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D 4.2

Title: A Community Map

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LIST OF ABREVIATIONS:

ABR	NAME
SB	Synthetic Biology
WP	Work package
EP	Exchange Program

EXECUTIVE SUMMARY

The present document describes Deliverable 4.1: *A Community Map* of the H2020 project *Fostering Synthetic Biology Standardisation Through International Collaboration* (acronym BioRoboost).

This Deliverable been generated in the context of WP4.

This text presents empirical data obtained during the BioRoboost Exchange Program; examines that data and offers conclusions based on both. The document has been structured as follows: firstly, a brief introduction of the Exchange Program (EP) is made. Secondly, results obtained from the data gathered by the participants in the EP are analysed: we study the different community characters and diversity and differences in standardisation in relation to views, purposes or attentions, among others (in total, 17 different concepts around standardisation are analysed); as well as the different ways of learning. A brief summary with conclusions of each section is provided. Finally, we provide a global conclusion based on the research.

TABLE OF CONTENTS

1. INTRODUCTION

BioRoboost's Work Package 4 was designed to explore the social foundations and mechanisms of standardisation, and to examine how members of the project consortium are arranged as a social community. The first part of Work Package 4 produced an analytic framework with which to identify and understand the social infrastructures that make standardisation possible. The second component was designed to examine social interactions and interconnections within the BioRoboost community. It intended to explore and document similarities and differences between members of the consortium, consider its diverse views and practices, and use those observations to reflect on synthetic biology standardisation. Crucially, it demonstrates the importance of social ties for the process of constructing standards.

Work Package 4 committed itself to using empirical data about the project community and its relationship to standardisation. The data was collected through the BioRoboost Exchange Programme, which brought different members of the community together for short visits and collaborative work. Those who participated in the exchanges collected qualitative data using ethnographic methods. The leaders of Work Packages 4 and 5 collected further data after the exchanges by using a questionnaire. That data underlies this text, which explores the character of BioRoboost parties and their interactions. It examines how parties can form links, explore, share and transfer ideas and practices, and establish social relationships necessary for standardisation.

The document first describes the BioRoboost Exchange Programme (EP). It presents an overview of its organisers' motivations and aims, and a detailed description of its design. It describes what participants were asked to accomplish and what methods they were asked to use. It explains the types of empirical data generated and their usefulness for the work package's goals. Second, the document employs the empirical materials to give an account of participants' experiences. Their observations provide insights into the character of the BioRoboost community and its standardisation efforts. Third, the empirical data is analysed to demonstrate the importance of social ties and community-building for standardisation efforts. It presents the participants' observations and reflections on enabling standards through social interactions. Finally, the document offers ideas on how the EP's insights into the BioRoboost community can serve the project's standardisation aims.

The BioRoboost Exchange Programme supported visits by doctoral students to research groups involved in the BioRoboost project. Groups volunteered to host visitors and students applied for a chance to participate. Over two weeks, the student participants would carry out work designed in partnership with their hosts. They were also asked to carry out ethnographic observations and to produce qualitative empirical data. After the exchanges, the students supplemented those data by answering a series of questions on how their experiences affected their work.

The EP supports Work Package 4's exploration of community networks. It involved participant observation and empirical data collection, both of which were specified in Task 4.2. The data produced offers insights into different people's views about standards and their standardisation efforts. As is demonstrated in detail below, the exchange data offers understanding of differences and similarities across the community, also specified in Task 4.2. These topics are important for characterising the project's participants. They are also crucial when evaluating the current status of standardisation and postulating strategies for advancing the cause. The EP contributes understanding of interconnections and how communities can be configured and coordinated through links and networks. The exchanges themselves constitute new ties which might serve as models or channels for the social and technical work necessary for standardisation.

2. THE BIOROBOOST EXCHANGE PROGRAM

The BioRoboost Exchange Programme was intended to serve multiple work packages (WP), including WP4 and WP5. It was designed in order to benefit many different parties in the BioRoboost consortium. And it was hoped that the EP could contribute to the principal aims of the project.

The EP was made possible by the structure of the BioRoboost project, its constitutive groups and the organisation of the consortium. BioRoboost requires interaction between different institutions. Its leaders are committed to fruitful collaborations and seek joint accomplishments. This interconnected structure made movement between research groups easier and encouraged openness to novel forms of collaboration. By relying on BioRoboost's structure, the EP also increased and diversified the interactions between project members. It strengthened the links that distinguish the project as an innovative contribution to standardisation in synthetic biology.

The EP organisers wanted to involve postgraduate students and to have them benefit from BioRoboost work. As is discussed below, the students' visits offered them a chance to gain skills that support their doctoral research. It allowed the students to develop ties with other institutions, which may support their future research. Mostly importantly, the EP enrolled the students as active contributors to the project. Their exchange work is not incidental; it forms part of multiple work packages and products.

Finally, the EP offered the organisers an opportunity to develop new methods for interdisciplinary work. By carrying out ethnographic observations during their visits, the participants practiced synthetic biology and produced social scientific data concurrently. The EP introduced and explored an experimental form of collaboration, which produced rich interdisciplinary results.

2.1 Planning

The BioRoboost EP consisted of four components: visits by student participants to different research groups; work and learning during their visits; ethnographic observations and data collection; and subsequent reflections on their experiences.

The EP organisers recruited host groups and student participants in several stages. First, principal investigators of the BioRoboost consortium were sent a call for participation. They were asked for information about their groups' research topics and for logistical information about potential dates and hosting capacities. The EP organisers selected 10 research groups as possible hosts. These were the most feasible given logistical limitations. More importantly, the EP organisers selected hosts that were doing two types of work:

- Measurement and characterisation practices and standards
- Modelling and digital data sharing standards (e.g. SBOL)

These topics contribute to BioRoboost's concern for standardisation. Moreover, limiting the EP to two topics made comparison across institutions easier. Such a comparison was necessary for exploring synthetic biology diversity and standardisation. Finally, the topics were especially relevant to WP4 and WP5, which oversaw most of the EP.

A call for participants was sent to students. They were asked to submit a curriculum vitae, a letter of interest and a ranking of up to three laboratories to visit. WP4 and WP5 Leaders reviewed the applications and selected the student participants. The visiting students then contacted their hosts and arranged their two-week visits, including plans for the work to be carried out.

2.2 Exchanges and ethnographies

Student participants were tasked with carrying out ethnographic observations during their visits. Ethnography, also called participant observation, is a common method in social scientific research. It involves carrying out detailed observations of a social group while existing as part of it. At the same time, researchers reflect and analyse their observations in order to develop an understanding of the group.

Before their visits, student participants were given guides on what ethnography involves and instructions on the basic methods for carrying out observations, taking notes and compiling a collection of data. The guidance documents were developed by WP4 and WP5 Leaders.

The students were given four observation forms. The first two were structured with specific questions and instructions. These were intended to help the students develop basic observation skills. For instance, they asked the students to provide detailed descriptions of their host institutions, including of physical spaces, routine practices and the makeup of the community. They asked the student to document the process of developing a detailed work plan for the visit. The students were also urged to compare their views on synthetic biology and standardisation with those of their hosts. The third form consisted of an unstructured diary. This was intended to serve as the students' principal document for data collection. They were offered basic guidance on the kinds of things to observe and how to record their observations, but the students were responsible for choosing what to focus on and how to describe it. The final form, to be completed at the end of the visit, asked students to reflect on the experience and to consider how the visit could influence their future work. Seven to nine months after their visits, the students were sent a set of questions and asked to reflect on if and how the exchange has affected their work and their thoughts on standardisation.

The EP's diversity of places, people, work, resources and conditions resulted in diverse data. That diversity ensured an expansive overview of the groups and people involved in the EP. It provided useful differences in how the students examined similar aspects of the host groups, such as different groups' use of automation and their different perspectives on the value of standards. Observations of similarities were equally important. These provided insights into what is currently shared, why and how. Standards of course are intended to be shared across the community. Differences and similarities observed are very useful for WP4, which is concerned in part with the character of the BioRoboost community. The students sent their ethnographic observations to the WP4 and WP5 Leaders. These examined the data and produced analyses of the results. Analytic methods included detailed reviews of the student texts and qualitative data coding, whereby common themes, ideas and experiences were identified and collated. Sections II ('Community Characters'), III ('Community Diversity'), IV ('Standardisation') and V ('Learning and Communities') below present and empirical material gathered by the students and an analysis developed by BioRoboost social scientists.

2.3 The Exchange Programme and Work Package 4

The EP has formed an important part of WP4. As a part of Task 4.2, it created the empirical data needed to explore the community's character and its members' interactions. It constituted an innovative way to explore interconnectedness (namely, by creating interconnections and asking those involved to reflect on their experiences).

The EP data was collected from a representative sample of BioRoboost institutions. The institutions are all members of the BioRoboost team. The types of work reflect interests of the different WPs. The tools and materials used are both common to synthetic biology and distinct of the host institutions, thus providing insights into similarities and differences.

The EP offered opportunities to consider how the community relates to standardisation. Participants' experiences included querying their host's views on synthetic biology standards. Participants were also encouraged to reflect of their own perspectives. The follow-up questionnaires demonstrated that participants' visits affected their research aims and practices. That is, the EP influenced not just their ideas, but also the work that they do and that they intend to do. This created an opportunity for WP4 to contribute directly to the BioRoboost project's standardisation practices.

The EP allowed WP4 to examine how different ideas and practices can be learned, transferred and used. It served as an exercise to understand the kinds of relationship that are necessary to create group coordination and order, crucial mechanisms for standardisation. It also revealed challenges that might be keeping standardisation from succeeding in the field. These insights expanded upon those developed during the first part of WP4 and discussed in the first text produced.

Finally, the EP contributed to the links between WP4 and WP5. Developing a tie between the two is an important WP4 task. WP4 and WP5 collaborated by designing the programme together, by producing the guidance documents together and by sharing the empirical results. This text also contributes to WP5 by presenting findings and arguments that may serve WP5 tasks and deliverables.

3. COMMUNITY CHARACTERS

3.1 Introduction

This section lays the foundations for subsequent discussions about community diversity, interactions and standardisation. It introduces the first series of results of the BioRoboost EP. Finally, by offering the reader a description of who was involved and what they look like, this section begins the process of describing the standardisation community. Standardisation requires communities of interrelated parties; each of those parties is particular. What relationships bind the parties together, create a community and so enable standards, will reflect the parties involved.

The EP introduced participants to different communities; they met other people and learned about their particularities. Doing so supported the project's aim of drawing people together around a shared goal. It also made possible the first part of WP4's second component: understanding the makeup of the BioRoboost community.

Ethnographies require detailed accounts of the parties involved in the study, and an understanding of their particular qualities. Such an understanding makes possible subsequent work on specific topics, such as standardisation. Put simply, to understand what she is exploring, an ethnographer must first develop an account of what it looks like. **The first task given to the EP participants was to produce a description of their host group, including such aspects as people, spaces, materials, routines and practices**. As noted earlier, this helped the participants learn the basics of ethnography. It also produced vital data on the community under study.

3.2 People and projects

Standards are developed and shared by multiple parties, such as those that constitute the BioRoboost consortium. As explained in "A Conceptual Analysis of Standards," standardisation involves community coordination. For instance, parties will employ a shared set of parts, or measure phenomena using the same protocols and units, or transfer information using the same methods and formats. As a result, understanding standardisation requires understanding the parties involved and how they are arranged.

