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ORIGINAL PAPER

Enrolling the Toggle Switch: Visionary Claims and the Capability of Modeling Objects in the Disciplinary Formation of Synthetic Biology

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Abstract Synthetic biology is a research field that has grown rapidly and attracted considerable attention. Most prominently, it has been labelled the 'engineering of biology'. While other attempts to label the field have been also pursued, the program of engineering can be considered the core of the field's disciplinary program, of its identity. This article addresses the success of the 'engineering program' in synthetic biology and argues that its success can partly be explained by distinct practices of persuasion that aim at persuading scientific, but also non-scientific audiences. The article explores two different modes of persuasion:, building tools as heuristic models and posing visionary claims. Objects such as the toggle switch or the synthetic oscillator in synthetic biology can more adequately be described as heuristic models of engineering instead of simply as prototypes of 'tools'. Posing visionary claims can be also understood as a persuasion practice, since the claims are used to construct the societal relevance of the field. Drawing upon Michel Callon's 'sociology of translation', I argue that both practices of persuasion aim at 'enrolling' entities into the disciplinary identity. The article is based on the textual analysis of rhetorical practices in three synthetic biology review articles which are considered seminal for the history of the field.

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Introduction

Synthetic biology has been prominently discussed and promoted as a disciplinary program of 'putting engineering into biology' [1]. Although early documents show competing projects of disciplinarization, many accounts refer to that frame. In this respect, synthetic biology is identified with a modular approach of components for achieving control of biological processes [2]. Moreover, the notion of 'design' is influenced by electrical engineering [3, 4]. Consequently, the media and public debate is dominated by the representation of engineering in biology: notions of 'designing' or 'redesigning' life have raised the awareness of citizens and journalists and are tied to such an image of the field [5].

Contrary to that, scholars in science and technology studies have explored the variety of epistemic practices, many of which many are distinct from 'engineering biology' [6–10]. Various studies have focused on the heterogeneous practices of collecting, sharing and constructing biological systems [11–13]. Whereas the medial representation of epistemic practices appears to be dominated by the image of 'engineering', exploratory research has outlined that different categories and research stances according to various tribes prevail in synthetic biology [6, 7]. By focusing on making objects, many practices in synthetic biology can be merely characterized as being more 'kludge' than 'rational design' [13]. In short, such studies are concerned to show how observed practices of 'making' differ from the proposed disciplinary program.

While these studies highlight the importance of analyzing epistemic practices in the scientific culture of synthetic biology, their main focus has been to show the heterogeneity in the field. However, less attention has been paid to those epistemic practices which are established to engage external audiences. How come that synthetic biology as an engineering approach has been – and still is – so successful among other scientific communities and the public with its ideas and approaches? Recent studies highlight that synthetic biology is particularly attractive among younger scholars, due to a specific image of 'making things work', similar to the IT community [14, 15]. Taking into account the relations between the program and its potential audiences, I will explore those practices that, no matter if directly or indirectly, aim at persuasion. How do presentations of specific practices refer to the engineering program of synthetic biology?

Michel Callon, in his attempt to develop a framework of power relations in science and technology, defined such persuasive activities as elements in a process of 'translation' [16]. In these processes, objects are established in designated roles (known as 'enrolment'), in order to become 'spokesmen' of an identity that is imposed on them [16]. Referring to Michel Callon's 'sociology of translation', I will explore two different practices of persuasion in synthetic biology: a) the practice of building objects as models and b) the construction of audiences by visionary claims.

The practice of building objects has been established as a techno-scientific practice in which the context of presentation is important for understanding the research object [17]. Different from scientific practices in the 'old' 'interventionist mode', the context of presentation is the exploration of capabilities and performances in techno-science. Taking advantage of these analyses, I suggest viewing examples of building objects highlighted in synthetic biology as modes of translating 'engineering biology'. This applies particularly to those biological objects qualified as 'tools' in biology, such as the toggle switch or the synthetic oscillator. I argue that the design of such objects can more adequately be described as a heuristic model than simply as a prototype of a 'tool'. By presenting evidence for their implementation, such models are not solely a neutral medium but an element of persuasion in 'building the discipline' of synthetic biology. In this context, techno-scientific objects become 'inscription devices' [18] for a variety of potential futures imposed on them in order to 'define a society' [19].

The second practice of persuasion on which the article focuses is visionary claims. Such visions are widespread in synthetic biology. They range from constructing organisms able to clean hazardous waste [20], producing cheap drugs for treating malaria in Asia and Africa [21–23] as far as to developing novel products and therapies in the pharmaceutical industry [24]. However, only recently it has been argued that futuristic visions are prevalent strategies of persuasion and 'discipline building' in synthetic biology [25, 26]. Most of these visions employ concrete industrial applications to legitimize the institutionalization of synthetic biology. By building historical analogies to the emergence of chemical disciplines, envisioned applications have been used as a legitimizing resource [26].[1]

This article explores textual characteristics and mechanisms of persuasion in these visionary claims by focusing on how relevance is tentatively constructed. Following Callon, such visionary claims orchestrate problems by relating future disciplinary problems to problems of societal audiences. Although the 'visionary' emergence of synthetic biology is widely covered in STS [8, 27–30], arrangements between visions and their roles in the construction of audiences in synthetic biology are paid less attention to. A textual analysis of visionary constructions and their agents might therefore contribute to a more detailed picture in the mechanisms of the uptake of synthetic biology.

By relating the 'displacement' of objects in the disciplinary program and their changing contexts of 'enrolment' in visionary claims, I seek to contribute to the ongoing debate in the sociology of expectations in emerging technologies [31–38]. Referring to Callon's approach, I argue that it is the transformation of biological artifacts as functionalized objects that drives 'enrolment' in synthetic biology.

Consequently, I explore the ways by which the enactment of audiences in discourses about future potentials is linked to the production and functionalization of

[1] Although such visionary practices can be attributed to only a few approaches in the field, these are especially important for the legitimization of the field.

objects and prototypes. Taking advantage of these analyses, I would also like to contribute to the recent discussion on the ways in which future relevance is constructed in emerging techno-sciences [10, 39]. I argue that it is the relation to objects which distinguishes the construction of futures in synthetic biology from other future technology discourses in this respect, for instance from the case of nanotechnology described by Cynthia Selin [31]. The article is structured as follows: In the first section, I provide an overview of the methodology, focusing on how persuasion practices can be studied and how the textual examples in this article have been chosen. In the second section, I elaborate on the techno-scientific making of objects as a heuristic model, using the genetic toggle switch as an example. Subsequently, I explore how society is constructed in various accounts of visionary claims. I conclude by relating these two different practices of persuasion in the framework of the 'sociology of translation'.

Methodology, Persuasion Practices, and 'enrolment'

According to Callon, persuasion practices can be studied by analyzing the way a particular problem is framed to correspond with the authors' intentions [40]. Consequently, STS scholars have examined persuasion practices by applying fine grained argumentation analyses of scientific texts and their transformation in the writing and publication process [41–43]. According to Law and Williams [41], such fine grained analysis is necessary since persuasion is not simply a means of marketing: Rather it becomes deeply related to the structure of the scientific article in that it 'helps to constitute the structure of knowledge, the status of the facts, and their relationships with other findings'.

