IGEM ANALYSIS

Improving the potential of iGEM

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Introduction

Synthetic biology or biotechnology in general is the world wide web of the last century. I believe it is going to change the world." This was claimed by Randy Rettberg, founder of the iGEM competition during The European Experience 2016 iGEM meeting. The World Wide Web changed the society into something unrecognizable and unlikely to humans living at the beginning of the last century and according to him, synthetic biology will change the world in the same extent. This is why he founded iGEM in the first place. "*Universities need to get behind the projects and give their students the opportunity to be part of something revolutionary".* He thinks that students who participate in iGEM will be a part of a process that will revolutionary change the way. We for example create chemicals, feed the world and cure diseases. He hopes that iGEM will contribute positively to this process (Reichman, 2013)

iGEM officially began in 2003 as a study course at the Massachusetts Institute of Technology (MIT). In this course students where challenged to develop biological devices to make cells blink. In the year 2004, instead of the normal course, a competition with five teams from various universities form the United States was held. A year later also teams from outside the United States took part in the competition (Community, 2015). Years prior to 2006 had no specific winners and therefore it can be said that the competition, as we know it today, began life in 2006. This means that the competition in its current format could have celebrated its tenth anniversary last year. Therefore, it is a good moment to draw up the balance and analyse what the influence and impact of iGEM was over the past 10 years.

In this study we will critical analyse iGEM. The 9 facets of iGEM are used to do this. These facets are respectively technology, teamwork, entrepreneurship, sharing, education, safety and security, responsibility and community. With this report we think that iGEM can be improved even further. We believe that iGEM has already proven its volubility for the world. However we think that there are always possibilities to improve even future and with this setting we have written this report.

Content

Competition

The iGEM competition is first of all a competition between the different iGEM teams. The teams have to compete against each other in different age categories and tracks. The best project in each track and category is awarded a prize. Furthermore, there are special prices for, for example, best human practices, best wiki and best part. Finally, the most valued prize for every team is the Grand Prize. This is the prize for the overall best project. Although a limited number of teams can win an award, every team can achieve a bronze, silver or gold medal. For every medal, the team has to meet specific requirements about among other things parts they have to register, collaborations and human practices.

In this part of the report, the competition itself is analyzed. Firstly, quantitative and qualitative data is collected about the competition itself. After this we have critically analyzed the competition and have especially focused on potential inequality within the iGEM competition.

Qualitative & Quantitative analysis

Participants

As described before, the iGEM competition, as we know it today, began life in 2006. Back in those days, there were 32 participants. Ever since then the number of participating teams has increased and with 280 teams in 2015, the number of teams has increased almost nine fold in 10 years (Figure 1).

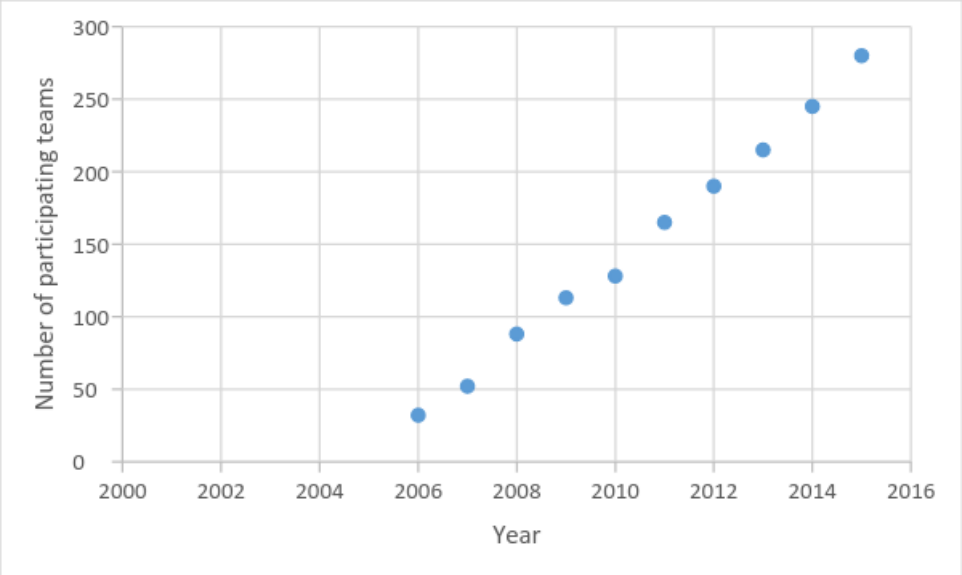

Figure 1: The number of participating teams.

In the beginning of the competition, the teams were mostly coming from North-America. Over the years this has been changed and since 2008, less than half of the teams is coming from North-America (Figure 2). This shift is mainly the result of the relative increase of participation teams from both Europe and Asia. Especially the relative share of Asia is increased enormously. On the other hand, the share of African teams is severely underrepresented. Only in 2010 and 2015 there where participants from the African continent and in both years this was only 1% of the total teams.

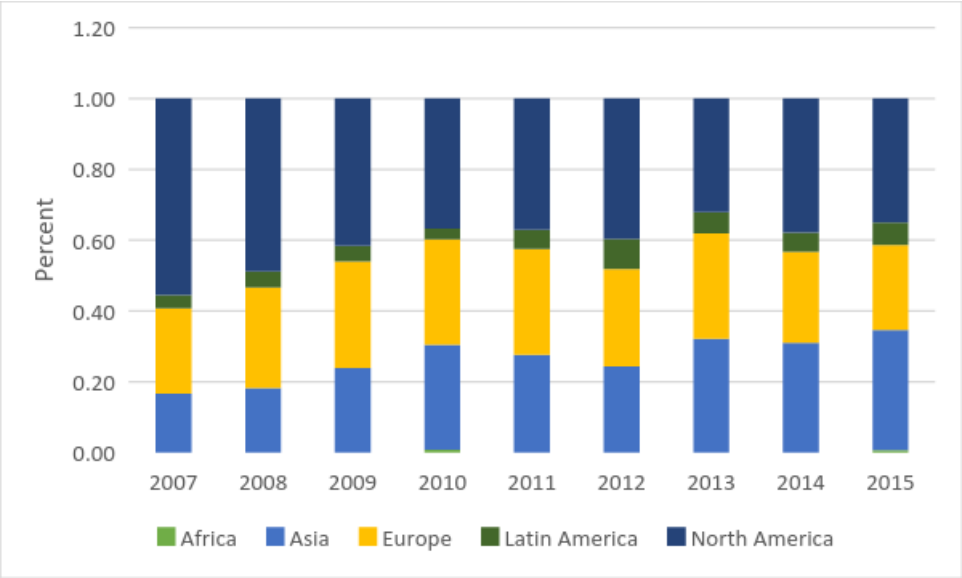

Figure 2: Relative share of the continents in the competition. There is no reliable data available about 2006.

The total number of participants is increased over the years, as expected, while the average number of participants per team fluctuates (Figure 3).

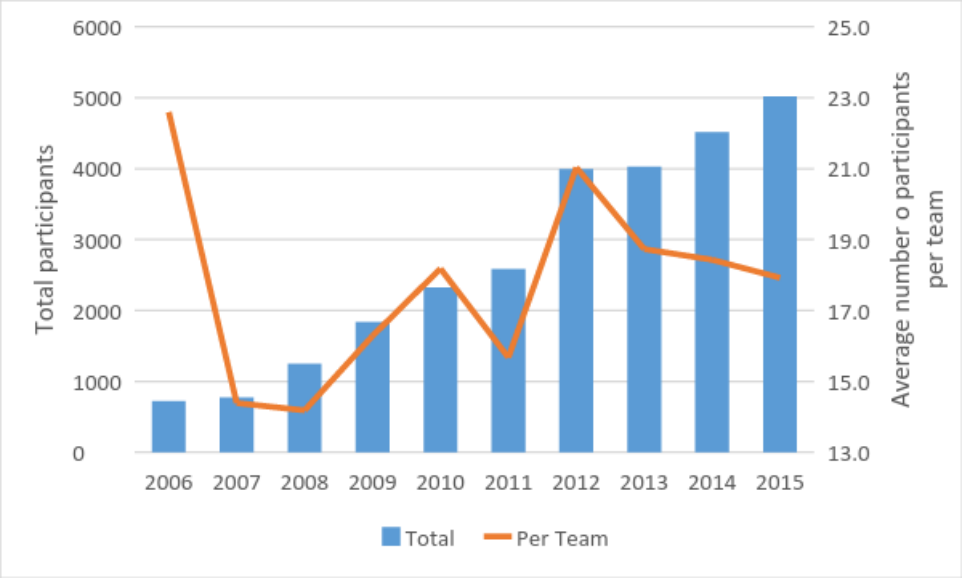

Figure 3: Total number of participants and the average number of participants per team.