3.2.1 People

EP participants did not only visit and work in another institution. The programme required them to develop relationships with their hosts in order to facilitate the exchange work. Learning about the host group's members helped the visitor find ways to 'sit inside' the group and identify opportunities to create fruitful relations.

The students' descriptions of their hosts portray different assemblies of individuals: groupings of people with distinct backgrounds, interests, expertise and skills. These are the people who will make and use standards. Their character influenced the visitors' experiences and will influence the process of standardisation and the form that standards take once completed.

The students first noted the composition of each community, focusing closely on what kinds of practitioners make up the teams. Michael[1] identified "1 postdoc, 6 PhD students, and a lab-technician," as well as occasional undergraduates. Sarah's hosts were similar. With "4 post-docs, 6-7 PhD students, a technician, an engineer, a secretary [and] the professor," Daniel's host group was larger but still fundamentally the same. However, Rose visited a community formed primarily by "ten postdocs and almost twenty PhD students." Each participant noted that the size and constitution of the groups shaped their experiences, and if and how they were able to form meaningful relationships.

Other participants focused on their hosts' backgrounds when describing the group that they visited. For instance, Emily found it insightful that their "study background varies, with engineering, computer science and computational biology being among them." That makeup helped Emily understand how her host community operated and what kinds of relationships were possible due to the range of expertise found. Isabel described some of her hosts' previous experiences in research institutions and infrastructure organisations in order to explain what relationships the laboratory has with other synthetic biology groups. Her hosts draw on ties with foundries and automation experts, and their approach to standards reflects those relationships.

The participants also described their host groups by referring to social properties, such as nationality. Of the five participants who discussed nationalities, all but one described communities either completely or almost entirely constituted by local nationalities. The fifth participant described a group that included people with five different nationalities, and in which those with a local nationality were a minority. This aspect of the communities affected the visitors in multiple ways, including how easily they could become integrated. For some, language barriers meant that they had difficulty understanding routine work and were instead limited to isolated interactions, thus placing restrictions on the kinds of relationships that could be formed.

In accordance with BioRoboost goals, attention was given to gender. In particular, the students observed gender distributions in their host institutions. All but one of the participants noted disparities. Emily described a group in which "the gender balance remains heavily on the men's side." Daniel and Isabel observed teams that "consist of mainly males," and in which "most of the members… are male," respectively. However, Michael visited a lab whose members are "mainly women." Lucy similarly described a community with a "80/20 balance in female/male."

3.2.2 Projects

The participants also described their host communities by documenting members' work. Unsurprisingly, the visitors found this especially interesting and relevant to standardisation in synthetic biology. The EP was designed to expose participants to others' work, and so close attention to their hosts' projects was necessary. The kinds of work undertaken by the groups affected how much attention each dedicated to standards and how they engage with standardisation efforts. Finally, the types of

[1] In order to ensure anonymity and confidentiality, each participant has been given a pseudonym

projects create opportunities for establishing relationships and enabling coordination, both of which are necessary for successful standards.

Michael described his hosts as people bound by a shared topic. Specifically, the group carried out multiple projects on “the optimisation of two main [pathways] via different synthetic biology tools which they develop.” Once established, those tools could be employed to other pathways. Rose also described a community focused on optimisation of pathways, such as “improvement of the natural photosynthesis through protein engineering.” Its members also pursue “the design and testing of new [pathways],” intended to operate more effectively than their natural counterparts. In these two examples, project goals served to bind the community together.

In other cases, projects drew communities together through methods and disciplinary principles. Emily described a group with a shared belief that “graduates from here should be able to work both in the wet lab as well as the dry lab.” As a result, all doctoral student at the lab “though in different proportions, work in the lab and at the computer.” Group members pursued different topics—“biological, engineering or computational focus on yeast or mammalian synthetic biology”—but all were expected to carry out “at least a small part of all aspects.” Rose noted something similar. Though she focused on her hosts’ work on optimising pathways, she also described their concern for modelling and computer design, which were “an important task for most of them.”

Michael, Rose and Emily documented shared kinds of work and emphasised their importance in defining the community and holding its members together. For some, ties were created by working on the same topics. For others, ties followed shared principles about what a successful practitioner should be able to do. The qualities define the communities under examination. They also identify ways in which people coordinate their work and share practices, both of which are mechanisms for standardisation.

3.3 Spaces and objects

A community exists in spaces, which can include physical spaces. It arranges those spaces according to its needs. Members carry out their work within specific material structures. Different scientific spaces can look very similar, and often feature the same material components, but each space is as specific as the community that exists within it. As such, space is a crucial element when describing a community. The EP participants wrote a great deal about material spaces and their physical experiences because becoming situated in a community requires learning how to exist and practice in its spaces.

3.3.1 Layouts and distributions

Participants described in detail the layout of their host institutions. Physical layout is not simply the starting point for observing and documenting space. It also offers an easy way to examine those groups’ character. How they structure and navigate their rooms and those rooms’ objects reflect how each community thinks it should be arranged, how it wants its people to interact with each other, what it wants to place prominently and what it considers to be less important. All of these choices affect how a group can be coordinated to enable and support specific aims, such as standardisation.

Most of the observations discussed how group members were distributed in different spaces, or in different parts of a shared space. The participants reflected on how distance and proximity shaped the experience of working with the group. Michael began his description by noting that the spaces at his host institution are “highly distributed,” as offices, laboratories and rooms for special equipment are located far from each other. He did not expect such an arrangement. Other made similar observations and described how people and their spaces were sorted in specific ways. Daniel described an institution in which “there is one office for PhD students, one for postdocs, one for the engineer/lab automation post-doc, one for the secretary and one for the professor.” The spaces were tied together by a corridor, but different kinds of members were placed in different spaces. Emily’s hosts were also arranged by their roles, with PhD students sharing one large space, while “three PIs have small offices next to each other, adjacent to that are two offices of the postdocs,” which surround the students’ area. Office spaces and laboratories exist in different buildings, creating a large physical separation between two kinds of work. Unlike these three, Sarah visited a group which carries out most of its work in a single room. She describes a space in which “desks are placed on one side of the room and the rest of the lab is on the other side, there is no physical separation of lab and office space.” She observed that such proximity eased interactions between people and between different kinds of work.

Isabel visited a similar open workspace. Although faculty sit in separate offices, doctoral students and postdoctoral researchers work in a space with “100 desks that have small walls to improve focus and increase privacy.” Isabel expected that “such a big working place would quickly become a major distraction,” but she observed that “since the building is well designed,” the environment is less distracting that other, less open spaces. The space reflects and serves a community that wants proximity and easy access to others without sacrificing focus. Other participants also described the practical effects of physical layouts. Like Sarah, Lucy visited a space with “office and lab blended at the same place.” She noted that such a space makes it possible to “see what is going on” with others’ work. It becomes “easier to ask a question about what one is doing in contrast to having the office at another place making you lose touch with the lab.” In both cases, the groups’ physical arrangement has an effect on its members’ interactions and how each person relates to others’ research. Easing access and interactions can support the types of relationships necessary for standardised practice.

Rose described a very different structuring of space. Her hosts’ laboratories were relatively small and spread across two wings in the building. She counted a total of six, along with four spaces with materials and tools for common procedures. Accordingly, “the groups are distributed in many different rooms.” As a result, she argued, “it is not easy to have an overview of what is going on in all of them.” Michael also described a layout which routine procedures are carried out in one room while visualisation, robotics and analytic work each have their own space. Last, Daniel noted that his hosts designated “different rooms for different kinds of work.” These participants reflected that such fragmented layouts create hurdles for the kind of awareness and practical unity that others observed during their exchanges.

3.3.2 Objects

The physical character of a community includes the objects and materials used by its members. Things like instruments and chemical substances are necessary for synthetic biology work. All of them contribute to the distinct character of each group. As such, understanding the communities that constitute the BioRoboost consortium requires understanding their materials. Moreover, standardisation efforts often focus on material objects, such as genetic components, chemical substances and experimental instruments. Their presence and use can serve as mechanisms for coordinating uniform practice.

Unsurprisingly, the participants referred to their hosts' material objects when describing the groups. Their work during the exchanges involved awareness and use of some of those objects. Exposure to new objects and materials was a motivation for some of the participants. For example, multiple students wanted to experience and learn about automation platforms not available in their home institutions.

Participants' observations consistently began by noting equipment commonly found in biological laboratories. Rose noted the presence of instruments like "plate lectors, incubators [and] microfluidics devices," and basic equipment like "pipettes, tubes, Petri dishes, flasks, bottles [and] gloves." Lucy also described a collection of "incubators, PCR, centrifuges, analytical balances, fridges, electrophorese instruments and horizontal and vertical laminar flow." Finally, Isabel identified "benchtop centrifuges, pipettes, hot water baths, spectrophotometers, plate readers [and] gel electrophoresis devices." The three participants described objects ostensibly common to them, but which they discovered to differ due to local conditions. Examining such objects helped the students reflect on how differences are found even in the most mundane parts of work. Those differences pose difficulties for drawing different groups together, but can also serve as starting points for standardisation, as discussed below.

Some students chose their exchange locations due to special equipment available there. Three participants dedicated their visits to learning how to operate automation platforms. They were primarily interested in learning how automation could affect routine workflows and how their home institutions might benefit from such equipment. Daniel described a "lab automation platform with an integrated Nikon microscope," used by some of his hosts to automate measurements of fluorescence. Isabel learned use to a "pipetting robot for performing BASIC assembly." In both cases, the participants designed programmes to carry out tasks common in their research.

Michael described a laboratory with two existing robots and with plans to purchase a third to "help in colony picking and fluorescence measurements." In additional to their roles in research, those robots formed a defining part of the group's approach to standardisation, as is discussed below. They also influenced the makeup of the community. The laboratory managers explained their ongoing discussions about "who will be in charge of controlling and programming the robot." Because many members of the community intend to use the platforms, the managers chose one person to oversee the instrument, "in order to improve the usability and the robustness." This is an example of how equipment shapes the community that puts it to use, and how it is employed is accordance with specific arrangements of group members. That is, it is an example of how a community's objects shape its character.

3.4 Behaviors

Understanding the character of communities requires understanding their people, places and objects. It also requires an understanding of what members of a community do: their behavior. Practices reveal as much about a community's character as do those who carry out the practices. And while they include research practices, a community's behaviors also include mundane activities. Participants were asked to observe and record quotidian behavior because it is vital to understanding how a community exists and operates. Common, taken-for-granted activities bind groups like laboratory teams together. Unlike specific research practices, mundane behaviors are shared by all. As a result, they give an effective picture of 'life inside' the community.

3.4.1 Routines

The participants described regular behaviors by producing accounts of 'regular days.' Many first focused on how people divided their time between different kinds of work. Michael described older doctoral students and postdoctoral researchers as spending most of their time carrying out 'desk work' such as data analysis, while "the younger students seem to be just reading papers and setting up their experiments for the next year." Isabel presented a similar account. During her visit, most doctoral students were "writing reports, publications or their PhD thesis." In both cases, regular days involved little experimental work. Sarah described her hosts' regular activities as consisting of "emails, research data analysis etc. at their computers." However, she also described a few group members who "spend a sporadic time doing lab work depending on the stage of experiments they are at." The only person who spent most of a regular day doing lab work was the group's lab manager.

Others described days characterised by mixed practice. Lucy described a community that spent most of its time in a "mix of bench work, analysing results and writing progress reports." The group also included a pair of bioinformaticians, whose regular workday proceeded "more on the computer than in the lab." Emily visited a group that features people who spent their days evenly between desk and lab, others who mostly "[worked] on reports, papers or posters," and one person who worked "mainly on computational models/Python analysis."

