biology**”
Medical Student

“On-point and complete presentation of the topic, the problems that were given were interesting and the mentoring was **just right. Thank you.**”
Chemical Engineering Student

Apart from successfully organising and hosting the SynBio Workshop, our team must, and is proud to, note the creation of **two new iGEM Teams for the 2019 Competition**. Both those teams were created by university students that participated in our workshop. Naturally, we are elated to observe that *our initiative sparked students' interest in Synthetic Biology* by creating their own iGEM teams.

Analysing the Greek Reality

The next step on our path to make an actual impact on greek society was to analyse how **immersed** the greek society is in the biotechnological advancements and what are the misconceptions that **disorientate** the general public. We focused on the educational system of Greece, engaged in discussions with specialists and came up with proposals.

↳ Synthetic Biology in Greece

Unfortunately, Synthetic Biology has not been included in the Greek educational system on an academic level, as most faculties of Biology in Greek Universities do not offer synthetic biology courses.

An exception that we were able to pin down, was the **Department of Biochemistry and Biotechnology of the University of Thessaly**, which offers a synthetic biology course for **undergraduate** students. This course focuses both on the *principles* of this newly founded field of biology and on its *applications*. It also makes references to the iGEM foundation, as one of the organisations that has been *actively promoting synthetic biology*.

Analysing the Greek Reality

Synthetic Biology in Greece

On a **master's degree level**, no program specifically focuses on synthetic biology, but there are some that are *closely related* to it. One noteworthy example, is the **“Systems Biology” postgraduate program** of the Faculty of **Biotechnology** of the **Agricultural University of Athens**, which approaches synthetic biology from a **computational** point of view.

There is also a variety of biotechnology programs and courses, either postgraduate or undergraduate, that do not directly refer to synthetic biology, but *could very well become solid foundations* for students that will later on become involved in synthetic biology.

Although it is difficult to bridge the gap that exists between higher education and synthetic biology in the modern Greek reality, we hope that **our actions and events** will bring them closer and that other iGEM teams will emerge, eventually creating a future where synthetic biology will be accessible to everyone that wishes to know more about it.

Analysing the Greek Reality

Discussions with Specialists

Dr. Maria Dokopoulou

Institute of Educational Policy, Greece

The national *Institute of Educational Policy*, as a faculty of the **Greek Ministry of Education, Research and Religious Affairs**, plays a major role in shaping the national **secondary** education, both by determining the scientific content of the national **curriculum** as well as by putting into action effective **educational policies**.

After the completion of our Education & Public Engagement Human Practices, our team discussed with Dr. Dokopoulou, analysing the students' **answers** on the questionnaires, their **comments** during the presentation and their overall **stance** towards our team, providing us with insight for our analysis.

Summing up our Human Practices, we further discussed the possibility of introducing Synthetic Biology to the high school curriculum, a move that we deemed to be daring.

Analysing the Greek Reality

Discussions with Specialists

This belief stems from observing the insufficiency in prerequisite biological knowledge at the secondary education level, as well as from the fact that biology is an exponentially developing scientific field. Both those facts, led us to support that Synthetic Biology could only be approached as part of **thematic seminars, presentations, school projects or teams**, whose main goal is to immerse high school students into the biotechnological and biological advancements.

Prof. Kosmas Haralampidis

*Biology Faculty, National and Kapodistrian
University of Athens, Greece*

Prof. Kosmas Haralampidis serves as assistant professor at the Biology faculty - Division of Botany at the University of Athens. Prof. Haralampidis specialises in molecular and developmental plant biology, and his research field is of great interest to our team.

Analysing the Greek Reality

Discussions with Specialists

We met professor Haralampidis in person, and discussed on the topics of *Synthetic Biology* and *genetically modified organisms*.

Regarding the introduction of *Synthetic Biology* to the **tertiary** education, Prof. Haralampidis pointed out two fundamental needs: Firstly, the need to **reinforce** undergraduate programs' curriculum with classes that are **prerequisites for Synthetic Biology**. Among others, he mentioned *molecular and developmental biology, microbiology and genetics*. Secondly, perceiving *Synthetic Biology* as an **interdisciplinary** field, Prof. Haralampidis indicated the need of **collaboration** between scientists and research fields.

Thus, he suggested the creation of a **Postgraduate Program** at the *Biology Faculty in collaboration with the School of Chemical Engineering or the School of Mechanical Engineering* that would address biologists, engineers, programmers and medical students.