The Tracks

Since 2009, iGEM teams have to participate in a specific track. The tracks allow teams to focus their project towards a specific subject area within synthetic biology and allow them to know who they will compete against for the track award. They started with 8 different tracks; respectively the tracks Environment, Food/Energy, Foundational Advance, Health/Medicine, Information, Processing, Manufacturing, New Application and Software Tools. In 2013, the ninth track, called Entrepreneurship, was officially introduced after a pilot year in 2012. The goal of this track is to foster development of a new industry where Synthetic Biology is the underlying technological platform. In 2014 it is decided to drastically change the tracks. *"The idea behind separating out Tracks and New Tracks is to highlight that the there are differences in the scope of work and also in the evaluation."*(iGEM, 2014) The track Food/Energy was replaced by the two separated tracks Food/Nutrion and Energy. Furthermore, the tracks Community Labs, Measurement, Microfluidics and a separated track for Policy & Practices have been added. Also, since 2014, there is a special track about the art of synthetic biology, named Art & Design. In 2015 they have decided to stop the Microfluidics track because it is narrow and instead of this track, they have introduced the track Hardware in which microfluidics is included. Furthermore, after running an experiment for three years, the track Entrepreneurship is no longer a track. Because it is believed that every team, irrespectively from the track, could write a business plan and therefore a special prize about entrepreneurship is introduced. Finally, after organizing a separate competition for high school teams for a few years, it is possible for them to participate in the regular iGEM competition since 2015.

The number of teams participating in every track in the years 2009 until 2015 can be found in Table 1.

Table 1: Number of teams participating in every track in the years 2009-2015.

Track	2009	2010	2011	2012	2013	2014	2015
Environment	16	16	25	30	36	45	33
Food/Energy	8	12	15	22	25	-	-
Foundational Advance	21	20	26	34	29	27	21
Health/Medicine	15	20	13	26	40	43	55
Information Processing	8	6	10	13	12	13	11
Manufacturing	14	17	15	11	13	14	18
New Application	13	20	31	28	24	26	31
Software Tools	8	6	8	10	8	11	8
Entrepreneurship	-	-	-	-	4	3	-
Art & Design	-	-	-	-	-	5	3
Community Labs	-	-	-	-	-	6	4
Energy	-	-	-	-	-	11	13
Food/Nutrition	-	-	-	-	-	9	13
Measurement	-	-	-	-	-	10	7
Microfluidics	-	-	-	-	-	2	-
Policy & Practices	-	-	-	-	-	2	-
Hardware	-	-	-	-	-	-	7
High schools	-	-	-	-	-	-	36

The Medals

One of the special things about the competition is that every team can earn a medal. Every year there are specific requirements to win a bronze, silver or a gold medal. In this part the medal requirements over the past five years are analyzed.

Bronze

In the year 2011, the requirements to win a bronze medal were:

- Team registration
- Complete Judging form
- Team Wiki
- Present a poster and a talk at the iGEM Jamboree
- At least one new submitted and well-characterized standard BioBrick Part or Device. A new application of and outstanding documentation (quantitative data showing the Part's/ Device's function) of a previously existing BioBrick part in the "Experience" section of that BioBrick's Registry entry also counts.

In the three following years, these requirements did not change in content. However, in 2014 a new requirement was added to the list:

- The description of each project must clearly attribute work done by the students and distinguish it from work done by others, including host labs, advisors, instructors, sponsors, professional website designers, artists, and commercial services. Please see the iGEM 2011 Imperial College Acknowledgements page for an example.

Silver

In addition to the Bronze Medal requirements, the requirements to win a silver medal were in 2011:

- Demonstrate that at least one new BioBrick Part or Device of your own design and construction works as expected.
- Characterize the operation of at least one new BioBrick Part or Device and enter this information in the "Main Page" section of that Part's/Device's Registry entry.

Two extra requirements were added in 2013:

- Submit this new part to the iGEM Parts Registry (submissions must adhere to the iGEM Registry guidelines).
- Your project may have implications for the environment, security, safety and ethics and/or ownership and sharing. Describe one or more ways in which these or other broader implications have been taken into consideration in the design and execution of your project.

In 2015 they reorganized the four requirements into three new requirements:

- Experimentally validate that at least one new BioBrick Part or Device of your own design and construction works as expected. Document the characterization of this part in the Main Page section of the Registry entry for that Part/Device. This working part must be different from the part you documented in Bronze medal criterion.
- Submit this new part to the iGEM Parts Registry. This part must be different from the part you documented in Bronze medal criterion. (Submissions must adhere to the iGEM Registry guidelines.)
- iGEM projects involve important questions beyond the bench, for example relating to (but not limited to) ethics, sustainability, social justice, safety, security, and intellectual property rights. We refer to these activities as Human Practices in iGEM. Demonstrate how your team has identified, investigated and addressed one or more of these issues in the context of your project.

Gold

In 2011 every team had to meet, in addition to the Bronze- and Silver Medal requirements, one or more of the following requirements, in order to receive a gold medal:

- Improve the function of an existing BioBrick Part or Device (created by another team or your own institution in a previous year) and enter this information in the Registry (in the "Experience" section of that BioBrick's Registry entry), and don't forget to create a new registry page for the improved part.
- Help another iGEM team by, for example, characterizing a part, debugging a construct, or modeling or simulating their system.
- Outline and detail a new approach to an issue of Human Practice in synthetic biology as it relates to your project, such as safety, security, ethics, or ownership, sharing, and innovation.

In 2013, a small change is made in the last optional requirement to win a gold medal:

- Your project may have implications for the environment, security, safety and ethics and/or ownership and sharing. Describe a novel approach that your team has used to help you and others consider these aspects of the design and outcomes of synthetic biology efforts. Please justify its novelty and how this approach might be adapted and scaled for others to use.

In 2014 this last requirement is further tightened:

- iGEM projects involve important questions beyond the bench, for example relating to (but not limited to) ethics, sustainability, social justice, safety, security, or intellectual property rights. Describe an approach that your team used to address at least one of these questions. Evaluate your approach, including whether it allowed you to answer your question(s), how it influenced the team's scientific project, and how it might be adapted for others to use (within and beyond iGEM). We encourage thoughtful and creative approaches, and those that draw on past Policy & Practice (formerly Human Practices) activities.

The requirements are changed again in 2015. Since this year, in addition to the Bronze and Silver Medal requirements, the teams has to convince the judges it has achieved at least two of the following goals:

- Choose one of these two options: (1) Expand on your silver medal Human Practices activity by demonstrating how you have integrated the investigated issues into the design and/or execution of your project. OR (2) Demonstrate an innovative Human Practices activity that relates to your project (this typically involves educational, public engagement, and/or public perception activities; see the Human Practices Hub for information and examples of innovative activities from previous teams).
- Help any registered iGEM team from a high-school, different track, another university, or institution in a significant way by, for example, mentoring a new team, characterizing a part, debugging a construct, modeling/simulating their system or helping validate a software/hardware solution to a synbio problem.
- Improve the function OR characterization of a previously existing BioBrick Part or Device (created by another team, or by your own team in in a previous year of iGEM), and enter this information in the part's page on the Registry. Please see the Registry Contribution help page for help on documenting a contribution to an existing part. This part must not come from your team's 2015 range of part numbers.
- Demonstrate a functional prototype of your project. Your prototype can derive from a previous project (that was not demonstrated to work) by your team or by another team. Show this system working under real-world conditions that you simulate in the lab. (Remember, biological materials may not be taken outside the lab.)

Number of medals

Figure 4 shows the percentage of teams with respectively no medal, a bronze medal, a silver medal or a gold medal.

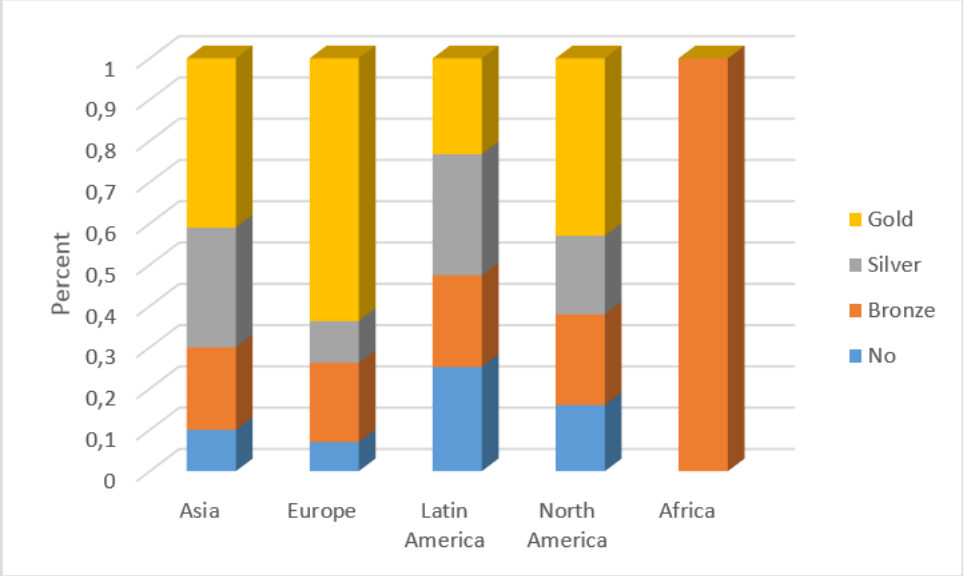

Figure 4: Total medal distribution. The percentage of teams with respectively no medal, bronze medal, silver medal or a gold medal.