Hence, studies of persuasion in scientific argumentation aim at studying the means by which scholars attempt to 'make other scholars interested in their identity'. For instance, Law and Williams examined the strategies of a research group to persuade reviewers and editors to accept their view of framing problems. [41] Within Callon's analytic framework [16], four 'moments' of translation are discerned: (a) 'problematisation', (b) 'interessement', defined as a series of processes by which the researchers aim to lock the other actors in the roles that have been proposed for them, (c) 'enrolment', and (d) 'mobilisation'. Whether persuasion strategies can be considered successful, that is, in Callon's terms, whether they were really able to 'enrol' their audience, can only be judged on by taking into account the reactions of the audience.

Callon and Law provide the example of a publication process in which the 'interessement' activities of a research group of German and British scientists, the 'Stiftung-Chinatown group', were unsuccessful with enrolling a particular journal to their identity by showing the reasons why the draft was rejected by the journal. In this case, interessement activities, enrolment and counter-enrolment of the journal could be presented, since the material provided contained information about the proposal given to the journal and the reasons for its rejection [40].

In this article, I suggest to study persuasion practices in synthetic biology by drawing upon two different methodological strategies, combining Callon's approach with approaches of techno-scientific argumentation of presenting objects. Following Callon, I argue that the way in which problems are constructed is most important for persuading the audience. Linguistic patterns of constructing problems and addressing audiences need to be studied in a detailed analysis, since context is needed to demonstrate how persuasive sentences are articulated in a way that the reader becomes allied. The present article concentrates on visionary claims which derive their persuasiveness from making the problem of their establishment relevant for others in the future [33].

There are, however, specific characteristics in argumentation and persuasion in new scientific fields such as synthetic biology that might differ from the cases studied by Callon and others in their emphasis on making things. In these fields, strategies of persuasion can be also revealed by analyzing the way in which specific objects are presented, since that allows to present a specific approach as exemplifying a 'feasible strategy'. I argue that the presentation of specific objects in synthetic biology can be understood as a persuasion practice.

Whether such persuasion practices are successful in 'enrolling' their audience cannot be directly shown. Citation figures and venues of presentation can provide evidence for the acceptance among scientific communities, however.

In order to evaluate the relevance of objects such as the genetic toggle switch for persuasion practices in synthetic biology, the here presented article analyses much cited review articles. It is based on the textual analysis of rhetorical practices in synthetic biology articles and part of a larger study on publication practices in this field which explores the specific role of review articles by means of utilizing scientometrics and methods of qualitative text analysis [44]. The documents were selected by means of citation analysis.

The resulting corpus has been analyzed and coded by applying both inductive and deductive coding strategies, utilizing MAXQDA as one of most advanced qualitative data analysis tools [45]. The main goal of the study is to combine genre-analytic aspects of these documents, presentation of arguments, construction of sentences, and context of references with semantic analysis for the meanings of research, e.g., its value and uses for scientific communities and broader society. That has been accomplished by constructing a seed code system that has been differentiated by further iterative coding steps. Thus, each document has been coded several times. Thereby, each coding enabled for a further strengthening of the code system. In order to yield a systematic account of the material, the codes have been further mapped to identify those categories that have been coded more frequently and those passages where many overlapping codes could be identified. By applying these coding mapping analyses, text passages have been identified where several rhetoric and semantic categories of justification have been coded, indicating the rhetoric effort its authors employed in the texts.

For the further detailed analysis of results, Kuckartz suggests 'individual case interpretations' for some documents that appear important or characteristic in some respect [45: 97]. The present paper follows this approach, focusing on objects such as the genetic toggle switch which are often mentioned in much cited review papers and on frequently coded linguistic patterns of persuasion in visionary claims identified by a qualitative content analysis of review papers [45].

Dealing with Objects in Synthetic Biology

In philosophical analyses of synthetic biology, practices of 'making objects' have been occasionally labeled as techno-scientific [11, 25, 46–48]. In an STS context, using the term applies to both dimensions of knowledge: what kind of knowledge is produced and how it is claimed. Following Haraway [49] in this respect, techno-scientific knowledge differs from traditional scientific knowledge in that it is not aimed at representing nature but at creating objects in which the boundaries between the natural and the artificial cannot meaningfully be drawn [50]. According to the analyses of epistemic objects, such techno-scientific practices are well institutionalized in synthetic biology [11, 50, 51]. New arrangements have been promoted as programs of research outside the traditional disciplinary organization of science in which dealing with devices such as modeling and optimizing represents the core of scientific activity [9]. Nevertheless, it remains unclear how to understand these arrangements in terms of what these objects represent as products of research.

Bensaude-Vincent et al. [17] offer an interpretation of such venues. They claim that techno-scientific objects differ in these occasions in that they are determined by 'the context of their presentation'. Consequently, a dedicated ontology of research objects is concerned with 'how things appear as objects of research' [17]. According to the authors, objects in techno-science are not instrumental to the control of propositions. Instead, they are both part and result of the research [17]. Thereby, objects in techno-science are performative; they become something different throughout the research. Capabilities of objects, not facts about nature are at the core. These capabilities, however, are not neutral. Uses and values are inscribed into these objects which relate to them [17]. Techno-scientific research is thus aimed at unraveling the capabilities of its objects that are useful for specific audiences [8].

Given the widespread practice of 'making' in the field, a focus on how objects are presented in different linguistic and material contexts could be a useful analytical strategy in exploring persuasion modes. Stances of object orientation can be established in the founding documents of the research field. Most prominently, the aims of non-natural objects appear to be meant for persuading techno-futuristic audiences that legitimate new ways of inquiry: To achieve the goal of artificial life, 're-designing" or 'constructing biological systems' are presented in such a way as to legitimate new ways of inquiry [52].

While epistemic practices of modelling, optimizing and building are not identity-related to the discipline of (ordinary) biology, the contrary is true for synthetic biology, i.e., making biological objects represents one of its core concepts/foundations [9, 53]. Proponents of the engineering approach in synthetic biology thus speak of a program of disciplinary transformation, a 'transformation of biology into an engineering discipline'. Such efforts can be dated back to the attempt to introduce abstraction hierarchies in the disciplinary realm of biology.[2] [15, 61] It was envisioned that biological parts, assembled to modules, should perform specific functions independently of their biological environment [56, 62]. Finally, a 'modular biology' will develop in which modules were expected to take over the integrating role the molecule previously occupied in molecular biology [63].

But although these theoretical elaborations of scientific transformations have been published prominently, they did not influence the research community in the first place. That was not due to a lack of scientific reputation [56]. Instead, what was missing was a persuasive approach that engages research findings into the new concept of modules and abstraction hierarchies.