The participants added to these descriptions overviews of routine daily scheduling. All noted similar workday lengths (approximately 9:00 – 17:00), though they also all noted that actual workday lengths varied considerably, often extending far past the official close of the day. The participants paid close attention to breaks in people's behavior, such as coffee breaks and meals. In general, the students noted disparities in how members of different communities arranged their time. Emily was surprised when she observed that most people took no breaks and most had their lunches at their desks. Michael also noted an absence of occasional breaks during his visit. Other communities structured their workday to include regular breaks. For instance, Lucy described coffee early in the morning, followed by a mid-morning breakfast and an early afternoon lunch. The students noted that these mundane, seemingly insignificant events had effects on how the community was drawn together and how its members related to each other, including how they interacted regarding their work.

Finally, the visiting students learned about regular events that constituted important parts of their host group's working. Michael explained that his hosts employed scheduled tasks and responsibilities, which rotated regularly. Each week, one person in the lab was "responsible for cleaning the dishes." Another was in charge of "preparing the most used media." These tasks structured how the group operated. Most of the participants noted regular group meetings and described their similarity to those they attend in their home institutions. Rose described a regular event that she found compelling. Her hosts held a weekly "Journal Club session," separate from regular laboratory meetings, at which routine laboratory matters were discussed and one person "gives a short talk about their work, progress or an interesting research paper." Rose noted the importance of this session because it provided a chance to discuss "organization issues, possible arguments and things that happen along the week," and so served as a mechanism for sustaining and repairing those things that bind the members into a community.

3.4.2 Interactions

Groups of people are defined in part by meaningful interactions between individuals: how members relate to each other and what they do together. The EP participants observed many different interactions; even the most basic of them at times stood out. For instance, Emily was surprised to note that his hosts "do not seem to usually greet each other to say good morning or goodbye." Her energetic greetings each day tended to be "answered with a tired and slightly confused smile." As she later saw, their interactions were more complicated (and less misanthropic). Ultimately, even these mundane relations shaped the community, its work and what it accomplished together. The students dedicated a lot of their attention to interactions during work. That is, they paid close attention to how their hosts engage with each other throughout a normal day at the office or the lab. Michael described a community in which practitioners "work very independently." Members of the group did not "interact for work-related issues," since each person appeared to have "their own plans and experiments." Interactions, Michael said, seemed unneeded and so did not occur. Occasional group interactions revolved around specific tasks, such as "discussing about a paper that someone in the group read." Michael viewed those interactions as exercises in binding the group through "work done by a person" that can serve the others.

Emily described a similar community, in which members "seem to work quietly and very focused." She found that she could "barely hear conversations during the day." Short exchanges occurred sporadically, always at people's desks and generally concerning "research-related issues or questions." Isabel observed the same kinds of interactions. Her hosts concentrated on their individual work; interactions were brief and focused on specific research topics.

Rose described a very different community. Although its members also worked independently, she observed "a good collaborative environment," in which people were routinely "asking each other and sharing the results." Lucy noted similar kinds of interactions. In her host laboratory, people consistently interacted and talked. She believed that this produced a "a nice working atmosphere although without disturbing each other." Finally, Sarah described a community in which "meetings occur regularly," including ones that were "spontaneous/on a basis of necessity."

Each group's members engaged with each other distinctly. Those relationships provide useful insights into the community's character. Crucially, they describe the types of interactions (or lack of interactions) necessary for (or that can undermine) standardisation. Standardisation requires coordination of community members. Regular interactions can serve as mechanisms to ensure uniform practice and consensus about standards.

3.4.3 Socialisation

Group behaviours and interactions include different forms of socialising, which serve to create and sustain a unified community. Interaction outside of work may seem to be little relevant to standardisation, but they form an important part of the process. Standardisation is fundamentally an arrangement of people tied together by shared ideas, objects and practices. Many ties, including socialising, help bind together those whose shared efforts make standards possible.

Socialising was also a necessary part of the EP participants' visits. Students sought to engage meaningfully with their hosts. Learning how people in the community relate to each other gave the participants insights into how to develop useful relations. Participating in socialisation was one way to foster those kinds of relationships. Observing and describing socialisation also offered insights into some of the things that make those unified community possible.

The students first noted social activities that occurred throughout regular workdays. All of the participants observed routine behaviour that created chances for group members to develop personal relations. The participants focused on activities with which they were familiar and which they could identify easily, such as occasional coffee breaks. Rose noted that her hosts made regular, though unscheduled, visits to the kitchen. She described short coffee breaks as "very common along the day." People did not take such breaks as a group. Individuals went to the kitchen "whenever they want," and "most of the time [found] someone there." Sarah's hosts had scheduled coffee break every morning, "largely taken together." Unlike these two, Emily described a community in which "there are not informal meetings in form of coffee." Isabel also visited a community that did not take group coffee breaks. Instead, members "drink their coffee at their desk while working." Coffee break may not seem important or substantial, but quotidian engagements form an important part of a community's character.

The same is true for shared meals. Rose described a community that took their lunch break together. Daniel observed "almost the entire group" stop their work and "go to lunch together in the cafeteria," talking about many different topics along the way. He noted that "the groups are formed randomly depending on the order in which people depart," and so the group did not fragment into regular clusters. Instead, members interacted with all others. Every Friday, Sarah's hosts had an extended meal early in the afternoon. They were joined by "other research groups there from companies and the university," and used the meal as a "good opportunity to mix." In these three cases, sharing meals served building the community in different ways. Lucy found that shared meals gave her a chance to create ties to her hosts. Conversations about "different sorts of paella" and about "difference in prices of beer and food" between their two countries allowed her to understand her hosts in ways other than their work. These conversations made it easier for her to find a place among her hosts and create relations that might serve future collaborations.

Other participants observed very different customs. Emily described a general "lack of common breaks," which she found to be "extraordinarily solitary even for a British workgroup." Isabel, who also visited a British laboratory, found that her hosts "mostly choose their own lunch time, provide their own food and eat either at their desk or outside the office." These group did not use routine activities for socialising and for building group relationships. The communities operated differently and featured different forms of regular interaction.

Finally, some the EP students described socialising that occurred outside of work times and spaces. For instance, Lucy noted plans to "have dinner today and then to the cinema." Emily, whose observations about regular interactions suggested a community with little interpersonal engagement, described a group that routinely visited the pub. After one outing, she wrote that the experience involved talking about "many different topics (including Brexit, of course)," as well as the city as a place to live and the university as a place to study. On a different evening, the group shared drinks to "celebrate the submission of a postdoc grant application." Again, those who attended participated in "lots of interesting talks (yes, again about Brexit as well)."

3.4.4 Behaviours and unity

The EP participants dedicated attention to routines, interactions and socialising because they formed an important part of their experience and helped them describe the community they visited. The students viewed interactions and socialising as crucial for building strong communities and creating group unity. Lucy argued that social events like group dinners "are important to get to know each other and create a good contact between everyone." Sarah observed that because members of the community had regular work and social interactions, "they all seem to get along well and work very cohesively and collaboratively." The other participants made similar observations or noted the opposite consequences when regular interactions and socialising are rare. Like people, projects, spaces, objects and practices, interactions and socialising define communities and serve as fundamental mechanisms for tying people together. Just like spaces physically bind people together and objects bring them into coordinated efforts, mundane engagements create and sustain social ties. Those ties are mechanisms for standardisation.

In summary

Section II has begun the process of exploring and describing the BioRoboost community. It has introduced the EP experience and the types of observations made by EP participants. And it introduced persons who form part the BioRoboost project. Social communities are composed of parties. In the case of BioRoboost and the EP, key parties are the research groups and the individuals who operate within them. Understanding the makeup of the community and making sense of its configurations begins by identifying and describing those parties. Getting a picture of who is part of the community—in this case, a project network—lays the foundation for understanding how such a community can develop and support standards.

4. COMMUNITY DIVERSITY

The BioRoboost Exchange Programme was meant to harness the consortium's diversity. Students participated in order to experience different types of research, to gain access to different kinds of equipment and to learn skills otherwise unavailable. Without such diversity, visiting another group would have less appeal and would deliver fewer benefits.

The previous section offered portraits of different groups based on the material produced by the student participants. This section compares different groups, focusing on important differences and similarities that characterise the diversity of the BioRoboost community. Such differences and similarities are crucial to the standardisation project and to producing a social scientific perspective on what is otherwise cast as strictly 'technical.'

Finally, examining similarities and differences is a basic form of ethnographic data analysis. Participants were asked to move past documenting their experiences and to begin reflecting on their accounts. The students developed skills for understanding links between groups and what standardisation involves beyond technical conformity. The participants gained awareness of how social diversity, which is found in all types of human practice, influences people's relationships and what those relationships produce.

4.1 Differences

Because they affect how members of a community relate to each other and how they can coordinate themselves, differences between members affect standardisation. It may be necessary to tamper or remove differences in order to make a community uniform. However, differences may also provide groups with new options and possibilities for designing and creating standards.

Understanding differences may help members of a community bind themselves together. To compare different forms of work and make sense of differences requires interacting with others. Groups need channels for transferring knowledge and know-how (like those used in the EP). They require methods for comparing and analysing differences, and for developing consensuses. Such interactions establish social ties and make it easier for people to coordinate themselves.

4.1.1 Differences in aims

Different groups set out to accomplish different things. Differences in aims have noticeable and important effects on how groups carry out their work. Different goals require different planning, practices, materials and tools. As a result, diverse aims can result in other forms of diversity, all relevant to standardisation.

Michael described what he considered fundamental differences between his home and host laboratories. The former "focuses on the first step of the synthetic biology chain," and so surveys and characterises natural entities and their properties. His hosts dedicate their efforts to "designing and implementing new synthetic biology tools." Michael argued that while both groups contribute to synthetic biology workflows, they do so at different steps of the process. Rose noted comparable differences. She surveys and characterises “environmental bacteria and their natural properties.” Her host group pursued different aims, and so did not produce data on the “ecology of bacterial communities from extreme and harsh environments” or carry out “functional analysis of the metagenomic data.” What she considered routine practice and results were unusual or irrelevant to her hosts. Finally, Emily observed that her home and host laboratories “only share very common growth/medium or cloning protocols.” She attributed these limited and superficial similarities to that fact that their “specific subjects differ within synthetic biology.” The three participants referred to these kinds of differences in order to explain broader differences in practices, resources and group organisation.

Students also compared disciplinary aims. They documented and discussed differences in their home and host groups’ commitments to building synthetic biology and to establishing standardisation. Sarah wrote that “[the] majority of the host’s work is microbiology and mine is molecular biology, synthetic biology and protein biochemistry.” One result, she claimed, is that her hosts were still “coming up with standard protocols and [standard operating procedures] and safety forms,” while in her home group, “[we] have these already in place.” Sarah believed that because her hosts were not pursuing synthetic biology as much as her group does, their routine practices and materials differed. Lucy also noted that “synthetic biology or even molecular biology is certainly not the general aim of [her host] lab.” Though the group’s members have a general understanding of the field, they are not committed to its advancement. Lucy went on to write that because “[synthetic biology] practices are not the main goal,” the group’s standardisation is “not completely up to date or fine with me.”