Critical analysis

Based on the statistical data it appears that the medal requirements are mainly focusing on science and policy and practice. This is understandable, since the iGEM competition is all about the use of synthetic biology in a socially responsible way. However, in our opinion, for example modeling can be considered as an important part of the competition as well. After all, mathematical models and computer simulations provide a great way to describe the functioning and operation of BioBrick Parts and Devices. Therefore, we think modeling has to be included in the medal requirements as well.

Currently, modeling is not a required part of the competition; therefore many teams do nothing with it. Probably, this is partly because many teams have no members with experience in modeling. These teams would be extremely disadvantaged if modeling becomes a hard requirement. Therefore, we propose to add an extra possible requirement that teams can meet to win a gold medal:

“Construct a mathematical model to aid in the design, understanding, and/or implementation of your project. Validate your model with measurements.”

This could give teams an extra motivation to use models in their project.

Another interesting point is the fact that over the years the medal requirements have become harder. Nowadays it is more difficult to win a medal. However, relatively many teams are still able to win a medal. After all, almost 90% of the teams wins at least a bronze medal. This raised the question whether the medal requirements are too soft. To analyze this proposition, we have asked the opinion of the headquarters. They told us that teams are not competing with each other for medals, so if every team convinced the judges that they had achieved the requisite level for a gold, they would give them all gold. They want teams to care about the things that matter to iGEM, such as openness, communication, sharing and thinking about the effect of your work on the world and the world on your work.

In their opinion every team has to be able to win a medal and all teams are judged subject to the same criteria. For new teams, teams from resource poor countries and high school teams without a -80 degree Celsius freezer it appears to be difficult to meet the requirements for a medal. Another important reason to not make the requirements too hard, a medal can give a boost for fundraising. Teams that win a medal, and especially teams that win a gold medal, will probably be able to obtain more funds in the year afterwards. This benefits the projects.

Based on the analysis we believe that it is not wise to drastically change the medal requirements in order to decrease the number of teams with a medal. The headquarters clearly stated that the goal of the medals is to make sure that iGEM teams focuses on the aspects they believe to be important. Also, the potential positive influence of a medal on fundraising is an important reason we think the medal requirements should not be too hard. However, we do believe that it is important to update the requirements every year. Among other things, new technology developments will make it easier to meet certain requirements. Therefore, just as in the past few years, the requirements have to be adapted every year and if required they have to be tightened.

Inequality within the competition

Within the competition there are a few aspects that are not the same for all the teams. This means that there is a form of inequality within the competition. In this part a few of the potential inequalities are evaluated.

The budget

One of the aspects that probably always has a significant influence on the success of a research project, is the budget. The differences in available budget between teams are expected to be large. This raises the question whether measures should be taken to reduce disparities. For example, setting an upper limit to the budget or dividing teams based on budget in different subdivisions could be an option.

Based on the survey it appears that the difference in budget are significant large. The survey responder with the smallest budget had a budget of around 500 euro, which is almost 10 times smaller than the responding team with the largest budget that had a budget of around 50.000 euro.

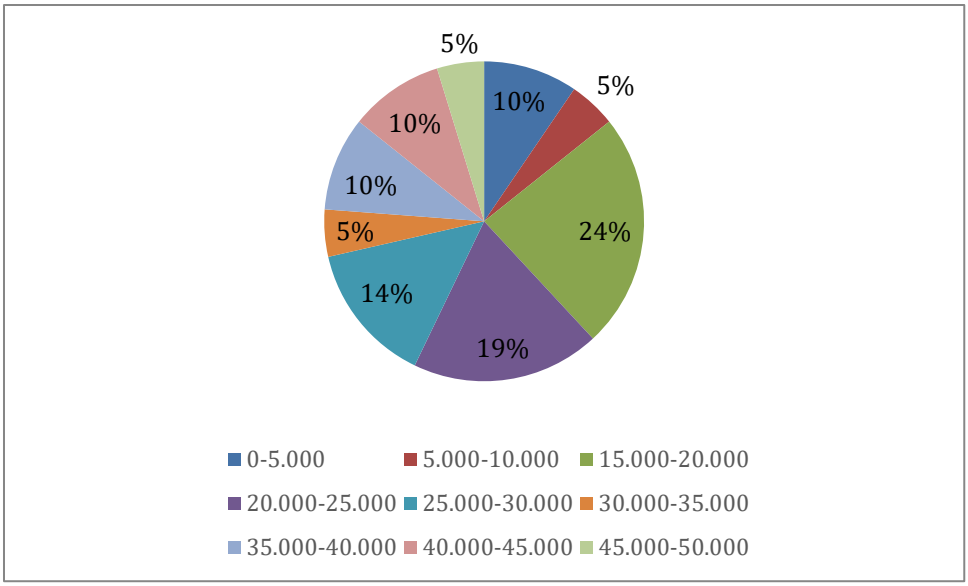

Figure 5: Budget distribution of the iGEM teams. Data based on the teams that have filled out the survey.

It has to be mentioned that the average budget of responding overgrad teams was slightly higher than the average budget of the undergrad teams. However, the differences within both groups were still in the order of magnitude of 30.000 euro. It appears that there is a relation between the medals and the budget of the teams. Most of the teams with a large budget also win a gold medal. Among the teams with a relatively small budget, the number of teams that has no medal is significant higher. Also the “chance” to win an award appears to be higher when the team has a large budget.

Based on this data it is not possible to conclude that there is a direct cause-effect relation between budget and results. For example, it is in theory also possible that the budgets of the winning teams are larger because of the fact that their project is very interesting. This could make finding funds easier. However, as described before, these enormous differences raise the question whether measures should be taken to level the resource. Therefore, the possibilities to take measures with respect to the budgets are analyzed.

The first proposal is to set a maximum budget. The main advantage of such a measure is the fact that the differences in budget will be narrowed and teams will have more equal opportunities therefore. Especially for teams with a small budget it could give them the feeling they are not hopeless participants. However, there are many objections to this proposal. First of all, it is almost impossible to exercise real control. Partly because such a control is based solely on trust. Teams could easily manipulate information about their budget. Secondly, it is questionable whether the budget could be considered as the only resource of a team. For example, the research facilities of a university play also an important role in the opportunities of a team. In our opinion, all of this will make it almost impossible to set a maximum budget.

A second possibility could be to set a minimum budget. This will, likewise a maximum budget, narrow the differences in budget. This will result in a situation where some teams are not able to participate in the competition anymore. This is not desirable in our opinion. Currently teams can decide for themselves whether it is meaningful to participate or not. An external party should, in our opinion, not decide this for them.

Another, totally different approach could be to fairly divide the available budget of all the teams between all the teams. However, this will also not solve the problem of the aforementioned differences in research facilities. Furthermore, this will probably impede raising funds. For example, many sponsors will only sponsor a specific university or local party and in many cases teams have specific sponsors for their project. Finally, it would be possible to divide teams, based on their budget, in different subclasses. Unfortunately, this will also be uncontrollable as well.

All the aforementioned possibilities implicate that narrowing the differences in the budget would be an improvement for the competition. However, fundraising could also be considered as part of the competition. Teams with a higher budget are apparently better in fundraising. Furthermore, it is expected that the possibilities for funding are partly depending on the research project of a team. A good research proposal and an interesting research topic will probably facilitate fundraising.

Another interesting question to ask is what is more important for the iGEM competition, equality between teams or the eventual results of the teams. When the results of the teams and therefore the success of the research projects are more important, it is not desirable to limit teams in their budget. This will in many cases not benefit the results of the project.

In our opinion the research project is the most important aspect of the competition. Teams should therefore not be limited in their budget. Instead of limiting 'wealthy' teams, the competition could better promote 'less wealthy' teams. Partly, this is already the case. For example, all participants get free access to Snapgene and Matlab. Furthermore, after paying the required fee, all teams have access to many DNA parts. This gives teams with fewer facilities also the possibility to participate. However, in our opinion the promotion of less wealthy or in more general, less experienced teams could be better. For example, the iGEM competition could start a more extensive coaching program. This can be done in different formats. Firstly, it is possible that inexperienced teams are coached by more experienced teams. This could be one of the possible requirements to win a gold medal. Then both teams can profit from it. Another possibility is to require overgrad teams with more experience students to coach new and inexperienced undergrad teams. It is also possible to use a team of experienced researchers to coach teams. Furthermore, a more committal initiative could be to use the forum in order to coach teams. Teams could ask help on the forum and other teams or experts can help them. To make this profitable for both teams, we propose a point system. Teams that help other teams can earn points and when they achieve a certain number of points, they could for example use this to meet one of the requirements to win a gold medal. Eventually, all these proposals hopefully result in a higher level across the spectrum of teams.

Travel costs

The travel costs between the different teams are large. Teams from for example Boston, New York or Philadelphia can travel for 50 to 100 euro per person while teams from Australia probably need 1000-1500 euro per person for traveling (Figure 6).