The Toggle Switch as a Model for Functionalized Objects in Biology

Such a persuasive approach has been achieved by the construction of biological models as engineered devices. In the early 2000s, a modular approach was exemplified by specific apparatuses which used DNA strands and plasmids to demonstrate that biological noise could be eliminated. Consequently, new ways of building biology were presented so as to render the engineering of biology possible [64–66]. Several DNA based elements of 'tools' or simply objects have been developed, such as genetic 'switches', 'logic gates' or 'oscillators' [67]. According to Michel Morange, these exemplifications of control partly explain why synthetic biology has been adopted by the scientific community [62]. One of the most successful of these exemplifications was the genetic toggle switch, which represents an easy, but empirically feasible model of a genetic regulatory circuit [64]. How are we to understand the persuasiveness of such objects?[3]

With regard to Bensaude-Vincent et al. [17], this persuasiveness might be understood as its 'context of presentation'. Different from other scientific objects, where context is determined by the exploration of capabilities, the functions and capabilities of the toggle switch seem to reach beyond that goal. Its epistemic function, namely, is not only to exemplify 'that something works' but to represent a heuristic model of how one should understand biology in the future.[4]

In my study of publication practices,[5] I have found many references to these models and prototypes in persuasive contexts,[6] indicating their diffusion amongst the research community. In some approaches of synthetic biology, these models have been influenced by the semantics of electrical engineering; both in their vocabulary and the nature of mechanisms employed [11, 12, 61, 70]. The toggle switch fits into both of these categories: Firstly, the semantics of the circuit refer to the basic vocabulary of electrical engineering. In electrical engineering the toggle switch represents the simplest form of an electrical switch. Secondly, genetic regulatory circuits are the means by which mechanisms in biological processes can be explained. These mechanisms, however, have seldom been applied to a concept in biology; particularly since 'control' or even 'law' is not a dominant scientific category in that field [71]. What was different in that case?

[2] In some accounts that aim at proposing the disciplinary program of synthetic biology one refers to a 'prehistory of synthetic biology' [2; 8]. Such a claim of continuity can often be found in scientific fields in early phases of their formation [54, 55]. This 'prehistory' is identified with the first occurrence of the term synthetic biology in the early 20th century [56: 50]. Most of these usages date even back to the time before 1920 [57: 230]. At that time, Jacques Loeb and Stephane Leduc aimed at establishing a 'technical biology' with the ultimate goal of constructing synthetic organisms [58, 59]. Biological organisms in this respect were thought of as ‚chemical machines' [59]. The thoughts of Leduc and Loeb, however, were mostly refuted by their peers at that time [see 57]. Nevertheless, this small episode is exploited to speak of a 'renaissance of synthetic biology' in the very recent development of the field [60].

[3] The 'persuasiveness' of objects should not be considered a strategic and intentional action of synthetic biologists but rather the outcome of a techno-scientific practice. I am grateful to reviewer comments for this clarification.

[4] Very recently, a new approach at the boundaries between conceptual history and STS has emerged that focuses on the epistemic quality and performativity of such heuristic models [68, 69]. Drawing on examples of different scientific fields, Benoit Godin argues that such models have many more functions than just translating research questions into propositions that provide a model of reality. On the contrary, heuristic models can be understood as a means of persuasion that relate their phenomenality to a specific semantic repertoire.

[5] See methods section for further details.

[6] These are particularly strong, for instance, in introductions and conclusions of review articles. (Swales 1990; Swales 1989). By the time this paper was being drafted, the article by Gardner et al. (2000) had been cited more than 1,750 times (Source: Web of Knowledge), 1,692 citations being listed in the Web of Science Core collection (provided by Thomson Reuters). According to the Web of Knowledge User Interface, 283 of these citations stem from articles with the document type 'Review Article'. (Date:10/12/2015).

The use of this kind of semantics is persuasive: It represents the idea that biological processes, though interrelated and complex, can be redefined as elements of control.[7] Consequently, such models can be understood as means of persuasion that 'control' in biology is a feasible goal. Such a persuasive meaning, indeed, can not only achieved by the authors of the toggle but needs to be understood as a collective work of reinterpreting these ideas one finds, for instance, in review articles. In the following, I will have a closer look at the case of the toggle switch to ground that argument. In order to unfold the interpretation, some building characteristics of the toggle switch will be sketched, demonstrating this DNA based mode of practice [64].

Technically, the toggle switch is constructed on a plasmid – a part of double helix DNA – which can also be separated into two independent strands. On the plasmid, ribosome binding sites, transcription promoters and repressors are arranged in a way to enable for transcription and to stop transcription. In the model, two genetic circuits had been realized that work in an antagonistic fashion. The antagonism is produced by the opposition of these genetic circuits, which are related in such a way that they repress each other's actions which are based on two simple mechanisms: By introduction of the first inducer, repressor 1 is activated while promoter 1 is at the same time blocked from transcribing repressor 2. As a consequence, promoter 2 can transcribe without disturbances. Analogously, the process works by introducing inductor to repressor 2 on its specific binding site. This system of repressible promoters can be influenced by the induction of heat or chemical substances [64]. By changing the position of the ribosome binding site, the velocity of the transcription can be changed. Furthermore and aside from producing repressor 1, promoter 2 activates the production of the green fluorescent protein (GFP) which takes over the role of the reporter in contemporary molecular biology [72]. Now the state of the switch becomes visible by the green color of the protein and has consequently reached its high state, while in the low state no color appears [64]. Consequently, the states of the genetic circuits are visible to the scientific observer. What has been accomplished with the toggle switch is the construction of an empirically tested toggle with two stable states in a component that is well known in the life sciences, the Escherichia coli bacterium.

I suggest viewing the genetic toggle switch as a model of how object creation in bioengineering becomes a new way of making claims. The toggle switch is a perfect example of techno-scientific research practice by means of presenting the object [17]. What does the toggle switch represent? The toggle switch does *not* represent a world out there. With its design Gardner et al. did not aim at exploring new characteristics of the bacterium or to learn about biological complexity in the transcription process. Instead, the toggle switch is presented in the context of translating the engineering concept of 'functional implementation' in a context where it is usually not used. Precisely, the goal of the toggle switch is to biologically implement the function of 'robustness' into the 'stability' of different cellular biological states: 'By robust, I mean that the toggle switch exhibits bi-stability over a wide range of parameter values and that the two states are tolerant for fluctuations' [64]. By translating robustness into a model of biological control, the genetic toggle switch becomes a model of what implementing a function could mean in biology. Hence, the toggle switch is persuasive in translating the idea of functionalities: The capacity to produce stable states.

By referring to Callon's concept of 'translation' [16], it can be argued that the genetic toggle switch is a way of bringing objects into concepts resembling a new techno-scientific research practice of biological engineering. By materializing the design of a genetic mechanism in a toggle switch, the toggle indicates that control of biological processes is possible. Callon interpreted such an argumentative strategy as 'interessement', meaning 'attempts to impose and stabilize the identity of the other actors it defines through its problematization' [16]. These strategies enable power in that they extract or displace certain objects from their contexts. In the case of the genetic toggle switch, displacement and extraction can be seen in the diverse strategies to make the different states 'tolerant for fluctuations'; that is, to extract them from their context of biological noise. In its intent to introduce the idea of 'building'

[7] These are complemented by attempts to baptize the field. Notions of control have influenced considerations as to how this new approach can be legitimately named. The first scientific actors therefore labeled these efforts as 'intentional biology' in order to demonstrate that nature can be transformed into a resource by constructionist approaches.

objects in biology, the toggle switch encompasses the existing heuristics by minimizing recalcitrant external sources.