Other participants made observations about different commitments to standardisation. Isabel described her host PI as someone committed both to disciplinary and standardisation aims. Her host pursued standardised cloning methods, but also “put effort in the development of standards for calibration of OD600 and green fluorescence measurements.” These types of standardisation were meant to support synthetic biology as it developed, though they are “not yet implemented in general lab practice.” Isabel acknowledged similar views on standardisation between home and host groups. However, she described many differences in “developing and implementing standards in generally used lab protocols.” Unlike her hosts, Isabel’s group does not have “such a standardised cloning system and parts registry yet.” The lack of automated cloning and a parts collection is a “major difference.” Those resources “[allow] the assembly of vectors in a very standardised manner,” and made her hosts’ standardisation efforts more advanced than those of her home laboratory. The example demonstrates how differences in aims can result in material differences.

4.1.2 Differences in routines

Differences in practice give a complementary perspective on community diversity. Unlike differences in aims, differences in what people do are tangible, rather than abstract. Moreover, practices are fundamental targets of standardisation. Making routine processes uniform, for instance, is an effective way to coordinate members of a community. Finally, comparing how different groups carry out 'the same thing,' such as fluorescence measurement, was a defining goal of the EP. The perceived potential of those comparisons was one of the initial motivations for creating the programme. What participants learned about how "small differences in each lab even for protocols with the same ingredients and desired outcomes" (Emily) helped them reflect critically on the consequences of diversity and standardisation.

Many comparisons drew on the participants' observations of routine practices, such as regular hours and everyday scheduling. Michael noted that his hosts begin work one hour later than he does in his home laboratory. His hosts have fewer breaks, but they are not subject to specific times. He believes that "we have more strict timetables," which establish a standard framework for practice. Michael visited Lucy's lab; she visited his. She also compared timetables, and also noted differences in the number and length of breaks. She argued that strict scheduling ensured that "work in between [breaks] will be more efficient." The lack of strict break times in her home lab means that work sessions are sometimes "extremely long" and not as productive. Rose, who also comes from a group with strict standard scheduling, noted the flexible hours in her host lab. However, unlike Michael and Lucy, she argued that self-managed, idiosyncratic hours produce more efficient work: "I found somehow this flexibility better than a strict schedule." That is, she observed the same things as Michael and Lucy, but came to different conclusions about the benefits of standardising timetables. Finally, she commented that though she found "flexibility better than a strict schedule," she was unsure if "it will work in [her home country] as I think that we are not used to that." Different cultures and customs influence—maybe limit—the possibility of standardisation.

The students also compared interpersonal relationships, which they had documented when describing their host groups. Isabel referred to workplace "atmosphere between co-workers." In her home lab, community members lunch and have breaks together; her hosts do not coordinate their days in the same way. As a result, she felt "somewhat isolated in the beginning since I did not get the time to properly meet the different members." She believed that this lack of unity makes it difficult to form close personal ties that can contribute to close work ties. Michael similarly noted that in his home group, members "have a more collaborative attitude." He attributed this to the fact that he works at a company. Its aims are more important than individuals' interests. At a university, he argued, individual projects take precedence and "interactions between the members of the group are limited." His hosts carried out "team building things at the office hours" in order to encourage closer relations. He observed that a lack of ties needed for coordinated behaviour led to group to actively create those ties. Michael also noted that those efforts offer a chance to implement relationships needed for successful standardisation.

4.1.3 Differences in practice

Some EP participants planned work that involved observing and learning about different ways to carry out 'the same' practices. Lucy described her principal aim as "[gaining] more insight into why we do certain standard procedures different from another institution," and hoped to identify any "fundamental reason for certain differences." Those comparisons help reveal the diversity of the BioRoboost community by demonstrating important differences. They can also help evaluate the possibility of transferring and coordinating practices in the service of standardisation.

The students documented many differences in commonplace practices, especially those that they normally took for granted. Sarah described making LB agar, a routine practice, and noted that her hosts "use separate ingredients which I have not done in a few years"; they also "use peptone in place [of] tryptone." She also observed that her hosts "measure the agar separately and add it to the broth and don't mix before autoclave." None of these differences seemed very important. However, the next day she learned to "make LB media with different pH values." She was surprised, because "I had always been told that if you are going to the effort of adjusting the pH of LB media then you are using the wrong media!" What her hosts considered normal and correct she had always viewed as flawed. The comparison challenged some of the assumptions that underlie her work.

Others described differences and reflected on the feasibility of adopting their hosts' routine methods (and so testing a simple form of standardisation). Michael noted that in his host lab, "the media are often prepared by the same person." What he considers a routine practice carried out by each person for her own experiments was structured very differently. While his hosts' standardisation "reduces variability in media preparation," he did not think it was possible to adapt it in his home institution. A large laboratory like his would have "a high number of workers asking the lab manager to do different media."

Small methodological differences occupied a great deal of the participants' attention. Michael noticed that his hosts used stickers, rather than lids, to cover their plates during experiments. During a subsequent conversation, Michael and members of the lab discussed differences between forms of covering plates. Some argued that lids are "easier and faster to use," but others argued against such a change in methodology. One of the hosts "decided to perform an experiment comparing the fluorescence of four different proteins using a lid or a sticker." The results suggested that "the lid works quite better in terms of fluorescence measure: it results in a higher signal." Michael and his hosts discussed the benefits and challenges of altering such routine practices. They recognised the technical benefits, but also noted the social difficulties of reorganising group routines.

Daniel mentioned differences in regular measurement techniques. Unlike his home practice, his hosts "tend to use bioluminescence (Lux-operon) as a measure for transcription in their growth experiments instead of fluorescence." When he asked about their choice, he was told that bioluminescence "[eliminates] the effect of background autofluorescence." More probing revealed that "a partner group switched to bioluminescence and in turn so did they." Daniel believed that "this means they think a lot about the standardisation, especially to generate comparable data." Reflecting on differences gave him insight into how different groups relate to each other, and how those relationships affect experimental practices and results. A methodological choice can be the result of a social aim (in this case, closer ties and coordination with a partner lab).

Lucy also focused on basic methodology by describing and reflecting upon cleaning and inoculation techniques. These routine practices are vital for successful experiments. She discussed different approaches to cleaning and disposing of used equipment. For instance, she observed that "MTPs are also reused after cleaning them with some bleach and autoclaving, we just throw them away." Her hosts do not have a "120°C oven for prevention of phage formation," as her home institution does. She was sceptical about the difference and her hosts' method because initial experimental results were not very successful. This case offered an example of the types of doubt and resistance that can result when comparing diverse techniques.

Others found promising practices when comparing their hosts' routines to those used in their home institutions. These included practices other than those used during laboratory experiments. Michael referred to his hosts' methods for engaging with recent scholarship. Individuals were tasked with examining publications and data and then presenting those to the rest of the group. As a result, the information is "shared with the rest of the people in the lab, which is efficient." Michael described the routine as "such a good practice," and reflected that it could be "interesting to implement this routine in [his home institution]." In this case, comparing and reflecting on differences offers a chance for learning and transferring practices between groups (one aim of the EP).

4.1.4 Differences in objects

Standardisation is often discussed with reference to objects. For instance, practitioners refer to standard genetic parts. Others discuss uniform configurations of instruments and common producers of materials. In all of these cases, practitioners refer to the things employed when carrying out practices like those discussed above.

EP participants paid close attention to their hosts' practices, but they also documented their hosts' objects and materials. Those resources were inevitably part of the practices observed and carried out. For instance, measuring fluorescence requires objects like plates, lenses and light sensors. Other experiments produced material entities, such as standard parts. As such, EP participants dedicated attention to the physical things present in their host institutions.

Differences in materials offer insights into the physical diversity of the community. Just as their help characterise each group, they provide a chance to compare how those groups relate to each other and how they can be tied together and coordinated. For instance, Rose observed that while she "did not [find] any striking difference" in wet-lab protocols, she found an "obvious huge difference in equipment." Looking at objects revealed both similarities and differences and how they related to each other.

Reflecting on materials is an alternate way to think about opportunities and limits of standardisation. It also offers a chance to consider the politics of standardisation. As some of the participants noted, assumptions about what constitutes a 'normal' inventory of supplies and tools will affect who is able to participate in standardisation efforts.

Daniel paid close attention to differences in instrumental systems. He documented how different groups construct their own systems or rely on commercial resources. For instance, his hosts carried out agarose gel electrophoresis using “a specialised setup that has been developed in one of the universities in which [the PI’s group] was stationed earlier.” The system had been “manufactured in the workshop of this university,” and served the group’s research well. Specifically, it allowed the group to “use less agarose gel, do faster runs and stain the DNA a lot faster.” At his home institution, researchers use a commercial system. He made a similar observation regarding tools for colony picking. While his hosts created a system by drawing together different component parts, at his home institution they use “a colony picking machine which is especially made for this.” That is, they purchased an instrument while his hosts fabricated a setup unique to their research. He reflected that such differences are a result of each group’s aims and their research needs. His hosts’ work focuses on designing and testing automation technologies. Idiosyncrasy was inevitable (perhaps even necessary). In his home lab, instruments are tools, rather than products. Commercial equipment serves their work.

EP participants described differences in physical layouts. Lucy and Isabel, both from the same home institution, compared setups and layout with their different hosts. Those comparisons gave each a different perspective on their home institution. Lucy wrote that because “there are less people working in [her host lab], the space is much more structured than [her home lab].” All elements have a “very defined place and hygiene standards are much higher.” Isabel, from the same group as Lucy, wrote that her home lab is “very well organized compared to [her host lab].” Equipment and materials have “their own designated spot and lab space is not used for storage of consumables,” unlike in her host institution. Though the two work at the same laboratory, their impressions of its order differ greatly due to the disparities between each of their host labs. The difference offers evidence of the community’s diversity and how that diversity can affect people’s understanding of other institutions and of their own.

Finally, participants compared the availability of different resources, including materials and instruments. Some of these comparisons preview later reflections by the students on the economic challenges to standardisation (and the associated inequities). For instance, Lucy observed and was “quite excited” about a novel technique for DNA straining. However, she soon noticed that her hosts’ strains were “more expensive than the ethidium bromide we use.” As a result, she was not sure that the technique “could be feasible for [her home lab] to incorporate.” Rose noted something similar. The disparity in financial support between her home and host institutions results in material disparities. Her host institution had “far more equipment and human resources,” and so had greater flexibility and potential for research. The “obvious huge difference in equipment” makes it difficult (or not feasible) for her to work in similar ways at her home lab.

4.2 Similarities

Comparing different groups within a community also involves identifying and examining similarities. Though the BioRoboost Exchange Programme was designed to expose participants to different ways of practicing synthetic biology, students learned as much about how their host groups are like their home ones.

Similarities are crucial for standardisation efforts. They may help the community find and strengthen ties. Similarities may reveal kinds of work already widespread and alike enough to be established as standard. However, similarities may also reveal widespread but counterproductive elements: shared and entrenched but hindering efforts to create standards.

4.2.1 Similarities in aims

The EP was designed to enable participants to explore different ways to do the same thing. As a result, the EP groups share some aims. Similar aims can be used to bring groups together and to coordinate their work. Put differently, they can help build the field and its standards.

Lucy described her home and host institutions as similar and different because they are committed to the same aims. Both groups look for new ways to "[measure] heterologous expression of fluorescent proteins in *E. coli*." The two groups explore "various methods and tools to obtain the same outcome." Lucy noted that the two groups "[compare] methods of operation in the context of standardisation of synthetic biology." That is, they share a commitment to standardisation. She explained that despite their "differences in operating protocols," the "[synthetic biology] atmosphere is almost the same between the two labs."