Figure 6: Traveling costs

From 2011 to 2013 the competition was split into three regions, respectively Europe, Asia and the Americas. Only the best teams from every region were allowed to go to Boston for the finals. The reason to have regional competitions was because of the increasing size of the Jamboree. In 2014, the organization hosted a giant jamboree so every team could participate in one conference. This has as main advantage that all the teams can meet each other, discuss their projects and eventually watch live the presentations of the final teams. However, the above mentioned differences in traveling costs result in an inequality within the competition. For teams from Australia, traveling will probably a large part of their budget, while for teams from North America this is probably not the case. Reintroduction of the region competition would partly solve this problem. However, for the teams that reach the finals, the problem will still remain.

We believe that the possibility to interact with teams from all over the world during the jamboree is more valuable than disadvantages of the inequality within the competition as a result of the differences in travel costs. Nevertheless, it cannot be declined that the differences in travel costs also result in an inequality within the competition.

Laws and policies

From European Union to Africa, China and Japan and all the way back to the U.S.A, various bans, laws, and labels can make synthetic biology difficult to keep up with. The differences possibly also result in an inequality within the competition.

In this report we will not especially compare legal differences between different countries. Interested readers can look into the analysis made by the Arizona State iGEM team from 2013. We will purely focus on the problems that the responders of the survey have encountered.

Based on the survey it appears that several teams had legal issues. About 30% of the teams encounter problems. From the teams that did encounter problems, multiple of them have mentioned that they did encounter problem because of uncertainties in the law about synthetic biology and SynBio products. It appears that in many countries the regulation about these subjects is not up to date or even almost absent. Therefore, there are many teams that operated in a grey area. One of the teams eventually decided to contact the government about this and they succeeded to start a collaboration with the government. Based on advises of this team, the government is currently chancing the regulation about synthetic biology. In our opinion this forms a nice example of potential volubility of iGEM.

Another interesting point is the fact that one of the teams mentioned that they worked with transgenic plants and that they have experienced that in Europe transgenic plants are rejected in advance by society and government. Even if there are no arguments and the product is safe, it is not allowed to use them. The fact that synthetic biology is rejected by governments purely because of fear, is something that more teams have mentioned.

Based on the survey it appears that most of the teams have no legal issues worth mentioning. However, there are also multiple teams that experienced legal problems because of incomplete legislation or because of general aversion against synthetic biology. The example of the team that started a collaboration with the government shows that iGEM could play an important role in this.

Technology & Entrepreneurship

Most iGEM teams spend about half a year on their project and although many teams are able to obtain very interesting results, for most projects further research is required to make them publishable or to turn them in a functional real life application. To analyze what happened with the iGEM projects after the jamboree, we have asked the iGEM teams in our survey whether somebody continued with the results of the project after the Jamboree.

First of all, we have asked the iGEM teams whether the results are published in a peer-reviewed journal. Based on the answers it appears that a majority of 84,6% did not publish their results. Almost 4% of the responders were already able to publish their results in a peer-reviewed journal and another 11.5% was still working on a publication. This data shows that most of the projects are not directly publishable or that teams spend no time on it after the jamboree.

In the year 2013, iGEM started a collaboration with ACS Synthetic Biology. The idea was that iGEM teams would get a possibility to publish their results in a strong academic journal. However, it appeared to be, from a logistic point of view, too difficult to continue the collaboration. Currently, they have a collaboration with PLOS Collections for the foreseeable future. iGEM teams can submit an article to the iGEM Collection after which members of the PLOS and members of the iGEM community can review the publications. The reviews will be posted as comments on the website and all reviewers will be asked to sign their review. Submissions will undergo technical checks by PLOS staff prior to being posted. Currently, there are six teams that have used the possibility to publish their results in this way.

Although most teams did use the possibility to publish their results in the PLOS iGEM collection, we believe that this kind of indicatives are important to make the results of iGEM more public available. Currently, every iGEM team makes a Wiki about their project. This can often give interested people very extensive and detailed information about the project. However, it can also be difficult to find the information in which you are interested and if you are not specially looking for some information, it is unlikely that you will get in touch with the interesting projects. Therefore, we think that iGEM should find a way to make the results and projects more easily accessible.

One of the possibilities is to start an own journal. This could give iGEM the possibility to publish and show their most interesting projects. However, the aforementioned logistic problems, lack of time of the teams, or no publishable results could also be a problem when iGEM starts an own journal. One possibility to partly take away these problems, is to make writing a publishable article one of the possible gold medal requirements teams can meet. Teams that meet the requirements and receive a gold medal will then be published in the iGEM journal. This would give external parties an easy way to see what the results are from the ‘best’ iGEM projects.

Another option could be to make it obligatory for teams to write an abstract about their project. Those abstracts can then be bundled and published as well. To make this bundle with abstracts uncluttered, we advise to use a standard format for those abstracts. The use of standard formats will be discussed in more detail in the paragraph Community, Sharing & Responsibility.

When the results, after the iGEM project are not published, this not necessarily means that the results will remain unused after the jamboree. Sometimes the research continues after the jamboree. For example, the project can be used as a starting point for a thesis project or a PHD student could continue with the project as part of its own project. Therefore, we have asked iGEM teams if the project is used for another research. Based on the responses it appears that almost 35% of the projects are used for another research project after the jamboree. In a later stadium, iGEM projects will indirectly still be published in journals.

Sometimes results can also not been published because the goal is to patent them. Therefore, we have asked the teams in our survey if parts of the project are patented. It appears that almost 2% of the projects are patented and for another 4% of the projects, the team or an external party is working on a patent. From the teams that did not patent their project, more than 4% of the responders told that this was because of problems with intellectual properties. Another 13% of the responders indicated that work is done to patent the product, but that because of differing reasons it appeared to be impossible. From the teams that patent their results, one of the teams already used the project as a beginning for a start-up. This was the UCL team that also won the best supporting entrepreneurship award.

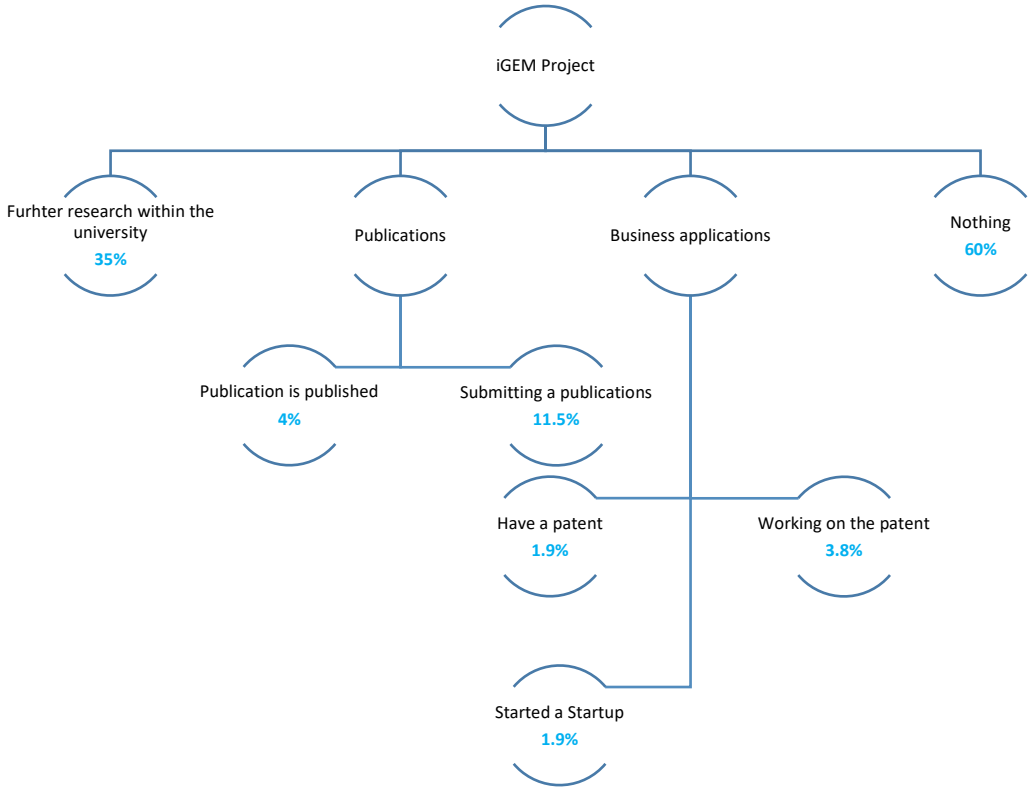

Figure 7. Summaries what happened with the iGEM projects after iGEM.

Community, Sharing & Responsibility

The iGEM community strives to bring likeminded people together, who wish to use synthetic biology to create a positive impact in the world. Currently 16,000 people have been involved in the iGEM community (iGEM HQ, 2016). However, there are much more people interested in science and these might also be interested in the activities of iGEM.