Analysing the Greek Reality

Discussions with Specialists

It was pointed out that such a program in the **undergraduate** level would be “**heavy and biased**” towards students, who must first *grasp the fundamentals* of biology and engineering and comprehend their principles in depth before moving on to the interdisciplinary field of Synthetic Biology. Moreover, Prof. Haralampidis mentioned that this graduate program would be of great interest to greek students, as many young scientists **immigrate** to other countries (U.S., U.K., Germany, The Netherlands, France) in order to pursue their passion for synthetic biology.

We then discussed the evolution of **genetically modified plants**, the misconceptions and the boundaries of human intervention. GMOs and GMO foods were a recurring theme in our Human Practices, as we presume it to be a sensitive topic in the greek society.

Analysing the Greek Reality

Discussions with Specialists

Prof. Haralampidis declared that “**we [humanity] would be hypocrites if we were to assume that we could survive without genetically modified organisms,**” referring both to GM foods and plants as well as to the production of pharmaceutical drugs. However, as he mentioned, scientists strive to propose **novel, more environmentally and consumer-friendly** solutions, compared to the existing ones.

And of course, **detailed knowledge** of the organisms and their genome will prove to be a strong asset in humanity’s journey to developing more robust and safe engineered biological systems.

Analysing the Greek Reality

Discussions with Specialists

Prof. Fragkiskos Kolissis

Professor Emeritus at the School of Chemical Engineering, NTUA, Greece & OMIC-Engine, Greece

Prof. Fragkiskos Kolissis, by our team's side since the beginning, found our intention of concluding our actions into a report most promising, suggesting its **publication on the OMIC-Engine webpage**, Greece's newly established **infrastructure for Synthetic Biology**. He also suggested the creation of a **video** that would explain synthetic biology, addressing high school students. The link for the video can be found on the next session.

Discussion & Suggestions

Retrospecting on our iGEM journey, our team came up with the following conclusion: Synthetic Biology, a promising interdisciplinary biotechnological field, may not be well established in Greece yet. However, one can observe the growing interest that gives rise to initiatives (iGEM Teams) and SynBio related infrastructures (OMIC Engine) that help reinforce Greece's position on the synthetic biology map as well as the country's capability for research and innovation.

By reaching that conclusion our team came up with the following **future plans and suggestions**:

- ▶ Participation in Public Engagement activities even after the iGEM Competition: reaching out to high school students, universities and the society. Our calendar already includes a **team interview** by a students' organisation of the School of Chemical Engineering.
- ▶ Creation and distribution of synthetic-biology-related educational material. Among this material, a **guide on organising a SynBio workshop was written**. Also, a [video](#) has been already created, taking a **linguistic approach** on explaining synthetic biology to greek high school students.

Discussion & Suggestions

- ▶ Our team encourages the creation of **Biotechnological high-school teams**, and be included in the *extra-curricular* activities of the secondary education. Through those teams, the engagement with biotechnological advancements would be more effective, an activity that would help students get acclimated to the laboratory procedures and various computational tools. Those teams could also evolve into iGEM teams or projects. Our team would be proud to foster such an initiative in schools all over Greece.
- ▶ Of course, support of newly-created iGEM Teams, by **mentoring** and sharing our iGEM experience.

Acknowledgements & References

Dr. Maria Dokopoulou, of the Biological section of the national Institute of Educational Policy, was by our team's side throughout our iGEM journey, mentoring us from May up until September. More specifically, Dr. Dokopoulou guided us through the process of setting our **goals**, making an **impactful presentation**, suitable to high school audiences, as well as preparing **questionnaires** that are scientifically valid, with strong **educational motives**.

Prof. Evangelia Pavlatou, from the **School of Chemical Engineering**, gave our team significant insight on organising our Human Practices activities, as well as on how to **process statistical data** from questionnaires. Along with Dr. Dokopoulou, she aided us on how to effectively organise engage students and communities and how to elaborately document our findings on this report.

Special thanks to **Prof. Kostas Kordatos** and **Dr. Afroditi Ntziouni** of the Inorganic and Analytical Chemistry Lab, School of Chemical Engineering of the National Technical University of Athens, who accepted our team as part of the Lab's team at the *2018 Athens Science Festival*.

Acknowledgements & References

Many thanks to **Dr. Kostas Vavitsas** for suggesting a **Panhellenic iGEM meeting** that turned into a successful **Workshop** for university students, as well as to **Prof. Emeritus Fragkiskos Kolissis** and **Prof. Georgios Skretas** for being part as keynote speaker and judge, respectively, at the aforementioned workshop.

We would also like to thank **Prof. Kosmas Haralampidis** of the Biology faculty, NKUA, for the delightful conversations.

References

Fredricks, J. A., Blumenfeld, P. C., & Paris, A. H. (2004). School Engagement: Potential of the Concept, State of the Evidence. *Review of Educational Research*, 74(1), 59–109. doi 10.3102/00346543074001059

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