Other participants documented similarities in how their home and host groups consider and pursue synthetic biology standards. Emily compared her work with her hosts' and found that their "specific subjects differ within synthetic biology." However, they and she "share an interest in how standardisation could move the field forward." They may "only share very common growth/medium or cloning protocols," but still have important links. Unlike Emily, Isabel found that her host and her labs are "very similar in terms of work, methods and tools." They also "share the interest of standardised cloning methods and standardised measurements protocols." Isabel viewed the two similarities as ways to create links between the two groups.

4.2.2 Similarities in practice

EP participants identified and documented similar practices when comparing her home and host institutions. Those similarities helped the students create links and carry out work with their hosts. They can help more broadly by finding existing and possible ways to coordinate different groups around shared ways to carry out synthetic biology.

Some students identified similar routine practices. Lucy paid attention to how her hosts take and collect notes, which she described as "quite similar to our way." She compared their use of laboratory notebooks and hand-written notes, followed by digital summaries. Although mundane, these similarities made it easier for her to understand and engage with her hosts' work. Daniel also discussed similarities between routine practice. He noted that in his host lab, "results that seem weird are immediately discussed in great detail." Doing so helps the group "steer the research in the right direction," and "[find] the right methods/results." These are also routine practice in his home institution. Though simple, such similarities helped him to compare the two groups' workflows and to identify opportunities to coordinate their practices.

Daniel observed multiple similarities and also explained their usefulness. One of the most important difference between his home and hosts institutions was the latter's use of an automated platform. He dedicated most of the visit to learn about it. However, Daniel noted that while the platform was new to him, his hosts used it for "analyses which I do have experience with." His project during the visit was to transform one of his routine practices into an automated process. Because his hosts had "some kind of experience" with that practice, it was "pretty easy to implement in the lab automation platform." It became easier to find possible ties between the two groups and to develop ways to carry out their research in similar ways.

Lucy wrote that like her home group, her hosts "focus on synthetic biology in general." She argued that they are similar because "most of the procedures or protocols I followed in the lab were not new to me." Emily also compared methodologies. She noted that her hosts used standard operating protocols and organised their data in ways similar to her own. Her home and host groups "share the same thoughts about the procedures." As a result, the "my host and home institution align well." Lucy and Emily both identified practices as similarities that can enable ties between groups and support standardisation.

In summary

Section II introduced people and places involved in the EP. This section examined their differences and similarities. Comparisons of this kind were crucial to the EP, both as qualities to document and as motivations to participate in the programme. The material presented here demonstrates how students moved past description to basic forms of critical observation.

Such comparisons further develop the description of the BioRoboost community. They contribute additional details but also add information about how parties relate to each other. Exploring a community's differences and similarities is vital to understanding how it operates. Finally, awareness of differences and similarities is vital to standardisation. By understanding how components of a network relate to each other, it becomes easier to understand how that network may produce uniform ideas, practices and objects.

5. STANDARDISATION

Synthetic biology standardisation is the focus of the BioRoboost project. The Exchange Programme explored standardisation in multiple ways. First, it enabled comparisons between groups regarding what different people think about standardisation, including how committed they are to the effort. Second, the EP gave participants a chance to observe and participate in different methods for creating standards. Third, students were encouraged to put their ethnographic observations to use by transferring what they learned during their exchanges to their home institutions. It was hoped that the EP could support broader project goals of advancing synthetic biology standardisation.

The participants' description of BioRoboost groups and their diversity contribute to an understanding of synthetic biology standardisation. Standards rely on people, arranged in specific ways, operating in a coordinated fashion with comparable materials, harnessing similarities and pursuing unity. The students observed and documented these and similar social dynamics. They also reflected on how they affect the process of standardising synthetic biology practices and products.

5.1 Different views

The participants noted the lack of a unified view on synthetic biology standardisation. Many were surprised to find that their group's perspective was not shared by their hosts. They observed and documented different perspective on standards. Some of their hosts dismissed standards entirely or dedicated no attention to them. Others pursued standardisation enthusiastically. Those who did pursue standardisation did so with different goals in mind. The EP gave participants a chance to learn about these differences, to have their own views counterpoised or challenged, and to expand their understanding of standardisation.

5.2 Attention given

The EP participants wrote a great deal about the differences in attention given to standardisation. Rose, whose own group focuses a lot on synthetic biology standards, found that many of her hosts "were not aware on the problem that BioRoboost is trying to address." Specifically, the group did not have "awareness about the lack of [standards]." She suggested that her group's research interests made her "aware on the problems of standardisation," and motivated her to address them. Rose reflected that while she already knew that "there is still a lot of work to do" in order to realise standardisation, the EP helped her realise the great diversity in people's concern for standards and their commitment to engaging with the effort.

Daniel's experience was very different. He noted that before participating in the EP, "the time I spent thinking about standards was very short." In contrast, his hosts "think a lot about the standardisation," which meant that he was exposed to a new way to engage with the concept of synthetic biology standardisation. As he observed his hosts' metrological tools, he learned that their preferences reflected efforts to enable collaboration with other research groups. He learned about how standards can play specific roles in synthetic biology and how they can enable otherwise difficult practices.

Unlike Rose and Daniel, Isabel found that her hosts and she had similar perspectives on standards. She wrote that in her host lab, "a lot of effort [had] already been put in the development of a standardised cloning method with standardised parts and carrier vectors." Sarah also described her hosts as a group trying to "put in place good standard practices to benefit their workflows." Their commitment to standardisation and their views on its benefits were not too different from those at Sarah's home institution. As such, she was not exposed to very different perspectives. However, her hosts' different kinds of practice help her discover that "more things can and do get standardised in other labs." As she put it, her "understanding has grown, not necessarily changed, on standards." Michael said something similar. Before his visit, he "knew that standards were important." However, he did not "realise where and how we should apply them." Like Isabel and Sarah, his view about standards did not change. Instead, it expanded and become "much more clear."

The participants offered thoughts on the consequences of different degrees of attention given to standardisation. Michael described his hosts as "very concerned about [standards]" and compared them to many others that he knows who are "working hard towards standardisation." Due to such attention, he believed that synthetic biologists will one day deliver "gold-standard practices that will be used in all—or the vast majority—of laboratories." Rose, who observed much less attention given to standardisation, lacked such optimism. As noted above, she was surprised that most of her hosts "had not even thought about [standards]." As a result, she realised that it will require a "bigger effort to accomplish the goals of a real establishment of standards."

5.3 Purpose and use

Different views on standards include different views on their potential uses. Groups define and organise standardisation in accordance with what they mean their standards to accomplish.

Daniel explained that his hosts employed standardisation to establish a successful automation platform. He found that while the group's automated system was meant to enable standard procedures, it "requires a great deal of standardisation on its own." As a result, his hosts made "everything around the automation platform very structured" and uniform. The lab's principal investigator emphasised that without such standardisation, they would not be able to accomplish their experimental goals. Emily made similar observations. She argued that standardisation is "irreplaceable for automatisation and artificial intelligence-designed experiments." Specifically, data standards could help the field develop technologies such as "data-hungry algorithms."

Others visited researchers who emphasised the uses of standardisation for improving scientific practice. Isabel's hosts were pursuing standardised methods and protocols. They argued that standardisation of fluorescence measurements will allow for superior "communication of transparent and comparable results." Isabel's hosts also convinced her that standardisation can "reveal faulty protocols which would have been hard to discover without standardised methods."

5.4 Confidence

Finally, EP participants documented different views on the likelihood of success. That is, they observed different degrees of confidence in the standardisation project. Rose provided insightful descriptions of such differing views. She observed a variety of perspectives among her hosts. Some of them were reluctant about synthetic biology standardisation and did not "truly believe that it is going to be possible in a near future." Effectively, they lacked confidence. Others were less hesitant to pursue standardisation but still did not commit themselves to its success. These hosts "value the effort of trying to reach standardisation, but they do not seem very hopeful on it." Finally, some hosts thought that standardisation "probably will be accomplished in the future but is not possible today." The third group advocated continuing efforts, believed that standardisation will eventually happen, but held fast to the belief that success will not come soon.

5.5 Standardisation benefits

When surveying views on standardisation, the EP participants explored their hosts' beliefs about why standardisation ought to be implemented. That is, the participants discussed and documented synthetic biologists' views on what justifies standardisation efforts like BioRoboost. Standardisation will require a great deal of time, effort and funding. To justify those costs, standards must deliver benefits.

Views on benefits are also crucial to understanding how the synthetic biology community approaches standardisation, and necessary for understanding how different members of the community create relationships and work together. Different perspectives on benefits help explain why particular groups engage with standards in particular ways. For instance, those whose principal needs are expediting processes will focus on standardising workflows. Those who need uniform constructs may dedicate their efforts to making standard components. Moreover, similar views on benefits (and their associated types of work) can help create links between groups and influence what the community looks likes. Divergent views on benefits can undermine unity and weaken links between members of the community.

5.6 Efficiency

Daniel participated in his hosts' efforts to create an automated platform for metrological procedures. He learned that developing the process needed to "execute an experiment on such a platform can take up a lot of time." Using the process to carry out different experiments also demands time and effort. However, a shared platform and process will "[allow] people to work in a very standardised way." Researchers will be able to "operate the lab automation platform on their own," and will not require time-consuming technical guidance when carrying out each new experiment. As a result, Daniel believed that "both the process and experimental set-ups need to be standardised" despite the cost of doing so. Emily made a similar argument, and claimed that standard experimental set-ups could save time and resources "in world-wide collaboration." She believed that establishing strong links between community groups could be accomplished by using standardisation.

Like Daniel and Emily, Isabel referred to increased efficiency when justifying synthetic biology standardisation. Her hosts developed a shared Python script to guide their automated construction platform. It "determines all reactions, parts and linkers required for the assembly of the final vector." The parts used are also standardised. She argued that a standard workflow and standard parts can reduce "the amount of time and effort that needs to be put into designing the assembly reactions." Isabel wrote that implementing a similar system in her home laboratory would demand a great deal of effort. Nonetheless, "using standardised cloning methods combined with standardised parts in an automated workflow can save us a lot of time."

5.7 Expanded abilities

Some of the participants argued that standardisation offered synthetic biologists new or improved capacities. Daniel, who celebrated increased efficiency, also claimed that a standard automated platform allows synthetic biologists to "[analyse] many more samples than would be possible without such a platform." The result is more data. Daniel believed that such an increase in the quantity of data "increases the need for standardisation."

Other focused on superior data quality. Isabel argued that "implementing standardisation techniques in lab protocols will greatly improve quality and reliability of results." She believed that automation results in consistent data, better as a result of their stability. Isabel also claimed that by using standardised metrology, synthetic biologists can "compare fluorescence measurements between different labs." By making interactions easier, synthetic biologists could transfer findings quickly and put others' work to use effectively. Isabel claimed that this would help synthetic biologists "thoroughly characterise different parts that can be used for more complex systems."

As noted above, Isabel claimed that standardisation can make faults conspicuous that would have been "hard to discover without standardised methods." Isabel again advocated for the necessary efforts because she believed that the result would be an improved field. However, she expanded her argument by writing that "the lack of standards is a weakness that imposes limits in our field." Isabel believed that standardisation would not only add new abilities. It would also fix existing flaws.