One of the main activities of the iGEM community is honesty in this field of knowledge and thus to share knowledge. A survey, performed in the UK in 2014, showed that the public still trusts scientists even though they do not always trust the scientific data itself. The trust though is fragile and this gap could facilitate a complete collapse in trust in science (Yarborough, 2014). To prevent this, scientists need to articulate better what makes their work deserving of the public's trust in the first place, according to Yarborough. Sharing knowledge happens both within the iGEM community as well as to external actors such as the remaining scientific world, industry, governments and laymen. Here, we present a strategy to strengthen the iGEM community even more, using its most vital power: sharing knowledge. To enable this, an action mode was planned for each moment in time to ensure involvement in the iGEM community.

Sharing knowledge as main activity of a community

To strengthen the iGEM community, it is important to attract new participants. For this, high school and college students should be motivated to compete. However, to motivate them to change their behavior into an iGEM participating behavior, something more needs to happen than solely attracting and motivating. According to the consumer acceptance of technology model of Kulviwat (2007): to accept a new technology and in this case a new project in their lives as iGEM, it is for any stakeholder important to be positive about it – both cognitive and affective. These two different factors are important and work together to accomplish acceptance and a behavioral change in favor of in this case actively participating in the iGEM community (figure 8). This theory is also applicable for the acceptance of the innovations made within the iGEM community.

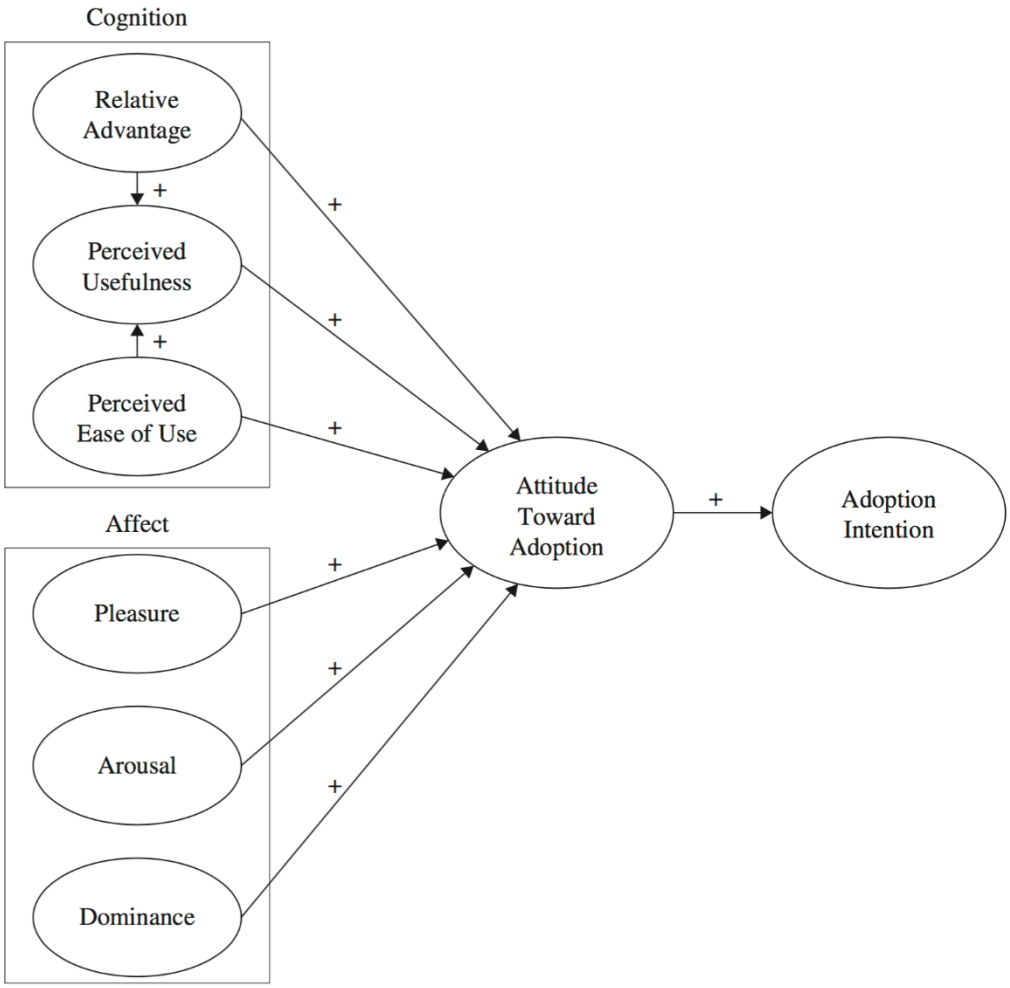

Figure 8. Proposed consumer acceptance of technology model by Kulviwat et al. (2007).

For the first part of the CAT-model (Consumer Acceptance of Technology) to be perceived as positive (the cognition part), the public should be able to notice that it is a good product, service, technology or any other kind of innovation. So the specifications of the innovations should be in line with expectations and interests of the innovations' public.

One of the things making the affective side of the CAT-model perceived as positive is trust in a specific technology, scientist, or related aspect. Trust in organizations is vital (Clark and Payne, 1997). Ever since the economic breakdown in 2008, it took years for the economic sector to recover and regain trust in the consumers — the people they so heavily rely on. For science however, this trust is just as vital. Scientists rely on funding from governments, industry, etc.; which all have to justify their actions to their stakeholders.

Since the current reputation of science, as stated by iGEM HQ, is not being open, scientists need to articulate better what problem needs to be solved, what the relative advantage is of their innovation towards this problem and what makes their work deserving the public's trust as being the best solution for this problem in the first place simultaneously. As an opponent, in iGEM, the participants are encouraged to share and publish their work, so the public is informed about their work. Since iGEM and its results could be much more recognized to get more people to know about it, we recommend several strategies on how and where the teams should be motivated to share their acquainted knowledge.

Openness and transparency is key in getting or retrieving trust. We think it is important to educate our future scientists in such a way that they will adopt the vision of integration of the stakeholders' interests while innovating and to communicate about it accordingly. A great place to start with this can for example be in the iGEM competition. To accomplish this integration, sharing knowledge is of great importance — towards all involved stakeholders.

Presenting an iGEM story

All teams deal with many different stakeholders while solving their selected problem. Even though the same problem and solution is presented to each of these stakeholders, not all communication methods will be as efficient for each stakeholder. For this, we advise the teams to make communications strategy; explore what stakeholders are involved, how they could be reached best and how the message should be told for this particular stakeholder group. Since main communication priority is towards the remaining scientific world, we will elaborate on that below.

As a side note, we would like to highlight the importance of being aware of the responsibility that scientists carry about their knowledge. Here you can think of different things, a negative example can be that the innovation might be misused with wrong intentions. However, this is not the only negative revealing; someone not understanding your approach in innovation, or being scared of something in your innovation is also not positive. For this, it is important to be and stay aware that you have to involve the thoughts and interests of your stakeholders in your story. Besides that, among others policy makers have been spurring innovators to include social and ethical aspects in their innovations (Lucivero et al., 2011). This means that ideally, the innovators (in this case the iGEM teams) are in contact with stakeholders during their innovation trajectory and accumulate the knowledge of and implement the wishes of these stakeholders already while they are making their product. So far, iGEM has been motivating their teams to implement this kind of "midstream modulation" (Flipse et al., 2013) (iGEM Human Practices, 2016), however the way the story is communicated might be improved in some cases.

One of the main communication aids of the iGEM teams is their Wiki page. This is mainly focused on reaching scientists and the iGEM community, meaning people with a scientific background. Though, comparing different Wiki pages to each other, even within the same university, many different structures arise on the Wikis. It is not immediately clear where to look for information if someone would be looking for it on an iGEM Wiki page. As opposed to scientific article, there is no clear structure. To create a similar clear structure in the iGEM Wiki pages, we suggest that each iGEM team structures its story similarly. Here we propose a structure in which iGEM teams can tell their story, keeping the importance of innovation science and the social and ethical aspects in mind.

- Aim of the project
  Just as in a scientific paper, it is important to set a context before running of to all results. It is important to know what the research is about and maybe even more importantly, why is it important that this specific research was conducted? What problem might this research solve and what implications would that have for the involved stakeholders? What stakeholders are actually involved in this topic (they may not be aware of it yet)? What kind of research was already done in this field? What questions are remaining and which of these are you trying to answer in this inquiry?

- Design stage
  For each problem, there are multiple scenarios possible. From each scenario though, another potential solution could arise. While the iGEM teams are familiarizing themselves with potential scenarios, they should be aware of the fact that there are things they do know, things they do not know and things they do not know they don't know it. Of course, this last category is the hardest to deal with. However, Schoemaker (1991) mentioned "series of scenarios help to compensate for the unusual errors in decision making", implicating the importance of these different scenarios. Which scenario is the most suitable in this specific context and what solution would work best, is mainly depending on the selection criteria elaborated below.

- Selection criteria for the design stage and their motivation
  After you have decided on a specific design space (stating what problem you exactly are trying to solve with this innovation) it is important for the stakeholders to show how you came to the selection of these potential solutions. For example technical aspects could be and issue, but also financial, cultural or any other criterion could make the scenario unsuitable. Basically, if something is not desired to be implemented in the solution, this should be communicated to the stakeholders. Furthermore, by applying the previous mentioned midterm modulation, these selection criteria can be formed in consultation with the stakeholders.