The model of the toggle switch has been given much attention throughout the research field. For instance, we find references to the model in many attempts of delineating synthetic biology.[8] Many of these accounts claim its contribution to the field.[9]

What makes the toggle switch successful? From our perspective of persuasion, the role of the toggle switch in the establishment of synthetic biology as a 'community of claims makers' is that it is capable of being both: a model of how to 'translate' the engineering metaphor of electrical engineering into biology and an object that uses DNA based elements well known to the addressed audience. The technology of the toggle switch is easy to reproduce, while at the same time inspiring in that it triggers conceptualizations of control and systemic independence. Consequently, in Callon's terms, the goal is that the genetic toggle switch becomes a 'spokesman' [16] for the 'engineering biology' project.

Yet, the design of the genetic toggle switch alone is not able to 'speak' for the materialization of functional biology in the future. The use of objects as exemplifications of a specific scientific engineering mode transcends the actual research performed in the models. Therefore, objects of control like the toggle switch are implicitly related to visionary claims of synthetic biology. To 'enrol' other scientists, scientific claims need to take up notions of future relevance.

Scientific claims of future relevance are thus a second source of persuasion which will be analyzed in the next section.

Resources of Enrolment in Visionary Claims in Synthetic Biology

Visions of technical futures are a particular feature of science. Science and technology have always been driven by visions and 'Leitbilder' of their imagined technical futures [73, 74]. Increasingly, however, visionary claims become the communicative settings in which technical objects are accessible to larger societal audiences [33, 75]. Future scenarios are the venues that gather proponents of scientific and technological changes. Various contributions to the debate within the Sociology of Expectations have reconstructed in what ways different media in emerging fields employ visions of the future to justify their claims [31, 35, 76].

Visionary claims therefore aim not only at making meaning of past and future activities. Instead they aim at binding audiences. They do so by making a problem in the future - e.g., an epistemic problem - a key to other problems which relate to these audiences.[10] This mode of persuasion influences the ways in which the notions of science and research are understood: By orienting epistemic problems to envisioned future needs, visionary claims in emerging technologies shape the notions of either basic or applied research to the more general notion of relevance [39, 77, 78]. Boundaries between basic and applied research become blurred. Several studies have explored how these notions of relevance are constructed around concrete 'matters of concern' [79].

In order to show this persuasive mode of visionary claims in writing, I will focus on the microstructures of text passages, on how they address their audience and thereby construct societal relevance. I have analyzed a sample of publications selected on the basis of citation rates within the scientific community of synthetic biology.[11] As an opportunity for analysis I identified review articles that aim at delineating the field. These types of documents were used in order to study the persuasion

[8] The Article has been cited 283 times according to Web of Science. See footnote 5 for details.

[9] One very recent example is an article entitled: 'Designer cell signal processing circuits for biotechnology '(Bradley et al. 2015) In its abstract it says: 'Great progress has been made in expanding the categories of characterized biological components that can be used for cellular signal manipulation, thereby allowing synthetic biologists to more rationally program increasingly complex behaviours into living cells. Here I present a current overview of the components and strategies that exist for designer cell signal processing and decision making, discuss how these have been implemented in prototype systems for therapeutic, environmental, and industrial biotechnological applications, and examine emerging challenges in this promising field.' Consequently, the article shows how the term 'characterization' becomes legitimately introduced in synthetic biology through the exemplification of the toggle switch and the oscillator to which the article refers.

[10] Michel Callon labeled such a mechanism the 'obligatory passage point' in his 'sociology of translation' [16].

[11] The main goal of this step is not to describe all publications but to identify the review documents for a detailed analysis. The criterion for the identification of the review articles should be their influence on the scientific community. I chose 'times cited' (as offered by web of Science) as the main criterion for selection. Although it is often contested in the bibliometric community, citations are still the main indicator for that attribute. Furthermore, citations are also the main focus of attention for scientific publications in extra scientific audiences.

modes on a micro level. Besides the goal of delineation, a purpose of most of these articles is to present synthetic biology to a broader audience. Based on methods of qualitative context analysis which have been described in the "Methodology" section of this article, I coded the material to identify linguistic and structural characteristics of the documents. In a second analysis I specifically focused on those text passages that employed persuasive strategies, that is, on text passages that aimed at framing a given problem. In many cases, these specific text passages have also been coded with regard to their rhetorical characteristics. Thereby I identified characteristic writing practices that directly relate the attempt to delineate synthetic biology to the attempt to provide the research field with orientation. Interestingly, these passages that employed programmatic speech have been also coded as textual markers for visionary claims of scientific, technical or societal futures of synthetic biology.

Taking into account the scientometric metadata of these documents, these visionary claims appear to be highly visible, in the sense that most of the visions about future uses of synthetic biology are embedded in highly cited publications.[12] Hence, the attempts to delineate the field function as loci or occasions of programmatic statements and communication towards a wider scholarly and non-scholarly audience.[13] In the following, some characteristic text passages are analyzed that highlight particular characteristics of the persuasive mode of visionary claims in the field.

I present three different examples of visionary persuasion in synthetic biology that have been derived from a larger body of highly cited review articles[14] and which have been chosen because of their specific textual characteristics. Drew Endy's 'Foundations for engineering biology' represents the most important foundational publication that aimed at establishing the field by utilizing engineering methods. The second text passage is taken from Andrianantoandro et al., who refer to established engineering disciplines as a reference for synthetic biology. The third text passage is taken from Purnick's and Weiss' review and envisions a second generation of engineering in synthetic biology that is more oriented towards the design of biological systems than on isolated modules. All three articles are highly programmatic in that they aim at orienting the field by referring to engineering either as a 'foundational tool' or as a specific mindset. Hence, the chosen articles cannot only be considered much cited documents but also to be highly influential for the intellectual development of the field. Accordingly, these texts can be perceived as highly persuasive texts, since they managed to 'enrol' different journals and different authors into their identity.

Persuasiveness in these passages will be studied according to three aspects. Firstly, it will be studied how the different claims of scientific, technical or societal futures address the audience. In the context of persuasion, addressing the audience can be understood as establishing the author-reader relationship through different modes of designation [83]. Such an approach refers to an established tradition of studying science rhetoric [42, 84–86]. According to Law and Williams, persuasive sentences (usually at the beginning) need to provide a 'context with which the reader can be allied' [41]. Concerning the textual type of visionary claims, I will highlight in particular how the audience is referred to, which audience is addressed, and in what terms.[15] Secondly, persuasiveness will be studied by means of how problems are constructed, i.e., to whom they relate and what the implications of these constructions are. Visionary claims of scientific or technical futures, it is proposed, derive their persuasive potential by making the problem of their establishment relevant to others in the future (Brown 2003); thus 'enrolling' the audience by the way in which a particularly problem is framed [40]. Yet, it cannot be directly shown whether 'enrolling the audience' has been achieved. However, citation figures present evidence of the acceptance these publications gain among various communities. Thirdly, persuasiveness will be studied by the ways in which both of these aspects, the construction of audiences and the construction of problems, change over time. The

[12] It is known from studies of scientific popularization and public understanding of science that citations also influence media coverage and will consequently also reach other, non-scientific audiences [see, for instance 80]. That may be an explanation for why visionary claims can be often found in review articles in synthetic biology which are usually much more often cited than other forms of scientific texts [81, 82]. In synthetic biology, review papers make up an untypically huge part of the publications in the field [44].