5.8 Predictability

Finally, some of the participants described standardisation as a method to ensure predictability. Lucy argued that standardisation makes it possible to "know in advance that certain protocols are sure to succeed." Standardisation efforts are justified by the surety that they provide. Lucy claimed that because synthetic biologists can be confident about certain procedures, they will not lose time employing ones that may not work. They can feel certain that products made with standard parts, methods and instruments will function as intended. Most basically, she said, "the same standard tools and standard implementation methods can make your [synthetic biology] experience a lot less frustrating."

5.9 Standardisation strategies

EP participants were asked to examine how their hosts' views on standardisation were put to action. That is, participants observed and documented how their hosts tried to implement standards. The students also queried people about what was necessary and what would be useful for establishing standardisation across the synthetic biology community.

The exercise revealed different standardisation strategies. First, the participants recorded many views about what the field should be doing but was yet to carry out. Second, the students documented thoughts on how to improve standardisation by allocating efforts most effectively. Finally, they documented thoughts on what the field needed to carry out in order to produce successful standards.

Crucially, once the participants reflected on their observations, they identified different standardisation requirements, modes and mechanisms beyond the immediate technical ones. That is, the students observed and discussed some of the social factors of standardisation. They paid great attention to the process of bringing groups together and configuring them into a standardisation community.

5.10 Collective ordering

Michael argued that without effective means of communication, standardisation is not possible. His hosts had developed a system through which "everybody in the lab is instantly informed about the new methodologies that they are going to try or implement." Lab members are subsequently told about results and implications. Michael believed that such interpersonal relations were useful mechanisms for creating standards. He even argued that the communication system itself "is also standardisation." In order to establish community-wide standards, Michael advocated regular meetings of community members "in order to share knowledge." That knowledge could include "new standard protocols" and "evaluations about the reliability of some techniques." Sarah also favoured community meetings as a good way to "share standard ways of working and ideas." She wrote that "often a lab will do something well but no one else knows about it." As a result, the rest of the community "can't implement something that is clearly of benefit."

Michael and Sarah identified a basic but vital form of social coordination and ordering: shared ways of exchanging information. Other participants made similar observations about groups' use of documentation. Daniel described that for each experimental procedure programmed into their automated platform, his hosts used a document that codifies "a sort of standard operating protocol." The documentation helps lab members "when they need to use that process" and allows them to work "in a very standardised way." Daniel also observed that clear codification "allows different people to help at different points/runs of the experiment." Coordinated, shared documentation supports coordinated, shared practice. Rose described "a big calendar in the corridor for the common things in the lab, and also a list of things to do." The public record of events and responsibilities created a common awareness of each member's work and the group's shared undertakings.

Daniel also discussed codification by describing his hosts' views on standard terminology. He asked one of his hosts about the "discrepancy in terminology between different automation platforms." The host began to laugh and agreed that the discrepancy makes uniform use of automation platforms challenging. He hoped for standardised terminology because it would make "switching between platforms" more feasible. Daniel argued that this could help the community standardise procedures and coordinate different varieties of automation platforms.

In addition to local methods for standardisation, the participants discussed community-wide strategies. Isabel and others proposed strong measures for community ordering. After her visit, Isabel wrote that the field must "make the development of standards top priority," as standardisation will "greatly increase the success of the synthetic biology community." She acknowledged that not all synthetic biologists are committed equally to standardisation. Nonetheless, she wrote, the field should support "the development of more standardised protocols" and "make their implementation mandatory." Isabel argued that mandating standards is the only way to overcome some of the principal challenges, discussed below. Sarah did not suggest such a forceful approach, but did propose small requirements to encourage coordinated practice. For instance, she suggested that publications might introduce "standard in terms of metadata reporting, calibration and hence reproducibility."

Finally, some recognised the importance of training in establishing standards. Rose proposed that as part of the standardisation project, "some effort should be made in the sense of forming people and making them conscious about the standardisation challenge." She believed that efforts to form practitioners "should start with our own groups." Local training in accordance with shared specification could help "accomplish a general standardisation." Sarah also emphasised the role of training. She argued that unless standardisation is "taught at an A-level, undergraduate, masters, even PhD level then it will fail to disseminate to the masses." Some improvements can be made without such a commitment to training. Nonetheless, Sarah wrote, without a strong effort to teach standards early and consistently, it will not be "entirely possible to make standardisation widespread."

5.11 Sponsorship and support

Last, EP participants discussed the need for different forms of sponsorship and support by the synthetic biology community. Many pointed out that until the members of the community accept and appreciate standards, standardisation will remain an ambition rather than a reality.

Daniel proposed the need for a community-wide consortium dedicated to developing and implementing standards. Such a group could "actively [debate] and [work] together to get to a workable consensus" on what form standards should take and how they should be established. Daniel also suggested that some form of "international 'committee' with stakeholders from throughout the field" could establish a standardisation framework. The committee could ensure widespread support by developing its plans "in dialogue with both the research community and industry."

Emily suggested that support could be engendered through economic means. She argued that the "valorisation of products of synthetic biology" could be used to encourage standardisation. She suggested that in order to have "access to the market… standards are required and have to be both established and met." Whether or not the claim is factually correct, Emily rightly identifies the potential for economic arguments. If standards can lead to superior processes and products, then it may be possible to enrol biotechnology industries in advocating for community standards.

Finally, the participants observed the need for collective unity and support. Daniel referred to "goodwill from people, labs, companies across the field." He imagined groups willing to change their idiosyncratic ways in order to "comply with the set standard." Daniel viewed this as the "the most difficult part," but also one that cannot be circumvented. Rose also noted that "cooperation between groups and shared projects play a major role in standardisation issues." Both of the participants referred to the basis of successful standards in social coordination. Standards cannot exist without a community and standardisation is fundamentally a form of social ordering.

5.12 Standardisation challenges

The participants' discussions about standardisation benefits and strategies were accompanied by extensive observations about difficulties. The students were given the chance to document and compare what different groups saw as the principal challenges facing synthetic biology standards. They also learned about why certain group had chosen not to pursue standardisation, or why others' efforts had failed so far.

The different kinds of challenges reflect the diversity of practitioners, forms of work, aims and expectations. Many difficulties were widely recognised; others were specific to an institution or a laboratory. As with their observations on strategies, the participants came to see that many standardisation challenges are not strictly technical. Just as many concern social factors. The participants' observations offer insights into the synthetic biology community. They indicate how different constituents are laid out and linked, and how present configurations may have to change in order for standardisation to succeed.

5.13 A lack of coordination

As has been noted above and as was discussed extensively in "A Conceptual Analysis of Standards," standardisation is a form of social coordination. A community must arrange itself appropriately and then operate jointly to create and sustain standards. Some of the participants argued that the synthetic biology community currently lacks such coordination.

Michael offered a simple example as indicative of broader difficulties. His hosts rely on a great deal of computational analysis. For fluorescence normalisation, they use a formula developed by a previous doctoral student. Michael noted that group members are deeply committed to this formula and "take care about everything and try to optimise every detail, even the smallest one." However, the team uses two different languages—R and Python—to carry out the same analysis. Moreover, "although everyone has the same analytical guidelines, they do not use the same script." Michael argues that this prevents effective coordination, since two people cannot work on the same analysis unless both know the same programming language and are familiar with the same script.

Others emphasised the lack of a system for effective communication and information synthesis. Emily wrote that "many great papers and experiments are out there." However, there is no "real platform to unite their findings." She argues that without such a system, it becomes difficult for different groups within the community to contribute distinct research and coordinate their work in the service of a shared mission. Emily suggested that a simple starting point might be "one single website collecting everything." She offered the iGEM Registry of Standard Biological Parts as an imperfect template.

5.14 Necessary tools

Some of the participants focused their exchange work primarily on equipment, such as automated platforms. These students celebrated such tools as "a good way towards standardisation." (Michael). However, they noted that relying heavily on equipment also poses difficulties for standardisation. Namely, financial burdens accompany novel equipment. Michael and his colleagues agree an automated platform will ease their standardisation effort, but they also "do not think [they] have the money to buy one in a near future." In summary, when the cost of equipment meets financial disparities, it can create accessibility problems. If few laboratories can afford automated platforms, such equipment cannot support standards successfully.

5.15 Academic problems

The participants also documented and discussed more prosaic difficulties, such as the professional cost of working on standards. One of Michael's hosts told him that "he thinks that standards are really important." Nonetheless, he is reluctant to carry out some necessary or useful efforts. For instance, he hesitates to "publish the things they use to do in their labs," meaning their unique methods. The host also hesitates to reveal "the things that they did and went wrong," even if such findings could help speed standardisation efforts. Daniel's hosts also discussed professional hindrances. They argued that developing standards or implementing ones developed by others would "bring along a great deal of 'worthless' work." That work would carry no immediate professional benefits.

Isabel discussed a similar difficulty. She associates standardisation with "an increased workload" that is not certain to be offset by identifiable benefits. Isabel noted that "developing standards takes time" and implementing them will "require even more time." Dedicating time to standardisation, with no surety of their worth, is not especially appealing, particularly for doctoral student with rigid deadlines and early-career researchers in need of numerous publications and attention-gathering accomplishments.

5.16 Lack of awareness and understanding

When exploring her hosts' views on standardisation, Rose observed that most of them "had not even thought about it." The difficulty is even more basic than those to do with professional challenges. Sarah observed that regarding standardisation, "information is not widespread." Her hosts found it difficult to understand what standardisation entails because "there is not a standard way of setting up standards." They do not know what is involved and what is necessary because the community does not have such shared understanding.

Other participants discussed a different form of insufficient understanding: the lack of necessary scientific knowledge. Rose observed that many of her hosts did not subscribe to standardisation because they believed "living organisms are not as predictable as other systems." The view is shared by many. However, some of Rose's hosts did not reject predictability completely. Instead, they argued that the problem was lack of scientific understanding. Emily documented similar beliefs. Her hosts argued that standardisation was much more difficult in mammalian synthetic biology, science "there are barely any [standards] published." In a frustratingly cyclical manner, lack of standardisation scholarship hinders standardisation research.

5.17 Resistance to change

Last, the students documented resistance to change, perhaps the most stubborn social difficulty facing standardisation. They discussed different ways in which synthetic biologists seem unwilling to transform themselves and their work to establish successful standards. Even those who already accept and employ standards seemed reluctant to "changing their own standards for globalised synbio standards." (Daniel)

Rose observed that most of her hosts "do not fully trust others' work." She reflected on this difficulty and concluded that "not trusting, or not relying on, others' work" is a principal reason for "this lack of standards." A synthetic biologist may appreciate another's work and recognise its value. However, she may still hesitate to make her own work dependent on standards established by the other.

Emily stated that many (if not most) groups within the synthetic biology community could resist standardisation because "often a 'here, it has always been done this way' policy is in place." Tradition and routine influence all synthetic biologists in their work. Those may be difficult to overcome "should certain standards tried to be implemented." A group understands its traditions and routines, subscribes to them with confidence and follows them with comfort. Others' traditions and routines are black boxes. One may import a method and use it successfully, but it will remain foreign when compared to local traditions. That undermines confidence and comfort, which are needed to establish community-wide standards.

Last, some of the participants documented sceptical views about the worth of standards. Even individuals who ascribe value to standards described an influential cohort of synthetic biologist who don't appreciate them. Isabel described a conversation with one of her hosts, who believes that "standardisation is really needed." That same host believes that standards tend not to be implemented because "individual research institutes, especially in industry, do not immediately benefit from [them]." Resistance to change cannot be overcome unless the results of change are held to be valuable.