- The design and methods
  Since the desires of stakeholders and innovators are aligned at this stage, the real design can be described now. This means in the context of iGEM describing the different parts that were made and what their function is in the entire innovation. Also include the methods used with their argumentations.

- Results
  As the design needs to be tested and if possible confirmed, experiments are performed. These characterizations have a huge impact on new iterations of the innovation trajectory and eventually also for the perception of the innovation by stakeholders. What conclusions can be drawn from these results? And what further research would be necessary in this field and how can this innovation be implemented in real world conditions?

- Discussion
  Assuming the made innovation is successful and implemented in real world, this innovation is going to have an impact on all stakeholders. It is of importance that these stakeholders are involved about the consequences they are facing considering this new innovation. Due to the implementation of "midstream modulation" and further consideration of social and ethical aspects important to these stakeholders, this should help herewith. Besides that, new problems, which were faced during the innovation trajectory, could be an entrance to new research. This closes the circle of innovation.

The Wiki page is however not the only place to share obtained knowledge. Considering the timescale of the iGEM competition, knowledge could be shared in many different forms and at many different times. Here, we elaborate on some potential sharing possibilities that will contribute in making the iGEM community coherent. The different timings we have a look at are "During the competition", "After the competition" and "As old iGEM participants".

During the competition

As mentioned earlier: to strengthen a community, its continuity is vital and it therefore should attract new participants. Motivation has much influence on someone's behavior, in this case participating in the iGEM competition. According to Deci and Ryan (1975), intrinsic motivation is opposed to external motivation much stronger. Even though intrinsic motivation is much stronger, it is much harder to influence. For each person it might be different what motivates him or her. A lot of effort is necessary and with no certainty. So, to be able to motivate more people at once, it is advisable to motivate externally. Two examples of external motivation are elaborated below.

Positive experiences of old iGEM team members

Success stories sell. When someone wins a prize, all journalists want to write their articles about it, because this is news that will sell. Everyone will want to know that news. Humans are captured by it; by its uniqueness, by its visual impact, but overall by its success. Proximity in these success stories would even help more (Galtung and Ruge, 1965). In most optimistic case, people that are close to the potential new generation tell these success stories (for example fellow students, PhD students, teachers or others in academia). Some sort of proud takes over then. This could be a strong method to motivate potential new iGEM participants. While making sure these success stories are above all also framed as inspirational, this could demonstrate the potential success new teams also could achieve. This combined with aspiration (intrinsic motivation) could lead towards a new-motivated generation for the iGEM community.

Financial motivation combined with sponsorship from governments

Finances can be an extremely strong external motivator. For example, in the Netherlands the government's aim was to get more teachers for high schools. For this, a campaigning program was set up for a couple of years, in which students who would get their master's degree in teaching, they would receive a scholarship of €5000. A potential translation to the iGEM competition could be a collaboration between the innovation departments of the governments and the iGEM competition. Within the Netherlands, the Topsectors are for example "responsible" for tracking innovations in different industry disciplines. The iGEM headquarters can for example try to collaborate with different government institutions that are also interested in innovations within this field. Then teams can be motivated to participate in an additional part of the competition, where the different teams need to prove to one of the selected governments that they are worth it to receive funding, enabling them to continue with their research, start a business etc. This can contribute significantly to innovations.

Assuming the students were motivated enough at this moment to become participants in iGEM, they have indirectly also chosen to become members of the iGEM community. However, we would like them to become active members and we would like them to stay active members. This means that we would like to motivate these new participants to be active in sharing knowledge and experiences towards each other and people that are potentially interested in iGEM. Sharing knowledge starts already with consistency in how different teams present their story on their Wiki pages. As described earlier, the iGEM community would benefit if the iGEM community has a specific, recognizable and useful way of communicating the innovation trajectories done by iGEM teams. Besides that there are other ways of share knowledge, during the competition and after, with other teams as well as with remaining scientists and other stakeholders.

Share knowledge inbetween iGEM teams

To start, the iGEM teams are able to share their knowledge with each other. Since every team gets its lectures at a different institution, from different lecturers, perceptions and specific knowledge are different between institutions. Collaborations as currently performed, are an excellent way of dispersing the knowledge; letting the teams benefit from the knowledge available. Also, not all teams might have all equipment available at their own institution. This might be due to prioritization of the specialization (the equipment is not a necessity on a daily basis) or for example due to financial issues. Then, it is possible to ask another team to help out.

Even though these kinds of collaborations are a good start, it could be more. Collaborations are at this moment an obligatory part of the competition and we suspect that this is the reason the teams seek for collaborations in the first place. If more teams are using the same components, these teams could also try to troubleshoot together, making this more efficiently. If it would be made more easily to establish these kinds of collaborations, teams might also be intrinsically more motivated to enhance collaborations. Helping each other gives a feeling of satisfaction. Since this satisfactory feeling was due to the iGEM community, this new generation might also be more dedicated to keep acquired contacts close. This also helps again in making the iGEM community coherent.

Using the Slack application

One of the currently facilitated methods of communicating and knowledge sharing is via the iGEM forum. This was proposed as a method in the beginning of the iGEM competition. Back in the day, forums were used much more extensively. From our investigation we concluded that the current iGEM forum is underused with only about 1500 views in the last year. Besides that, not many new threads are created each year. The main platforms we used to connect and communicate with other teams were Facebook groups, emails and Twitter. A drawback about these platforms is that they do not let the teams seek for new collaborations and ask or answer questions. In these platforms, you would have to find a team manually about whom you would know they are able to help and send them an email. If collaborating with this team does not work out, you would have to look for another team manually again. Since the iGEM forum seems to be outdated and underused, we propose to replace the iGEM forum with a Slack team.

Slack is a chat application aimed at large teams and companies. The advantage of Slack over other messaging apps is that all comments and files exchanged are searchable and Slack contains the possibility to create different channels between the members of the team. It allows communities, groups or teams to join through a specific URL or invitation so replacing community platforms such as Facebook or LinkedIn (Wikipedia, 2016). Besides that, no personal information such as phone numbers is necessary to be a member of such a team. So “rather than host a forum or digital community themselves, or use social media platforms to engage, many community managers are turning to Slack as a place to quickly and easily build tight-knit communities” (Hootsuite blog, 2016), because ”Slack is more like instant messaging, forums, and email all rolled into one app” (PC mag, 2016).

The main use of Slack is in industry and collaboration of big teams. It has even been called “the killer of email”. It provides a central place for communication with real time messages instead of emails, reducing the time spent replying emails and increasing productivity and communication. The messages tend to be shorter and more casual than emails, making them more personal, easier and faster to reply (MIT Technology Review, 2016).

The reason of this migration to Slack is the ease of use of the service, the exclusivity of the chats and that it fits for use of communities and platforms. This translates in usage numbers as in its first year, 2015, it reached 500.000 daily active users, to more than quadruple them in their second year with

2.3 million daily active users.

There should be a general team with all the team accounts where general discussions can take place and collaborations/discussions during the Jamboree so teams can communicate easier. Besides those different channels for example with teams from the same area, same topic, undergrad, overgrad and high school can be established. Additionally, we propose that initially each team should have one account as a team and then in a later phase we can add all team members as well.

After the competition

Assuming the Giant Jamboree was a success, the participants are enthusiastic about it and might be willing to stay involved in the iGEM community. At this moment, it is important to keep this enthusiasm high. Since the phases in which the undergrad and overgrad teams are at in their study program after the Jamboree, it is advisable to approach these groups differently.

Undergrad teams

It will most likely take quite some time (years) until the undergrad teams are graduated and would have a significant amount of time to dedicate to the iGEM community again. For this reason, it is advisable to keep the expectations of devotion low. For example pleasant and enjoyable activities are good. It can also help to motivate them to keep in touch with other iGEM teams, knowing how they are doing in life and bond over iGEM activities. At their turn, these social activities have a positive impact on their relations, creating proximity. In the meanwhile, iGEM headquarters should stay up to date on when these originally undergrad teams would be available to actively participate in the iGEM community.

Overgrad teams

These iGEM teams are very likely to be busy with graduation projects and finishing their study program. It is not difficult to understand that this has the highest priority for these team members and not much involvement can be expected immediately after the Jamboree. However, after they have been able to finish their study program, they would even be more valuable for the iGEM community if they could actively participate in it. Whether they are going for a PhD position and continue in research, start a career in industry or any other discipline, a side project like iGEM is more likely to fit in their lives if it is incorporated from the beginning. For this, we advice the iGEM headquarters to provide the overgrad teams with a short survey at the Jamboree to make a prospect of who would be willing to be involved (e.g. advising new teams, volunteering at the Jamboree, or anything else) and from which moment on they would be available. Headquarters should communicate clearly what expectations they have considering this collaboration and the participant should communicate how much effort and time they would be willing and are able to put into the iGEM community. From here, mutual trust, motivation and effort to keep the relationship working is necessary.