[13] In a similar vein, Elena Simakova interpreted the engagement of researchers in interviews as the settings about future stories in nanotechnology as a means of 'making nano matter' [39].

[14] Results of the study are not presented here, but the methods section provides an overview of the general approach.

[15] Other approaches dealing with the textual aspects of persuasion are [41–43, 87].

following text passages are thus representative for the different periods in the establishment of the field.

The Early Period: Drew Endy's Vision

In the early period (2002–2005), the field of synthetic biology is driven by strong visionary claims aiming at establishing the field. A prominent example of that 'establishing use' of pathetic speech in visionary claims is Drew Endy's presentation of synthetic biology as a means to efficiently serve human needs [4]. Endy was highly influential in pushing forward the idea of an 'intentional biology' specifically designed to fulfill human purposes [26, 61]. Therefore, Endy mobilized enormous rhetorical resources to persuade audiences of the necessity of understanding biology as a 'foundational technology':

> Many times over, individuals and groups have adapted and applied different resources from nature to the service of human needs such as shelter, food, health and happiness; notably, natural resources are limited while our need in aggregate, maybe unbounded. In this context, we should attempt to develop foundational technologies that make it easier and more efficient to satisfy human needs" [4].

By relating the text to the proposed scheme of persuasion, I identified a distinctive pattern in the text. Firstly, by regarding the construction of the audience, Drew Endy lays out a strategy which is quite unique: The audience is not addressed in the modern terms of 'society', but in the universal sense of humanity. According to Perelman and Olbrechts-Tyteca [88], such an account can be framed as a means to construct a *universal audience*.[16] That strategy typically applies to the kind of speech that aims at binding divergent perspectives. Jeanne Fahnestock argues in her study on the use of rhetorical traditions that universal images often employ analogies to religious narrations [89]. One can find such analogies to religious narrations in the text with the semantics of creation: By highlighting the differences between natural resources and unbounded needs, the text passage appears to refer to the Christian notion of humans as creators that do not adapt to but change their biological niche. By referring to the universal history of human creation, Drew Endy places synthetic biology in the context of transforming nature. In that context, nature is understood as a resource for human purposes. It is these purposes - 'our needs' as humans- which transcend and encompass the space of possibilities provided by nature. The advantage of such creational discourse in rhetoric is that such discourses provide resources of legitimation [90].

Consequently, the way in which the audience is addressed in Endy's vision employs narrative elements. In narrative theory, narrations are conceptualized as elements aiming at deepening the relationship between the author and the reader. The connections between authors and readers are achieved through the use of a common story as social knowledge. Empirical research has revealed that these strategies often yield more persuasive effects [91].[17] The story in Drew Endy's text is about humans who begin to adapt to their biological niche and finally come up with shaping their environment. Referring to a pattern of religious texts [92], Drew Endy connects the past, the present and the future. Thereby, the text produces a circular image of temporality[18] ('many times over' instead of 'in former times') that, at first sight, opposes a linear semantic of scientific progress. It is the marker of 'in this context' which reminds the reader that a circular pattern might be dissolved. By establishing the claim of 'attempting foundational technologies,' the cumulative and linear image of science is reconstructed. Synthetic biology is engaged as a powerful tool in the construction of the future for humanity. Hence, the way in which synthetic biology is introduced shows elements of 'grand narratives'.[19] Grand narratives are often parts of programmatic

[16] According to Perelman and Olbrechts-Tyteca, this refers to the 'choice of presentation' which is one element by which the persuasiveness of the discourse might be improved. They argue that the presentation of the arguments, their style and interpretation needs to relate to the audience's preferences [88]. Of course, again, such an effect on the audience cannot directly be studied in textual analysis alone but needs to be complemented by analyses of how the audience reacts to the presentations of claims [76: 868].

[17] The results suggest that audiences are more willing to accept normative evaluations from narratives than from logical or scientific arguments [91: 13616].

[18] Temporality is an important aspect of building future expectations. Cynthia Selin in her study on the emergence of the nanotechnology discourse holds that the temporal distance is only implicitly incorporated in visionary claims: 'The recourse to time built into an expectation can be short or longer term, yet is rarely made explicit' [31: 211].

[19] Examples of these 'grand narratives' are typically legitimating narrations such as 'the natural state' treaty in the 17th century.

rhetoric that offer choices to create a bond with a new community [93].

Secondly, following the proposed model of persuasion, I am interested in how problems are constructed in the passage. The textual strategy appears to be quite unique also in this respect: the terms 'problems', 'challenges' or even 'diseases' do not appear. Rather, the author uses the term 'needs' in order to convince others of taking up the claim of establishing foundational technologies. Usually, by the term 'needs' basic needs are associated, things that are necessary for survival. By relating the term 'needs' to the quality of 'unboundedness,' such an association is extended to other objects that could make human life more valuable. Furthermore, the unboundedness of needs is presented as the reason why a strategy of adaptation to nature might not succeed. Consequently, foundational technologies are presented as solutions to the problem of unbounded needs. Foundational technologies are presented as a superior strategy: Such technologies are not only feasible but also 'more efficient and easier to accomplish to satisfy human needs'.(ibd.) In the context of scientific persuasion, of producing 'arrays' that can be taken up by scientific readers, such constructions are mechanisms of value allocation: the value proposed for one such person or event is a function of its position in that array' [41]. Contributions to general human needs are a characteristic pattern in publications of the first period of synthetic biology. Through that construction of the problem, the disciplinary program of engineering biology becomes related to the possibility of human life with unbounded needs. By referring to Callon, the text tries to 'interest' other issues into the disciplinary program.

To sum it up, the text passage in which the visionary claim is embedded shows similarities to religious texts, approaching the audience by the use of 'pathos'. Such a format can often be found in contexts where new issues or topics are established. The example demonstrates the rhetorical effort that is mobilized by using pathetic speech and a narrative textual structure. Since such patterns emerge in the early phases of scientific movements, Bensaude-Vincent interprets the text as a means of discipline building [26]. However, there are also other texts in which synthetic biology can be understood as a means to pursue Synthetic as a distinct disciplinary project[20]: In the early 2000s, a series of programmatic statements was published that tried to present to what ends synthetic biology should be pursued [2, 4, 52, 94].[21]

The Second Period: Synthetic Biology and the Scientific Community

Publications after 2005 refer more directly to the effect synthetic biology will have upon other scientific disciplines. In this second period, the transformative effects of 'putting engineering into biology' are highlighted.

> Synthetic biology will revolutionize how we conceptualize and approach the engineering of biological systems. The visions and applications of this emerging field will influence many other scientific and engineering disciplines, as well as affect various aspects of daily life and society [2].

