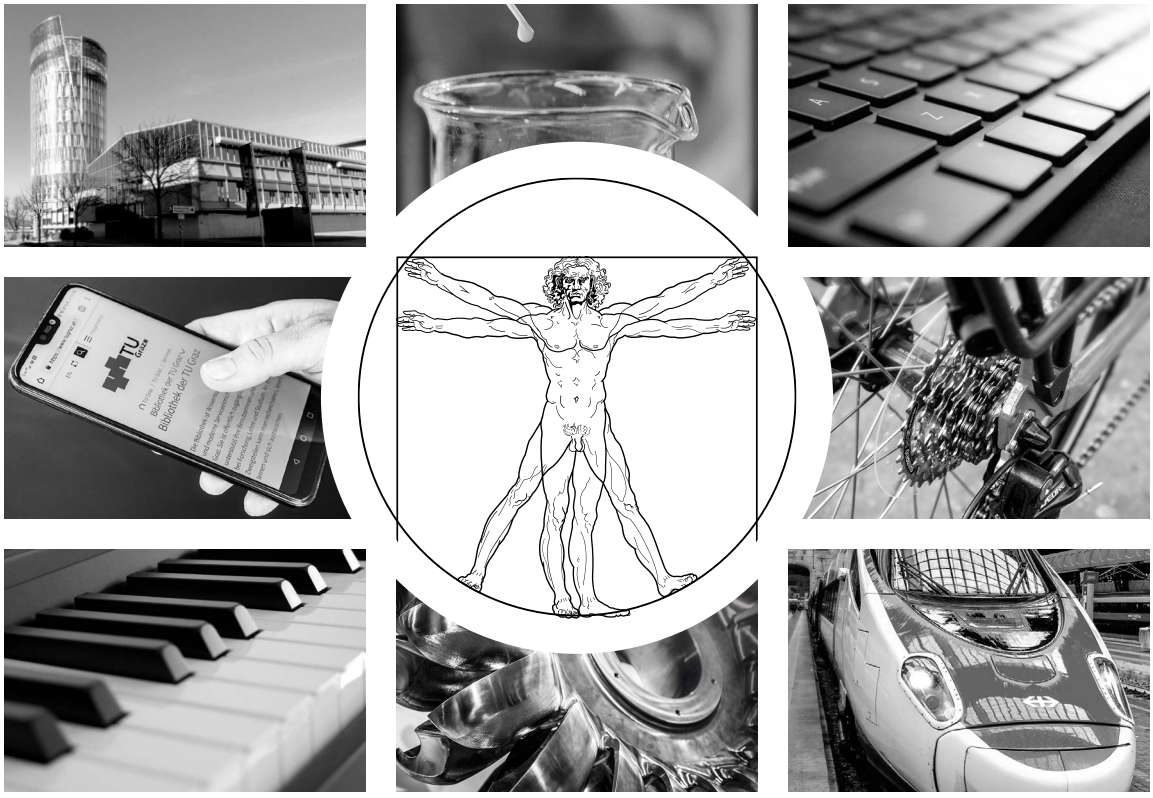
SCIENCE, TECHNOLOGY AND SOCIETY



Günter Getzinger | Michaela Jahrbacher | Roman Prună (eds.)

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Critical Issues in Science, Technology and Society Studies

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Preface

Critical Issues in Science, Technology and Society Studies

Conference Proceedings of the STS Conference Graz 2024, May 6th – 8th

The annual STS Conference Graz provides a space for scholars from all parts of the world to present and discuss their research with peers. In their papers, the conference participants address the complex ways in which science, technology and society coevolve and mutually shape one another. Without exception, the participants of the conference aim to provide a better understanding of the world(s) in which we live. This includes the assessment of emerging technologies, the scrutiny of ethical, legal and social aspects of contemporary scientific practices as well as the transition to environmentally friendly and socially desirable techno-scientific futures.

This volume of proceeding documents is part of the work that has been presented at the 22nd STS Conference in Graz in 2024. It presents the wealth of ideas discussed at this occasion and fosters collaboration. The STS Conference Graz is the joint annual conference of the Science, Technology and Society (STS) Unit at Graz University of Technology, the Interdisciplinary Research Centre for Technology, Work and Culture (IFZ) and the Institute for Advanced Studies on Science, Technology and Society (IASSTS).

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Using software for Research: The Role of Transparency, Reputation and Compliance in Practicing Trust

Judith Hartstein[1,2], Alexander Schniedermann[1], Nathalie Schwichtenberg[1]

[1]German Centre for Higher Education Research and Science Studies, Germany

[2]Humboldt-Universität zu Berlin, Germany

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Abstract. What makes researchers trust in software? We propose that some - but not all - considerations before software-for-research use are disciplinary practices. The representative DZHW Science Survey provided us with n ~ 1,300 complete responses from researchers about their considerations preceding software use. On this data, we performed multiple and simple correspondence analyses to explore patterns concerning trust in research software.
According to multiple correspondence analysis, the relevance of considerations in general is an in-participant characteristic. With simple correspondence analysis, we find that transparency-related considerations are disciplinary practices, while reputation-related considerations are shared across disciplines. We gained mixed results on compliance-related considerations.
We suggest that infrastructure designers should be aware of the pre-established relevance of software-literacy-related and methods-related considerations in some fields as opposed to others.

1. Introduction

In modern science, various domains of research practice involve computational methods or computer-assisted creative work. The range of practices spans from writing with digital tools to empirical research with a completely digital observation-analysis pipeline. While researchers are still divided into a panoply of academic disciplines or fields which differ in their epistemic practices, they share the goal to obtain insights. It is widely acknowledged that the reliability of research results crucially depends on good practices during the research process across fields. But software-use-related epistemic practices have not yet been systematically investigated as disciplinary practices. Our article addresses this research gap with correspondence analysis applied to survey data on considerations about research software.

Software solutions for digital methods, such as cataloguing and searching or statistical computations, are often transferred from one field to the other. On the one hand, research methods embodied as software carry implicit assumptions, sometimes without the users noticing. On the other hand, using software for research is to put faith in it working as expected and to accept its epistemic consequences. Therefrom arises a dissonance which we aim at better understanding with our research: How is trust in software built? And how does this vary by discipline?

We argue that when it comes to research software use, transparency as a 'trust technology' (see Grand et al. 2012) privileges the 'Hard Sciences' over the 'Soft Sciences'. Our study shows that when assessing research software before using it, researchers from the Engineering Sciences and the Natural Sciences consider transparency-related software attributes more often than researchers from the Humanities and the Social Sciences do. Moreover, transparency does not complement but rather adds to reputation-related heuristics for when to trust in research software. Besides, we gained mixed results on compliance-related characteristics of which some are considered in the Life Sciences more than in other fields.

Empirical researchers across disciplines use software in their everyday work: knowledge is produced (as opposed to 'found', see Bonde Thylstrup et al. 2019) through data with software. Therefore, mathematical and computational modelling in research is part of the epistemic work from data to conclusions (Gramelsberger et al. 2024), which is why software practices have recently come into focus for achieving reproducibility with archived data (Davenport et al. 2020).

Software reuse means transferring a fixed configuration of research methods from one research context to another which bears epistemic risks. For computer systems in general, Friedman and Nissenbaum (1996) describe how values embedded throughout systems design travel with the system from the context of production to the context of use, which can lead to biases which are hard to overcome. Fast forward 28 years later, Kinder-Kurlanda and Fahimi (2024) still observe algorithmic fairness is hard to achieve (and even to define) in practice.

Some would argue that automation and artificial intelligence could help to cancel out biases in general, a perspective which is discussed as technological solutionism (see Morozov 2014). But still, research with software is, at its core, human reasoning. According to Bechmann and Bowker (2019), software use is not deterministic on the data which are given, but human intervention is necessary to find meaning in patterns even despite when research relies on machine learning. Another example is computational visualization, where sense making is a joint achievement by computers and humans (see e.g. Börner and Polley 2014).

Researchers trust software with their epistemic work even though reasoning with software is neither objective nor infallible. However, when assessing the suitability of third-party software for their own research goal, researchers can only rely on limited information. To fully grasp epistemic consequences of software use for research, we need to know which characteristics help to build trust and how this is different in different disciplines. To this end, our key concepts are transparency, reputation and compliance.

Open Science enthusiasts demand *transparency* to foster reliability (understood as reproducibility/replicability) of research results to enforce or justify trust in science: the 'FAIR for research software' principles even claim that 'source code is the most reusable form of software' (Chue Hong et al. 2021, p. 11). Moreover, Open Science is discussed as 'new "trust technology"' (Grand et al. 2012) and transparency is considered a decisive factor for trustworthiness, i.e. maintaining scientific integrity (Hardwicke and Vazire 2023; Aczel et al. 2019; Vazire 2017). So, transparency is the most central and most undisputed discursive figure in the Open Science movement.

The role of *reputation* for trust in research software has only rarely been explicitly addressed in the literature. However, Giddens (1990) argued that trust in abstract systems is only possible for lay persons through "access points" (the people involved in their creation or who are "responsible", p.83). Accordingly, scholars have pointed to provenance of data as essential to trust and reproducibility (Viglas 2013; Glavic 2021), more recently also of software (Dhruv and Dubey 2023). In general, researchers use reputation as a heuristic for the reliability of research results (Origgi 2017) up to the extent that quantitative performance indicators of individual researchers determine the perception of their research claims (Müller and de Rijcke 2017).

The *compliance* of research with disciplinary standards and agreed upon methods makes retrieved results acceptable and valid for the scientific peers and identifies a researcher as a member of a certain community or profession (Bowker and Star 1999; Fujimura 1988). While research is generally perceived as creative and uncertain, still standardized methods and (software) tools as well as predefined plans of action are common in modern research (Whitley 1985; Fujimura 1987, 1988; Latour 1987). Disciplinary standards define the rules of formal communication, hence provide 'literary technologies' (Shapin and Schaffer 1985; see also Csiszar 2020), while the clinical sciences have adopted completely standardized and pre-planned research designs (Keating and Cambrosio 2012). Particularly, using distinctive research software can show compliance with agreed upon 'theory-method packages' which solve problems in a way that is accepted within the community (Fujimura 1988). However, software use does not reproduce determined sequences of events and outcomes, but compliance with technical standards always involves creative deviation and skilful tinkering (Suchman 1985; Timmermans and Epstein 2010).

Overall, transparency, reputation and compliance differ in their individual-society-science configuration. Transparency refers to the user's ability to assess a given resource directly; reputation refers to the user's perception of a resource by the proxy of the context of production; and compliance refers to the user's perception of a resource by the proxy of its fit with (socially constructed) norms.

We expected to find disciplinary differences in how trust in research software is built, because practices of software use are epistemic practices. We implicitly understand discipline as culture here, therefore drawing from concepts such as 'academic tribes' (Becher 1989), 'epistemic cultures' (Knorr-Cetina 1999), 'regimes of knowledge production' (Marcovich and Shinn 2012) and 'epistemic regimes' (Gläser et al. 2018). Discipline as concept has been criticised as vague (Multrus 2004) and conflicting with organizational structures (Trowler 2014). However, we approach a researcher's discipline as a key demographic information obtained about them via a standardized online survey. A nested categorization helps us to keep in mind that disciplines as cultural categories are, of course, not mutually unrelated.

Within this article, we will elaborate on how we found the continuum explanatory between different disciplines-as-cultures for some but not all practices of trust in research software. We first describe how we operationalize trust practices as ten types of *considerations before use* in a standardized survey. With correspondence analysis, we investigate how these trust practices differ between disciplines.

2. Data & Methods

With Faulkner (2012), we derive 'attitudes of trust' towards software from the 'act of trust' that is using software. Hereinafter, we speak of users' *practices of building trust in software (for research)* as *trust practices*. For our operationalisation of trust practices, we consider the decision to use software as a critical point (in line with Solomon's (2005) 'decision vectors'). Accordingly, we asked participants in an online survey about a specific set of trust-related considerations which they might make before the decision to use software for research with the goal to fan out the different trust practices. We included trust practices regarding transparency, reputation and compliance which have not yet been investigated with a focus on software.

2.1. Data

We developed a survey module on 'Trust within Science' as our contribution to the DZHW Science Survey of 2023 which is a large trend survey among German researchers (Fabian et al. 2024). To investigate how trust in research software is built and how this is different among disciplines, we posed the following question to survey participants: “Which questions do you ask yourself before you use software for your research?” and provided a Likert-5-scale (end-verbalised with ‘always ask myself’ and ‘never ask myself’) for each of the considerations (see Table 1).

Table 1. This table shows the expressions which were provided in the survey (English translation from German original) under the umbrella question ‘Which questions do you ask yourself before you use software for your research?’ and how they map to their short form (‘type of consideration’).

Survey expression	**Type of consideration**
Is this software established in the field?	establishment (software)
Is the method implemented in the software established in the field?	establishment (method)
Which institution is behind this software?	institution
Where was this software released?	publication venue
Who recommended this software to me?	recommending person
Who made this software?	producing person
Is this software described in a comprehensible manner?	description
Can I check this software myself? Do I have the competence for this?	verifiability
Does this software stand up to my scrutiny?	verification
Does this software follow relevant disciplinary guidelines?	disciplinary guidelines

We obtained 1,702 observations from randomly sampled survey participants. We used 'How often do you use third-party software for your research?' to filter out those never using software from answering the questions on considerations[1]. After filtering, 228 to 317 observations remained for each of the five broader research fields as defined by the German Research Foundation and 12 to 118 observations for each of the twenty-two disciplines corresponding to the nested classification of disciplines.

[1] Participants who articulated that they never use third-party software, were excluded from answering questions on considerations already during the survey.

2.2. Methods

In our study, we used considerations of researchers before their decision to use software for research to better understand when software is perceived as trustworthy in different disciplines. The variables of interest are categorical (disciplines) and ordinal (relevance of considerations) which is why we chose multiple and simple correspondence analysis (Blasius 2001) as quantitative method tailored to a nominal level of measurement. For computation and visualization, we used R (R Core Team 2024) as well as contributed packages, especially FactoMineR (Le et al. 2016), factoextra (Kassambara and Mundt 2020), tidyverse (Wickham et al. 2019) and haven (Wickham et al. 2023). Also, the investigation was preregistered as a project in the Open Science Frameworkwhere we also provide supplementary material[2].

Our correspondence analysis of trust practices had two aspects. Firstly, we used multiple correspondence analysis with disciplines as supporting variables to investigate trust practices as in-person characteristic. Secondly, we conducted ten simple correspondence analyses to investigate whether the individual types of considerations correspond with the twenty-two disciplines.

With the results of simple correspondence analyses at hand, we interpreted a trust practice as disciplinary practice when the relevance of consideration was ordered along the first dimension of the correspondence plot *and* the explained variance was high. We tested the order with Spearman's rho: the Dim1-coordinates of the values {never, 2,3,4, always} were compared to {1,2,3,4,5} with the rank correlation mapping to the interval [-1,1]. If the absolute value of rho was close to 1, then we interpreted the trust practice as ordered in correspondence with disciplines. We considered the explained variance in Dim1 "high" if it was over 50% in simple correspondence plots for contingency tables of size 22x5 (twenty-two disciplines times five value expressions).

In general, distances in correspondence analysis plots must not be interpreted as ordinal or metric, but in our specific case, we only referred to one dimension and interpreted it as ordinal scale only if the Likert scale variable was ordered accordingly. Therefrom we then derived an order for the categorical variable.

[2] Preregistration: https://doi.org/10.17605/OSF.IO/8GM9K, project: https://osf.io/6jvbf/, supplement: https://osf.io/b4fw3/

2.3. Remarks and limitations

We acknowledge path-dependency in our findings as the co-evolution of method application and theory building shaped our analyses and thus, their outcome. The categorization into transparency-related, reputation-related and compliance-related considerations was derived as interpretation from the results of the simple correspondence analysis. Also, our analyses are based on a small (but representative) sample of the German researcher population. As research culture is intertwined with broader cultural contexts, organizational governance and national research policies, further research is needed as to whether our results apply to the global researcher population.

3. Results

Our study suggests that transparency-related trust practices differ between disciplines, that reputation-related trust practices are shared across disciplines, and that compliance-related trust practices fall into two categories: considerations on methods divide and considerations on guidelines unite disciplines. In this section, we firstly provide an overview and show that software use for research is prevalent across disciplines, that trust practices in research software are bimodal, and that multiple correspondence analysis indicates a sceptics-to-believers spectrum of attitudes towards research software. Second, we elaborate on disciplinary differences regarding these trust practices.

3.1. Prevalence of software use and of trust in research software

3.1.1. Software is used across disciplines

Software use is prevalent in all disciplines (see Table 2): only 11% (Engineering and Natural Sciences) up to 29% (Humanities) never use software at all. The non-users were filtered out during the survey and are thus not included in the results on considerations.

Table 2. The table shows the answers to the survey question ‘Do you personally use software for research?’. The totals and percentages of answers in the different answering options (‘Never’, 2, 3, 4, ‘Always’) are given for each of the five broader research fields.

research area	**never**		**2**		**3**		**4**		**always**		**total**	
Humanities	91	29%	61	20%	53	17%	37	12%	67	22%	309	100%
Social and Behavioural Sciences	79	19%	67	17%	54	13%	73	18%	133	33%	406	100%
Life Sciences	31	12%	43	17%	53	21%	58	23%	70	27%	255	100%
Natural Sciences	36	11%	70	21%	67	20%	76	22%	92	27%	341	100%
Engineering Sciences	30	11%	57	21%	59	22%	58	22%	64	24%	268	100%
not assigned	7	18%	7	18%	9	22%	7	18%	10	25%	40	100%

3.1.2. Considerations before use show a bimodal distribution

The individual considerations before software use vary in their importance for the users. Judged by the median[3] answer (see Table 3), the establishment of software and of the implemented method as well as a comprehensive description of the software are most important (each has median = 4), whereas the person producing the software is rather unimportant (median = 2).

However, each of the distribution of considerations before software use among all participants (see figure 1) is bimodal except for ‘the person producing the software’. The answer 'I never consider this.' stands out in all bar charts. These two patterns are unexpected for a Likert-scale-question and suggest further investigation.

[3] Please note that we have not computed arithmetic means, because the median is the appropriate measure of central tendency for ordinal data.

Figure 1. The figure shows the relevance of trust dimensions across disciplines as bar chart. For each of the considerations the category is given, which was assigned during the interpretation of study results, above the name of the consideration. The height of the bars expresses the total number of the answers in the different answering options ('Never', 2 3, 4, 'Always') to the question whether participants consider the respective attribute/characteristic of software before software use.

3.1.3. Considerations before use show disciplinary differences

The relevance of considerations before using software for research shows a high variance between fields (see figure 2). Overall, researchers from the Humanities consider the provided aspects less often than researchers from other fields. However, the mere counting of relevance does only tell us that disciplines build trust in software for research differently, but not so much how they differ. Thus, to pursue our research goal to find out how disciplines differ in their research practices, we turn to correspondence analysis.

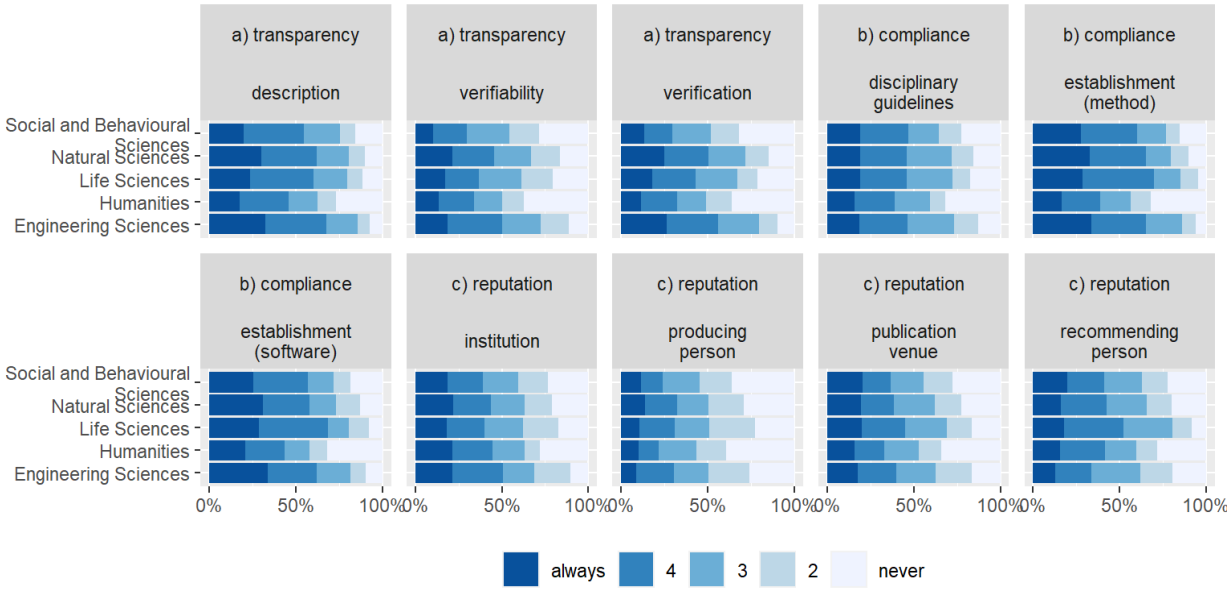

Figure 2. The figure shows the relevance of considerations before use across disciplines as stacked bar chart by fields.

3.1.4. Trust practices arrange on a continuum of sceptics and believers

The multiple correspondence analysis (figure 3) shows that our conceptualization of trust practices in ten dimensions is at least coherent as the barycenters of the relevance expressions of all ten considerations are perfectly ordered (|rho|=1)) along Dim1. This means that participants who never consider one of the software characteristics are also unlikely to consider other ones. We refer to this group as “believers” as they employ more unconditional modes of using research software. In contrast, participants who always consider one characteristic are likely to always consider another. We refer to this group as “skeptics” as they seem to scrutinize software or at least show risk awareness.