As old iGEM participants

As old iGEM participants and active members of the iGEM community, their task is to have interactions with the new iGEM participants and sort of form the bridge between iGEM headquarters. This new iGEM generation will in turn feel grateful that they were able to get help form the community and are more probable to help newer generations in the future. As for the old iGEM participants, it could establish a happy feeling that they could return something to the community in the same way that they received a grateful feeling earlier. Like this, sharing of knowledge will be positive enforced.

Conclusions

Concluding, iGEM headquarters has made a huge effort to make the iGEM community a growing success as it is today. The past decade, it has grown enormously in people involved and in interested people. To strengthen the community even more, we think the value of sharing knowledge is extremely powerful. While sharing knowledge both internally and externally, the community strength as well as the involvement with other stakeholders will be improved.

Education & Teamwork

In this chapter we will focus upon education. We will analyze what teams did to educate the public, but also what the influence of iGEM and the teams was on their own education or personal development.

In our survey we have asked the responders whether their team did develop educational tools. It appears that about half of the teams did develop a tool or did something northwardly to mention with education. Most of the teams developed a tool to explain the basic concepts of synthetic biology. For example, multiple teams made a video or pamphlets. There were also two teams that used LEGO to explain the concepts of BioBricks and one team even used Minecraft to explain their project. The team of Leuven developed a card game about synthetic biology. They have noticed that the knowledge about synthetic biology is very low in Belgium. Traditional education methods were in their opinion often too complicated or boring and that is why they have decided to develop a card game.

We also have asked whether the teams did evaluate their tools and if so, whether they were successful to their purpose. Almost 40% of the teams had not the time or opportunity to do this. The teams that were able to test their tool mostly used their tool in a real live setting. For example, they used the tool to educate school children, used it in outreach events or the tool let the tool be reviewed by experts.

Most of the educational activities were targeting high school students; almost 56% of the responders were engaged in educational activities for high school students. With respectively 48% and 40%, the university students and adults were also popular targets groups. Only 23% of the responders educated elementary school children and 10% of the responders reached a target audience outside one of these groups.

Based on the survey we can conclude that there are many teams that are engaged in educational activities. Some of those teams have developed very interesting tools, that could also be very useful for other iGEM teams. We advise to make those tools more accessible. For example, iGEM could make a page with tools about education. Teams that think that they have developed an interesting tool could then register their tool. Other teams that would like to do some educational activities, but do not have the time to develop extensive tools for this, would have easy access to multiple tools. For example, the aforementioned card game can be used by other teams to educate high school children in their own neighborhood. It would also be interesting if teams could evaluate the tools afterwards. In this way the usefulness of tools can be extensively tested and with the iGEM community we can build on an extensive curriculum to teach the public about synthetic biology. Eventually such an education page can contribute to the increase of the general level of knowledge about synthetic biology or SynBio products. As mentioned before, especially in Europe, synthetic biology or biotechnology in more general, is not widely accepted. More and better education about the subject could change this. In our opinion, iGEM could and should take the lead in this. An education page with interesting education tools would already help a lot.

A very important group that has to be educated are the policy makers. As described in the chapter Competition, in multiple countries the regulation of synthetic biology or biotechnology in general, is not sufficient. We have asked teams whether they have interacted with policy makers about rules and laws with regard to their project and applications. Almost 70% of the teams answered no to this question. Most of the remaining responders described that they had conversations, debates and/or

gave advise to policy makers. Two of the responders were even able to get more influence in the decisions of policy makers.

iGEM teams have to educate the public about their project and synthetic biology in general, but the public can also educate or influence iGEM teams. Therefore, we have asked in the survey if to some extent the local community did have an impact on the project. Most of the teams stated that the local community did not influence the project or the influence appeared to be negligible. However, there were also multiple teams that certainly were influenced by the local community. For example, multiple teams stated that their project was about local problems or products. In those cases the local community often gave advises or helped them even with the project.

Beside the local community, teams can also collaborate with other external companies and in this way improve their project. About 40% of the teams stated in the survey that they collaborated with external parties. Multiple of those teams have worked with other iGEM teams and also a few teams mentioned that they worked together with organizations to organize policy & practice related activities, such as workshops or exhibitions. Most teams indicated they would not have been able to get certain results or do specific activities without the help of those external parties. Furthermore a few teams mentioned that they worked together with experts in a specific field to improve their project. For some of the projects this has resulted in significant changes or improvements of their project. For example, one of the team mentioned that they had a lot of data that was manually impossible to manage. An external party eventually helped them to manage the data and this helped them a lot.

The aforementioned examples show the potential benefits of collaborations. However, it also appeared that most of the teams did not collaborate with external parties. We think this is regrettable. Fortunately, iGEM headquarters agreed with us on this point and therefore collaboration between teams has become a hard requirement to win a silver medal since this year.

Finally we have asked the responders on a scale of 1 to 5, where 1 is not at all and 5 is really large, how valuable participation in the iGEM competition was for them.

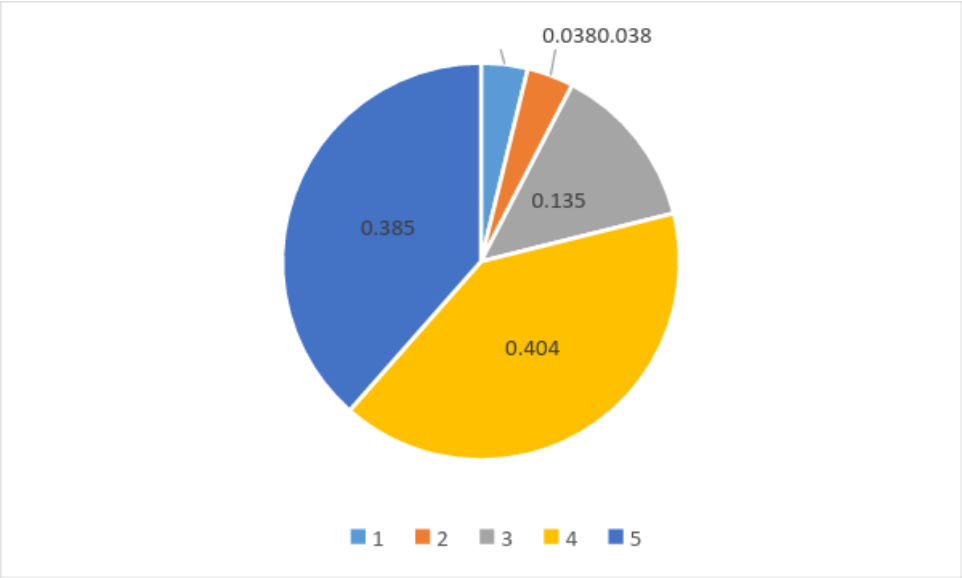

Figure 9. Answer distribution to the question: On a scale of 1 to 5, where 1 is not at all and 5 is really large, how valuable was your participation in the iGEM competition for yourself?

Based on the figure we can conclude that iGEM was very valuable for most participants. For most of the advisors iGEM helped them to improve their instructor skills, to find good students for PhD positions or iGEM helped them with their own research. For most of the students that fill out the survey, the iGEM project helped them to become better researchers and to develop skills outside the lab, such as the communication with external parties and fundraising. A few students also noticed that iGEM let them think about real life problems, develop real products and present their project in the real world. Furthermore, multiple students experienced that working in a team with students from different backgrounds was very educational. They have noticed that the methods and ways of thinking can be very different. Sometimes this can result in frictions, but in most cases it helps to improve you project. Therefore, we believe that it is wise for supervisors to make a team of students from different backgrounds. We have experienced ourselves that this actually contributes to the results of your project. In conclusion, it appears that beside the scientific importance, iGEM also contributes to the development of students and advisors.

Safety and Security

iGEM is all about the use of synthetic biology in a social responsible way and biosafety issues are an important aspect of the competition therefore. In 2011, an extensive research is done into how the iGEM teams have quantitatively and qualitatively dealt with new safety requirements in recent years(Guan, Schmidt, Pei, Wei, & Ma, 2013). They found an increase in the number of teams reporting safety aspects and a general improvement in the safety assessment of their projects. Although the student's safety awareness has improved, certain gaps must still be filled before iGEM can fully live up to its role as an educational competition.

They have noticed that at that moment the safety-relevant characteristics of the registered parts were inadequate. Therefore, one of the suggestions they have made was to start with a mandatory safety evaluation for the biological parts in the Registry, which would provide future users with substantial safety documentation. Another point of interest was the fact that safety issues go beyond single parts to encompass higher-order constructs. This includes descriptions of the context dependency of parts in devices or systems, which are completely lacking from the Registry. Therefore, in their opinion more research has to be done into the safety issues of total constructs and final products.

In subsequent years, there were no major changes in the safety and security policy of iGEM. In our opinion, iGEM could play a much more important role in the general development of safety and security of synthetic biology. To improve the safety of our project, we have talked to safety experts of the TU Delft, who are specialized in risk analysis. They told us that one of the main problems of the risk- and safety analysis about synthetic biology is the fact that there is a lack of statistical data. For example, there is much more data available about the chemical industry or about the chance of a dike burst. We think that iGEM should take the lead in the data collection about synthetic biology. There are multiple ways to do this. First of all, in our opinion it would be wise to consider the introduction of a specific track about biosafety. In that case, teams participating in this track work to create more general knowledge about the safety of synthetic biology. For example, they could do research into biosafety issues of specific constructs or into the real impact of horizontal gene transfer. Another, in our opinion, interesting possibility could be to start a project, like Interlab, about biosafety. In this way, iGEM could start a large-scale and multi-annual project to collected the required data about biosafety and could therefore play a key role in the development of synthetic biology.