The audience is addressed by the utilization of the personal pronoun 'we' in the first sentence. By providing context, it becomes obvious that primarily a scientific audience is addressed. The audience is constructed in a way as to transgress the boundaries of molecular engineering, by stating that 'many other scientific and engineering disciplines' may be affected through synthetic biology. Consequently, not only biological but also engineering communities are part of the audience. The way audience is addressed in that small passage is direct and not narrative; there are no elements of pathos or religious speech.

Consequently, the problems are constructed in order to refer to these scientific audiences. Again the term 'problem', 'challenge' or 'quest' does not appear in

[20] The label 'synthetic biology' emerged as a term to conquer that niche of disciplinary transformation. Campos explored how the term 'synthetic biology developed among biologists and biotechnologists to establish a transformation of biology. Initially, the new program was supposed to be labeled 'intentional biology', a concept which was put forward particularly by Drew Endy and Robert Carlson [61]. As biologists refused to accept that all previous biological research might be labeled 'unintentional, the term' ' synthetic biology' was introduced. Hence, the initial aim to underline the engineering effort is less obvious.

[21] Bensaude-Vincent has uncovered that besides 'putting engineering into biology', 'chemical biology' was another disciplinary project by way of which synthetic biology was supposed to be be oriented to follow the model of Synthetic Organic Chemistry [95]. Benner and Sismour are the main scientific actors that pushed forward these ideas, but others followed them by relating synthetic biology to its envisioned disciplinary ancestors [21].

the text. Instead, what one can find are solutions to problems that are not made explicit. Different from Drew Endy's vision, the contributions of synthetic biology are placed in a purely scientific context. Interestingly, these contributions are not only theories and methods but 'visions' and 'applications'. By claiming a change in the conceptualization of what 'engineering of biological systems' could mean, the text indicates that an engineering approach can be perceived as a scientific challenge. This might be interpreted as a means of 'interessement': [41]. The passage is constructed in order to include those interested in 'engineering'.[22] The emphasis, however, is not put on the problem but on solutions of the field and their impact upon other scientific fields and society. The impact of synthetic biology is the perception of problems in other disciplines. By claiming the importance of the visions of synthetic biology, the main influence of synthetic biology upon science is its ability to imagine potential scientific and technical futures. In other words: visions are perceived to be the most influential part of the methodological program of synthetic biology.

As concerns the language used, the text appears to be more stable than the first example. There are no changes in tense and collectivizing speech. The author constantly uses the future tense by using the will-future to clearly express that the future impact upon science and society is really going to happen. Furthermore, the choice of words relates to the futuristic discourse: Changes and transformations are going to be disruptive in the way that synthetic biology will 'revolutionize' the way in which engineering biology can be practiced. To sum it up, the text seems to express more similarities to political texts in which the use of science for society is more indirectly expressed.

Synthetic Biology and "Societal Challenges"

Finally, in the third document, visionary claims are also related to meta-scientific concepts [96] and social-political semantics of 'challenges' towards which science ought to be oriented in the future to produce relevance [97–100]. In the corpus of documents I have analyzed I found various accounts of how synthetic biology shall be established to contribute to proposed challenges of global 'human health' [101] and 'environmental challenges' [102, 103]. In these accounts, the usefulness of synthetic biology is exemplified by the promises of contributions to the most pressing problems:

> Synthetic biology has the potential to transform how we interact with our environment and how we approach human health. (…) synthetic biology has the potential to fabricate practical organisms that could clean hazardous waste inaccessible places, to use plants to sense chemicals and respond accordingly, to produce clean fuel in an efficient and sustainable fashion, or to recognize and destroy tumors [104].

Similarly to the second example, the audience is addressed by using the first form plural. Contrary to the second textual example, this usage is more extensive ('how we interact, how we approach'). Such a repetitive pattern seems to indicate that the text strategically aims at establishing an author reader relationship. However, it remains unclear which audience is referred to. Different from the first example, it is not obvious whether scientific audiences or other realms of society are addressed. Is it a specifically scientific community? The phrase 'how we interact with our environment' seems to contradict this interpretation. It seems that the text does not intend to address a universal audience of humanity. Instead it may be the universal audience of natural sciences to which the text passage refers: The production of fuels, the recognition of tumors, the cleaning of waste and the sensing of chemicals are mentioned. The effect on the reader is that the appeal becomes more inclusive. Thereby the text seems to employ similarities to political programs in which terms are constructed in a way as to connect many different communities.

In consideration of temporal aspects, it is interesting to note that the authors use the present tense instead of the 'will' future in the preceding example. The futuristic discourse is indicated by the utilization of the term 'potential' in the whole passage ('synthetic biology has the potential'). On the one hand, the utilization of 'potential' can be understood as a means to hedge a visionary claim [105].

On the other hand, the term 'potential' does also relate to the way in which problems are put in the text. Contrary to the second example, the term 'potential'

[22] Similarly, Law and Williams interpret the opening paragraphs of the DIVEMA group article as a tool to bind to the program: ‚The aim is to mobilize those with an interest in chemotherapy. An array of claims and hypotheses about Divema and its compounds is so designed as to be attractive to those concerned with the chemical treatment of cancer [41: 540].

more clearly relates to the problematic nature of science: 'Potential' indicates in that context that desirable changes are only going to happen if the subject will gain sufficient resources. The problems of synthetic biology, hence, are related in a way to refer to other problems. According to Callon, problems with the establishment of synthetic biology are obligatory passage points; problems of synthetic biology are constructed as problems of other scientific communities. It is interesting that the nature and the semantics of these problems relate to recent debates about scientific usefulness [106–108]: The debate on societal challenges. For instance, the phrase 'how we interact with our environment and approach human health' can be easily associated to that discourse. The great challenges of environmental change and global health are addressed at the same time. The reference to these meta-scientific concepts makes the problem appear more legitimate and may consequently influence how the relevance of the proposed contribution towards its solution is perceived. The claim can thus be indirectly read as a request for support beyond the scientific community.

Finally, the authors establish the idea that synthetic biology will respond to 'challenges' by engaging objects that will solve these problems. Through engaging objects, the picture of the potential future becomes more concrete than in the previous example. The textual strategy has the character of a promise that is hedged by utilizing the word 'potentials'. The persuasive character of the 'promise' is that it is objects that will do things for us. As 'practical' organisms produced by nature, these objects are artificial and natural at the same time. They will engage hazardous waste, sense chemicals, and fight cancer. This is a society in which problems are solved by objects, though hired by the Synthetic Biologist. Thus, the envisioned future society becomes more concrete through the 'nature' of these objects [109].

To sum it up, all of these three accounts of visionary claims in synthetic biology display a persuasive character. They intensely utilize a repertoire of established policy concepts in order to reach their audiences. Yet, the way in which visionary claims are expressed to relate to problems and the way in which audiences are addressed by visionary claims change throughout the emergence of the specialty. The audience in the different cases is constructed as humanity, as a scientific community or as a society. In addition to that, the ways in which problems are constructed are different in the examples: It is instructive how the problems of the audience itself become increasingly more precise: They become more closely related to a particular audience. But the construction of problems becomes also more legitimate - in terms of the authoritative semantic repertoire of societal problems. Also, the rhetorical means to support visionary claims become more related to socio-historical aspects such as great challenges [69, 110]. Consequently, different narrative patterns are utilized throughout the different periods. It seems that the persuasive character of the texts becomes more prominent with the increasing establishment of the discipline.