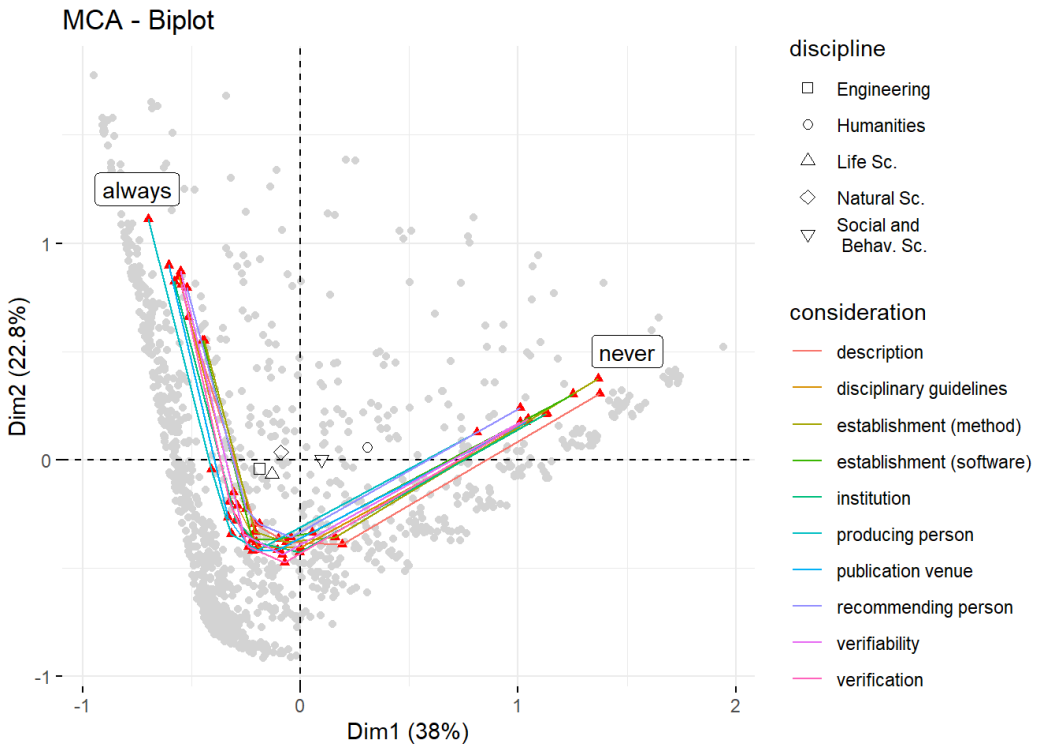

Figure 3. The figure shows the multiple correspondence analysis biplot of all ten trust dimensions together with coarse grained disciplines (dfg5) as supporting variables. Red triangles indicate the barycenters for the different answering options ('Never', 2,3,4, 'Always') to each question. Coloured lines indicate the distribution of said barycenters. Green triangles indicate the barycenters for each discipline. Grey dots indicate the individual observations.

The barycenters of the five broader research fields as supporting variables are all close to the coordinate origin. Whereas we might perceive a weak tendency for researchers in the Humanities of being believers and researchers in Engineering to being sceptics, still the inertia of the different fields is quite low as is the explained variance in Dim1.

3.2. Disciplinarity of considerations before use

The simple correspondence analyses for each of the ten considerations in five expressions with disciplines in twenty-two categories shows that some trust practices correspond more with disciplines than others. Accordingly, we sorted the practices into the following three categories: disciplinary practices, weak disciplinary practices and shared practices. As described above, we considered a trust dimension to be a disciplinary practice if it appeared ordered in the first dimension of the correspondence plot *and* the explained variance was high. We tested that with Spearman's rho which is the rank correlation measure of choice for ordinal variables. An overview of results is given in Table 3, and the correspondence plots in detail are provided with the supplementary material.

Table 3. The table shows the following for all dimensions of trust (i.e. consideration) under investigation: a) the category which was assigned during our interpretation of results, b) the name of the consideration, c) the median of the relevance of the consideration across all disciplines (in fine grained classification – dfg22), e) the extent to which the relevance of the respective consideration is ordered along Dim1 in the results of simple correspondence analyses with disciplines (|rho| close to 1 implies order, |rho| close to zero implied no order), f) the percentage of variance explained in Dim1 of simple correspondence analyses with disciplines, g) the type of practice which was assigned during interpretation of results, h) for (weak) disciplinary practices the names of the disciplines who most tend to never consider this dimension and i) who most tend to always consider this dimension.

category	**consideration**	**median**	**|rho|**	**% variance**	**type of practice**	**never**	**always**
a) transparency	description	4	1.0	60.19	disciplinary practice	Jurisprudence	Computer Sc., Systems & Electrical Eng.
a) transparency	verification	3	1.0	63.75	disciplinary practice	Literary Studies	Computer Sc., Systems & Electrical Eng.
a) transparency	verifiability	3	1.0	54.68	disciplinary practice	Literary Studies	Computer Sc., Systems & Electrical Eng.
b) compliance	establishment (method)	4	0.9	75.26	weak disciplinary practice	Literary Studies	Agric., Forestry and Vet. Med.
b) compliance	establishment (software)	4	0.8	64.35	weak disciplinary practice	Literary Studies	Agric., Forestry and Vet. Med.
c) reputation	recommending person	3	0.7	44.27	shared practice	NA	NA
c) reputation	producing person	2	0.3	47.14	shared practice	NA	NA
c) reputation	publication venue	3	0.3	47.78	shared practice	NA	NA
c) reputation	institution	3	0.1	47.43	shared practice	NA	NA
b) compliance	disciplinary guidelines	3	0.0	49.25	shared practice	NA	NA

3.2.1. Transparency-related considerations are disciplinary practices

We categorized the transparency-related practices as disciplinary practices, because considerations on a comprehensive description of the software, on verification by the user, and on verifiability by the user are definitely different in different disciplines – all three are clearly ordered along Dim1 (|rho|=1) with 54% to 64% explained variance. Broadly speaking, software-literacy-related considerations discriminate the (Computer) Sciences from the Humanities. Whereas many engineers and natural scientists consider software documentation, their own competence of verification as well as verification itself important, many researchers from the Humanities and the Social Sciences do not include such topics in their decisions to use software.

The consideration of a comprehensive description of the software highly corresponds with disciplines, while being very relevant over all (median=4). The 60.2 % of variance are explained in the first dimension and the relevance of this consideration is ordered along this dimension. The comprehensive description is most important for researchers in Computer Science and the Geosciences, whereas researchers in Jurisprudence and Literary Studies tend to never consider this before using software for research.

The consideration of the estimated competence of verifying the software oneself corresponds with disciplines in a similar way and is of medium relevance (median=3). The explained variance in the first dimension is 54.7 % and the relevance is ordered along the first dimension. This type of consideration is most famous among researchers in Computer Science and Mechanical and Industrial Engineering, whereas researchers in Literary Studies and the Social Sciences least consider this.

A similar picture shows for the actual verification of software which is also of medium relevance (median=3). The explained variance in the first dimension is 63.8 % and the importance of this consideration is ordered along the first dimension. Again, this consideration tells researchers in Computer Sciences and Mechanical and Industrial engineering apart from those in Literary Studies and Social Sciences.

In all three cases, the extreme coordinates for disciplines exceed the extreme coordinates for relevance of consideration. That means that the barycenter of Computer Science is further away from the coordinate origin than the barycenter of „always“ (in the same direction of Dim1) and the barycenter of Literary Studies is further away from the coordinate origin than the barycenter of „never“, accordingly.

3.2.2. Reputation-related considerations are shared practices across disciplines

We categorized reputation-related considerations as shared practices because they only show few, if any, disciplinary ordering (|rho| ≤ 0.7) and the explained variance in Dim1 is fewer than 50% for all these considerations.

The person recommending a software could be a borderline case for the disciplinarity of trust practices, judged by |rho|=0.7, but in this case this means that the barycenter of the neutral expression (“3”) was shifted to an extreme position and the extreme expression “always” was shifted to the middle. Thus, this practice must not be classified as disciplinary practice but as shared practice. Besides, this type of consideration is the least relevant, judged by the median answer (median = 2).

Further reputation-related trust practices, i.e. the person producing the software, the publication venue of the software and the institution behind the software are even less sorted (|rho| ≤ 0.5) and are thus also to be considered shared practices of trust.

3.2.3. Compliance-related considerations: methods divide, guidelines unite

Compliance-related practices fall into two categories. The establishment of the implemented method (1> |rho| >= 0.9) has over 75% variance explained in Dim1, whereas the establishment of the software itself (0.9>|rho|>0.8) still has over 60%, so both are partly ordered close to the maximum and can be considered weak disciplinary practices. However, adherence to disciplinary guidelines is completely unordered (|rho| = 0) and is therefore a shared practice.

The correspondence analyses of compliance-related considerations yielded differences between generic and governmental trust practices. On the one hand, trust practices towards discursively emerging phenomena, i.e. (perceived) establishment of method and software, are discipline-specific while also being most relevant (median=4). On the other hand, trust practices towards disciplinary guidelines, which are supposed to be made explicitly consensual through a broader process, are shared practices and of medium relevance (median=3).

The consideration of the establishment of method is almost ordered – only the coordinates of “always” and “4” are switched, while still 75.3% of variance are explained in the first dimension. This consideration is most important in the Life Sciences whereas unimportant in the Humanities. As the relevance is not perfectly but almost ordered, we interpret this as a weak disciplinary practice.

The relevance of the establishment of software shows similar tendencies as the establishment of the method, but here, the two pairs “always”/“4” as well as “2”/”3” are switched within, but still 65.3 % of variance are explained. Again, the Life Sciences are more likely to always consider this, whereas researchers in the Humanities are more

likely to never consider this. As the extrema tend to point into different directions, we still categorized this as a weak disciplinary practice, but this is also a borderline case.

In contrast, the relevance of considerations on whether the software meets disciplinary guidelines is very clearly a shared practice. It is totally unordered in correspondence with the twenty-two disciplines.

4. Conclusion

In our introduction, we have pointed out that across all academic disciplines, a) science with software is part of most researchers' everyday work, b) software as a configuration of research methods has epistemic consequences, and c) epistemic risks arise from transferring software from one research context to the other. Thus, researchers across fields must build trust in research software – accordingly, our aim was to understand disciplinary practices of trust in software.

Our study has shown that transparency, reputation and compliance differ in their relevance for building trust in research software. While transparency-related considerations divide the researcher population into 'Hard Sciences' and 'Soft Sciences' (see Snow 1959), reputation-related considerations unite researchers across disciplines. We gained mixed results on compliance-related considerations: while compliance with disciplinary standards in general is important across fields, the relevance of establishment of a software or the implemented method weakly distinguishes between fields.

Our multiple correspondence analysis revealed that researchers across disciplines arrange on a spectrum between always and never considering the ten trust dimensions when assessing software. With Giddens (1990) we know that trust is related to lack of information and risk awareness. When we relate this to the spectrum we found of sceptics and believers, we may conclude that the believers are rather unaware of (epistemic) risks (or consequences) of software use. While Giddens (1990) stated that "[r]espect for technical knowledge usually exists in conjunction with a pragmatic attitude towards abstract systems based upon attitudes of scepticism or reserve." (p. 90), nowadays it seems that a relevant portion of people are not sceptical towards software at all, judged by the fact that they never ask themselves any questions about software before use.

We found that the importance of transparency-related considerations is field specific: according to simple correspondence analyses, researchers from the Engineering Sciences tend to always assess research software before use based on its description, verification and verifiability whereas researchers from the Humanities tend to never

consider these attributes – and Natural Sciences, Life Science as well as Behavioral and Social Sciences arrange between the extrema.

Thus, although transparency is called for by the Open Science movement in general (Grand et al. 2012; Hardwicke and Vazire 2023; Aczel et al. 2020; Vazire 2017) as well as specifically for software (Chue Hong et al. 2022; Barker et al. 2022; Lamprecht et al. 2020), we found that not all researchers from all disciplines can benefit from it, when it comes to software. This parallels earlier results about software users outside science by Zenkl and Griesbacher (2020) who found that "technology affinity" is an important factor for having trust in automated driving: in automated driving "security" is of central concern, and those who are enthusiastic about the opportunities which are opened up by technology are more likely to trust than others, despite knowing about the risks. Accordingly, we conclude that researchers can only benefit from transparency when they are able to use the given information for their assessment, which varies by field.

In contrast, the relevance of reputation-related considerations does not correspond with disciplines according to our analyses. Whether researchers assess software based on the recommending person, producing person, publication venue or institution is not related to the user's disciplinary background. Thus, across disciplines, researchers assess software by its context of production.

The widespread use of reputation as heuristic for whether to trust in others' research is not surprising per se as related mechanisms have been discussed in the literature (see Merton 1968; Origgi 2017; Müller and de Rijcke 17) for decades. To this background, contextual information is called for regarding research data and software (Viglas 2013; Glavic 2021; Dhruv and Dubey 2023).

However, reputation does not complement transparency according to our findings. It would have been plausible if those who can directly assess software (by description or verification) did not use reputation as a heuristic so much. That would mean that researchers from Engineering would use reputation less than researchers from the Humanities. But instead, from the fact that reputation-related trust practices did not arrange with disciplines, we deduce that reputation adds to transparency as a trust technology rather than complementing it.

Regarding compliance, we found two different types of correspondence with disciplines. Considerations on establishment are weak disciplinary practices and tend to be more relevant for researchers from the Life Sciences than the Humanities while the consideration of compliance with disciplinary guidelines is a shared practice.

It is not surprising that the assessment of software based on its compliance with disciplinary guidelines is independent from disciplines, as explicitly agreed upon ways of doing science permeate all scientific fields. In that sense, our results confirm the perspective of discipline-as-culture (see Becher 1989; Knorr-Cetina 1999). Here, disciplinary guidelines serve as codified norms that establish a many-to-one power dynamic and social 'regimes' that judge on community membership (see Marcovich and Shinn 2012; Gläser et al. 2018). However, disciplinary guidelines are not fixed but the emergence of new 'theory-method packages' initiates new research trends (Fujimura 1988; Galison 2010) with new guidelines to adopt. For example, the Life Sciences communities reacted to the problematization of the published record as part of the replication crisis with calls for reevaluating the dominant epistemic regime and its modes and standards for research practices (see Ioannidis 2005; Hosseini et al. 2022). These calls, however, led not only to the development of new formal standards or even bureaucracies such as preregistration or mandatory data publishing (Penders 2022), but also turned into distinct social movements, yet new cultures within research (see Peterson and Panofsky 2023).

However, the establishment of a particular software or method has shown to be more important in the Life Sciences than in the Humanities. We know that epistemic reforms can result in very specific standards and tools that become mandatory aspects of proper research, i.e. for writing biomedical reports (Altman and Simera 2016), and assume that software use follows this trend: using established software is then not only an act of finding 'the right tools for the job' (Clarke and Fujimura 1992), but signals being a skilled expert who has access to professional resources. This is even irrespective of the actual practice of software use during the actual research process which often remains inaccessible to outsiders such as readers of a paper, but in turn, exact reference and mentioning of the used software become crucial. Not surprisingly, disciplinary assignment has been found as a factor that explains the co-citation of software packages (Li and Yan 2018). A similar signifying role has been found in other accounts of standardization and the usage of procedural techniques, i.e. medical treatment protocols (Timmermans and Berg 2003; Timmermans and Epstein 2010).

Overall, the difference in individual-science-society configurations of trust practices plays out differently in different fields. Researchers from the Humanities do not benefit from transparency when assessing software and can only derive their trust in the software from its context of production (i.e. reputation-related characteristics). At the same time, derivative trust is open to all – also to software literate researchers – and empirically all disciplines alike use reputation-related considerations for software assessment. This makes affordances for derivative trust seem democratic whereas affordances for direct trust distribute support unevenly among disciplines. Being aware of this fact could

prevent the research community from reinforcing the divide between the “two cultures” (Snow 1959), now, when manifold overarching research (data) infrastructures are developed. We recommend putting emphasis on shared practices when designing new research infrastructures.

We conclude that trust practices as epistemic practices are a promising research topic which could not be covered in full in our study. While we contextualized our findings with theoretical and empirical works of others, what drives disciplinary differences in practicing trust remains an unsolved puzzle. We intend to address this follow-up research question in the future and with additional data.

CRediT (https://credit.niso.org/)

JH: Conceptualization; Investigation; Methodology; Formal Analysis; Writing – original draft; Writing – review & editing; Visualization

AS: Conceptualization; Writing – review & editing; Methodology; Writing – original draft

NS: Conceptualization; Writing – review & editing; Methodology; Writing – original draft

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Conflicts of interest

The authors declare no conflicts of interest.

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Between the Lines: Exploring Science Narratives in Bulgarian Mass Media through Embedded Topic Modeling and Sentiment Analysis

Svetlomir Zdravkov[1], Martin Jordanov Ivanov[1]

[1]Institute of Philosophy and Sociology, Bulgarian Academy of Sciences, Bulgaria

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Abstract. In Bulgaria, as in many other countries in Eastern Europe, the status of science in society changed rapidly after the fall of the Iron Curtain, which created an unfavorable environment for the development of the public image of science. This study explores the coverage of science related news in Bulgarian mass media from 2018 to 2023, using embedded topic modeling and sentiment analysis on over 1.7 million articles from seven major outlets with varying editorial profiles. The findings reveal that science related news is around 0,89% of total news. Also, there is significant variability in science coverage, influenced by each outlet's ideological orientation. Media with liberal and pro-European orientations prioritize scientific topics, while mainstream and government-supporting outlets show the least emphasis. Key topics include "Politics and Science", "Human Health and Biology" and "Astrophysics." Sentiment analysis highlights negative perceptions of climate change and positive views on astrophysics and technological advancements. The paper concludes with speculative explanations of these results. It notes that the results could be explained by a shift towards regulatory science in the Bulgarian context, where some scientific topics are increasingly seen as a tool for managing risks and informing policy.

1. Introduction. Institutional and media context of Bulgarian science

In Bulgaria, as in many other countries in Eastern Europe, the status of science in society changed rapidly after the fall of the Iron Curtain. Its status declined after decades of being praised as one of society's most important pillars (Petryna, 2003). According to sociologist Markku Kivinen (2002), under socialism, science was seen as an instrument of ideological supremacy, symbolizing the progress and modernization achieved under socialist rule. It was heavily promoted and funded by the state, integrated into central planning, and directed towards collective welfare and economic goals. State investment in scientific education and research underscored its importance as a tool for national development and social improvement. As in other socialist countries, science in Bulgaria

played a crucial and valued role in both society and the state (Petkova & Boyadjieva, 1994). The Bulgarian Communist Politburo quickly recognized the growing technological gap with the West and launched a centrally planned scientific and technological revolution aimed at modernizing the country and solving many of its economic and social problems, giving science a cult-like status (Ivanov, 2008).

In stark contrast, contemporary Bulgaria ranks among the least focused on science in the EU when considering its expenditure on science, research, and development as a percentage of its national budget and GDP. The average R&D intensity in the EU, measured as a percentage of GDP is 2.22% in 2022, which is around 262 euro per inhabitant. However, Bulgaria recorded an R&D intensity of just 0.77%, significantly lower than the EU average (around 27 euro per inhabitant), placing Bulgaria among the lowest in the EU for R&D expenditure (Eurostat, 2024). The disparity highlights the significant challenges Bulgaria faces in maintaining and advancing its scientific infrastructure amidst financial constraints, which have profound implications for the country's research output, scientific infrastructure, and retention of talented scientists. This shift in the status of science is starkly illustrated by Bulgaria's response to the COVID-19 pandemic, as the underfunded and neglected institutions was not recognised as an authority on the subject (Tchalakov et al., 2021). With an adult vaccination rate of only 24,9%, Bulgaria has the lowest rate of vaccination in the EU (ECDPC, 2021). The erosion of trust in science and medicine has significant repercussions for public health and the overall well-being of society.

This decline in the status of science in Bulgarian society is also influenced by the condition of the media landscape. In Bulgaria, a country known for high levels of political media parallelism and low levels of press freedom, the media landscape is heavily aligned with the political system, predominantly focusing on political advocacy (Boshnakova & Dankova, 2023). Additionally, the lack of consistent and transparent communication from scientific authorities has exacerbated public mistrust. Instead, people are increasingly turning to alternative sources of information, including social media, religious leaders, and political figures, who may not always promote scientifically accurate information (Mitev, 2021). This raises concerns about how scientific news is reported, as the political influence on media content may skew or overshadow scientific reporting. Despite the importance of this issue, there is a lack of comprehensive studies examining the impact of political media parallelism on the coverage of science-related news in Bulgaria. This gap in research highlights the need for further investigation into how media practices affect public understanding and engagement with science in politically charged environments.

Our study has two main aims. First, we aim to provide an exploratory analysis and measure how science-related news is reported in the Bulgarian media. Second, we aim to demonstrate the usefulness of a bundle of automated analysis techniques that are

underused in the field of public understanding of science (for notable exceptions, see Zorzi et al., 2023; Süerdem, 2018). The article begins with data collection, for which we used the web-scraping technique, using the Python library Selenium to extract data from online sources. This is followed by the application of BERTopic for embedded topic modeling, which allowed us to identify latent topics in the texts. We also used an GPT-3.5 Turbo to perform sentiment analysis, categorizing articles as positive, negative or neutral. We then present descriptive data. Finally, we combine the results of embedded topic modeling and sentiment analysis to map the difference in science-related news reporting in the media landscape. Our intention is to provide descriptive results from our study, so we do not go into the theoretical framework. Nevertheless, when we collected all the data, we found a pattern of science-related news coverage that clustered certain topics, media and sentiments. Therefore, we conclude by hypothesizing that these differences can be explained by the shift from science to regulatory science (Yearley, 1994), which polarizes sentiment between media.

2. Methodology

2.1. Web Scraping

In our study, we used an automated technique called web scraping, a method for systematically extracting large amounts of data from websites. The importance of this technique is highlighted in numerous academic papers that explore different dimensions of social life. For example, Lupton (2014) discusses the commodification of patient opinion in healthcare, Brooker et al. (2018) examine stigma and public discourse in the media, and Milian (2016) explores advertising practices in education. Building on these foundations, discussions by Noortje Marres and Esther Weltevrede (2013) provide deep insights into the methodological implications of scraping in social research. Marres and Weltevrede highlight that web scraping not only collects data, but also introduces pre-ordered categories of analysis embedded in the online platforms themselves.

2.2. Embedded topic modelling

After creating our initial database, we analyzed it using an advanced technique called embedded topic modeling, specifically through a package known as BERTopic (Egger & Yu, 2022; Grootendorst, 2022). Several advantages of BERTopic meet the needs of our research on Bulgarian science related news. First, BERTopic's ability to capture context through its underlying BERT model is crucial for interpreting the nuanced discussions in these forums. This contextual understanding is essential when discussions are rich in technical language and scientific discourse, allowing the model to distinguish between different uses of terms based on their context within conversations.

Secondly, the dynamic nature of BERTopic allows it to adapt to the data, identifying a range of topics from broad themes to more nuanced discussions. This adaptability is particularly beneficial in science-related news, where discussions can range from non-scientific articulations of scientists' actions to specific debates on particular scientific discoveries. BERTopic's flexibility ensures that even the most intricate details within conversations are accurately captured. In addition, BERTopic supports multiple languages, making it highly effective for processing and analyzing discussions in Bulgarian. This feature is essential for capturing the unique linguistic nuances present in forum discussions, ensuring that the analysis is both accurate and culturally relevant. Lastly, a key advantage of BERTopic is its hierarchical topic reduction capability. This feature allows us to categorize topics into a structured hierarchy, facilitating a more organized analysis of the science articles.