In summary

Standardisation is the focus of the BioRoboost project and the EP was designed to explore standardisation in different ways. During their experiences, the participants practiced standardisation and discussed and debated standards with their hosts. They also reflected on what motivates standardisation, how it may affect synthetic biology and how it may be carried out.

Section IV made use of the participants' observations and reflections to develop its portrait of the community into a discussion of standardisation. It has offered insights into how different parties of the community approach standards, how they understand them and how they are trying to establish and employ them. The section thus puts descriptions and comparisons from Sections II and III to use in addressing fundamental project goals.

6. LEARNING AND COMMUNITIES

It was hoped that the EP visits would enable learning. The ethnographic methods were intended to enable an alternative way of doing so, including by paying greater attention to social phenomena often overlooked by scientific and technological practitioners. The EP designers and organisers also believed that the exercise in moving between groups might foster new relations between different groups. These could serve as vehicles for communication and coordination, both of which are necessary for successful standardisation.

Participants learned during their visits. Some developed new skills with equipment. Others learned different methods for carrying out routine procedures. One carried out an extensive survey of standardisation literature. All were exposed to different ways of thinking about standards. The EP supported that learning. It also intended participants to transfer their learning back to their home institutions. Some of the lessons might be implemented as additions or modifications to their groups' work. EP experiences might then have a practical impact on BioRoboost members.

6.1 Lessons learned

Before they arrived at their host institutions, EP participants prepared a plan for what they intended to learn during their visit. That plan was reviewed and revised at the start of the exchange. During their stay, the participants paid close attention to what had the potential to contribute to their own work. Once back at their home institutions, the students reflected on how the lessons they learned could be implemented there.

Crucially, the participants gained insights into the role of learning for standardisation. The students came to realise that learning is a mechanism for standardisation. Learning and standardising both depend on communities. Becoming part of a community requires would-be members to gain necessary understanding and know-how. Implementing standardisation involves creating a community of standard-users with particular understanding and know-how. Put simply, being a member of a standards community requires learning how to be a member. Moreover, developing channels that enable learning from others and teaching to others creates links between groups. Those links serve bringing people together around shared standards.

6.2 New techniques learned

The EP participants all sought to learn new abilities. Which abilities depended on the participant and the host, but gaining skills formed part of all the exchanges. During her visit, Rose noted that a defining part of her experience was "to know about techniques that may be useful."

Michael dedicated his visit to learning about his hosts' work with automation and computational analysis. He set out to "learn how to use machine learning." It was his intention to "apply the algorithms and methods I learned to many parts of my research." Moreover, Michael wanted to transfer machine learning techniques to others in his home institution, who would then be able to "apply [machine learning] to other things that we do."

Daniel made similar claims about learning automation skills. He described his primary goal during the visit as "that I will leave with a basic know-how on lab automation." Learning about automation involved learning different techniques and developing multiple skills. Daniel described these as ranging from "platform set-up, to programming and ultimately handling." These will contribute to his work, but they will also "help with the implementation of automation at my home institution." Like Michael, Daniel meant to transfer his learning to others and so shape the entire group.

All of the participants learned new technical skills. Some also learned techniques for community organisation. Rose wrote that "one of the most important things I [learned] from the Exchange Programme was the different organisation of people in the lab." Among others, she identified "task division, shared responsibilities and well-defined roles." These techniques, which do not consist of technological abilities like those mentioned by Michael and Daniel above, gave Rose insight into "how a big group with so many scientists can work cooperatively." She expressed the importance of such skills for synthetic biology standardisation, a collaborative effort that requires the successful ordering of a large community.

Emily also learned techniques for community organisation. These included her hosts' techniques for recording and communication. She appreciated "the standardised form they used to keep lab notes." She also noted her hosts' policy of keeping "lab journals and progress accessible and understandable for others." She found this "organisation system" to be efficient and productive. Lucy made similar observations. Her hosts stored protocols and procedures in "an efficient and logical way." She believed that doing so can "greatly enhance the efficiency in the lab." Both Emily and Lucy reflected that implementing those lessons about community organisation could benefit their home institutions.

6.3 Self-reflection and re-thinking

The exchanges encouraged participants to compare what they saw to what they do at home. As a result, learning also took the form of self-reflection and re-thinking of what the students held to be normal and self-evident.

Daniel described the exchange as an exercise in "stepping out of the familiar environment" and entering "a new institution with its own habits and workflow." Observing different routines and comparing them to those he practiced every day in his home institution gave him a chance to "critically asses my own workflows." Michael made similar statements. He also concluded that upon returning home, it would be "a good idea to share the things I found out to differ." Specifically, he intended to encourage his colleagues to "discuss which is the best way to do every task" and to consider implementing some of his hosts' workflow techniques. An exercise in self-analysis and evaluation might help his group "improve our lab procedures and make them quite more robust."

Daniel wrote that comparing his methods to "how things are done in a group which uses very similar techniques," encouraged him to review even commonplace techniques. In fact, comparing specific techniques made Daniel "think about everything I do in the lab." He now tends to "contemplate about lab practices that before I would just carry out." Daniel summarised this "very valuable lesson" as recognising that a locally accepted practice is not "the only or even best way to do it."

6.4 New awareness

Self-reflection is a form of awareness. During his visit, Daniel became aware of the diversity of ways to do 'the same thing.' His view on his own methods changed because he developed a different way to understand their validity. New forms of awareness were important lessons gained by participants in multiple ways.

Several students gained awareness of particular relevance to the BioRoboost project: greater consciousness of standards and standardisation. Isabel reflected that having completed her exchange, she was "now more aware of the importance of standardisation in synthetic biology." That awareness was accompanied by greater familiarity with "the research that is currently done to develop and implement standards." She felt that gaining these insights helped her better her understanding of what things "were needed and were currently done to improve standardisation between labs." Emily, who dedicated time to reviewing synthetic biology scholarship on standardisation, wrote that her effort "made me realise how many international researchers are calling for such a standard system." Isabel and Emily gained new insight into the place of standardisation in synthetic biology, as well as consciousness of previous and ongoing efforts to implement it.

Crucially, the EP participants noted their greater awareness of the role played by social factors in creating and using synthetic biology standards. Rose reflected that before the exchange, she "thought that standards in scientific issues were more important than those on social aspects of laboratory work." The ethnographic work that carried out during her exchange provided a chance to observe and reflect on social phenomena that she had normally overlooked or considered not very significant. After the exchange, Rose recognised that technical and social elements of standardisation "must go hand in hand."

6.5 Implementing lessons

The EP organisers and participants hoped that lessons learned could also be transferred from the host to the home institutions. Transferring lessons requires some form of implementation. If lessons go entirely unused, then their transfer remains fairly superficial. If they are employed only by the participant, then the EP has affected only those immediately involved. Ties built between groups would be ephemeral, since they depend on a single individual who might leave her home institution at some point. As such, putting lessons to use in the wide group makes links sturdier and shapes the broader community in a more substantial way. Finally, putting one group's work in another is a simple way to explore what can exist successfully in multiple places at the same time. That is, what can be uniform and stable across a community: what can be standardised.

There is no single way to put lessons from the exchanges to work in the home institution. The methods will differ with things like the kind of lessons learned by the students and the character of the home institutions. Implementing a laboratory method will demand demonstrating it to colleagues. Conveying a body of knowledge, such as a theoretical framework, might require distributing texts and carrying out seminars. And to introduce an instrument, the group would have to acquire it. Moreover, there is no way to be certain that a lesson will work. Not everything will be transferable, and even those things transferred may not work as well as it was hoped that they would.

There is a need to evaluate how effective implementation of lessons is. Such an evaluation will shape future efforts to create links between groups and to coordinate the community in order to establish standards.

6.6 Awareness and commitment

For many of the participants, implementation begins with creating awareness and encouraging commitment. That is, participants wanted their colleagues to know more about standards and to dedicate efforts to standardisation.

After her visit, Isabel tried to share her new insights. She tried to “raise awareness about the importance of standardisation in our research group.” She believed that only once the rest of her team possessed fundamental understanding of standards could they carry out standardisation work. Michael made similar plans. He intended to “extend my new view about standards to my colleagues.” Crucially, he also wanted to encourage ongoing discussion by asking them about “their impressions about my experience.” Such reflections would allow him to consider how relevant his colleagues found what he learned and what they felt was worth pursuing. These kinds of conversations could foster enthusiasm for pursuing standardisation.

Basic awareness was complemented by insights into specific elements of synthetic biology work. Transferring lessons could be eased by demonstrating what might be implemented in which specific places. Isabel chose “the idea of a standardised cloning method using standard parts.” She found this to be “clearly a major part of standardising synthetic biology.” Moreover, it is a routine practice and so might have a great impact on the entire team. Michael decided to hold a laboratory meeting in order to begin a conversation about how the group could “improve our methodologies in order to standardise them.” Like Isabel, Michael focused on specific methods. He decided to identify which methods through a group discussion, rather than selecting a method himself. Daniel reflected that “the first step in thinking about the standardisation is rather local.” That is, standardisation begins by thinking about how to implement practices in one’s institution. Once a group has considered “what would be good to standardise and how to do it” locally can standardisation be successful on “a more global scale.” Daniel argued that shaping the community begins with attempts to shape groups. The EP gave him a chance to start doing so.

6.7 Protocols and methods

As the participants noted, implementing lessons can be achieved by introducing or modifying specific methods. It is first necessary to select which of the multiple lessons learned can and should be implemented. Sarah intended to review her group's common procedures and identify what "I feel we do well and things we don't." Elements that can be improved offer chances to introduce new ideas and practices. She focused on standard operation procedures, such as ensuring "even mixing before pouring plates" and improving "maintenance on certain pieces of key equipment." Sarah felt that routine practices offered opportunities to introduce new methods and so standardise basics. Emily argued that what to implement should reflect what can be tracked most easily. If basic procedures are standardised, then practitioners will "adapt any protocol a little bit to their own project and lab settings." The field will need "an extensive documentation that allows other people to see what has been adapted and why." Emily believed that what is best to implement is what can be evaluated for its impact most easily.

Isabel suggested transferring measurement protocols from her host to her home laboratory. Specifically, she wanted to "implement the protocol for standardisation of fluorescence measurements." She felt that this "greatly improves quality and reliability of reported results." In order to put her learning to work, she began to prepare "standard curves for the different dyes for our plate reader at different settings." Once ready, she wrote, she will "push towards the implementation." Isabel hoped that this would improve her lab's work and make it easier to coordinate different groups, an important step toward standardisation.

Michael identified computational techniques as the principal lessons to implement. He intended to "apply the algorithms and methods I learned to many parts of my research" and to teach colleagues how to do the same. He believed that these lessons had the greatest chance of successful transfer because they had relevance for "not only the investigations strictly related to synthetic biology." Other, such as "genomic and metagenomic analysis," would also benefit. As a result, the lessons would have a greater impact on his team and tie together home and host institutions most strongly.

Daniel's home institution had "recently decided to also standardise our intra-lab data processing and visualisation methods." Introducing and implementing lessons from his host group provided an opportunity to standardise both within and across laboratories. He "discussed implementing [his hosts'] way of data visualisation" and his colleagues agreed to consider doing so "during further development of our standardised process." This is an example of using local efforts to build ties between groups and so shape the community as a whole.