Thus, visionary claims seem to become more strategic by aiming at 'enrolling' other items and problems into their identity. However, the visions themselves and their temporal qualities are not hedged [105, 111] in order to be responsive to the expectations of scientific communities.[23] Referring to Callon's account [16, 40, 112], the chosen textual examples of visionary claims indicate that one of the reasons for a successful enrolment might be seen in the integration of specific concepts eligible to construct the legitimacy of the problems engaged to persuade.

How do these findings relate to a 'persuasion tale'[24] of synthetic biology we want to tell? What is specific in the persuasion regime of the field?

A Society with Synthetic Objects? Strategies of Enrolment in Synthetic Biology

In the preceding sections I have introduced two different epistemic practices of synthetic biology: Creating biological objects as models for control, exemplified by the genetic toggle switch, and the mechanisms of persuasion in visionary claims of the field. In Science and Technology Studies, both forms of epistemic practices have been explored separately as a feature of contemporary techno-science. Is there a connection between the

[23] This might contradict Cynthia Selin's observations regarding the strategies for acquiring legitimacy in nanotechnology [2]. Selin claimed a two-headed strategy of visionary communication: Scientists use the distant future and its promises to gain funding and legitimacy with politicians, but continue to reject the vision when seeking legitimacy within their own communities of practice (…) [2: 213].

[24] The term 'persuasion tale' was used in order to refer to the 'tale of emergence' of synthetic biology, a term employed by Molyneux-Hodgson and Meyer [28].

presentation of models as objects and the writing practices of 'goals posing'?[25]

Epistemic objects such as the genetic toggle switch function as a persuasion model for the community of practitioners. The idea of a switch represents the control mechanical engineering provides to its addressees while at the same time translating the concept by using elements belonging to the world of molecular engineering. It gives proof to the claim that biological interactions can be described as objects. Objects like the genetic toggle switch take the form of prototypes without which one cannot know what is possible. Such 'tools' represent the idea of *making* 'biological systems".

n accordance with the perspective of the sociology of translation, these epistemic objects have an even wider function in the arrangement of synthetic biology as a disciplinary program: They enable for the re-labeling of elements or basic units: By making DNA elements into tools, basic units in synthetic biology are described, according to the engineering paradigm, as being objects, not interactions. That is the prerequisite for what Callon described as 'enrolment'. In order to build alliances in the scientific community, the relations of the objects in a set of statements need to be strengthened: 'No matter how constraining the trapping device and no matter how convincing the argument, success is never assured. In other words, the device of interessement does not necessarily lead to alliances, i.e., to an actual enrolment. The issue here is to transform a question into a series of statements, which are more certain' [16].

In visionary claims about societal and technical futures, objects are enrolled as components for the construction of the disciplinary program of synthetic biology. Without the re-labeling of objects for the goal of functionalization such an attempt would certainly not have been plausible to the engineering community. The transformation of objects is an indispensable prerequisite for the construction of the program of synthetic biology.

I argue that the epistemic practice of translating engineered objects as models of control into the realm of biology catalyzes visionary claims which, in turn, engage these models as their objects. Object oriented practices are therefore inscribed into claims about the scientific future: The use of objects as exemplifications of a specific scientific engineering mode transcends the actual research performed in the models. Recently, these scientific practices have been coined 'proof of principle activities' in synthetic biology [8]. Instead of producing the desired end product or innovation, the 'value' of these practices for the epistemic establishment of the field 'lies in proving that synthetic biologists were correct to think it was possible to create something' [8].

But the definition of objects has also consequences for the disciplinary program as a means of 'defining society' [19]: By presenting tools for making the building of objects possible, the potential futures take a more concrete shape. It is a society with objects in which they behave to respond according to human needs. It is the bacteria that will clean hazardous waste for us and realizes the potential of synthetic biology by constructing the future of a society which will be able to tackle its environmental problems. The transformational promise of 'putting engineering into biology' is linked and reassured by such a conception of society. In other words: the disciplinary projects pushed forward by Drew Endy, Rob Carlson and others aim at defining a new role for science of biology in a society in which biological objects have a say in responding to challenges. On the other hand, the meaning of society is also more stabilized by the challenges which are addressed through these objects, demarcating 'society' in the notion of 'relevance' [39]. They are the means by help of which societal relevance is constructed. It is therefore the objects which can be more easily related to concrete 'matters of concern' [79].

The most binding disciplinary projects in synthetic biology propose themselves by justifying their research through the value they provide to society. Bensaude-Vincent et al. identified this value orientation with the techno-scientific mode of research where capacities of objects are to be explored instead of proposing facts about nature. Exploring these capacities cannot be distinguished from the context which provides its value. Consequently, the capabilities of objects do also depend 'on what humans think and do' [17]. Different from other disciplinary programs, values in synthetic biology seem to be influenced by the way in which objects are presented and posed in research. The attempts 'to define society' [19] are more strategically inscribed into

[25] In an interview with a leading scholar in the field, the interviewee complained about this writing practice in synthetic biology. 'Even in the first PhD papers', he admitted, (…)'you will find these sentences about what synthetic biology aims at and how it seeks to contribute to certain problems. If you think of cancer research, you will soon find how strange that is: No one would expect you to begin an article by 'cancer research aims' or 'cancer research contributes to" [113].

specific objects. Consequently, their value for generalized audiences is constructed in such a way as to show that they are more strongly intertwined.

Such a pattern of enrolling objects in visionary claims making distinguishes synthetic biology from other emerging techno-scientific fields such as nanotechnology. Indeed, many accounts of nanotechnology and Nanobiotechnology refer to the needs of society in the way that 'the concept of nanotechnology is bound not simply to a quality of scale (…) but also to a social characterization that accompanies the technology' [31] or to other 'societal benefits' [114]. But these relations remain rather unspecific, especially in situations when future stories about societal relevance are told.[26] On the occasion of scientific or technical futures,[27] 'nano' is not engaged in employing a specific topic in the ways in which future societal needs shall be addressed [39]. In other words, it remains unclear which society is addressed through the use nanotechnology because of competing disciplinary projects.

The differences between the societal meanings of the term relate to the construction of the disciplinary identity. While many observers agree that Drexler's role in establishing the discourse on nanotechnology cannot be overstated, his disciplinary program did not succeed in the sense that it was taken up by a larger community [31]. In fact, his vision of a new science of a 'molecular manufacturing where atom by atom control of product structures guide a sequence of chemical reactions' was frequently cited but his imagined expectations were not shared [116]. Consequently, Nanotechnology has been finally established as an umbrella term for the convergence in the unit of analysis, yet the 'meaning' of the term did not relate to a dedicated disciplinary program. Or as Cynthia Selin put it: 'We can see that Drexlers term was taken up, but the second battle of maintaining the meaning was lost or misplaced. Part of this defeat deals with the space for others to own the term' [31]. Currently, the meaning of the term has been made 'to symbolize the state of the art of small technology in many discrete disciplines' (…) The revolutionary character proposed by Drexler is misplaced, and nanotechnology becomes instead a widely dispersed, nearly unidentifiable domain that lurks everywhere at the same time – a poltergeist [31].