To identify science-related topics, we first used BERTopic to create clusters of articles based on their content. After generating these clusters, we examined the top 50 keywords generated by the algorithm and associated with each topic. By manually checking these keywords, we identified which topics were related to science. This method involved checking for the presence of terms and phrases that explicitly mentioned scientific fields (astronomy, mathematics, medicine, etc) or scientists (biologists, sociologists, etc). This careful manual classification provided a solid basis for the subsequent sentiment analysis and qualitative review, allowing us to effectively analyze the representation of science in the Bulgarian mass media.

The preliminary topic names were generated based on the top keywords extracted from each cluster. However, to ensure that these names were accurate and unambiguous, a manual review was carried out. This involved adjusting the names where necessary to ensure that they accurately reflected the content of the clusters. An essential part of this process was the reading of documents representative (these articles being in the center) of each cluster. This step was crucial in understanding the context and nuances of the topics, which allowed for more precise and meaningful topic names. By examining these representative documents, we gained deeper insights into the main themes of each cluster, which helped to refine and confirm the topic names. The final step was to assess the coherence of the topics using coherence scores. Through iteration, we refined the model to improve the quality of the topics, eventually arriving at names that were concise, descriptive and representative of the main themes within each cluster.

This type of classification technique creates categories inductively using an automated algorithm. As a result, the science-related topics do not adhere to any initial definitions or taxonomies. Therefore, this technique should be considered exploratory rather than one that allows for direct comparison. This is also the reason why we do not delve further into the definitions of the themes.

2.3. Sentiment analysis

Sentiment analysis, a crucial subfield of natural language processing (NLP), offers numerous benefits for academic research. Firstly, it enables the categorization of text into positive, negative, or neutral sentiments, providing insights into public opinion and emotional tone behind the text. This capability is invaluable across various domains, including business, politics, and social sciences, allowing researchers to understand public attitudes and responses effectively. One of the key advantages of sentiment analysis is its ability to handle vast amounts of data efficiently. By extracting meaningful information from large datasets, researchers can identify trends, patterns, and shifts in public opinion over time (Tan et al., 2023).

In the business sector, sentiment analysis helps companies gauge customer satisfaction, enhance brand reputation, and make data-driven decisions. In politics, it aids in understanding public opinion towards policies, candidates, and political parties, thus informing campaign strategies and public engagement efforts. Moreover, in finance, sentiment analysis can predict stock market trends and investment opportunities by analyzing news articles and social media posts (Feldman, 2013.). Furthermore, sentiment analysis facilitates the analysis of unstructured data, turning qualitative feedback into quantifiable insights. Overall, the integration of sentiment analysis in academic research enhances the depth and breadth of analysis, enabling a comprehensive understanding of public sentiment and its implications across various fields (Birjali et al., 2021).

We utilized a large language model (LLM) to categorize them by sentiment, adding a new analytical dimension to differentiate the scientific topics. Several sentiment extraction methods were tested, including the spaCy sentiment library. However, these methods showed low accuracy. The highest accuracy was achieved using GPT-4 Turbo, but due to its high cost, we opted for GPT-3.5 Turbo, which provided approximately 90% accuracy. This balance between cost and performance made GPT-3.5 Turbo a suitable choice for our study. Using GPT-3.5 Turbo allowed us to effectively analyze the sentiment of the articles, identifying whether the content was positive, negative, or neutral. This sentiment analysis is crucial as it enables us to understand the tone and emotional context of the science narratives within the Bulgarian media. By combining topic modeling with sentiment analysis, we can offer a comprehensive view of how science is discussed and perceived in different media outlets. We categorize every topic as negative (-1), neutral (0) and positive (+1), and then we calculate the average sentiment for every topic or media.

The integration of these advanced NLP tools not only improves the accuracy of our sentiment analysis but also enhances our ability to provide nuanced insights into media reporting of science related news. This dual-layered approach ensures a robust and

detailed analysis, contributing significantly to the field of media studies and public understanding of science.

3. Data

Our dataset consists of articles collected from seven major Bulgarian media outlets for the period between 2018 and 2023, each with distinct types and political orientations. The diversity of these sources allows for a comprehensive analysis of how different media portray science in Bulgaria. The first media outlet in our dataset is PIK, a tabloid known for its sensationalist content. We collected a total of 144,255 articles (1733 science related) from this source. Blitz, an online news platform with a pro-Russian and conservative stance, contributed a substantial 468,469 articles (6782 science related). This significant volume reflects Blitz's prolific output and strong influence in the Bulgarian media landscape. Trud, another key source, is described as clientelist with centrist and conservative leanings, and its editorial politics are vaccine-skeptic. From Trud, we gathered 284,603 articles (4221 science related). DUMA, the official newspaper of the Bulgarian Socialist Party, provided 125,773 articles (2367 science related). This outlet's pro-Russian and conservative orientation aligns with its political affiliation (Yakimova, 2022). It should be noted that due to the nearly 50-year rule of the Communist Party, conservative ideology in Bulgaria is aligned with statism, traditional values, and often the glorification of the socialist period (Konstantinov, 2024), unlike in the West, where conservatism is typically associated with free market values. Dnevnik, a liberal media outlet with a pro-Western orientation, added 173,783 articles to our dataset (3539 science related). This source is known for its critical stance towards the government and support for European and American perspectives. Nova, a mainstream media outlet that generally supports the government, contributed 265,618 articles (2774 science related). Nova's large audience and government alignment make it a significant player in the media landscape. Finally, Telegraph, a tabloid with a pro-Russian bias, added 308,662 articles (4008 science related). Its content often leans towards sensationalism and aligns with conservative viewpoints (ibid). This diverse collection of articles from varied media types and political orientations provides a rich dataset for analyzing the portrayal of science in Bulgarian mass media. The dataset includes a total of 1,771,163 articles, ensuring a comprehensive and balanced examination of how different media outlets influence public perception of science. After selecting only articles related to science, we ended up with 25424 articles.

After implementing all the procedures, we categorized the articles using several dimensions: probability, sentiment, representativeness, total publications, publication time, and topics. These categories form the basis for our analysis, detailed in the second section of our study. This multi-faceted approach allows for both qualitative and

quantitative analysis. Firstly, calculating the relative weights of each topic enables us to filter topics based on other variables, such as publication time or media source. This step is crucial for understanding the prominence and evolution of specific science topics over time. Secondly, by identifying "probability" and "representative articles," which are central to each topic cluster, we can conduct a qualitative analysis. These representative articles provide a clear picture of the core content and discourse within each topic, serving as a basis for in-depth examination. Through the text we give examples from the titles of the most representative articles according to a category (for example, negative sentiment, Dnevnik, “Animal Behavior & Domestic Care”) This methodology ensures that our analysis is not only data-driven but also contextually rich, offering insights into how different media outlets portray scientific topics. Using these comprehensive categorizations, we present a detailed analysis that highlights trends, sentiments, and the overall representation of science in Bulgarian mass media.

4. Results

4.1. Science related publication between 2018 and 2023 according to the embedded topic modeling.

This analysis examines the coverage of various scientific topics in Bulgarian media from 2018 to 2023, based on the frequency of articles and their percentage of total yearly content (fig. 1). We are not going to list all the categories due to the limitations of the article. As we can see from the fig. 1 the science related articles vary from 1,4 percent to 0,56%. In 2018 the most prominent were the topics "Politics and Science" (31.88%) and "Human Health and Biology" (16.29%). "Astrophysics & Extraterrestrial Exploration" and "Earth Sciences" also received notable attention, while "Nobels" and "Energetics & Energy Solutions" were least covered.

In 2019 the “Politics and Science" (27.07%) and "Human Health and Biology" (10.10%) remained top topics. "Astrophysics and Extraterrestrial Exploration" continued to be significant. "Nobels" and "Energetics & Energy Solutions" were again among the least covered. The focus in 2020 shifted heavily to "Human Health and Biology" (81.64%) due to COVID-19, out of 2176 articles. "Politics and Science" (28.12%) remained significant. "Nobels" and "Energetics and Energy Solutions" had minimal coverage.

In 2021 Politics and Science" led (38.35%), followed by "Human Health and Biology" (54.17%). Other significant topics included "Astrophysics & Extraterrestrial Exploration" and "Education and Science Finance" with "Nobels" and "Energetics & Energy Solutions" remaining low. In 2022 "Politics and Science" (28.18%) and "Human Health and Biology" (12.47%) were still prominent. "Astrophysics" & Extraterrestrial Exploration" and "Education and Science Finance" were notable, while "Nobels" and "Animal Behavior &

Domestic Care" had low coverage. For 2023 "Politics and Science" (31.95%) and "Human Health and Biology" (8.54%) were the most prominent. "Astrophysics & Extraterrestrial Exploration" and "Climate and Weather" were also significant, while "Nobels" and "Animal Behavior & Domestic Care" remained least covered.

In summary, the data indicates that Bulgarian media prioritizes topics related to political impacts on science and health issues, particularly during times of crisis such as the COVID-19 pandemic. This focus underscores the significant role of the media in shaping public discourse around critical scientific issues. Conversely, topics like Nobel achievements, animal behavior, and energy solutions receive relatively little coverage, highlighting potential areas for increased media attention and public engagement.

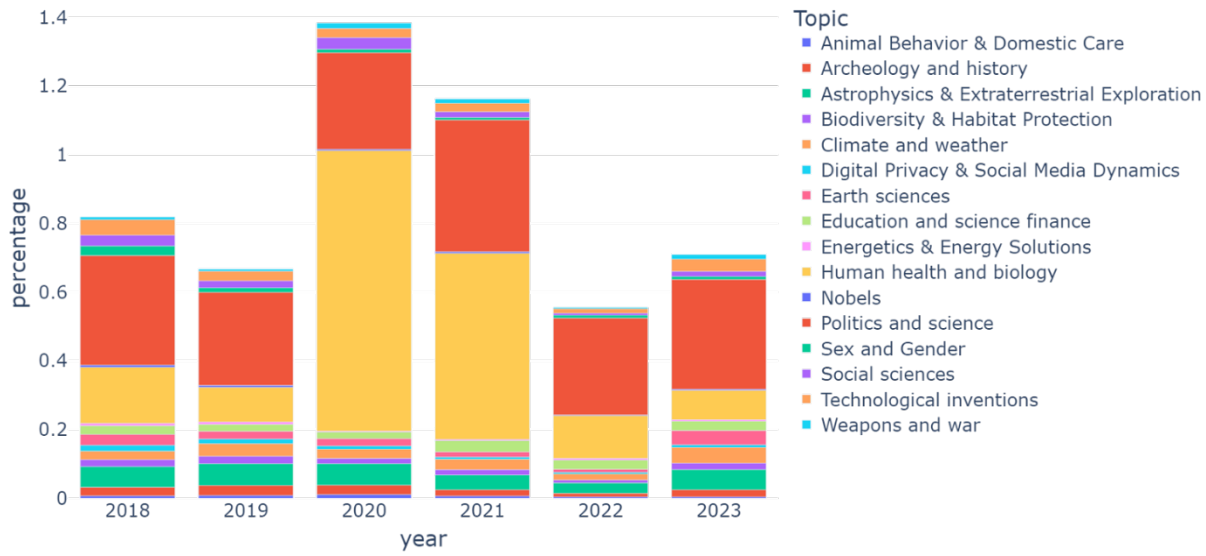

Figure 1. Percentage of science related news by year (2018-2023).

4.2. Media mapping by using BERTopic. Contrasting Approaches to Science Journalism in Bulgarian Media.

We mapped the studied media sources using a scatter plot (fig. 2). The vertical axis of this plot represents the percentage of scientific articles as part of the total articles published by each media outlet, while the horizontal axis represents the total number of articles of the media. From this mapping, it is evident that Dnevnik, a liberal media outlet, features the highest percentage of science-related news, indicating a strong emphasis on scientific reporting relative to its total content. The second highest is Duma, the socialist newspaper, which also shows a significant focus on science despite having a lower overall article count. Interestingly, NOVA, one of the most popular and mainstream media outlets, has the lowest percentage of science-related news. This disparity highlights how different editorial policies and audience targeting strategies can influence

the amount of scientific content published. This scatter plot not only visualizes the distribution of scientific articles across various media sources but also underscores the contrasting approaches to science journalism in Bulgarian mass media.

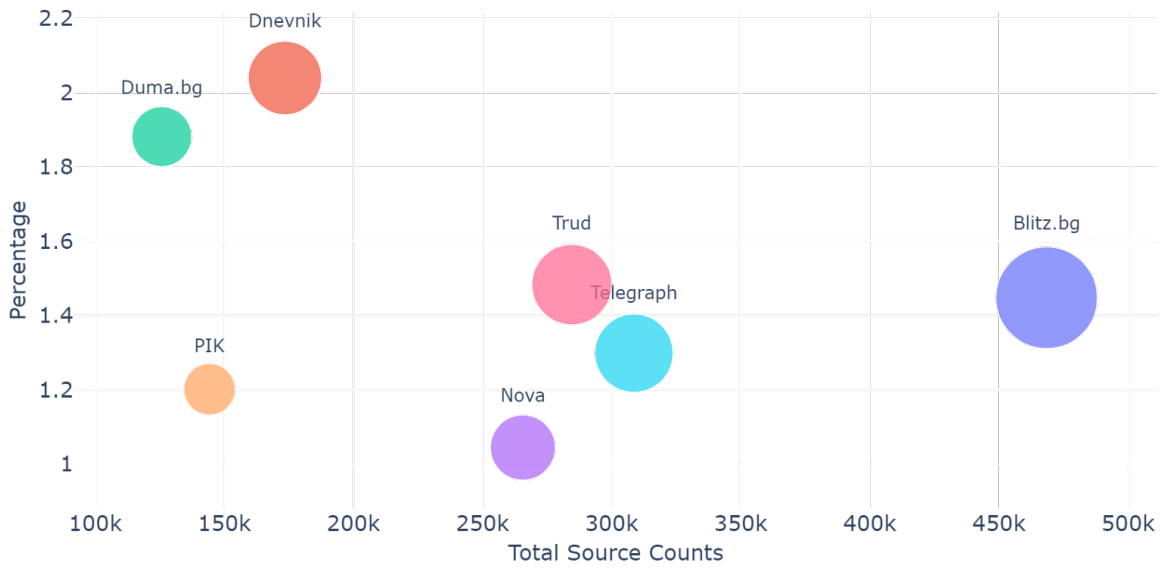

Figure 2. Map of the studied media based on number of articles and total percentage science related articles.

In our analysis, we examined articles with the highest probability levels, which are representative of each media outlet's approach to science reporting. For Blitz, a conservative media outlet, the representative article was titled "How we increased Bulgaria's population from 5.5 to 9 million thanks to scientific management during socialism." This reflects a nostalgic view of the socialist past, aligning with the outlet's statist leanings influenced by Bulgaria's totalitarian history. Dnevnik, a liberal media outlet, featured a study comparing Nazism and Communism, underscoring its anti-statist, pro-market, and pro-personal freedoms stance. This contrasts sharply with Blitz, highlighting the ideological diversity in Bulgarian media. Telegraph, another conservative and pro-Russian tabloid, showcased an article discussing how trust in vaccines was undermined by repression and censorship during the COVID-19 pandemic, indicating an anti-vaccine sentiment prevalent in its coverage.

PIK, known for its sensationalism, is represented by a study about hospital admissions due to acute alcohol intoxication, reflecting its preference for sensational scientific stories. Trud, another conservative media source, had an article on how Americans want to send Bulgarian yogurt to Mars, blending humor with a defense of Bulgarian cultural identity against globalization. Lastly, DUMA, the official newspaper of the Bulgarian Socialist Party, featured an article commemorating the USSR's launch of the first artificial Earth satellite, emphasizing its pro-Russian orientation and historical reverence for

Soviet achievements. These examples highlight the varied approaches to science reporting across Bulgarian media, influenced by each outlet's ideological stance and audience preferences. This diversity underscores the importance of context in media analysis, particularly in understanding how scientific topics are framed and presented to the public.

4.3. Analyzing Sentiment in Bulgarian Media's Science Reporting.

Our sentiment analysis of science-related topics in Bulgarian media reveals a spectrum of perceptions, from highly negative to notably positive. These sentiments provide valuable insights into public and media attitudes towards various scientific fields, reflecting broader societal concerns, interests, and hopes.

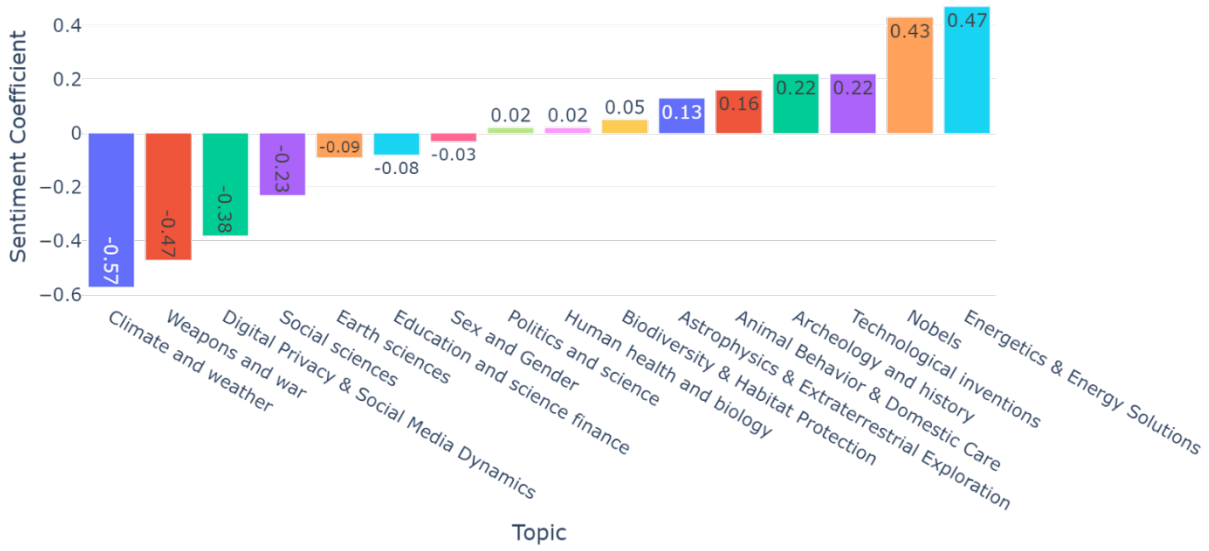

Figure 3. Sentiment analysis of the topics.

Negative Sentiment Scores

"Climate and Weather" stands out with the most negative sentiment score of -0.57. This significant negativity likely stems from widespread discussions about climate change and its dire consequences, such as extreme weather events and environmental degradation. The consistent coverage of these alarming topics underscores a deep-rooted concern for the future of our planet. Following closely is "Weapons and War", with a sentiment score of -0.47. This category naturally evokes negative emotions due to the destructive and tragic nature of warfare and military technologies. Discussions here often focus on conflicts, armament developments, and the human toll of war, contributing to the overall negative sentiment. "Digital Privacy & Social Media Dynamics" has a sentiment score of -0.38, highlighting concerns over privacy issues and the negative impacts of social media

on individual well-being and societal cohesion. The proliferation of data breaches, privacy scandals, and the mental health implications of social media use are likely drivers of this negative sentiment.

Social Sciences (sentiment score: -0.23) and Earth Sciences (-0.09) also lean towards negative perceptions. Social Sciences often involve contentious issues such as inequality, social justice, and political debates, which can provoke strong, often critical, reactions. Earth Sciences, while crucial for understanding environmental processes, are frequently associated with negative news about natural disasters and environmental degradation. Education and Science Finance (-0.08) and "Sex and Gender" (-0.03) are slightly negative, reflecting concerns over educational funding, access, and ongoing gender-related issues.

Closest to Neutral Sentiment Scores

As arbitrary as it is, we consider the scores between -0.05 to 0,05 to be neutral as in the practice score of 0,00 is rarely achieved. In this category we have “Politics and Science" and "Human Health and Biology” both have neutral sentiment scores of 0.02, indicating balanced discussions. "Politics and Science" likely covers both the positive impacts of science-informed policies and the controversies surrounding political interference in scientific matters. Similarly, "Human Health & Biology” combines the breakthroughs and advancements in medicine with ongoing health crises and challenges, resulting in a neutral overall sentiment. “Biodiversity & Habitat Protection” (0.05) edges towards positivity, reflecting the growing awareness and efforts towards conservation and environmental protection. This slight positivity suggests a cautious optimism about the effectiveness of these efforts and the public's support for biodiversity initiatives "Sex and Gender" (-0.03) is also in this category.

Positive Sentiment Scores

With the highest positive sentiment score of 0.47, “Energetics and energy solutions” reflects media enthusiasm for advancements in sustainable energy technologies. Coverage highlights innovations in renewable energy and energy efficiency, emphasizing the importance of these developments in combating "Climate" change and promoting environmental sustainability. News about Nobel Prizes scored 0.43, showcasing the media’s admiration for groundbreaking contributions in various fields. Stories often celebrate the achievements of Nobel laureates, their inspiring journeys, and the significant impact of their work, fostering a sense of pride and inspiration. "Technological Inventions" received a positive sentiment score of 0.22. Media reports focus on cutting-edge developments in areas like AI, robotics, and biotechnology, highlighting the potential benefits for improving everyday life and addressing global challenges. This reflects an optimistic view of technology’s transformative power. Also scoring 0.22,

"Archeology and History" coverage is driven by fascinating discoveries and historical insights. Positive sentiment is fueled by stories about significant archeological finds and efforts to preserve history, emphasizing the importance of cultural heritage and our connection to the past. "Astrophysics & Extraterrestrial Exploration" (0.13) evokes a positive sentiment, driven by the excitement with space exploration and astronomical discoveries, but nevertheless more on the neutral side.