We also researched how safety is respected in other areas and fields. It appears that in many areas the analysis of possible safety issues is done in a more systematic way. For example, in aerospace engineering they have protocols to analyze risks and safety of many different types of events. We would propose to introduce more systematics in the analysis of risks of synthetic biology as well. Risk matrices are probably one of the most widespread tools for risk evaluation. They are mainly used to determine the size of a risk and whether or not the risk is sufficiently controlled (Figure 10).

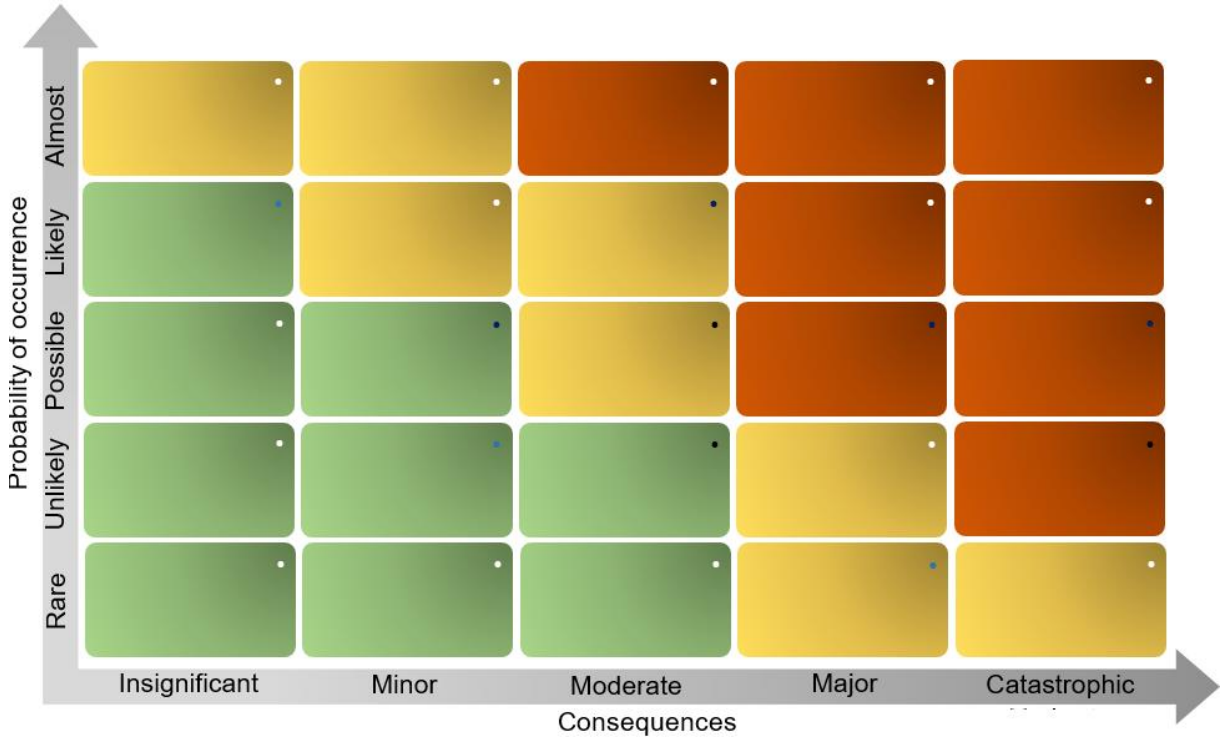

Figure 10. Risk Matrix

A risk matrix has two dimensions, respectively probability of occurrence/likelihood and impact. It looks at how large the impact is of a specific event and how likely it is that it will happen. These two dimensions create a matrix. The combination of probability and impact will give any event a place on a risk matrix.

Impact

There are multiple ways of looking at impact. In most cases the impact is judged from one of the four perspectives from the acronym PEAR: People, Environment, Assets and Reputation. Any event can be judged against these four categories. For instance: the explosion of a barrel with chemicals will firstly have a high impact on the contributors. The chemicals might have an impact on the environment and also the reputation of the organization that owns the barrel could be damaged. Furthermore, it could also have an impact on the asset of the organization.

Probability

The probability tells you how often a specific event theoretical will happen. For example, the probability of the explosion of a barrel with chemicals during the year is 0.01. This means that every 100 years a barrel will explode.

Sometimes it is difficult to determine what the probability of occurrence is. In many areas they look at the past and scores higher if the event has occurred more. However, as described before, there is not always enough data available about synthetic biology.

For the situation where there is a lack of data, expert judgment could provide an alternative. Expert judgment implies that the opinions of one expert or a group of experts is/are used to find a solution to a specific question. Their response is based on experience or knowledge or both.

One widely used technique for expert judgment is the so-called Delphi method. The technique is designed as a group communication process, which aims to achieve a convergence of opinion on a specific real-world issue. For the Delphi method a team of carefully chosen experts is required. In the first round, the experts will answer questions about the subject of interest. All the answers of the experts will be fed back anonymously. The experts have to take the opinions of the other experts into account and in this way they are encouraged to adjust their opinion. After this, a second comparable round with questions and feedback will start. Eventually this becomes an iterative process with multiple question and feedback rounds. The idea of this process is that the answers of the experts become more comparable every round and eventually the ultimate goal is to converge to one right answer(Linstone & Turoff, 1975). We would strongly recommend other iGEM teams to use this type of method to help you with analyzing the project.

As mentioned before, in our opinion the risk matrix is a very useful method to analyze risk issues of a project. Therefore, we have developed a hands-on safety application that can be used by iGEM teams to analyze the safety issues of their project. In this application aspects such as the used chemicals, types of used microorganism, etc. will be taken into account. The teams can use the tool to get in a more systematic and a visible insight into the risk issues of their project.

References

Clark, M. C., & Payne, R. L. (1997). The nature and structure of workers' trust in management. Journal of Organizational Behavior, 18(3), 205-224.

Deci, E. L., & Ryan, R. M. (1975). Intrinsic motivation. John Wiley & Sons, Inc.

Flipse, S.M., van der Sanden, M.C.A. & Osseweijer, P. Sci Eng Ethics (2013) 19: 1141. doi:10.1007/s11948-012-9411-6

Galtung, J., & Ruge, M. H. (1965). The structure of foreign news the presentation of the Congo, Cuba and Cyprus Crises in four Norwegian newspapers. Journal of peace research, 2(1), 64-90.

Guan, Z.-J., Schmidt, M., Pei, L., Wei, W., & Ma, K.-P. (2013). Biosafety considerations of synthetic biology in the international genetically engineered machine (iGEM) competition. BioScience, 63(1), 25-34.

Hootsuite blog (2016). https://blog.hootsuite.com/why-community-builders-are-choosing-slack/, why slack is exploding (as a community – Building Platform), accessed on 01/10/2016.

Community, iGEM. (2015). About. Retrieved from http://igem.org/About

iGEM HQ (2016). iGEM Facets, http://igem.org/Facets, accessed on 07/10/2016

iGEM HQ (2016). iGEM Human Practices, http://igem.org/Human_Practices, accessed on 06/10/2016

iGEM. (2014). iGEM 2014 Tracks and New Tracks. Retrieved from http://2014.igem.org/Tracks

Kulviwat, S., Bruner, I. I., Gordon, C., Kumar, A., Nasco, S. A., & Clark, T. (2007). Toward a unified theory of consumer acceptance technology. Psychology & Marketing, 24(12), 1059-1084.

Linstone, H. A., & Turoff, M. (1975). The Delphi method: Techniques and applications (Vol. 29): Addison-Wesley Reading, MA.

Lucivero, F., Swierstra, T., & Boenink, M. (2011). Assessing expectations: Towards a toolbox for an ethics of emerging technologies. NanoEthics, 5(2), 129–141.

MIT Technology Review, https://www.technologyreview.com/s/600771/10-breakthrough-technologies-2016-slack/, Slack A service built for the era of mobile phones and short text messages is changing the workplace., accessed on 01/10/2016.

Reichman, A. (2013). Randy Rettberg: Be Part of the Revolution. Retrieved from http://www.getsynbio.com/randy-rettberg-be-part-of-the-revolution/

Schoemaker, P. J. (1991). When and how to use scenario planning: a heuristic approach with illustration. Journal of forecasting, 10(6), 549-564.

PC mag (2016). http://www.pcmag.com/article2/0,2817,2477507,00.asp, Slack, accessed on 01/01/2016.

Yarborough, M. (2014). Openness in science is key to keeping public trust. Nature, 515(7527), 313-313.

Wikipedia (2016). Slack (software), https://en.wikipedia.org/wiki/Slack_(software), accessed on 01/01/2016.