Contrary to that, the term 'synthetic biology' employs more semantic stability in the sense that putting engineering into biology can be identified as the dominant representation throughout various empirical studies [10]. Despite the many different categories and approaches that seem to indicate heterogeneity in the field, the semantic representation of synthetic biology among other communities seems to be much more bound to a concrete methodological program.[28] In synthetic biology, practices of persuasion employ a sharply demarcated disciplinary program to enroll other scientists.

Vagueness, however, seemed to be a strategic element for the disciplinary construction of nanotechnology. According to Greg Myers, the strength of a vague terminology is that 'terms and interest of one group (can) to be translated into ones of another group' [118]. In the case of synthetic biology, however, the attempt to define society is based on the 'transformational promise' to reconfigure biology. The term 'synthetic biology' cannot be understood as a flexible strategic resource [39] like the 'Nano' prefix. Consequently, a minimalistic strategy comparable to nanotechnology cannot be pursued. Instead, the disciplinary claim of synthetic biology needs to be more strongly legitimized by resources eligible to translate the identity to other audiences. The presented practices can be understood as resources in that process. Biological processes need to be translated into objects and presented to relate to specific contexts in which a society that is defined by using these objects becomes relevant.

This context also affects the role visionary claims have in the construction of the disciplinary program: Visions in synthetic biology take more concrete stances towards their objects and seem to be fundamentally related to their disciplinary program, of which engineering seems to be the most prominent one. This may explain why- as I hope my study to show- defining goals can be considered to be the most elaborated written practice in the analyzed corpus of review articles.

[26] This does even more apply to 'Converging Technologies' [115] as another concept that has been introduced to the science policy interface with the attempt to follow the footsteps of nanotechnology. Whereas many technological developments can be related to the concept (1202008), no dedicated epistemic practice has been established.

[27] Simakova explored various sites where such societal relevance can be addressed, most of them not oriented only towards scientific but other societal audiences such as instance technology transfer offices or educational programs.

[28] According to Calvert and Fujimura [117: 160], the search for a binding disciplinary program in the realm of other sciences can be interpreted as a means to achieve greater epistemic credibility.

Conclusion

In this article I have tried to interpret how two different epistemic practices in synthetic biology act in translating the disciplinary program of synthetic biology which has been prominently framed as 'putting engineering into biology'; the practice of 'making objects' and the writing practice of posing 'visionary claims'. Following Callon, I have argued that both of these two practices can be interpreted as to how they relate to persuasion. Persuasion can be either interpreted as the specific context of presentation of the design of objects [17] or as the textual aim of visionary claims [40, 41]. Both of these strategies aim at different audiences but contribute to the 'enrolment' of elements into the disciplinary identity of synthetic biology. However, 'persuasion is a tentative matter, a constant attempt to propose a set of relationships and values' [41]. Consequently, I found that the establishment of synthetic biology can be understood as a complex interplay of different forms or 'modes of persuasion'.

The first mode of persuasion could be labeled 'presenting objects as heuristic models'. By presenting objects as the heuristic model of an idea, not only the idea but also the way in which the claims are made become legitimized.

By relating to a particular example of the toggle switch, I tried to reconstruct how the design of the switch translates the engineering idea of implementing a function into the biological context. Referring to the ontology of objects [17], I found that the presentation of the toggle switch is persuasive in that its techno-scientific exploration of capabilities, e.g., the capability of robustness or stability, is presented in a context where it has not been used before. Accordingly, the design of the switch has inspired researchers exactly because of the claim that functional implementation has not been pursued in biology. Relating to Callon's 'sociology of translation' [16], the interessement can be understood as an attempt to show that such an approach is feasible despite the complexity and noisiness of biological states. Therefore many pieces of research have the character of giving proof to principal research [8] that is oriented towards legitimating future research in the field.

The second mode of persuasion could be labeled 'the visionary construction of future problems'. Visionary claims in science and technology are often used to bind audiences by claiming their relevance. Consequently, the orientation towards future goals becomes a distinct feature of the disciplinary program: Many accounts of defining or delineating the field refer to envisioned goals of synthetic biology. I conceived these claims as occasions in which the relevance of synthetic biology could be communicated to different audiences. In this article, which is part of a larger research project of mine, I highlighted three textual examples of synthetic biology review papers that employed three different types of visionary claims. According to the mode of persuasion, it was analyzed how the texts differ in the way audiences were addressed at various stages of the emergence of the field.

Having a closer look at these statements, it was found that they employ different claims about the scientific and technical futures. These differences were closely related to the problems of the different audiences and contexts which were addressed. They were placed in the universal space of humanity, the scientific community or in a policy context. I also noted differences in the way in which these audiences were addressed: The first example of visionary claims used rhetoric styles similar to religious text. The others related to existing semantics and rhetoric of scientific usefulness. This is also reflected in the textual structure: Whereas visions in the early documents take the narrative form of a grand history, these narrations disappear in the second period. Therefore, the chosen examples show that the audiences addressed and the argumentative format vary considerably.

More specifically, the examples indicate that the claims for the future of synthetic biology become increasingly attached to debates of problems of their audiences. Disciplinary problems of synthetic biology, for instance, are held accountable to contribute to 'matters of concern' like the great challenges of health and environment in the policy realm [97, 99, 101, 119]. In a societal context where competing expectations about future potentials are raised by scientists and other societal actors, this appears to be a feasible way of communicating the value of the research beyond disciplinary instances. Claims of future industrial relevance are a distinct feature that distinguishes synthetic biology from other approaches in the life sciences, which complements the intellectual indeterminacy of the subject [120].

Thereby, it could be shown how relevance is constructed through the way in which audiences are addressed.

By proposing the interplay between both practices and modes of persuasion, it was claimed that there seems to be a connection between a specific orientation towards objects in research practice and the prevailing visionary claims of future potentials in writing pieces. These can be seen in their contribution to the disciplinary program: By relabeling the basic elements of inquiry as tools, these become objects instead of interactions. It was suggested to interpret these strategies as a prerequisite for 'enrolment'. By analyzing visionary claims, we have seen that the societal relevance of synthetic biology is constructed through the value artificial biological agents provide to society. Although tools of inquiry like the toggle switch do not appear in these situations, they are an integral part of the persuasion regime. Without the 'materialized' idea of objectifying biology, claims of building artificial objects that fight cancer might have lost credibility.

Thereby, I also try to point out how the construction of future societal relevance might differ in discourses of emerging techno-sciences. Different to Nanotechnology, which has only been used as an umbrella term for diverse practices on a specific scale of research [47], some accounts of synthetic biology claim to reach disciplinary status [26, 95]. Whereas the relevance of nanotechnology does not appear to be specific in the textual claims because of the 'strategic vagueness' [118] of the term, the future relevance of synthetic biology becomes more concrete by the enrolment of objects. The transformative power of synthetic biology can be described more adequately by investigating the changing construction of its objects. The key is to analyze how these objects and their underlying biological processes correspond with specific contexts of a society that gets co-defined by (potentially) using these objects.

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