Differences between media in regard to their sentiment

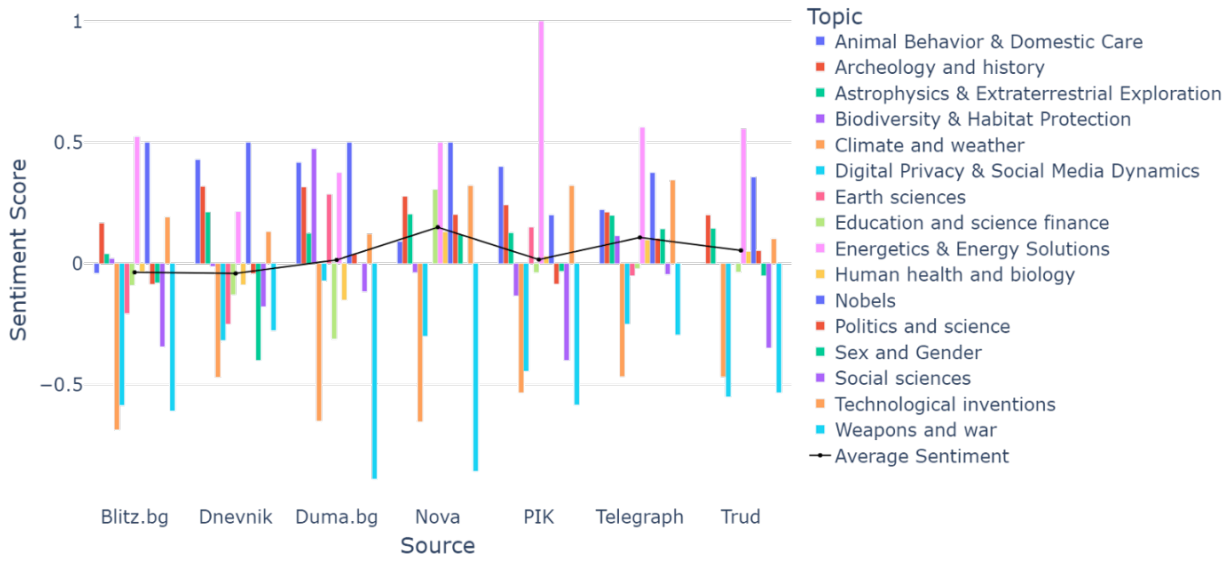

Figure 4. Sentiment Coefficients by Source and Topic.

Our sentiment analysis across various Bulgarian media sources reveals notable differences in how scientific topics are perceived and reported. Each media outlet exhibits unique editorial stances, resulting in diverse sentiments ranging from highly negative to positive. Here, we compare these sentiments, focusing on topics that show significant differentiation between the media.

Sentiments towards “Biodiversity and Habitat Protection” are mixed. Duma.bg stands out with a highly positive sentiment of 0.47, emphasizing its strong support for environmental issues, if we dwell into the articles we see that Duma is represented by an article about finding new animal species. Conversely, PIK (“DISCLOSURE: Greens made Natura 2000 in Bulgaria without scientific data”) and Nova show negative sentiments, with scores of -0.13 and -0.04, respectively, indicating less favorable coverage. Sentiments towards Earth sciences are varied, with Duma.bg showing a positive sentiment of 0.29, highlighting support for environmental sciences. Blitz.bg and Dnevnik are slightly negative, scoring -0.21 and -0.25, respectively, indicating more critical coverage.

Sentiments towards “Education and Science Finance” are mixed, with Nova displaying a positive sentiment of 0.31, emphasizing optimism about educational and scientific funding. Duma.bg shows a negative sentiment of -0.31, reflecting concerns over funding issues. These differences highlight contrasting views on the state of education and science finance across different media. Sentiments towards "Human Health and Biology” are generally neutral, but the media still differentiate. For example Dnevnik (“Two French academies have asked the state to stop funding homeopathy”) reports the topic slightly negative (-0,9) with slight positivity from Nova (“New antibiotic effective against resistant bacteria developed”), scoring 0.13, and slight negativity from Duma.bg, scoring -0.15, reflecting a balanced view of health-related topics across media. Nobel-related articles are consistently positive across all sources, with consistent high scores indicating widespread admiration for Nobel laureates. Blitz.bg, Dnevnik, and Duma.bg all score 0.50, while PIK shows lower positivity with a score of 0.20.

Sentiments towards "Politics and Science" are mixed, with Nova (“Bulgarian students with world recognition in astronomy”) and Telegraph showing positive sentiments, scoring 0.20 and 0.10, respectively, reflecting favorable views on the intersection of "Politics and Science". Blitz.bg and PIK (“BREAKING EXPOSURE ON BSP CASH: Cornelia Ninova blew nearly 6 mln on sociologists and close advisers”) are slightly negative, scoring -0.09 and -0.08, respectively, indicating more critical coverage. These mixed sentiments reflect differing perspectives on how politics influences scientific endeavors. "Sex and Gender" issues are polarized, with Telegraph (“They revealed the secret of female sex appeal”) showing a positive sentiment of 0.14, reflecting support for gender issues. Dnevnik (“In search of balance: do antidepressants stand between sex and health”) is strongly negative, scoring -0.40, indicating critical views on current sex and gender-related discussions.

5. Summary and Discussion

Our study aimed to explore how science-related news is reported in Bulgaria. The lack of funding and all the consequences from this, but also due to lack of media freedom and its preoccupation with political advocacy, create preconditions for a poor media presence of science in the media. We leveraged advanced textual data analysis methods named Embedded Topic Modelling and sentiment analysis to map and analyze the portrayal of science over a five-year period (2018-2023). The dataset consists of articles from seven major Bulgarian media outlets representing a spectrum of editorial stances, from liberal to conservative, and pro-European to pro-Russian.

Our results show that science-related articles account for about 0.89% of total articles. In comparison, the National Science Board reports that science-related news in the US

is around 2% (2014), other studies with a broader definition of science and technology news report 13.25% (comparing tokens in sci-tech news to total word tokens) in English and Italian newspapers (Zorzi et al., 2023). The results suggest the need for a more refined definition and discussion of what exactly should be considered science-related news. One of the limitations of our methodology is that it includes only topics in which the top 50 keywords contain at least one science-related term or reference to a scientist (e.g., biology, astronomy, biologist, astronomer). This rigid approach to selection reduces the number of false positives but, on the other hand, increases the number of false negatives. Furthermore, this effect is exacerbated by the technological aspect of BERTopic, which might rank these science or scientist keywords lower than the 50th keyword, excluding them from our selection. Therefore, readers should take into account that our approach is biased towards lowering the overall results.

A significant portion of these topics focuses on the topic “Politics and Science” (approximately one-third) (“Prof. Ph. Denkov [the prime minister of Bulgaria] is among the top 2% of the world's best scientists.”) which includes articles about the interactions between science and politics. Additionally, a large part of the second largest topic, “Human Health and Biology” is heavily politicized due to the political aspects of the COVID-19 pandemic. Dnevnik, with a liberal and pro-European orientation, and DUMA (official Newspaper of the Bulgarian Socialist Party), aligned with socialist and pro-Russian views, have the highest percentage of science-related news, indicating a stronger editorial emphasis on scientific reporting. In contrast, NOVA, a mainstream outlet that generally supports the government, features the lowest percentage of science-related articles, highlighting how editorial policies and audience targeting strategies influence the amount of scientific content published.

The sentiment analysis reveals that topics related to "Climate and Weather" received the most negative sentiment scores, reflecting widespread concerns about "Climate" change and its impacts. Similarly, topics like "Weapons and War", and "Digital Privacy & Social Media Dynamics" also scored negatively, highlighting public anxiety around these issues. On the other hand, "Astrophysics" & Extraterrestrial Exploration and Energy Solutions received positive sentiment scores, indicating public fascination and optimism towards these areas.

Furthermore, our methodology successfully detected very subtle differences (relative to the size of our initial database) between the studied media. While the majority of topics, such as 'Astrophysics & Extraterrestrial Exploration' (reported with neutral sentiment), 'Technological Inventions' (reported positively), and 'Climate and Weather' (reported negatively), are consistently reported across all the studied media, some topics exhibit different sentiments depending on the media outlet. 'Politics and Science' and 'Human Health and Biology' (mainly due to the controversies around COVID-19) are the most popular and, at the same time, divisive topics. Other divisive topics, though not as

popular, include 'Sex and Gender,' 'Earth Sciences,' and 'Biodiversity,' which are also part of the broader ideological and political struggles within Bulgarian society. These topics are the most politicized, and therefore, the media align their reporting on these topics according to their ideological or other orientations. For example, in the context of COVID-19 science-related news, anti-government media (PIK, Dnevnik, Duma, Blitz) report negatively, while pro-government media report with more neutral or positive sentiments. However, we will propose another explanation that draws on the notion of 'regulatory science.'

How to explain the differences in media reporting? From science-related news to regulatory science-related news.

Why are some science-related topics instrumentalized in ideological, political, and media struggles while others are not? One possible explanation can be found in the notion of regulatory science, a central theme in Science and Technology Studies (STS). According to Yearley (1994:252), “there has begun to be a switch from science being seen as a way of increasing production to a view of it as a means of handling risks and of achieving regulation.” In other words, “When science represents a heuristic for cognitively managing risk and uncertainty, it thrives; alternatively, when it is seen as a tool for bodily regulation, it suffers the stigma permeating all politically charged environments” (Gauchat, 2015:266). Being politically charged, these topics become stakes in the local political struggles.

In our case, we can detect politically loaded science related news thanks to sentiment analysis. Media reports on topics such as “Human Health and Biology”, which is its most obvious example particularly in the context of COVID-19, illustrate this shift. The focus of science shifted from understanding microbiology and biology (represented by articles about the benefits of Vitamin D) as tools to extend and save human life, to being used as political tools to regulate human behavior and the body through public institutions. The same conclusion can be drawn for the theme of “Politics and Science” where science becomes an instrument for legitimizing a wide range of political agendas (legitimacy of the prime minister for being from academia). Media coverage on this topic shows how science is often used to support or oppose political decisions, reflecting Yearley's concept of regulatory science. “Earth sciences and biodiversity” also fall into this category and have been well studied in this regard (Jasanoff, 1990). In our case it is linked to the debate of keeping biodiversity versus the farmer interests. Liberal media tends to support and advocate for the regulatory use of science, emphasizing the importance of scientific input in policy-making. In contrast, conservative media often portrays regulatory science with skepticism, highlighting concerns about government overreach and the implications of regulation on personal freedoms, which is seen as alien to Bulgarian traditions.

In comparison, topics like “Astrophysics” and “Technological Inventions” are reported positively by all media. If we follow our “regulatory science” explanation, these topics are viewed as ways of increasing production and are therefore interpreted outside of the political ideologies framework (Gauchat, 2012). Additionally, these science themes, at least in Bulgaria, are not institutionalized within the state or closely tied to the political domain, which is why they are often republished after being translated from foreign sources.

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Trust in Science? Revisiting Participatory Science and Framing Knowledge as a Gift

Franziska Sörgel[1]

[1]Institute for Technology Assessment and Systems Analysis (ITAS), Karlsruhe Institute of Technology (KIT), Germany

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Abstract. This article critically examines the intricate dynamics of trust in (open) science. Drawing from observations in participatory formats, such as citizen dialogues during the Karlsruhe Institute for Technology's Science Week, the article identifies a tendency among scientists to withhold certain forms of knowledge, particularly negative knowledge. Inspired by Marcel Mauss' theory of the gift, it explores how reframing trust as a reciprocal and moral transaction can offer valuable insights into fostering transparent and equitable knowledge exchange practices. Through a nuanced exploration of reciprocity and transparency, the article challenges conventional notions of scientific trust and highlights the ethical dimensions of knowledge sharing. Ultimately, it aims to contribute to a deeper understanding of trust in science and promote more ethical and inclusive knowledge exchange practices in contemporary scientific inquiry.

1. Introduction

In the last couple of years, the German[1] research and innovation landscape has experienced a notable transformation characterised by a pronounced emphasis on participation in civil society and open science. This shift is exemplified by recent initiatives such as the 'Participation Strategy for Research'[2] introduced by the Federal Ministry of Education and Research (BMBF) in Germany in June 2023 while a similar transformation was already indicated around 20 years ago with the 'Berlin Declaration on Open Access to Knowledge in the Sciences and Humanities'[3], which had been signed by nearly 800

[1] Author's note: While the focus is on the German research landscape, the author will also draw parallels with similar trends in other Western universities throughout the article as such strategies seem relevant for a broader research landscape.

[2] See: Participation Strategy by the BMBF 2023

[3] See: Open Access Initiative by the Max Planck Society

universities by November 2023. These strategies do not only seek to integrate civil society groups into research processes by involving them in committees and incentivising collaboration between researchers and the public; they are also indicating a general shift towards an open science that ought to be available to 'everyone', meaning those who have the resources and competencies (or, e.g. cultural capital, following Bourdieu (1986)). While these two exemplary initiatives are specific to Germany, similar structures may also be emerging in other countries (e.g. UKRI's strategy for open science[4], 'Ouvrir la science!' in France[5] or Spain's National Open Science Strategy ENCA[6]). At the heart of this shift is recognising the value of diverse perspectives in shaping research agendas and fostering collaboration between researchers and civil society. It reflects a broader societal expectation that science should not remain confined within the ivory tower but should be open and accessible to the public as we know it, for example, from Mode 2 (Gibbons et al., 1994; Nowotny et al., 2013). Several key expectations in science policy are linked with the concept of open science. Nevertheless, we can observe that for considerations of trust in science, perspectives often emerge from the viewpoint of the public, specifically on how to gain the public's trust in science.

Firstly, open science promotes higher transparency and additional quality assurance in the research process, enhancing reproducibility and strengthening trust in scientific endeavours (e.g. Winker et al., 2023). Secondly, it facilitates the faster re-utilisation of research findings, which aims to increase the efficiency and performance of the scientific system (e.g. ZBW, 2023). Thirdly, open science suggests supporting more effective knowledge transfer to the economy and society, stimulating innovations based on scientific findings (e.g. Fell, 2019). Lastly, it encourages non-scientists involvement in the research process, aiming for greater societal relevance and acceptance of research priorities (EU's Open Science Policy 2020-2024[7]). In both scholarly literature and the expectations set forth by political actors, there is a prevailing belief that individuals with a solid grasp of scientific concepts possess a more sophisticated understanding of science (e.g. Hilgartner, 2015). This notion suggests that citizens with extensive scientific knowledge are better equipped to assess the reliability and credibility of scientific institutions. Moreover, research indicates a strong correlation between scientific trust and individuals' evaluations of research institutions' goals and actions, a relationship significantly influenced by their level of scientific knowledge. Scholars argue that scientific knowledge enables individuals to assess scientific trust rationally, with performance-based evaluations as critical criteria (e.g. Böhme & Stehr, 1986; Reichmann, 2011).

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[4] See: United Kingdom Research and Innovation's (UKRI) Strategy on Open Research

[5] See: Ouvrir la Science in France

[6] See: National Strategy For Open Science (ENCA) in Spain

[7] See: EU's Open Science Strategy 2020-2024

However, the emergence of this imperative, as reflected in political calls for increased openness in science, prompts critical inquiry into the appropriateness of political intrusion into scientific spheres and their advocacy for public engagement and participatory communication formats. While opening science to broader participation is undoubtedly appealing (e.g. Rössig et al., 2023; Hecker et al., 2018; Marres, 2011), it necessitates a critical examination of the implications of such openness (Hosseini, 2024) referring to the question of how open scientific knowledge should be. In this context, several questions arise: What is the role of governmental bodies in mandating openness in scientific research, and what are the implications for the autonomy and self-regulation of the scientific community? The imposition of mandates from governmental bodies raises concerns about the erosion of self-regulatory mechanisms (Maasen & Weingart, 2006) within the scientific community. This prompts me to question the underlying dynamics of trust between politics and science. If the requirement for openness is consistently enforced, can we still consider scientific engagement with the public as voluntary? Moreover, what does the prevailing perspective on trust in science from the public's viewpoint mean? Should we not strive to allow for a general diversity of perspectives here, which also includes questioning the trust of scientists in the public and in their own system.

In light of these considerations, this article critically examines the diverse perspectives on trust, specifically through serendipitous findings from a current research project. It explores how participatory science, knowledge management, and governmental intervention intersect in shaping science strategies. By introducing Marcel Mauss's theory of the Gift (1925), it explores the tensions arising from the imperative for openness while preserving the integrity and autonomy of scientific inquiry. Furthermore, it prompts reflection on the evolving relationship between politics and science, highlighting implications for trust within the scientific community. By embracing diverse perspectives, effectively managing knowledge forms, and leveraging theoretical insights such as Mauss's theory of the Gift, researchers can adeptly navigate the complexities of contemporary research environments and contribute to meaningful societal engagement. Additionally, the article advocates for continuous dialogue and reflection on participatory research's ethical and practical dimensions, thereby advancing towards a more equitable and impactful scientific enterprise.

2. Sharing Knowledge: An Approach

As the introduction indicates, promoting civil participation and open scientific practice has political implications (Koenig et al., 2023; Mayer et al., 2020). Accordingly, participation formats as they take place at universities are a product of these political demands. During the research for a project called 'Participatory Procedures and Processes in Research Organizations' (PaFo) at the Karlsruhe Institute of Technology (KIT)[8], an array of such participatory formats has been observed, particularly emphasising citizen dialogues. These dialogues emerged as pivotal platforms where researchers and citizens collaboratively delve into pressing societal issues and craft research inquiries for one day that potentially influence KIT's research agenda. This participatory approach underscores a steadfast commitment to inclusive research practices, fostering the acknowledgement of diverse perspectives in shaping the research landscape. The primary objective of the project's empirical study has been to measure the impact of citizen dialogues on the university's research agenda, namely the KIT. Specifically, it aims to investigate whether the university's administration effectively communicates the knowledge and contributions of participants to relevant researchers and whether these insights subsequently influence ongoing academic work. Additionally, the study examines the event's effect on the participants themselves, exploring whether engagement with scientific discourse alters, e.g. their ways of thinking and acting. To facilitate this, a matrix has been developed as a multi-methodological framework, outlining the categories and indicators necessary for assessment, which are explored through various instruments such as questionnaires, interviews, and document analysis, to name but a few. I used qualitative and quantitative methods to comprehensively understand actors' expectations as part of a multimethodological approach. I used participant observation and go-alongs to engage directly with attendees in real-time during the event. Additionally, I conducted focus group interviews during coffee breaks to capture collective dynamics and immediate reactions as the event unfolded. I collected quantitative data through questionnaires, which gathered demographic information and details about the general composition of the attendees. Photographs were also taken throughout the event, providing visual material that could later be used to trigger memories and stimulate discussions during post-event interviews. So far, I have conducted 25 qualitative interviews following the event with participants, including citizens, university administrators, and researchers. These interviews were transcribed, analysed, and coded to extract key themes and insights. The photographs taken during the event were revisited during these interviews to help interviewees recall specific moments or experiences. Both the qualitative and quantitative data serve as critical

[8] Author's note: The university provides core funding for the project.

sources of information for the matrix, which is continuously shaped and refined based on these inputs and is reviewed and adjusted annually with each citizen dialogue.

However, amidst these participatory endeavours, insightful but serendipitous observations surfaced during interviews with participating scientists and researchers, prompting me to reflect on these findings, which I would like to elaborate upon here. While these qualitative findings are serendipitous and not sufficiently developed to be the focal point of this analysis, the investigation and general observations from the scientific system indicate trends that merit further exploration. The observations now prompt me to use them as the starting point for this paper and to elaborate on trust in science within the context of the openness of our system. The data itself is relatively young and still developing. Yet, it provides a clear basis for further investigation into the issues and questions raised in this paper, mainly as I have been gathering more data, so the thesis is gaining strength.

2.1. Sharing Knowledge: What Knowledge?

Several interviews with citizens and researchers made it apparent that not all knowledge is openly shared within scientific communities. This revelation provoked me to explore the dynamics of knowledge sharing and identify distinct knowledge structures. In the mentioned research, scientists' and researchers' recognition and management of various knowledge forms became central when asked about their way and attitude towards knowledge exchange. Further, researchers often unconsciously refer to knowledge forms that include positive, missing (Seidl, 2010), and negative knowledge (Oser, 2005), each playing a distinct role in shaping research agendas and informing decision-making processes. Hence, I briefly summarise what to understand under these terms: (1) Positive knowledge, in distinction to the following definitions, encompasses the information and insights that are well-established and widely accepted within a given field of study. It represents the body of knowledge that forms the basis for scientific inquiry and serves as a foundation for further research and innovation. (2) Missing knowledge, on the other hand, in philosophical considerations, refers to the gaps and uncertainties in our understanding of a particular phenomenon or issue. These gaps may arise due to limitations in existing research, unanswered questions, or areas where empirical evidence is lacking. Identifying missing knowledge is critical for directing future research efforts and addressing areas of uncertainty within the scientific discourse (e.g. Seidl, 2010). (3) Now, turning to the concept of negative knowledge, as conceptualised by Fritz Oser (2005), it represents a unique and intriguing knowledge dimension often overlooked in traditional research paradigms. Negative knowledge pertains to insights gained from recognising and understanding processes, methodologies, or phenomena by discerning how they do not function or operate as expected. It involves understanding what does not work, which can be just as informative and valuable as understanding what does.

However, negative knowledge poses challenges to transparent knowledge exchange, as it may involve acknowledging failures, limitations, or areas of uncertainty within research endeavours. In principle, Oser's conceptualisation of negative knowledge would highlight the importance of transparency and openness within scientific communities (e.g. Merton 1957). Withholding or neglecting to share negative knowledge can hinder progress and contribute to the perpetuation of misconceptions or flawed assumptions. By acknowledging and sharing negative knowledge, researchers could contribute to a more comprehensive and nuanced understanding of phenomena, facilitating more informed decision-making and advancing scientific knowledge.

Now, as indicated, during conversations with several scientists involved in participatory formats aimed at informing the public, I observed that negative knowledge often remains unshared within scientific communities. This poses a challenge to transparent knowledge exchange and highlights the need for increased openness. Thus, this observation prompts me to question why scientists withhold this form of knowledge and what this reservation reveals about current science communication practices.

Despite the theoretical importance of distributing scientific knowledge, scientists often feel constrained in their knowledge-sharing practices. They perceive pressure to limit their disclosures to performance-based knowledge and positive findings, driven by the desire to enhance their credibility and that of the scientific community. Furthermore, there is a prevalent reluctance among scientists to share their 'research islands', reflecting a persistent perception of isolation and separation between the realms of science and society. This reluctance stems from viewing political calls for increased transparency and public engagement as transient trends rather than enduring commitments to societal integration. It suggests that various factors pressure scientists. As described above, the focus on performance is a significant criticism, as reflected in performance evaluations and impact assessments. An obvious assumption may be the strengthening of these criteria and the current narrow focus on science communication, as proposed, e.g. by the German BMBF, which additionally suggests a proper framework and is surrounded by its #FactoryWisskomm initiative.[9] The efforts are not fundamentally misplaced, but these demands seem to consider scientists insufficiently. Accordingly, an important observation in this context is that scientific projects are now engaging with these 'impact assessments' and positioning themselves to shape legitimacy arguments (Bahr et al., 2022), potentially to anticipate and avoid further criticism. In essence, while scholarly

[9] There seem to be plenty of such science communication strategies worldwide: e.g. Engage.EU at WU, Vienna; COALESCE by Science for Change in Barcelona; Research in Conversation at Oxford University; Pursuit-Platform at University of Melbourne

literature and political discourse emphasise the importance of scientific knowledge in fostering trust and collaboration between science and society, empirical observations reveal significant barriers and complexities in achieving this ideal. Recognising and addressing these discrepancies is crucial for bridging the gap between scientific expertise and public understanding, fostering a more robust and inclusive scientific enterprise.