6.8 Practices and experiments

In addition to implementing methods, the participants suggested ways to implement lessons through experimental design and practices. Isabel, who suggested implementing her hosts' measurement methods, also wanted to use her lessons to shape experimental design. After the exchange, she dedicated efforts to developing "a good way to standardise plate reader experiments" using her hosts' techniques. The result would be coordinated experimental design within and between labs. Lucy mentioned adding new steps to routine experimental procedures in her home laboratory. These included simple steps like "putting a piece of tape after autoclaving when the cycle was completed correctly." She learned during the exchange that this small act could reveal "possible problems with the autoclave." Lucy argued that even simple modification could better local practice and make different groups' work more alike.

Those participants whose exchanges focused on instruments viewed laboratory equipment as a place to implement lessons and to advance standardisation. Daniel completed his visit with a desire to "transfer the gathered experience on lab automation platforms." The knowledge he gained provided him with "the opportunity to help set up such a system in my own lab." His lessons could contribute to the "implementation of the platform that will be acquired by my home institution." He also identified techniques such as "the minimalistic and super-fast agarose gel-electrophoresis setup" as knowledge to transfer and implement through equipment.

6.9 Community structures and collective behaviour

Participants recognised that implementing lessons also involved implementing *social* lessons. These took many different forms.

Rose saw promise in transferring lessons about collective behaviour and coordination. She intended to encourage her colleagues to "detail their daily routines and work" and share those descriptions with the rest of the group, as was done by her hosts. She felt that ensuring "we can all have access and be able to follow their projects" would enable greater coordination and easier collaboration between members of the groups. Daniel believed that with his lessons about collective behaviour he "will be able to contribute greatly" to his group's work and to standardisation between groups. He identified "the standardisation of our workflow, which now tends to be very person specific" as a lesson to implement. He hoped to establish a form of social coordination similar to that used by his hosts. Emily suggested that even "a standard way of naming files," as employed by her hosts, could be implemented in order to coordinate group behaviour.

Participants commonly discussed the importance of creating links between different groups. Daniel wrote that the EP "connected me with experts in the field of lab automation." Those ties, and the transfer of knowledge and know-how that they enable, will "be an asset in the build-up of our own platform." Implementing channels for discussion and exchange could encourage collective behaviours that support standardisation across the community. Isabel intended to maintain her collaboration with the host group by establishing such a link. She believed that both group "can benefit from the collaboration to develop improved standardisation methods."

Isabel went on to write that those connections could enable more than transfer of knowledge and know-how. Establishing them could make joint projects easier to develop and to sustain. She offered as an example working together to develop standard protocols. These could be designed in collaboration and then "be tested [at both groups] for comparability." Once the two were satisfied with the protocol and had confirmed its stability, it could be communication to the broader community, were it "can be validated by other members." Establishing ties, developing and implementing standardised protocols, and distributing those for broader evaluation and enrolment are forms of social coordination that Isabel believed could serve standardisation.

6.10 Challenges faced

Learning and implementing lessons have hurdles. Some of these are the same ones faced by attempts to coordinate a community and to establish standards. The challenges must be examined because they cannot be circumvented. Moreover, addressing them offers possible solutions to difficulties in standardisation efforts.

Multiple participants mentioned people's resistance to change as a conspicuous and substantial challenge when trying to implement lessons taken from their hosts. Michael observed one of his hosts—who had participated in the EP herself—attempt to convince her colleagues to consider adopting a system that she learned during her visit. Michael noted that she "explained how the system works, and after that everybody asked her questions." Many of those question suggested that "all the members of the lab were reluctant" to consider implementing her lessons. She eventually convinced them, but not without considerable effort. Michael described similar dynamics in the broader synthetic biology community. By watching people's interactions at community meetings, he came to realise that people across the field "will be reluctant at first." Nonetheless, he believed that with extended discussion "we could reach a consensus."

Reluctance to change is particularly important because implementing lessons and establishing standards necessitate change. Daniel compared his hosts' work with automated platforms and comparable work at his home laboratory. He concluded that his group will need to "change some aspects of our experiments in order to be able to use the automation platform to its full potential." He was certain that "there will be some resistance." Securing blueprints of his hosts' designs will be relatively easy. Convincing other members of his lab to adopt those designs will be much more difficult, since they have "been working the other way for their entire career."

Sarah also discussed the comfort of convention and its detrimental effect on implementing changes. She noted that "people generally don't like changing their ways," which results in "resistance for some things as changes in procedure." Simply put, "there are too many researchers happy with the way things currently work." As a result, they view the "extra time, effort and cost" involved in altering practices to be unwarranted. Sarah argued that implementing a particular change, such as adopting a standard, will be difficult to accomplish unless "it solves a major issue we are experiencing."

In summary

Section V has reflected on what impact the EP has had on its participants. It focused on how the process of learning has affected the students' subsequent work. It also considered how learning can shape the makeup and configuration of the community. All of these relate to the project's standardisation aims.

Standards rely on communities, which have to be established and sustained. Communities rely on links between their constituent parties, and channels for exchanging information and enabling learning create strong links. EP participants' reflections on learning address a crucial aspect of the project and its supporting scheme: creating partnerships and communities. Learning to use learning can serve standardisation.

7. FINAL THOUGHTS

BioRoboost Task 4.2 involved the study of those networks of people, practice and objects that together constitute a standardisation community. Its empirical research, carried out through the BioRoboost Exchange Programme, provided the necessary data. Its principal product, this text, was to document findings and offer insights into synthetic biology standardisation. In five sections, empirical findings have been presented so as to construct a portrait of BioRoboost groups, examine their characters and relations, and reflect on efforts to establish standards. The achievements of the EP participants have also been presented and their viewpoints form an invaluable part of this document.

7.1 The community landscape

As was expected, the EP data indicates the diversity of the BioRoboost community. That the parties involved have different characters was not a surprise. Insights came from the different qualities that define each group as distinct. The participants' observations capture the many different aspects that distinguish each host groups as something particular, rather than just the local franchise of an encompassing project. Put differently, the community's diversity is a multifaceted diversity.

One consequence is that the diversity is difficult to observe and document in its entirety. The EP participants were given suggestions about what aspects of their hosts character they might want to examine and record. The students pursued facets that they found to be especially noteworthy. The results reflect these differences. The demonstrate the complexity of a community by showing how many qualities define its population, and suggest the challenges involved in characterising its makeup.

A multifaceted diversity is difficult to capture. Its complexity also makes it hard to analyse and understand. What qualities are especially relevant and which can be dismissed as unimportant, how different qualities should be studied, and how the overall character of the community should be understood are examples of the difficulties faced when trying to give meaning to the many different qualities recorded through observations. This challenge does not only affect those, like the EP participants and the BioRoboost social scientists, who are explicitly concerned with studying social communities. It is also relevant for those who want to comprehend the community that they want to organise around shared ideas, practices and objects. That is, developing a way to approach and understand community diversity is necessary for those involved in standardisation (like the BioRoboost consortium).

Finally, because of its complexity, the character of a community and of its constituents can be understood simplistically. It becomes easy (perhaps tempting) to overlook or dismiss qualities that do not seem immediately useful. These include the kinds of social qualities that the EP participants came to see as central to characterising a group and understanding how it engages with standards.

7.2 Making sense of the community

Understanding the community requires recording and making sense of its many parties. It involves identifying and examining similarities and differences between those parties. The participants showed that comparing people and groups can take many forms. They also learned that which similarities and differences are conspicuous and which are informative are not always those expected to be. And when the different observations are compared, it becomes clear that different people focus on different comparisons, and also carry out the same comparisons in different ways.

Examining similarities and differences is one way of considering what a community's diversity entails. Most basically, because comparing different groups makes it possible to translate descriptions of individual groups into an understanding of how groups stand in relation to each other. Where and how similarities and differences exist matter to standardisation efforts because, as has been noted, standards depend upon coordination. Similarities are useful tools for developing coordination. Differences can undermine or even prevent coordination, but they can also make clear what needs to be addressed in order to bring a community's constituents into the necessary order.

Making sense of a community also involves carrying out an important part of Task 4.2: understanding networks of ideas, practices, people, institutions, objects, resources and other components. These support the community and its activities, including standardisation. Understanding what different parties share and what they do not is one way to understand how a community's elements are arranged and how they keep it existing as it does. That is, an understanding of diversity provides an understanding of a community's supporting structures.

Finally, as the participants suggested, understanding what makes different groups alike and what makes them differ helps consider possible networks. A community's current arrangements do not need to stay as they are. In order to make standards viable and widespread, the community will probably need to be reconfigured. Doing so effectively begins by comprehending what constitutes the groups and what ties and separates them.

7.3 About and for standards

The participants documented their hosts' relationships to standards and standardisation, and reflected on their own. As discussed above, the students were often surprised by their observations, and those observations had identifiable impacts on the participants' views, ambitions and practices.

The participants produced material on what members of the community find appealing about standards and what they hope to accomplish with them. The participants and their hosts considered what hurdles have to be overcome to make synthetic biology standards a reality. The students' observations include descriptions of what people are trying in their efforts, what they intend to try, and what they think ought to be tried. Last, their data gives a description of different contexts for standards and a variety of those who will employ them. These observations are both *about* standardisation and *for* standardisation.

The participants' observations do not only document what they saw and what people think about standards. They also suggest ways to advance standardisation. A lot of this comes from the participants' discussions about how groups operate as social units: collections of people bound together in certain ways and acting in relation to each other. The students recorded and reflected on how interpersonal relationships supported the group's work and how different forms of standardisation already existed in that work. These offered lessons on what can be transferred and employed at their home institutions. Producing observations about the community and its engagement with standards allowed the students to find ways to support standardisation efforts of their own.

Among these were methods for involving people in the work. That is, ways to make their colleagues aware of synthetic biology standardisation, to expand on their existing knowledge, and to suggest useful approaches to incorporating standardisation into local research. Making people involved also involved creating meaningful relationships between host and home groups. That is, making people involved with each other and across institutions. Doing so is a form of creating new networks, which can support new community arrangement, which can support successful standards. Ultimately, standardisation requires getting people involved in a shared effort. The participants discovered ways to cultivate participation.

7.4 Next

The BioRoboost Exchange Programme and this text offer lessons for the BioRoboost project and for broader standardisation efforts. They also suggest what the project can do with the material presented here.

This text presents empirical data, examines that data and offers conclusions based on both. What ties these together is learning from EP observations. Observations underlie this document's portraits of groups and of the community. But they also offer different ways to think about the BioRoboost consortium. What the participants saw—especially those things that tend to be ignored—can shape how the community sees itself and what it can be.

The EP also suggests the need to produce more observations. A second round of the EP was delayed indefinitely due to the covid-19 pandemic. If and when it becomes possible to carry it out, it will offer an opportunity to expand the description of the community and to produce more understanding of how communities and their standards operate. More importantly, teaching more members of the BioRoboost community (and not simply its students) to employ ethnographic skills can enable new ways to view and exist within the community. Learning to observe is learning to view standardisation in new ways. Observation can broaden understandings of what standardisation requires and entails, just as the EP participants discovered the importance of the non-technical in making standards work.

Finally, this effort demonstrates the importance of learning to learn. Gaining knowledge from others is a routine part of research. Publications and presentations offer materials that can be used by the community to develop new knowledge. But communicating findings and reading about results does not allow for substantial and detailed learning. As the EP participants showed, learning skills and transferring them is an important part of creating networks, supporting communities and advancing standardisation. Dedicating time and energy to creating new tools for instruction may help a community like the BioRoboost consortium come together, coordinate its efforts and accomplish its goals.