Given this context, it is crucial to clarify the relationship between (non-)knowledge and trust and, moreover, another prerequisite, namely autonomy. Trust occurs when one cannot know or verify. In this sense, trust is a meta-emotion, a feeling underpinned by other feelings (Sörgel, 2024: e.g. 192). Through this, trust can dissolve power dynamics. For instance, Ingold writes: 'To trust someone is to act with that person in mind, in the hope and expectation that she will do likewise – responding in ways favourable to you – so long as you do nothing to curb her autonomy to act otherwise (Ingold, 2000: 69–70).'

In this vein, I would now like to turn to Marcel Mauss's theory of the gift and understand it as an inspiration to reflect on trust and its related implications and to make it fruitful for our understanding of science and sharing knowledge.

3. Marcel Mauss's Theory of the Gift to Reframe our Understanding of Trust

Marcel Mauss, a prominent French sociologist and anthropologist, is renowned for his work in understanding the complex social phenomena of gift-giving across different cultures and societies. His seminal book, *The Gift: Forms and Functions of Exchange in Archaic Societies* (1925), remains foundational in anthropology and sociology. At the heart of Mauss' theory is exploring the multifaceted nature of gift-giving practices within traditional societies. He investigates the intricate dynamics of gift exchange, elucidating how these exchanges serve not merely as economic transactions but as profound social and moral phenomena. Mauss emphasises that gifts are never given or received in isolation; they are imbued with social meanings and expectations, shaping relationships, identities, and social structures within communities. Mauss identifies three essential obligations inherent in gift exchange: the obligation to give, the obligation to receive, and the obligation to reciprocate (Mauss, 2002: 17ff.). These obligations form the basis of a complex system of social ties and obligations, fostering mutual interdependence and solidarity within communities. Moreover, Mauss highlights the symbolic significance of gifts, not to be confused with presents, which transcend their material value to convey social status, power dynamics, and cultural norms (Mauss, 2002).

> Thus, it is indeed ownership that one obtains with the gift that one receives. But it is ownership of a certain kind. One could say that it partakes of all kinds of legal principles that we, more modern, have carefully isolated from one another. It is ownership and possession, a pledge and something hired out, a thing sold and bought, and at the same time deposited, mandated, and bequeathed to be passed on to another. For it is only given you on condition that you use it for another or pass it on to a third person, the 'distant partner', the murimuri. Such is the nature of this economic, legal, and moral entity (…) (Mauss, 2002: 30).

Yet, Mauss explores the role of reciprocity in the gift exchange, emphasising its importance in maintaining social cohesion and reinforcing social bonds. According to Mauss, reciprocity is not merely an economic exchange but a moral imperative, reflecting a society's values and norms. Central to his theory is the concept of 'total prestation' (*préstation totale* often translated as 'total service') (Mauss, 2002: e.g. 4), wherein the gift is not simply a one-time transaction but entails a series of reciprocal exchanges, creating an ongoing cycle of obligations and counter-obligations, representing every facet of the society it originates from. The gift encompasses economic, political, kinship, legal, mythological, religious, magical, practical, personal, and social dimensions. When such an item circulates within the social milieu, the giver effectively reconfigures the social fabric, which underpins the gift's inherent power. Thus, the act of giving necessitates a subsequent act of receiving and reciprocating, thereby perpetuating social cohesion and mutual dependence (Mauss, 2002: 62). Mauss' understanding of trust, therefore, results from the mutual obligation of reciprocity and the mutual assurance of acknowledgement and appreciation, while preserving the individual's autonomy.

3.1. Rethinking Trust in Science

Even if we cannot be sure whether the French sociologist Marcel Mauss fully grasped the complexity of the gift in so-called archaic groups, the observations nevertheless provide valuable indications of the gift's social implications. I would like to shed further light on these aspects and make them fruitful for understanding trust in science from two perspectives. So, let me ask how to rethink trust in science as a reciprocal and moral transaction rather than a plain non-word to match socially acceptable expectations. As noted, scientific knowledge and expertise are not merely commodities to be traded but valued resources with social significance and ethical implications. I want to posit a dual perspective on trust, emphasising the interplay between trustworthy exchange and moral obligations in fostering mutual trust between scientists and society.

Trustworthy exchange entails not only the dissemination of scientific knowledge but also the establishment of transparent and ethical practices that uphold the integrity of the scientific endeavour. Simultaneously, moral obligations underscore the ethical responsibilities of scientists to engage with society in a manner that fosters mutual understanding, respect, and accountability. By reframing trust as a gift, I prompt reflection on the norms and conditions necessary for promoting genuine knowledge exchange and

scientific self-regulation. It underscores the importance of recognising scientific knowledge as a social construct shaped by reciprocal interactions and moral imperatives. Moreover, this perspective flips the coin on trust *in* science.

On the one hand, and I assume this is the common perspective for political stakeholders (e.g. Santirocchi et al., 2023; The British Academy, Policy Report 2024), the first perspective revolves around trust in science from the public's standpoint. Hence, the public and policymakers expect research and science to be credible, reliable, and trustworthy. The public and policymakers rely on scientists to deliver neutral and objective information, enabling them to make evidence-based decisions on challenges like climate change or other (related) crises and the implementation of scientific and technological advancements in areas such as the environment, healthcare, and technology (e.g. Grønli Åm, 2011: 18). On the other hand, the second perspective delves into trust in science from the standpoint of scientists towards society, emphasising the reciprocal nature of trust and the handling of 'open knowledge'. We can recognise tendencies in our research results that there is a loss of trust on the part of science in society and that the points mentioned above of not sharing knowledge give the impression that phenomena such as misinformation (e.g. fake news or the manipulation of facts) or the accusation of unscientificness result in reticence and isolation. This withdrawal has the opposite effect to that intended by the political calls. And yet, after all these political interventions, we have to ask ourselves if we regard the dissemination of knowledge as more than a sterile or technical business. In this context, several critical points and gaps arise within this system. The central importance of publications in the scientific community is underscored despite the challenges posed by fake publishers.

Discussions revolve around implementing an Open Access model to facilitate global access to scientific articles and accelerate knowledge exchange. While highlighting the benefits of Open Access, concerns emerge about potential data misuse, science parasites, and worries regarding data tracking and espionage by major publishers (e.g. Charité, Berlin, 2020: 'Wie erkenne ich Raubjournale?' (Engl. How can I detect predatory journals?), ZBW (2023): 'Open Access Mythen. Was ist dran?' (Engl. Open Access Myths: What's the Truth?)). Concurrently, scepticism arises towards digital workflows and platform dependence in the publication process (Franzen, 2016), cautioning against predatory publishers and scientific publishers' monetisation of user data (Koerber et al., 2023). Criticisms are levelled at the inadequate recognition of publishers relative to the efforts of scientists in publications and peer reviews. Overall, there is a discourse on the advantages of Open Access for scientific progress, juxtaposed with the challenges and risks associated with the dominance of major publishers and the trade of scientific data. These discussions converge with the recognition of unequal access to scientific knowledge, where disparities hinder collaboration and competitiveness driven by the pressure to publish in prestigious journals, which may compromise data sharing and

communal benefits. This competitive atmosphere undermines reciprocity and erodes trust within the scientific community. Additionally, the replication crisis underscores the reproducibility challenges in science, questioning the reliability of findings and the integrity of researchers, thus further weakening trust and diminishing the perceived value of shared knowledge.

Let me, therefore, refer to the main points above and transfer them to the current academic system. Relating now to the understanding of trust being founded on the principle of reciprocity. Just as in gift-giving, where giving and receiving create social bonds, trust emerges through mutual actions and fulfilling obligations. Trust is strengthened when both parties honour their promises and attend to each other. Trust is not merely a rational decision but also possesses symbolic value. It represents mutual recognition and respect, akin to the symbolic significance of gifts in traditional societies. This symbolic value contributes to the depth and stability of relationships. When applying this to the scientific system, particularly in the context of the availability and dissemination of knowledge, the sharing and exchanging of knowledge can be viewed as a form of a 'gift' that fosters trust, collaboration, and the advancement of collective understanding. Researchers share their findings, methodologies, and data, which others can build upon, critique, and expand. This exchange is analogous to gift-giving, where sharing knowledge could create social bonds and mutual obligations among scientists. Trust is built when researchers consistently contribute valuable insights and honour the norms of transparency, reproducibility, and acknowledgement of others' work (e.g. Shapin, 2004). The symbolic value of this trust is significant, as it represents mutual recognition and respect within the scientific community, thereby contributing to the depth and stability of professional relationships.

3.2. Reciprocity Through Autonomy

Especially in light of current political events (e.g. this year's protests on the Israel-Palestinian war at universities in the US (Harvard, Columbia, and Brown Universities) and Australia (Sydney, Monash, Queensland Universities) but also various European countries, e.g. UK (Oxford, Exeter, Bristol Universities), France (Sciences Po), Belgium (Ghent University), Germany (Berlin Universities) that questioned free speech and academic freedom, and imposed accusations of antisemitism), it is essential to maintain the autonomy and integrity of the scientific enterprise while ensuring that collaborative efforts are conducted to uphold scientific standards and principles and critically evaluate political actors' expectations and interventions in this context. While calls for increased transparency and public engagement are commendable, they must balance preserving scientific autonomy and preventing undue interference in the research process (e.g. Böschen 2018; Franzen, 2014). A genuine collaboration between science and society can only thrive in an environment that respects each actor's roles and responsibilities

while fostering meaningful dialogue and mutual understanding. Even though it is not conducive to the relationship between science and political actors when the latter seek advice, recommendations for action in critical situations have been formulated by the scientific community on a large scale for years, only to be ignored.

Furthermore, within the discourse surrounding the cultivation of reciprocal knowledge exchange norms, it is imperative to critically engage with the role of governmental entities, exemplified by the Federal Ministry of Education and Research (BMBF) in Germany. While acknowledging the BMBF's laudable initiatives to enhance civil society participation in research endeavours, a nuanced examination is warranted. Despite the apparent enthusiasm for fostering public engagement, a discerning approach is necessary to mitigate potential encroachments upon scientific autonomy and the imposition of authoritarian directives upon research agendas (Kölbel, 2016). It behoves stakeholders to recognise that while promoting greater accessibility of science to society is a commendable aspiration, safeguarding scientific integrity necessitates a reasonable balance. Thus, while extolling the BMBF's endeavours, it is incumbent upon the scholarly community to advocate for a framework wherein scientific inquiry remains driven by intellectual curiosity rather than bureaucratic mandates (Kölbel, 2016).

One of Mauss's criticisms of Western societies in his book's concluding chapter (Mauss, 2002: 83 ff.) is its tendency to reduce social relationships to economic transactions, diminishing the exchange's social and moral dimensions. In capitalist societies, the emphasis on monetary value and profit often supersedes considerations of social cohesion and solidarity, leading to the commodification of goods and services and the alienation of individuals from their labour and communities. Moreover, he argues that capitalist structures disrupt the reciprocity inherent in gift exchange by promoting unequal power dynamics and exploitation. In contrast to the egalitarian ethos of gift economies, where gifts are given and received without expectation of immediate return, capitalist systems often perpetuate inequalities and reinforce hierarchies based on wealth and privilege. Additionally, Mauss critiques capitalism for undermining traditional cultural practices and values associated with gift-giving. As capitalist economies expand and globalise, traditional gift economies and reciprocal social relations are often marginalised or supplanted by market-based exchanges, eroding social cohesion and losing cultural heritage. Mauss's critique underscores the social and moral implications of economic systems based on profit-driven exchange. It highlights the need to reevaluate societal values and prioritise collective well-being over individual gain. His work inspires debates on the relationship between economic structures, social relations, and human flourishing in contemporary societies.

This strongly resonates with the established academic system in Germany, but in general goes for Western countries' universities, revealing profound challenges and shortcomings within higher education (e.g. see the vivid description of for-profit education

and general conditions of the educational system in the US by Clark 2019; Bosanquet et al. 2020). Firstly, the commodification of knowledge within academia is evident in the increasing commercialisation of research outcomes. Universities are pressured to prioritise research projects that promise immediate financial returns or commercial applications (Harvey & Stensaker, 2008), often at the expense of fundamental research that may not yield immediate economic benefits. For instance, disciplines like the humanities and pure sciences, which may not directly translate into marketable products or services, are often undervalued and underfunded compared to fields with more apparent commercial potential, such as engineering or natural sciences. Moreover, the pervasive culture of metrics and performance indicators in academia perpetuates a narrow focus on quantifiable outputs, such as publication counts and citation metrics (Stensaker and Harvey, 2008 & 2010), rather than the quality and impact of research. This emphasis on quantitative measures can stifle innovation and intellectual risk-taking, as scholars may feel pressured to conform to established paradigms or pursue research topics that are more likely to yield high citation rates, regardless of their intrinsic academic value. This trend exemplifies the 'publish or perish' mentality, where scholars prioritise quantity over quality to secure tenure or funding (e.g. Bahr et al., 2022: 61-62).

Furthermore, the rise of precarious employment practices within academia exacerbates inequalities and undermines academic freedom (Shapin, 2004: 57). Adjunct faculty and contract researchers often face unstable employment conditions, low pay, limited access to resources and institutional support. This precariousness undermines the academic staff's well-being and professional development and compromises the quality and continuity of education and research. For instance, researchers on short-term contracts may be hesitant to pursue long-term projects or engage in interdisciplinary collaborations due to the uncertainty of their employment status. In addition, the increasing commercialisation of higher education has led to a proliferation of profit-driven initiatives, such as privatised degree programs and corporate-sponsored research centres, which prioritise financial returns over the public good. This trend not only undermines the autonomy and integrity of academic institutions but also risks compromising the impartiality and objectivity of research outcomes.

4. Conclusion

In conclusion, the transformation in the German research and innovation landscape towards open science and civic participation marks a significant shift towards greater inclusivity and collaboration (even if this seems to be the case for the European and, in general, Western countries' research landscape). Initiatives such as the 'Participation Strategy for Research' and the 'Berlin Declaration for Open Access to Knowledge in the Sciences and Humanities' exemplify this commitment to integrating civil society into research processes and fostering openness in science. However, this shift towards open science raises critical questions about the implications of increased political intervention in scientific spheres and the potential erosion of self-regulatory mechanisms within the scientific community.

The concept of openness in science extends beyond mere accessibility to knowledge; it encompasses transparency, accountability, and ethical conduct. As seen in the discussions surrounding participatory science, knowledge management, and governmental intervention, the imperative for openness necessitates careful consideration of the balance between promoting accessibility and preserving scientific integrity and autonomy. The imposition of mandates from governmental bodies prompts reflections on the dynamics of trust between politics and science and the voluntary nature of scientific engagement with the public.

Furthermore, exploring diverse forms of knowledge, including positive, missing, and negative, underscores the complexity of knowledge exchange within scientific communities. While positive knowledge forms the basis of scientific inquiry, missing and negative knowledge reveals gaps, uncertainties, and failures inherent in the research process. The reluctance to share negative knowledge highlights the challenges in fostering transparent knowledge exchange and calls for increased openness within scientific communication practices.

Therefore, I introduced Marcel Mauss's theory of the gift, in which trust in science is reframed as a reciprocal and moral transaction that relies on transparent knowledge exchange and mutual understanding between scientists and society. By acknowledging scientific knowledge exchange's social and ethical dimensions, researchers can navigate the complexities of contemporary research environments and contribute to meaningful societal engagement. However, challenges persist within the academic system, including the commodification of knowledge, the emphasis on quantifiable outputs, and the rise of precarious employment practices. These challenges underscore the need for a fundamental reevaluation of the role of higher education in society and the values that underpin it. By addressing these challenges and embracing the principles of openness, reciprocity, and ethical conduct, the scientific community can take significant strides in

fostering trust, collaboration, and innovation. However, to genuinely advance towards a more equitable and impactful scientific enterprise, reforming the structural foundations of academic employment is crucial. One area needing attention is the precarious nature of university employment contracts. This mainly affects PhD candidates and post-doctoral researchers, who often find themselves trapped in a cycle of temporary contracts with disproportionate dependency on professors, which in turn can lead to the consolidation of power around individual figures and increase the risk of power abuse.

To address these issues, institutions must introduce new employment models that provide greater stability and long-term opportunities. Political actors must also address the perception that they lack trust in university employees and their work ethic, fostering a healthier relationship between academia and policy. These potential changes call for critical reflection on the meta-emotion of ‘trust’ within the scientific community. While complete trust in scientists could raise concerns about unchecked authority and the entrenchment of power, it is equally important that scientists remain conscious of the power dynamics between themselves and society, particularly in the context of their public role.

The imposition of externally driven programmes and policies highlights a trend of control mechanisms over which scientists have little influence. It underscores the need for a systemic review of how academia allocates and manages public funds. Ensuring that these investments lead to meaningful and high-quality research outputs rather than being driven solely by quantitative metrics like publication counts is crucial. It is imperative to re-evaluate the criteria used to judge scientific quality.

Additionally, the relationship between universities and political institutions must be scrutinised. Questions regarding how universities should engage with politics, the nature of their dependency on political agendas, and who evaluates the excellence of universities need to be addressed. The current evaluation and selection systems that label institutions as ‘excellent’ should be revisited to ensure they are fostering academic excellence rather than merely reinforcing existing power structures.

These initial steps would serve as a foundation for creating a more transparent, equitable, and sustainable scientific landscape where trust is earned and nurtured without compromising researchers’ autonomy.

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Antecedents of Virus Conspiracy Beliefs

Ahmet Suerdem[1], Martin Jordanov Ivanov[2], Svetlomir Zdravkov[2]

[1]Bilgi University, Istanbul, Türkiye

[2]Institute of Philosophy and Sociology, Bulgarian Academy of Sciences, Bulgaria

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Abstract. Problem: The COVID-19 "infodemic," marked by a mix of accurate and misleading information, significantly disrupted public health responses by promoting confusion, risky behaviors, and distrust in health authorities. Misinformation, including incorrect prevention tips and conspiracy theories about the virus's origins and vaccine efficacy, fueled public skepticism and led to widespread non-compliance with health guidelines. This environment highlighted the role of conspiracy beliefs, which thrive during crises as individuals seek certainty and control, ultimately rejecting scientific advice and exacerbating public health challenges. The study aims to examine the relationship between virus conspiracy beliefs and various individual and country-level variables, to develop better communication strategies and policies for effectively managing public behavior during health crises.
Methods: This study utilizes multilevel modeling to analyze data from the Eurobarometer 95.2 survey, conducted during the COVID-19 pandemic across 39 countries. The hierarchical structure of the data allows for the examination of both individual and country-level variables influencing virus conspiracy beliefs. The primary dependent variable is the belief in the statement "Viruses have been produced in government laboratories to control our freedom." Independent variables include individual coping mechanisms for uncertainty, levels of scientific knowledge, and attitudes towards science, which are assessed to determine their impact on forming conspiracy beliefs during a crisis. Moderators such as attitudes towards science and maternal education are also included to analyze their influence on these beliefs.
Discussion: Findings suggest that individuals' values towards faith or science significantly influence their susceptibility to virus conspiracy beliefs (VCB), particularly under conditions of uncertainty. Those who prioritize faith remain stable in their beliefs, while those who value science may increase in conspiracy beliefs when faced with existential threats. It highlights the necessity of tailoring science communication and public health strategies to diverse value systems and cultural contexts to combat misinformation effectively. Additionally, the effectiveness of educational interventions

varies with familial and socio-cultural backgrounds, emphasizing the need for customized approaches to enhance scientific literacy and critical thinking across different demographic groups.

Introduction

The COVID-19 pandemic was not only a formidable public health challenge but also a significant crisis of misinformation, often referred to as an "infodemic." This term, as defined by the World Health Organization, describes the overwhelming flood of information—both accurate and misleading—that accompanies a health crisis. The rapid dissemination of such information created confusion and leads to risky behaviors that compromise health, foster mistrust in health authorities, and undermine the effectiveness of public health responses. Misinformation ranged from incorrect advice on prevention and treatment methods to conspiracy theories about the virus's origins and the effectiveness of vaccines. This pervasive spread of misinformation hindered public health efforts by sowing confusion and distrust among the public. For instance, myths about the virus being artificially created or exaggerated led to underestimation of the threat, discouraging adherence to safety measures such as mask-wearing and social distancing. The consequences of this misinformation problem were profound, complicating the efforts of health officials to manage the spread of the virus effectively and to implement coherent public health responses. Addressing this issue requires improve communication strategies to counteract misinformation.

The infodemic, marked by a flood of both accurate and misleading information, created a complex backdrop for individuals navigating the crisis. The impact of this information varied significantly, influenced by individuals' ability to assess critically the credibility of sources and content. During crises, the need for control and understanding intensifies. In the absence of clear explanations or solutions, some individuals gravitate towards apparent patterns or narratives, regardless of their veracity, to compensate for this uncertainty. A key trait among these individuals is a low tolerance of ambiguity (ToA; Frenkel-Brunswik, 1949), which drives a heightened need for certainty and control. This psychological predisposition often leads to the adoption of conspiracy beliefs as a means to impose order and predictability in their lives. The COVID-19 pandemic, with its wide-reaching and intricate impacts, lacked straightforward explanations and contributed to global uncertainty, thus providing fertile ground for conspiracy theories to flourish (Van Bavel et al., 2020). The infodemic, with its blend of truth and falsehoods, offered a fertile ground for those in search of definitive answers.

Conspiracy beliefs are typically defined as a subset of erroneous beliefs where the cause of an event is attributed to a secret plot by powerful actors with a nefarious agenda, often operating outside the bounds of legality (Swami & Furnham, 2014). Belief in conspiracy theories often emerge during crises such as political instability, economic downturns, or public health emergencies. In times of crisis, individual differences in conspiracy beliefs may affect the degree of adherence to necessary collective responses. Accurate beliefs foster helpful behaviours; erroneous beliefs foster unhelpful behaviours. Empirical evidence suggests that the aversive feelings that people experience in crises (i.e., fear, uncertainty, not feeling in control) stimulate a need to control and make sense of the situation, which increases the likelihood of perceiving conspiracies in such social situations (van Prooijen and Douglas, 2017).

Conspiracy beliefs, while offering individuals a perceived sense of control by reducing feelings of uncertainty and helplessness, pose significant risks, particularly during crises affecting public health. These beliefs can lead to a fundamental opposition to and rejection of the scientific method, a phenomenon that becomes critically detrimental not only to the believers themselves but also to society at large (Lewandowsky et al. 2013). Such beliefs can have harmful effects on public health efforts, as they may lead to skepticism and resistance towards medical advice and interventions. This skepticism is particularly pronounced among those who subscribe to conspiracy beliefs, as they are less likely to trust and follow the expert recommendations provided by scientists, epidemiologists, and physicians on measures to mitigate the effects of the crisis. Such skepticism can hinder effective disease control and prevention strategies, resulting in poorer health outcomes and prolonged crises (Poland & Jacobson, 2011). For example, beliefs that AIDS was a conspiracy to eradicate Black populations have negatively influenced prevention behaviors, such as the use of condoms or pre-exposure prophylaxis (Bogart et al., 2010). Ultimately, conspiracy beliefs not only mislead the public but also hinder effective public health responses by fostering distrust and non-compliance with science and health guidelines. Understanding the drivers behind these conspiracy beliefs is crucial for addressing the infodemics and helping to guide public behavior during ongoing and future crises.

Previous Work

Conspiratorial anti-science (CAS) and Virus conspiracy belief

As previously noted, a core element of conspiracy belief systems is a profound skepticism toward established science and the scientific community. This skepticism frequently aligns with anti-science sentiments, termed "conspiratorial anti-science" (CAS) beliefs by Boer and Aiking (2024), this concept highlights a perceived conflict between ordinary

citizens and the societal elite, which includes academics and experts. Many CAS theories feature narratives of scientists colluding with powerful entities such as governments or major corporations in sinister activities. These theories thrive on rumors that use such suspicions as their central argument, suggesting that these collaborations are intentionally designed to manipulate or harm the public. These rumors often focus on common themes such as the effects, origins, or supposed cures for various ailments, weaving a complex web of misinformation that challenges public understanding and response to scientific and medical advice.

In the context of COVID-19, rumours affecting CAS beliefs have varied widely. Some claim the virus is a hoax, exaggerated by governments to control the populace or justify harsh policies. Others believe the virus is a human-manufactured entity—allegedly engineered as a bioweapon by China to undermine Western nations. Additionally, there are theories that reject established medical advice, promoting alternative remedies as more effective treatments (Van Bavel et al., 2020). These diverse and often conflicting conspiracy theories about COVID-19 illustrate a broader pattern within conspiracy belief systems: a network of reinforcing suspicions that connect disparate beliefs about the origin of the virus. This interconnectedness suggests that acceptance of one conspiracy theory can make a person more susceptible to accepting others, even if they are unrelated (Goertzel, 1994). According to van Prooijen , & van Lange (2014), conspiracy belief systems are monological (i.e., interconnected and mutually supportive) in nature. According to Boer and Aiking (2024), despite the abundance of the rumours about the origin of the virus, the people who endorse a CAS worldview collectively agree on the notion that scientists collaborate with often malevolent, hidden forces that are responsible for spreading the virus, which we would name as a **virus conspiracy belief.**

Antecedents of conspiracy beliefs:

However, the monological nature of conspiracy beliefs is context-dependent. While belief systems within a specific domain, such as virus conspiracies, tend to be monological, they might be loosely coupled with beliefs in another domain. For example, an individual who strongly believes in various conspiracy theories related to the origin and spread of a virus may not necessarily endorse conspiracy theories about a hidden cure for cancer to the same extent. A typical explanation of conspiracy beliefs often describes them as a self-sustaining, monological system, heavily influenced by psychological traits such as a low tolerance for ambiguity and a tendency towards a paranoiac mistrust of authorities. A mistrusting mindset, often a defensive response characterized by intolerance to ambiguity, typically arises from perceived vulnerability and a sense of being under threat. This perception is usually linked to various individual differences in psychological factors such as low self-esteem, poor psychological well-being, feelings of powerlessness, and anger. This perspective suggests that individuals who exhibit these traits are more likely

to adopt conspiracy theories without selection as they provide simple, albeit flawed, explanations for complex societal events, thereby reducing psychological discomfort associated with uncertainty. However, focusing solely on psychological traits can lead to an over-pathologization of conspiracy beliefs, potentially oversimplifying the diverse and multifaceted reasons people might be drawn to different theories in different contexts. This assumption risks reducing all conspiracy belief adherence to individual psychological abnormalities or deficiencies, overlooking broader socio-cultural and political factors that also play significant roles (Sutton & Douglas, 2014).

A more nuanced perspective suggests that conspiracy beliefs are interconnected to the extent that they resonate with broader belief systems. According to research by Douglas, Sutton, and Cichocka (2017), conspiracy theories attract followers by addressing key social psychological needs. These include the epistemic need for understanding and certainty, the existential need for control and security, and the social need for enhancing self-image and group identity. Additionally, a range of sociological, demographic, and political factors significantly influence the allure of conspiracy theories. Their review of the empirical studies have shown that conspiracy beliefs are linked to various socio-psychological factors including perceived threats from societal changes, uncertainty, powerlessness, lack of socio-political control, perceptions of lower social status, less analytic thinking, lower levels of education and income, and membership in disadvantaged social groups. Political extremes, whether on the left or right, also show a higher propensity for endorsing conspiracy beliefs. These findings suggest that conspiracy beliefs are not just isolated thoughts but are intertwined with broader psychological and social dynamics. This comprehensive approach goes beyond simplistic, reductionist models to acknowledge the complex interplay between individual psychological motives and broader societal dynamics, offering deeper insight into the pervasive nature of conspiracy beliefs.

Hence, the antecedents of individual differences in conspiracy beliefs are context-dependent and may vary according to the domain of a particular conspiracy theory, reflecting the complex interplay between individual predispositions and the specific cultural, social, and political environments in which these beliefs are formed. For example, the appeal of a conspiracy theory may be stronger in communities experiencing significant socio-economic challenges, where feelings of disenfranchisement and injustice are prevalent. This suggests that while psychological needs drive the initial attraction to conspiracy theories, the context in which individuals find themselves can significantly influence the extent and nature of this belief adherence. Moreover, believing in a particular conspiracy theory instead of another one can have different motivators. For instance, the belief that a cure for cancer exists but is deliberately concealed by pharmaceutical companies often taps into deep-seated suspicions about corporate greed and the ethical integrity of the pharmaceutical industry. This type of conspiracy theory is

fueled by the perception that these companies prioritize profit over patient health, exploiting the sick for financial gain. These kinds of beliefs do not always stand on unsupported allegations, as they are sometimes grounded in historical instances where pharmaceutical companies have indeed engaged in unethical practices. They may have positive consequences since their adherents often call for more regulation of the pharmaceutical industry, arguing that stricter oversight could prevent such unethical behaviors and ensure that life-saving treatments are made available to the public. In contrast, virus conspiracy beliefs often stem from a distrust of government and scientific authorities rather than corporate entities. These theories may be driven by fears of government overreach, concerns about personal liberties, and skepticism towards the motivations behind public health measures. They may have negative consequences, such as violating public health measures, as well as causing divisiveness and political fragmentation

In the context of COVID-19 conspiracy beliefs, through a meta-review of the literature van Mulukom et al. (2022) identified several potential antecedents. Their review outlined diverse factors influencing individual susceptibility to COVID-19 conspiracy theories. These factors range from personal traits, such as intolerance to uncertainty and personality profiles, to broader demographic and social influences, including education and group identity dynamics. Key psychological traits like a low tolerance of ambiguity and a preference for intuitive over analytical thinking have been linked to higher susceptibility. Additionally, the study highlights the pivotal role of attitudes towards science, where distrust and low scientific literacy correlate with stronger belief in conspiracies. Social dimensions, particularly the influence of social media and trust in authorities, also significantly affect the endorsement and spread of misinformation. Understanding these multifaceted drivers is crucial for developing targeted interventions to counteract conspiracy theories effectively during the pandemic.

The Present Study

The aim of the present study is to test the relation between virus conspiracy beliefs and individual- and country-level variables. These variables were derived from Eurobarometer 95.2, aimed to measure “European citizens’ knowledge and attitudes toward science and technology” (European Commission, 2021). The variables include some items that we expected to act as proxies for virus conspiracy beliefs and its antecedents as mentioned in the previous lines. The main analysis in this study was conducted using a nested regression model and multilevel modeling approach.

Methodology

Multilevel modeling is a statistical method that accounts for data with individual and group level structures, where observations are grouped within different levels. It allows researchers to consider both within-group and between-group variations, providing insights into how individual-level factors interact with group-level influences. A key aspect of the analysis is the comparison of two explanations for the observed country differences. Traditional multiple regression techniques treat units of analysis as independent observations, which can lead to underestimated standard errors and overstated statistical significance when hierarchical structures are not recognized. Multilevel models, however, can correctly estimate the effects of individual- and group-level variables. By using a multilevel modeling approach, we aimed to disentangle the effects of individual-level and country-level factors on virus conspiracy beliefs. This approach allows for a more accurate understanding of the complex relationships among variables, as it considers the potential influence of multiple levels of factors on the data being studied.

Sample

We used the data collected by the Eurobarometer 95.2 survey which is particularly valuable for investigating virus conspiracy beliefs because it was conducted during the COVID-19 pandemic, making it highly representative of the current context. It was carried out in 39 countries, including the 27 EU member states, candidate countries, and other European nations, provides a comprehensive dataset that captures the prevalence and determinants of virus conspiracy beliefs across a diverse range of populations. The timing of the survey is crucial, as it allows examining the factors associated with the emergence and spread of virus conspiracy theories during a global health crisis. The survey's extensive geographical coverage enables cross-national comparisons, shedding light on the context-dependent nature of conspiracy beliefs and their antecedent. In summary, the Eurobarometer 95.2 survey's representative sample, large sample size, and extensive coverage of relevant items make it an invaluable resource for investigating the factors that shape the emergence and spread of virus conspiracy theories across EU populations.

Variables

The dependent variable in this study is the response to the item "Viruses have been produced in government laboratories to control our freedom," (1: True; 2: False; correct answer) which serves as a proxy for virus conspiracy beliefs. While a similar study by Boer and Aiking (2024) constructed a summated index of "conspiratorial anti-science" (CAS) by combining this item with another statement about cancer cures being hidden

by commercial interests, we have concerns regarding the use of such an integrated index as mentioned before.

It is crucial to recognize that the factors influencing an individual's belief in conspiracy theories may vary depending on the specific domain of the conspiracy. People may have distinct motivations for subscribing to one conspiracy theory over another. For instance, the factors driving belief in a conspiracy about the origin of viruses may differ from those underlying belief in a conspiracy about hidden cancer cures. This is supported by the moderate correlation of 0.42 between the two items. This correlation may not be strong enough to assume that these items are measuring the same underlying construct. A latent variable, such as CAS, should be represented by a set of indicators that comprehensively capture the construct's breadth. With only two indicators, the latent variable may not be adequately represented, as the indicators may not cover the full range of CAS (for example, climate change item was not included in the construction of CAS, as it is very weakly correlated with these items. This raises concerns about the ad hoc selection of the items for the index construction). Moreover, indicators are often imperfect measures of the latent construct, and there is usually some degree of measurement error associated with each indicator. When using only two indicators, the impact of measurement error on the latent variable estimate may be more pronounced. This is because there are fewer indicators to "average out" the errors, which can lead to less precise estimates of the latent variable. .In summary, almost weak correlation between the two conspiracy belief items and the limited number of indicators suggest that constructing a single CAS index may not be the most appropriate approach.

By focusing on a single item specifically related to virus conspiracy beliefs, this study aims to capture the unique factors associated with this particular domain of conspiratorial thinking. This approach allows for a more targeted investigation of the psychological, social, and contextual factors that shape the acceptance of virus-related conspiracy theories during the COVID-19 pandemic. Furthermore, using a single item as the dependent variable reduces the potential for confounding effects that may arise from combining multiple conspiracy beliefs into a single index. By examining virus conspiracy beliefs in isolation, the study can provide clearer insights into the specific determinants of this type of conspiratorial thinking and its potential impact on public health responses during the pandemic.

Independent variables

Coping with uncertainty and threat: As previously discussed, the concept of a general conspiracy mentality is considered a common underlying factor in explaining belief in various conspiracy theories. As a proxy for this construct, we used the item: "*Our lives are threatened by organized crime and terrorism, from which we urgently need to protect ourselves*."

Thinking styles and cognitive biases: Individuals who have lower scientific knowledge are less able to distinguish between true and false information. As a proxy we used a summated index of science knowledge quiz items such as "*Antibiotics kill viruses as well as bacteria*."

Moderators

Attitudes towards science: Higher positive attitudes towards science is associated with fewer unfounded beliefs. As a proxy, we selected the item: **"***We depend too much on science and not enough on faith*."

Mother's education: Mother's education significantly impacts parenting practices and interactions with their children, shaping childhood formation, which in turn can influence an adult's approach to complex societal issues like virus conspiracy theories (VCT).

Control variables

In addition to these items, we have included several socio-demographic variables as control variables. These include, age, gender, education, religiosity, left-right orientation, social class and life satisfaction. Besides these socio-demographic variables, we have also included using online social networks and blogs (e.g. video hosting websites) as the main source of information.

Results

We tested two hypotheses about the effects of the antecedent variables on VCB.

> **Hypothesis 1a: The effects of "coping with uncertainty and threat" and "esteeming science more than faith" and their interaction on VCB. As the level of "coping with uncertainty and threat" increases VCB would decrease. As the level of "esteeming science more than faith" increases VCB would decrease. A significant interaction effect is expected.**
>
> **Hypothesis 1b: The effects are dependent on the country context.**

As discussed earlier, many studies identified coping with uncertainty as a main antecedent of VCB. In this study, we contribute to this mainstream thesis by adding and testing the moderating effect of valuing science more than faith.

When faced with the uncertainty and existential anxiety caused by the COVID-19 pandemic, some individuals may turn to their faith as a way to cope. By placing more value on faith than science, they may find comfort and meaning in religious or spiritual explanations rather than scientific ones, making them more susceptible to conspiracy theories that align with their faith-based worldview. Moreover, people who value faith more than science may be more prone to confirmation bias, seeking out information that supports their existing beliefs while dismissing contradictory evidence. When confronted with uncertainty and threat, they may selectively attend to conspiracy theories that confirm their faith-based perspective. Lastly, faith-based beliefs can be deeply ingrained and resistant to change, even when presented with contradictory evidence. Individuals who strongly value faith may cling to their beliefs during the pandemic and be more likely to embrace conspiracy theories that provide a sense of certainty and control.

Hierarchical regression

Stepwise, the following models were tested: Null model[1] that only includes the intercept (no predictors); next, we added socio-demographic variables as control variables; then we added the independent variable (threatened by uncertainty) and social media as main source of information; finally, we added the interaction between the IV and the moderator (faith vs science). Analysis of Variance for the models shows that each model significantly improves the fit compared to the previous, more constrained model, confirming the interaction effect.

An interesting finding is a counter-evidence against the mainstream hypothesis that being threatened by uncertainty is the major cause of conspiracy belief. While the effect is significant in the standalone model 3, it becomes insignificant when the significant interaction is added (Table 1). When we check the interaction lines, for the line representing -1 standard deviation below the mean of the faith vs science, the slope is almost flat, indicating that for those people who esteem faith more than science, threatened by uncertainty has little to no effect on the VCB (Figure 1). Conversely, the line for +1 standard deviation above the mean shows a sharply declining slope, suggesting that the dependent variable significantly decreases when the moderator is high, that is, for those people who esteem science more, not endorsing VCB falls much

[1] A null model in stepwise regression refers to the initial model that contains no predictor variables, only including the intercept. It provides a baseline against which more complex models can be compared to assess improvement in fit.

faster when feelings of unthreatened increases. This counterintuitive result suggests that even among those who generally trust science, increased existential threats or uncertainties can lead to a paradoxical increase in conspiracy beliefs. This might occur because heightened uncertainty can undermine trust in currently available scientific explanations and lead individuals to seek alternative explanations, including conspiracy theories.

Table 1. Hierarchical Regression Analysis of the Effects of Uncertainty and Esteem for Science on Virus Conspiracy Beliefs (VCB)

Predictor	**Model 1**	**Model 2**	**Model 3**
Regression coefficients and standard errors			
Intercept	1.56 (0.02)**	1.69 (0.03)**	1.28 (0.03)**
Age	0.03 (0.00)**	0.03 (0.00)**	0.03 (0.00)**
Gender(2=woman)**	0.00 (0.01)	0.00 (0.01)	0.00 (0.01)
Education	0.03 (0.00)**	0.02 (0.00)**	0.02 (0.00)**
Religiosity	-0.03 (0.00)**	-0.03 (0.00)**	-0.02 (0.00)**
Social class	0.04 (0.00)**	0.03 (0.00)**	0.03 (0.00)**
Life satisfaction	-0.10 (0.00)**	-0.09 (0.00)**	-0.09 (0.00)**
Mother's education		0.04 (0.00)**	0.04 (0.00)**
Social media		-0.11 (0.01)**	-0.09 (0.01)**
Threatened by uncertainty		-0.13 (0.01)**	-0.02 (0.02)
Faith vs Science			0.11 (0.01)**
Uncertainty:Science			-0.03 (0.01)**
Note: * p < .05, ** p < .01, *** p < .001			

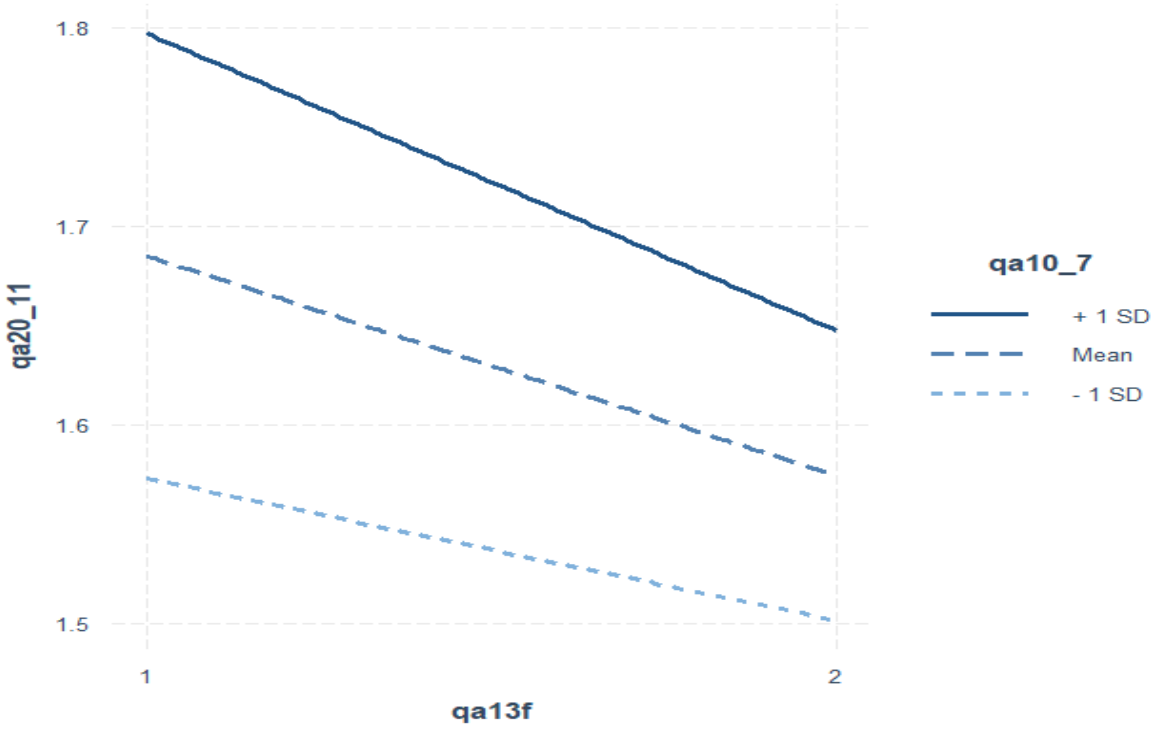

Figure 1. The Interaction plot Effects of Uncertainty (qa13f) and Esteem for Science (qa10_7) on Virus Conspiracy Beliefs (VCB, qa20_11)

Multilevel regression

However, this result is due to cross-national differences. For the multilevel regression, the significant random effects for the interaction term suggest that the relationship between threatened by uncertainty and science vs faith, varies by country, which could be important for understanding how these variables interact in different cultural or national contexts (Figure 2).

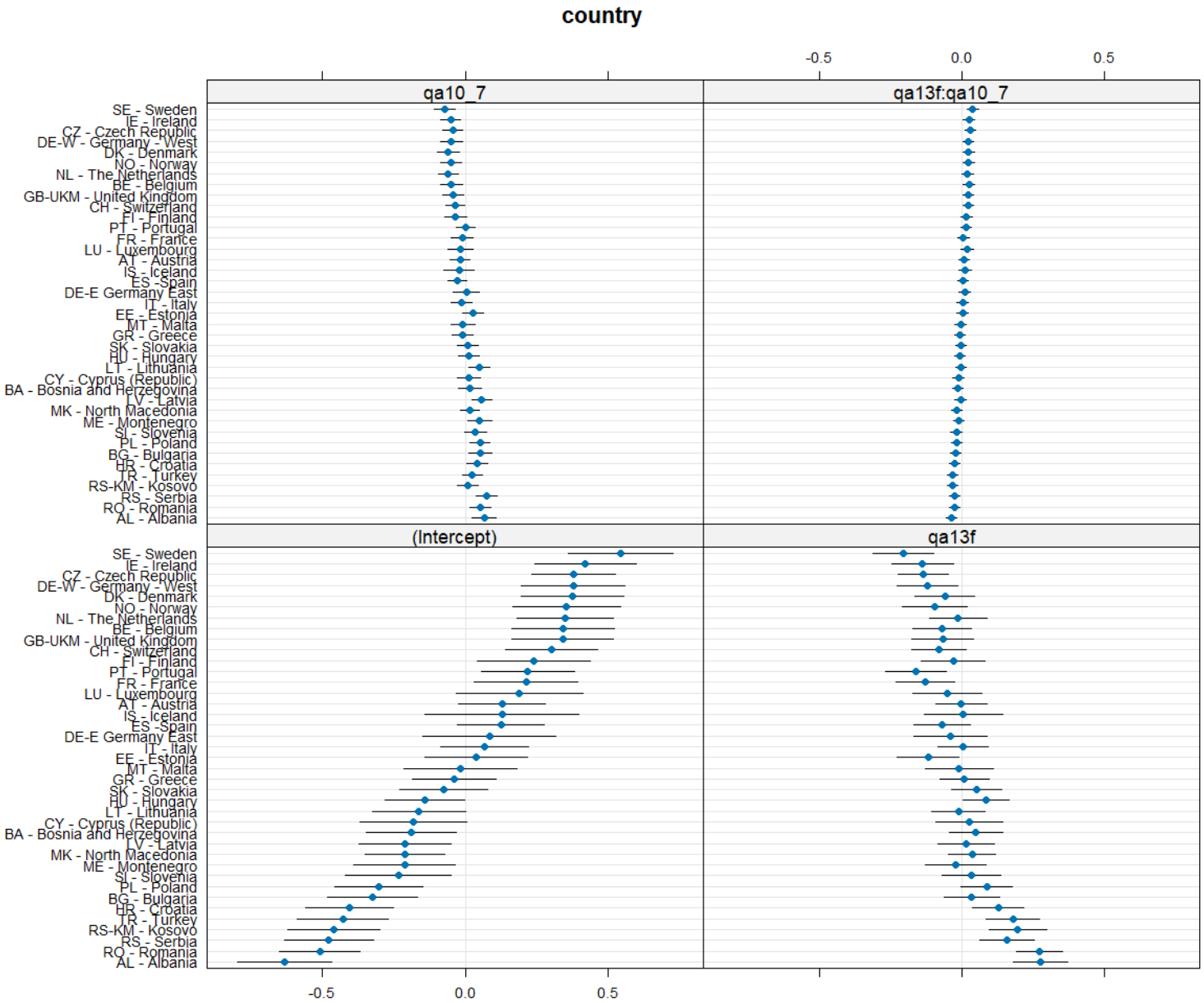

Figure 2. Multilevel regression: Country Effects of Uncertainty (qa13f) and Esteem for Science (qa10_7) on Virus Conspiracy Beliefs (VCB, qa20_11)

While the interaction effect is positive for the countries where not believing in virus conspiracy theories (VCT) is high, and feelings of being threatened by uncertainty are low, it is the reverse for the countries where the former is low and the latter is high. That is, in countries like Sweden, Czech Republic, (former) West Germany, Denmark, the Netherlands, Belgium, and France the interaction effect is positive, implying that for those who generally trust science, increased existential threats or uncertainties can lead to a paradoxical increase in conspiracy beliefs. This suggests that in these countries, higher trust in scientific approaches does not necessarily insulate individuals from the influence of conspiracy theories when faced with significant uncertainty. A common point in these countries is the rise of secular extreme right parties, which often promote nationalist and anti-establishment sentiments that can resonate during times of crisis. These parties sometimes leverage conspiracy theories to explain complex socio-political events in a simplified manner, appealing to the fears and uncertainties of the populace.

On the other hand, in countries like Albania, Romania, Serbia, Bulgaria, and Turkey, where there is a lower baseline trust in science and higher perceived threats or uncertainties, the interaction effect is negative, implying a decrease in the belief in virus conspiracy theories (VCT). This trend aligns with expectations based on the cultural and social dynamics of these countries. Here, faith or traditional beliefs may provide a framework that offers comfort and meaning, potentially mitigating the allure of conspiracy theories during uncertain times.

Hypothesis 2a: The effects of the level of "scientific knowledge", "familial educational background" and their interaction on VCB. We are expecting positive effects for both and significant interaction effect

Hypothesis 2b: The effects are dependent on the country context.

Common sense and research consistently imply that individuals with lower scientific knowledge are more susceptible to conspiracy theories and misinformation, possibly due to hasty reasoning processes (Landrum, 2019; Prooijen, 2017). However, this effect is not always straightforward. Susceptibility may also be influenced by factors such as belief in simple solutions, overconfidence in one's own reasoning abilities, and epistemic beliefs, which are often formed during early childhood. Mother's education plays an important role in this formation. Previous research suggests that a mother's level of education significantly influences her child's health outcomes and educational attainment (e.g. Ross & Mirowsky, 2011). The theory of resource substitution suggests that the beneficial effects of education on outcomes like analytical thinking are greater for individuals with fewer alternative resources, such as those from less educated family backgrounds. This theory can be extended to understanding VCT effects, where mother's education might play a compensatory role, enhancing resilience against misinformation

in less resourceful environments. Mothers with higher education levels are likely to foster environments that promote the acquisition of scientific knowledge and critical thinking skills.

Hierarchical regression

Besides the null and control models, we added the model with scientific knowledge as IV, and the interaction model (knowledge X mother's education). We included the mother's education as a proxy for the familial educational context. Ideally, we should include both father's and mother's education to avoid gender stereotypes. However, although it is changing for middle-class families in a few developed countries, the mother is still the main caregiver in most situations. Hence, to keep the model parsimonious and not to reduce the power of the statistical tests we used only the mother's education as a proxy for familial background. The goal is to find a balance between model complexity and explanatory power.

Analysis of Variance for the models shows that each model significantly improves the fit compared to the previous, more constrained models, confirming the interaction effect.

The results indeed provide evidence for our hypothesis, showing that the interaction effect is negatively significant, and the positive effect of knowledge increases when the interaction is added (Table 2). This suggests that while a higher level of knowledge generally reduces susceptibility to virus conspiracy theories (VCT), this effect is moderated by mother's education.

When examining the interaction effects in relation to mother's education and scientific knowledge, the analysis reveals a distinct pattern in the slopes of the regression lines.

Specifically, for individuals whose mothers' education is one standard deviation below the mean, the slope of the regression line is steeper compared to those whose mothers' education is one standard deviation above the mean. This pattern becomes less evident at higher levels of scientific knowledge. This interaction suggests that educational interventions aimed at increasing scientific literacy might have differential impacts depending on the educational background of one's mother. It highlights the importance of tailored educational approaches that consider the familial and socio-cultural context of individuals. For those from less educated backgrounds, increasing scientific knowledge could yield significant benefits in terms of reducing susceptibility to misinformation. Conversely, for those from more educated backgrounds, interventions might need to focus more on enhancing existing knowledge and applying it critically. These findings are in line with the theory of resource substitution.

Table 2. Hierarchical Regression Analysis of the Effects of Scientific Knowledge and Mother's education on Virus Conspiracy Beliefs (VCB)

Regression coefficients and standard errors			
Variable	**Model 1 (b, SE)**	**Model 2 (b, SE)**	**Model 3 (b, SE)**
Intercept	1.56 (0.02) ***	0.87 (0.02) ***	0.69 (0.03) ***
age	0.03 (0.00) ***	0.02 (0.00) ***	0.02 (0.00) ***
gender(2=woman)	0.00 (0.01)	0.03 (0.01) ***	0.03 (0.01) ***
education	0.03 (0.00) ***	0.01 (0.00) ***	0.01 (0.00) ***
religiosity	-0.03 (0.00) ***	-0.01 (0.00) ***	-0.01 (0.00) ***
Social class	0.04 (0.00) ***	0.03 (0.00) ***	0.02 (0.00) ***
Life satisfaction	-0.10 (0.00) ***	-0.06 (0.00) ***	-0.06 (0.00) ***
social media		-0.07 (0.01) ***	-0.07 (0.01) ***
Science knowledge		0.33 (0.00) ***	0.39 (0.01) ***
Mother's education			0.07 (0.01) ***
Know:Mother			-0.02 (0.00) *
Note: * p < .05, ** p < .01, *** p < .001			

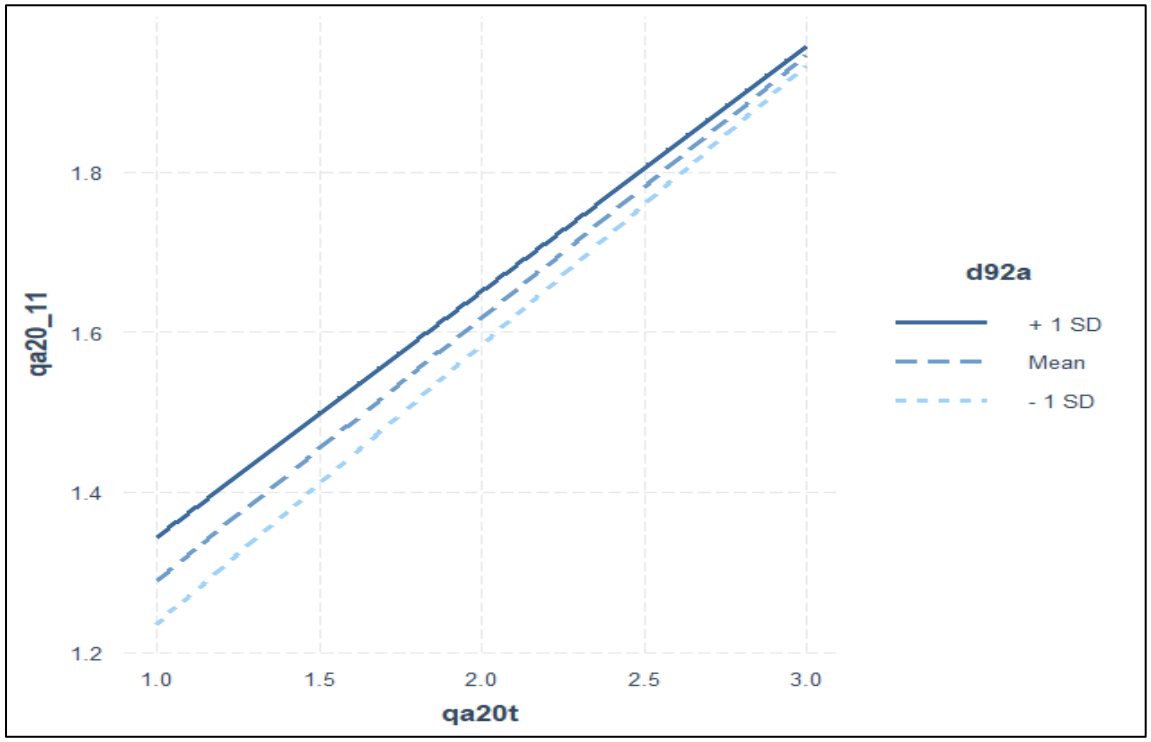

Figure 3. Interaction plot the Effects of Scientific Knowledge(qa20t) and Mother's education (d92a) on Virus Conspiracy Beliefs (VCB)

Multilevel regression

The presence of significant random effects and their correlations suggest that the model accounts for complex variability in the data, which is crucial for accurate predictions and inferences, especially in multi-country studies. For the multilevel regression, the significant random effects for the interaction term suggest that the effect of the interaction between knowledge and mother’s education varies by country, which could be important for understanding how these variables interact in different cultural or national contexts (Figure 2). In more affluent countries, where human development is already high, the interaction effect between knowledge and mother's education on VCB is not significant. This could be due to a generally higher baseline of education and access to information, which might mitigate the influence of individual differences in mother's education. Conversely, in less affluent countries, this interaction effect is positively significant. This indicates that in contexts where general education levels may be lower, the educational background of a mother significantly enhances the effect of knowledge in reducing susceptibility to VCB. This could be because in these settings, the influence of a mother's education might play a more critical role in shaping an individual's perceptions and resilience against misinformation.

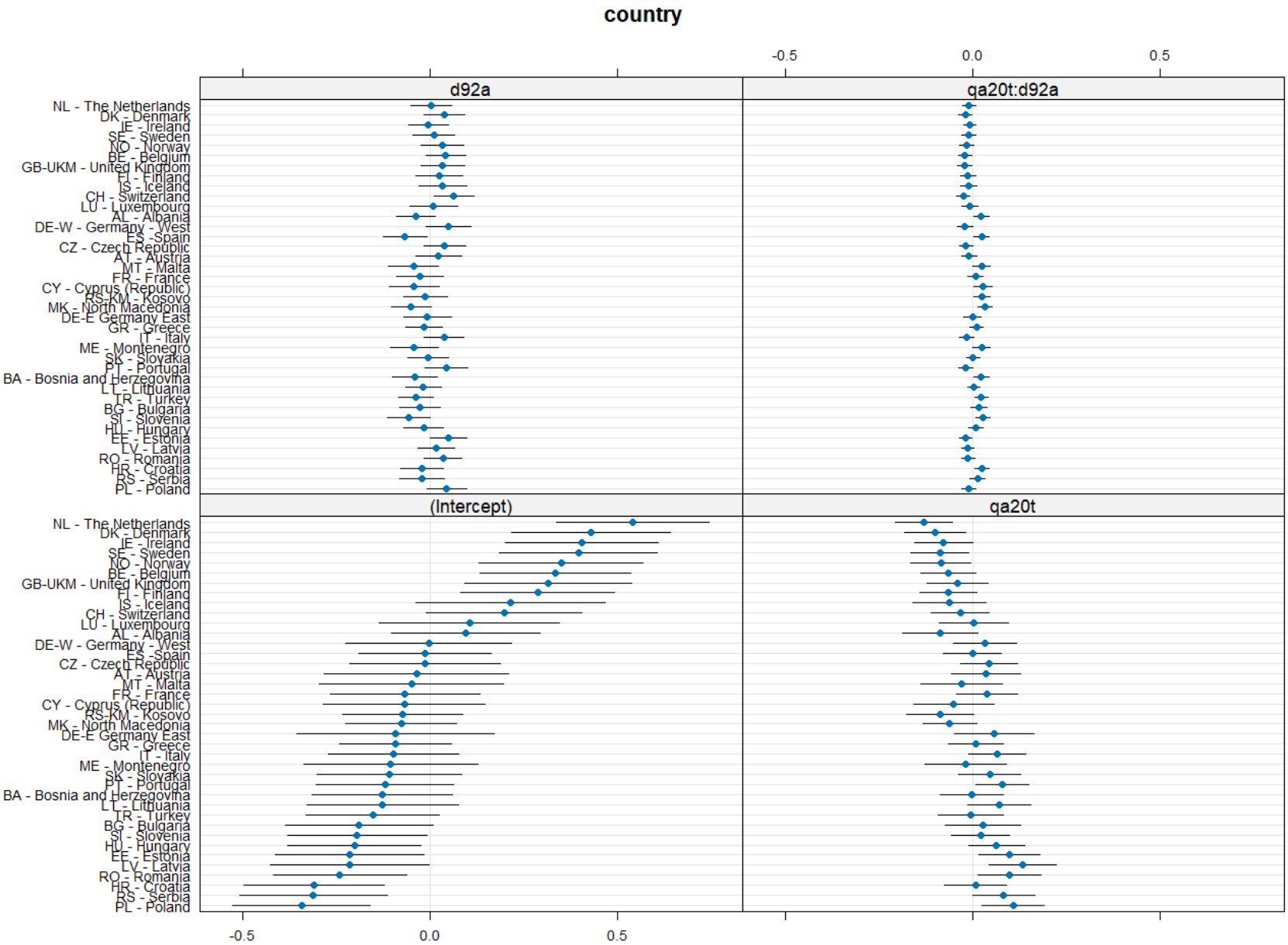

Figure 4. Multilevel regression: Country Effects of Scientific Knowledge(qa20t) and Mother's education (d92a) on Virus Conspiracy Beliefs (VCB)

Discussion

This study offers valuable insights into the factors that lead to conspiratorial, anti-scientific beliefs, with a particular emphasis on virus conspiracy beliefs (VCB). Gaining a deep understanding of these antecedents is essential for crafting targeted interventions that can successfully curtail the spread and influence of such beliefs. This knowledge is not only crucial for informing effective public health strategies but also has significant implications for policy-making. By addressing these underlying factors, interventions can be better designed to disrupt the cycle of misinformation and enhance public health outcomes.

The effect of the interaction between coping with uncertainty and threat and esteeming science more than faith on VCB.

The findings from this study reveal complex dynamics in how individuals' values towards faith or science influence their reactions to uncertainty and their susceptibility to conspiracy theories. For those who prioritize faith over science, uncertainty does not significantly increase conspiracy beliefs, possibly because they rely on faith or other forms of knowledge that provide stability beyond the fluctuating nature of scientific discourse. In contrast, individuals who hold science in high regard might experience a paradoxical increase in conspiracy beliefs under increased existential threats, as such uncertainties can shake their trust in current scientific explanations, prompting them to seek alternative, even conspiratorial, explanations.

Individual Level Implications

For effective science communication, it is crucial to tailor strategies to these differing value systems. For faith-oriented individuals, especially youth, partnerships with local educators and respected community figures can help integrate scientific literacy with faith-based values, debunking conspiracies. For those who value science, emphasizing the adaptability and robustness of the scientific method during crises can help maintain trust. Educational initiatives should also foster critical evaluation skills to combat misinformation and build resilience against the destabilizing effects of uncertainty.

Country Level Implications

At the country level, understanding these dynamics is vital for designing public health communications, particularly in crises like pandemics. In countries with high esteem for science, promoting critical information evaluation can generally mitigate conspiracy beliefs, but during high uncertainty, additional strategies to reinforce trust in science are

necessary. Conversely, in countries with lower scientific trust, enhancing educational frameworks to improve critical thinking and scientific literacy is crucial. Tailoring messages to the specific cultural and social contexts of different countries, and addressing how uncertainty impacts perceptions directly, can help reduce the spread of conspiracy theories.

The effect of thinking styles and cognitive biases on VCB

Individual Level Implications

The findings underscore the importance of contextualizing educational interventions within the familial and socio-cultural backgrounds of individuals to enhance scientific literacy effectively. The impact of these interventions appears to vary significantly based on the educational level of one's mother, suggesting that a one-size-fits-all approach may not be as effective. For individuals from less educated backgrounds, targeted programs aimed at building foundational scientific knowledge can be crucial in reducing susceptibility to misinformation. Conversely, for those from more educated backgrounds, the focus should shift towards enhancing critical thinking and the application of scientific knowledge. This tailored approach can ensure that educational initiatives are more directly aligned with the needs and existing knowledge bases of different demographic groups, potentially leading to more successful outcomes in combating misinformation.

Country level Implications

The findings at the country level suggest that public health campaigns and educational programs need to be tailored to the specific cultural and economic contexts of different countries. In less affluent countries, programs that focus on enhancing education at a family level, particularly targeting mothers and caregivers, could be particularly effective. Furthermore, resources for combating VCB through education and public health initiatives might be prioritized differently based on these findings. More resources might be needed in less affluent countries to address the significant interaction effects of knowledge and mother's education.

Conclusion

This study not only highlights the complex interplay between individual values toward faith or science and their susceptibility to conspiracy theories but also emphasizes the influential role of a mother’s educational background in shaping responses to virus conspiracy beliefs (VCB). The research uncovers two pivotal hypotheses: first that the level of esteem for science versus faith affects how individuals cope with uncertainty and

existential threats, with those valuing faith showing less susceptibility to conspiracy theories in uncertain times, possibly due to their reliance on stable, faith-based knowledge systems. Conversely, those who highly regard science may experience an increase in conspiracy beliefs during such times as their trust in current scientific explanations falters. The second hypothesis underscores the impact of a mother's education on the effectiveness of educational interventions aimed at combating VCB. For individuals from less educated backgrounds, basic scientific education is crucial, whereas for those with more educated mothers, enhancing critical thinking and application of scientific knowledge is more pertinent. Both hypotheses stress the need for tailored approaches in both individual and country-level public health strategies to effectively mitigate misinformation and enhance overall scientific literacy and public health outcomes.

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Thematic Field B:

Digitalization of Society, Society and AI

Some narratives constructed by German MPs regulating digital innovation

Sebastian Wucherer[1]

[1]HafenCity Universität Hamburg (HCU), Germany

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Abstract. This contribution investigates the narrative work being done by members of parliament (MP) of the German Bundestag in parliamentary speeches concerned with legislation on digital technologies. Bringing together the book Code and other Laws of Cyberspace by Lawrence Lessig and narratives as conceptual lens, I focus on some selected narratives and some conflicts they make apparent. A general underlying struggle between the allegedly right levels of chaos and order could be identified and broken up into several sub-narratives. The paper shows how, in trying to craft coherent narratives, MPs find themselves caught up in difficult dilemmas of trying to balance out some dimensions of state sovereignty like societal wellbeing and economic success. I argue that political work may benefit from taking up traditionally unusual narratives and ensure conceptually richer and more reflected debates within and about digitalisation in parliamentary processes.

1. Introduction

Are 25 years a long time? A glance at a watch or a calendar alone cannot answer that question, as the answer necessarily depends on the context the question was asked in. The context of this contribution is a revisit of the hallmark book Code and other Laws of Cyberspace (Code from now onwards) written by Lawrence Lessig in 1999—25 years ago. In said book, Lessig introduced what should become a certain dictum in the digital world and somewhat of a maxim in some of its numerous communities until today: Code is Law. It describes the idea that how computer code is written and what it enables or disables, essentially acts like law in digital spaces. Now, in Code, Lessig, a lawyer who later went on to among other things found Creative Commons, discussed property (rights), state authority in digital spaces, and how different code architectures have very different repercussions on these aspects within digital practices. Yet down to the present day, his thoughts do not seem to have lost all that much of the relevance it had more than two decades ago, as not only recent discussions of blockchain advocates show (Quinn, 2022). In that sense, 25 years, even though I am talking about ‘the digital’ here,

does not seem to be an incredibly long time. However, not only those who have used the internet in the 1990s (I did not) know that what has been and is sometimes still called the cyberspace is far from being the same that it was when Code was published. Not just the aesthetics but code architectures, practices, written and unwritten rules and what very generally is considered 'normal' on the web has changed immensely. So, in that sense, 25 years actually seem to be a very long time after all.

1.1. Approaching Lessig

My main focus in this revisiting of Lessig's work is on the narratives involved in the political process of the lawmaking concerned with the internet and digitalisation in a broader sense. If *code is law*, but state regulation does partially steer which code gets written and implemented and which not, the narrative foundations of these acts of regulation need to be considered. This paper then aims to investigate some of the narratives around laws concerned with digital innovation in the German context.

Narratives have increasingly become an analytic tool not only in the social sciences, with a number of authors having identified a *Narrative Turn* (see for example de Fina and Georgakopoulou, 2015). Numerous terms exist that one could utilise in the analysis of narratives—super narratives, master narratives, visions, hypes, trends, ideologies, agendas, expectations, frames, and others. For varying reasons, none of them neatly describe my analytical focus. Yet all of them are narratives in some sense, which I, on the most basic level, understand as the *structuring* of ideas, values and knowledge (Herman, 2009, p.2) in order to make sense of the complexities of the world. What has, however, loosely guided my research process was the notion of *Sociotechnical Imaginaries*. Coined by Jasanoff and Kim, they are defined as "collectively held, institutionally stabilized, and publicly performed visions of desirable futures, animated by shared understandings of forms of social life and social order attainable through, and supportive of, advances in science and technology" (Jasanoff, 2015a). Lawmaking on digital topics is an apt example of a process that involves such sociotechnical imaginaries. They necessarily play a role in crafting and negotiating new legislation in parliamentary processes and in turn get reinforced by the new laws passed, 'embedding' them further in sociocultural and -technical thought, practices, and infrastructure (see also Jasanoff, 2015b). The goal of this work however is specifically *not* the identification and description of one such imaginary. I will only use this concept to guide my thinking on the topics at hand.

To Lessig, "[t]he point about politics is process. Politics is the process by which we reason about how things ought to be" (Lessig, 1999, p.59), describing well my angle of attack here: Digitalisation is often seen as a mostly technological process, concerned maybe with network coverage or throughput rates. Obviously, that is part of it. However, what

oftentimes gets overlooked is how digitalisation is just as well about the power of narratives, the power of how the stories we construct about past, present and future very much are (un)making our shared realities. These narratives cannot come to be without the ideas of what we value and how things 'ought to be' on a broader level. Hence when Lessig argued that code is law and how commercial and political motives have played and will play a considerable roll in the shaping of digital realities, this very much includes the narrative work of these actors as well.

Let me illustrate this with an example very close to Lessig's account. On the one hand, there were (and still are) those that conceive of 'the internet' as a space and place predestined to do business. Their vision was and is to utilise digital infrastructures–perhaps not only, but with certainty–to enable commercial activity. Other individuals, collectives and organisations much rather wanted and want to keep more of what the internet was in its very beginnings, a space of mostly unregulated and oftentimes completely anonymous exchange between people. Both visions or (parts of larger) sociotechnical imaginaries were built on very opposing narratives about what a 'desirable future' looks like, and what actors would contribute in what ways to achieve it. These different envisionings of possible sociotechnical futures are what gives these actors direction for action. Their internalised stories–narratives in some form–induce, incite and impel *change*.

As described in some detail below, my material consists of the protocols of plenary talks given in the *Bundestag*. I investigate these not to analyse the actual laws that get debated there but, as implied, shed light on broader narratives and imaginaries being utilised on various instances of lawmaking. For example, making laws that enable or disable anonymity on the web, as Lessig discussed (1999, p.25ff.), necessitates a reason why, and the reason why, whatever it is, has to be woven into a larger vision of the future that the law is leading society towards. In Judy Wajcmann's words:

> "[W]e need to ask why a technical reason was found to be compelling, when it could have been challenged, and what counts as technical superiority in specific circumstances. […] A range of social factors affect which of the technical options are selected, and these choices shape technologies and, thereby, their social implications" (Wajcman, 2015, p.28)

Wajcman only seconds Lessig here, who made the point numerous times that law, just as technological innovation, is anything but neutral. Laws are not just *there*, and no law could be described as *logical* or *natural*. They do not just come into being, as they are always part of situated and larger stories, beliefs, ideas, assumptions, and are hence never neutral or objective. What the law is, how it is constituted and what it entails is always situated in time, space and narratives (see for example pages p.25, 60, 97f., 212-234).

1.2. Aims of this contribution

In general, this contribution aims to further perspectives at the intersections of STS, the digital, law and politics, at which considerable work has been done before (see Jasanoff, 2004, Jasanoff and Kim, 2009, Jasanoff and Kim, 2015, Fourcade and Gordon, 2020, Bareis and Katzenbach, 2021, Grundmann and Stehr, 2012, Owen, 2015, Ralf Kopp, 2019, and many others). However, parliaments as means to make public political processes in order to justify state action, often remain understudied.

As the question was opened up on the conference, I also want to clarify that my work is not suggesting the notion that law is or ought to *follow* politics, as past debates particularly in Austria have discussed (Galaktionow and Gupta, 2019). My point is merely to open up perspectives on the parliamentary part of the entire legislative process, not least because parliaments constitute a democratic institution acting under particularly close scrutiny of media and publics (Vliegenthart et al., 2016).

What's more, this work more generally is also about what STS has always been about: Opening up discussions about technological developments, asking how and why they come to be and what consequences a development may have, to question techno-deterministic thinking and further the idea that sociotechnical development is indeed an open-ended process.

However, I also want to make clear that this contribution is meant to be exploratory, as it is based on a corpus of a size that is manageable for this kind of analysis and form of publication. I thus do not perceive of it as concluding thoughts, but really as a starting point for further work on related topics and contexts.

2. Material & Methodology

2.1. Material

This paper is based on the qualitative analysis of ~100 talks given in the Bundestag between 1984 and 2021. They are part of a larger corpus consisting of around 1800 talks, all concerned with digitalisation in some sense which have been broken up into incidents of a length between 1 and ~30 lines. With *Code is Law* being the conceptual lens, I extracted those incidents that specifically touched upon ideas of the *role of politics in digitalisation processes* as well as *specific* or *vague future visions.* Looking into incidents with these co-occurrences enabled me to attain some insights on how politicians interpreted their role in the process of digitalisation and put this into relationship with some of the visions of a digitalised future that they deem 'desirable'. Overall, 764 single

incidents were considered for the analysis, of which most was conducted via the software ATLAS.ti (ATLAS.ti, 2024).

2.2. Methodology

	Zukunftsvision: konkret	Zukunftsvision: vage
	256	350
Treib/Vorrs.: Politische Arbeit 276	40	77
ZZ. Jahr: 1983 4	1	1
ZZ. Jahr: 1984 8	1	2
ZZ. Jahr: 1996 8	2	4
ZZ. Jahr: 2003 3	0	0
ZZ. Jahr: 2004 7	2	5
ZZ. Jahr: 2008 3	0	1
ZZ. Jahr: 2009 22	1	7
ZZ. Jahr: 2011 11	2	2
ZZ. Jahr: 2012 62	2	21
ZZ. Jahr: 2013 16	5	3
ZZ. Jahr: 2014 77	7	13
ZZ. Jahr: 2015 93	16	28
ZZ. Jahr: 2016 150	31	63
ZZ. Jahr: 2017 159	42	56
ZZ. Jahr: 2018 267	67	80
ZZ. Jahr: 2019 161	39	40
ZZ. Jahr: 2020 123	28	18
ZZ. Jahr: 2021 52	10	7

Figure 4. Table from ATLAS.ti showing the number of incidents with relevant co-occurrences; specific visions in first column, vague visions in second column, political work in first row and respective years all rows after.

Concerning my methodology, I loosely relied on a Grounded Theory (GT) approach, although I did adapt the process to my situation (Charmaz, 2014, Morse et al., 2016, Strübing, 2018). Classic examples of GT studies do enter the field rather disinterested and react to what topics prove useful along the way, expanding the material until a point of ‘saturation’ is reached. Now, I was able use an existing and pre-coded corpus, looking at it with a fresh conceptual lens, looking for aspects I did not consider before. I thus re-coded the selected incidents, developed new codes and identified some recurring concepts, themes and narratives that I describe in the following sections. These are all original findings for this contribution (see also chapter XXX for limitations).

3. Analysis

This paper presents a focused analysis of selected narratives within the Bundestag discussions on digital innovation. While counterexamples exist, the narratives described do provide significant insights into the narrative strategies employed within the German parliament.

The analysis is structured along one key narrative or conflict described in section 3.1. I will then lay out four sub-narratives discussing specific aspects of the key narrative. I follow up with a brief intervention on narratives resisting those described before. Each part consists of some representative quotes either from Code or an MP's speech and some reflections on the narratives invoked. Quotes from MPs have been translated from German to English, all original talks are available in German via the Bundestag's website (Deutscher Bundestag, 2024). To add some context when quoting direct excerpts from the speeches, I added the speaker's name, indicate special roles filled by the speaker if applicable (e.g. minister or chancellor), and the date the speech was delivered.

3.1. An underlying conflict

There is one conflict in the narrative work done by the MPs that I found central to several more specific narratives, one Lessig did very much imply, too. It is the question of how much order is needed and how much chaos is bearable in social and/or sociotechnical systems.

Of all the actors involved in the making of society and digital technology particularly, a myriad of different assessments of the right and sensible levels of order and chaos are present. From the invention of the law itself, the man-made straightening of rivers, up to the appearance of industrial assembly lines and recent discourses on gender, the struggle for order and the wish to be in control of one's circumstances has been a phenomenon throughout human history.

Now, chaos and order are very abstract concepts and are closely tied to the more palpable, yet less analytically clear categories of security and freedom. Security (Sicherheit in German) however, is a term that is mentioned numerous times in the protocols that were included in this analysis and it is a topic that is hidden everywhere in Code as well, even though as a word its only used about ten times in the entire book. Somewhat generalising, I oftentimes found the political talks to reveal the idea that it is order that leads to positively perceived forms of security, and that in turn freedom leads to a negatively perceived form of chaos. It is the regulatory work of law then that is believed to bring this conflict into balance—to establish just enough order so that security is ensured and to prevent chaos in so far that freedom is not curtailed too much.

Lessig tried to spark this very debate already in 1999. Forestalling parts of my conclusion, this debate and how it is led to this very day in parliamentary discussions is somewhat stagnant in its lines of argument, making it exceedingly interesting for such an analysis.

3.2. Controlling Code

> "Cyberspace, the story went, could only be free. Freedom was its nature. [And t]hat cyberspace was a place that governments could not control" (Lessig, 1999)

> "Ladies and gentlemen, what we are doing with these measures is nothing else but transferring established and proven measures from the so-called analogue world to the so-called digital world. In the analogue world, we are setting minimum requirements for food and household appliances. We do the same for banks and financial service providers in the area of risk management. [...] For a long time, we have [for example also] been obliging property owners to grit their sidewalks in winter to prevent accidents involving people. Nothing else is what we are doing now in area of IT." (Deutscher Bundestag, 2024, Federal Minister of the Interior Dr. Thomas de Maizière, 20 March 2015)

The first more specific aspect that was very recurringly appearing in many talks was the idea of *controlling code*, meaning primarily the idea that what is being done with code and what code does is something *in need* to be controlled by state. What can be done with code often should be constrained and restricted, oftentimes explicitly in the name of safety and security for diverse stakeholders (citizens, companies, the state, etc.). What I found particularly interesting about this idea are its conceptual roots, which seem to be twofold:

1. Politics and politicians in Germany very much took on the narrative of the 'free internet' summarised by Lessig in the quote above. Just like many 'netizens' did (and do), MPs perceive(d) the internet as something that was inherently chaotic and unruly. As Lessig noted (Lessig, 1999, p.IXff.), modern states of the Westphalian tradition are averse to most spaces and places deemed unruly. However, since 'the internet' was very obviously a different space than peoples private, tangible premises, and because it really did not care too much about national borders, the question was, how state could justify exercising similar controlling power in digital spaces.
2. The current conceptual framework in Germany treats the digital and analogue realms as equivalent in both character and thus in their appropriate approach by lawmakers, suggesting that rules governing the analogue world can be *directly applied to the digital*. Lessig has critiqued this approach, arguing that it oversimplifies and poses potential dangers (Lessig, 1999, p.3ff.). This conceptualisation, however, has facilitated the implementation of restrictive control architectures in digital environments.

Combine this conceptual eradication of differences between analogue and digital spaces with the strong belief that everything digital is inherently averse to any kind of government(tality), and the preconditions are set actually for two different readings of the idea of c*ontrolling code*. In the first one, the actor in control is the state, which ought to be *controlling code* via legislation. In the second reading, the actor in control is the code itself, that is code architectures, enabled to be *controlling people* or their behaviour.

In light of Lessig's observation that states tend to ally with commerce, the first reading is the precondition for the second reading. That is because only the idea that code can and should be controlled by state enables the preconditions for architectures of code not only *being controlled*, but at the same time enabled to be *controlling code* in the sense of *being in control* of online practices, norms and behaviour that favours the agendas of said alliance of states and commerce. I will look into this alliance in the next sub-narrative.

3.3. Code and Commerce

> "If commerce is going to define the emerging architectures of cyberspace, isn't the role of government to ensure that those public values that are not in commerce's interest are also built into the architecture? [...] Isn't it absolutely clear that there must be limits to [the] presumption [t]hat public values are not exhausted by the sum of what IBM might desire?" (Lessig, 1999, p.59)

> "If we want to maintain the entire value chain in our country, we have to be pioneers, as we have been with all other industrial revolutions[.] … We have always been pioneers, we have always played along very well. Now Industry 4.0 is coming, which means the smart factory is coming. That means total networking, self-organization in production. People, machines, systems, logistics, products, even customers and business partners are networked with each other. Completely different service models, smart services, will emerge because everyone will communicate and cooperate with each other. I believe this is a huge opportunity. [...] Change is not the risk. If we don't back the change, then we will be left behind. Let's do what we did in other industrial revolutions: Let's be pioneers." (Deutscher Bundestag, 2024, Jens Koeppen, 13 November 2015)

Lessig laid out in much detail how state and commercial actors would likely forge a certain alliance of convenience aiming for an internet that favours order over chaos and thus particularly facilitates commercial actions while hindering a more organic development of architectures, norms and practices. He should be proven right, as today's internet and almost every technology containing digital aspects is driven by commercial interests (just think of the 'Big Five', Google, Amazon, Apple, Meta and Microsoft and their collective power over much of any international digital structure). The question here, too, is how this was narratively constructed or at least made possible as desirable future.

In my analysis, the sub-narrative that emerged as perhaps the most dominant one enabling the political support for the commercialisation of digital (infra-)structures is that of *competition*. As very creatively constructed in the quote above, commercial success is seen as both, a natural aspiration and, specifically in the German context, as a historically

grounded obligation (Miller, 2015). Relative success in the past is often used as a reason to strive for similar or greater success in the future, thus naturalising a modern understanding of human and national trajectories as progress necessarily being a pursuit towards the *better* (Reckwitz, 2021).

I want the description of this narrative not be understood as fundamental critique. I am not in a position to assess how much orientation towards commerce is useful. The point here is simply that what Lessig saw as the most probable future is in fact very much reflected in the narrative constructions of the Bundestag speeches given in the 2000s and 2010s:

> "Of course, the Internet does not stop at national borders. It is therefore important to find and implement European and international solutions and standards for this area. Germany should set a good example here and take on a pioneering role. After all, a high level of IT security not only means an increase in public safety, but also a location advantage for the economy and companies. We should therefore examine regulations for increasing the security of IT products by introducing a quality seal in the further legislative process." (Deutscher Bundestag, 2024, Gerold Reichenbach, 9 March 2017)

3.4. Sovereignty

> "Ladies and gentlemen, IT security is an indispensable prerequisite for digitalisation. [...] Without security in the network, without a maximum of what we can do to protect our systems, everything that will define us in the future will be null and void. Industry 4.0 is null and void without IT security, and cloud technology would be completely pointless without cyber security." (Deutscher Bundestag, 2024, Christina Kampmann, 20 March 2015)

> "In the area of digitalization, I am particularly concerned about a Europe-wide digital identity, which we are now establishing in Germany via the chip in the ID card and making it accessible as a wallet in the smartphone. I believe that this could really achieve European sovereignty." (Deutscher Bundestag, 2024, Federal Chancellor Dr. Angela Merkel, 23 June 2021)

The last aspect of the greater narrative of order that I want to include is the idea of state sovereignty (which here, simplifying things somewhat, includes the idea of European sovereignty). The discourse around sovereignty does go very much into what Lessig called the struggle between East Coast Code and West Coast Code (Lessig, 1999, p.53f.).

Concerning East Coast Code, German politicians saw and still see most unregulated spaces as something in need of ordering. In short, chaos is perceived as an imperfection, which is often rooted in a sense of risk that unregulated spaces implicate for everyone involved in these spaces (regardless of chaos sometimes being a feature more than a problem). Examples are numerous, from discussions about a 'NetNanny' in the 1990s (Deutscher Bundestag, 2024, Hans-Otto Wilhelm, 26 September 1996) up to the everlasting discourse on data security. Although the concern made explicit is often about creating security for people and/or companies, I suggest a different reading: Unregulated spaces, specifically those of digital nature, are (uncounsciously?) perceived as

undermining state authority. Regulations enabling ‘architectures of control’ can thus be interpreted as a means to establish state authority. The struggle for sovereignty leads to the normalisation and facilitation of kinds of code architectures that very much reflect what Lessig predicted. As the idea of state sovereignty is becoming much more complex and multidimensional as our world gets more complex and ‘networked’, digitality is subtly perceived of as a threat to sovereignty. Especially in Germany, and it holding a self-image as organised, orderly country, the subtle call for state sovereignty has become a central narrative figure.

3.5. Trust but verify

> “When commerce writes code, then code can be controlled, because commercial entities can be controlled. Thus, the power of East over West increases as West Coast Code becomes increasingly commercial.” (Lessig, 1999, p.53)

This section and narrative are concerned with ideas of chaos, touching on important narratives about what actors can and should be trusted in digital spaces. As Lessig expected for example in his elaboration on trusted systems (1999, p.122-139), a certain level of trust is necessary for any interaction, both analogue or digital. However, the talks analysed for this contribution exhibited considerably more trust towards commercial actors and their endeavours than they did towards private citizens and their motifs. This is *not* to say that the narratives employed were framing citizens as generally erratic or even criminal (although just the *possibility* of criminal acts are often an instrument used to demand more order and control). However, it *is* to say that since spaces created and practices applied by commercial actors are in more need of effective architectures of control, their intentions align much better with state’s concerns about unregulated digital spaces, just as Lessig implied. The protocols now show that commercial freedom, on the one hand, is seen to be enabled more by order than by chaos. Civil freedom, on the other hand, may not be seen as equivalent to pure chaos, but is described to be in need of a different mixture of chaos and order. Eventually, trust in the benefits of commercial expanse is oftentimes larger than trust in the benefits of citizens liberties:

> “If you talk to young entrepreneurs who have set up their start-up in Silicon Valley, for example, they say that they didn't go there because the infrastructure is particularly good. In reality, the opposite is the case: a 5 Mbps connection costs $50 in San Francisco–not to mention the road infrastructure. The companies located there have only one interest, namely to develop their business model without major bureaucratic hurdles and to be able to scale up in a huge market. Europe can do that too. That is why we need to work on implementing this digital single market in Europe.” (Minister of Transport and Digital Infrastructures Alexander Dobrindt, 9 September 2016)

Now, interestingly enough, this placing of commercial interests above civil interests in the past and the digital realities this allowed to manifest is in recent years actually becoming a challenge for German politics itself, as shown in the following quote:

> "What I will never understand in the German debate is why, in the end, there is so much more willingness to provide Apple, Google, Facebook or even Alibaba with your own personal data every day than when your own state sets a framework for using data for the benefit of the individual—anonymized or pseudonymized—for research and added value for all patients. Then there is a basic mistrust. As long as this is the case and there is a basic trust in large American corporations and a basic mistrust in our own state, we will not make any progress in digitalization." (Deutscher Bundestag, 2024, Minister of Health Jens Spahn, 3 July 2020)

Here, then Minister of Health Jens Spahn laments people trusting companies more than the state, as these commercial players have become so ubiquitous and their code, *their law*, enabled by state regulation, so widely accepted by the people online that state authority is perceived to be negatively affected by the amount of trust towards commercial code/law. In a similar instance, then Minster of Justice Katharina Barley spoke of a fight 'David vs. Goliath' in which for her Goliath represents "the concentrated economic power and the companies" and David representing everything and everyone else, including the international community of states (Deutscher Bundestag, 2024, Minister of Justice Dr. Katharina Barley, 23 March 2018).

3.6. Resistance

> "CDU/CSU and FDP want to invest indiscriminately in everything that has 'artificial intelligence' written all over it, without taking into account the ecological and social follow-up costs. The AI race is thus leading to a material battle with gigantic energy consumption, which is further accelerating climate change. In this way, the potential of digitalisation, which undoubtedly exists, is being wasted. It could help to bring about socio-ecological change. However, this requires a departure from these wild fantasies of growth." (Deutscher Bundestag, 2024, Jessica Tatti, 14 February 2020)

To end the analysis, I want to stress that the insights presented before are not exhaustive. This paper is a short overview over some narratives employed in the political discourse. The narratives shown are not unanimous consensus in any political party, but they are being discussed and challenged even within governing parties and coalitions. However, most explicit critical voices do usually come from oppositional parties. "For far too long, the narrative of digitalization has been a narrative of progress driven by industry and interests, along the lines of 'there's the technology, there's the progress'. We can see that this is not the case" (Deutscher Bundestag, 2024, Dieter Janecek, 14 February 2020) for example, is a way of critiquing a modernist framing of progress and it being driven primarily by technology and commercial development that, judging by my analysis, is very unlikely to have been uttered by a politician of any non-oppositional party.

To conclude the analysis, the key conflict of order and chaos and its several sub-narratives do recur over decades of parliamentary debate and can thus be a useful tool in analysing not only past, but also future debates on the topic. An in depth look into resisting narratives and imaginaries will require further work.

4. Conclusions

4.1. The underlying conflict

Modern states and their governments around the world lead a complicated relationship with everything digital (Kohl, 2017). It is particularly in those debates around digital technologies that politicians in Germany time and time again found and find themselves caught up in conflicts and dilemmas weighing among others three target dimension of new policy against each other:

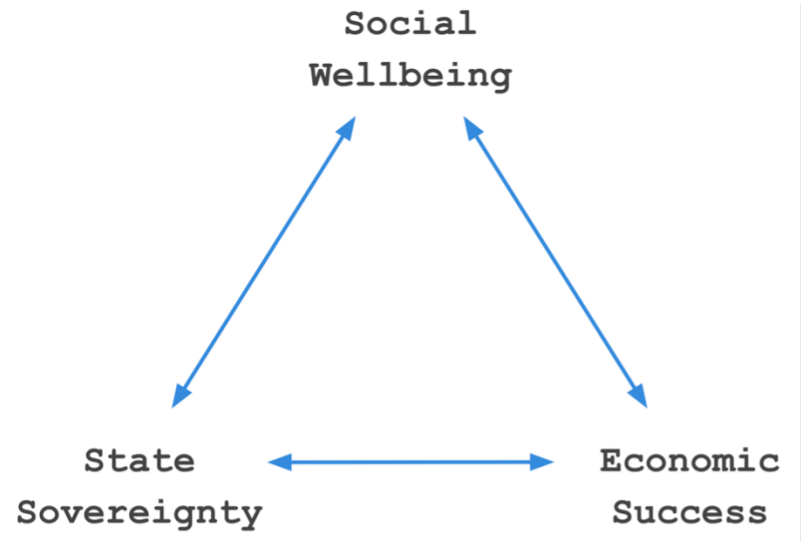

Figure 2. Three key target dimensions of political work as derived from the material

Politics, or so it assumes, aims at digital innovation that balances the three aspects with each other. Naturally, how not only Lessig has shown, policy frameworks that are able to maximise effects for each of these dimensions is seldomly possible (think of intellectual property rights, think of data privacy, think of taxing trans-border e-commerce, et cetera). These inescapable conflicts lead to difficulties in creating narratives and policy that can be perceived as coherent, holistic and advantageous for the great diversity of actors oftentimes being affected. Hence, to develop digital imaginaries that are deemed desirable by state, commerce and citizens alike, and to craft policy frameworks that steer towards that shared imagination demands exceptionally sophisticated narratives. Seen this way, the narrative analysis very much supports the topicality of Lessig's perspective: Code understood as law requires intense processes of (e)valuation. This contribution was able to show the role narratives play in these processes.

The narratives employed in German politics are based to a considerable part on valuations of security and order while working under the assumption that more of both is generally beneficial for all entities using digital technology (except those with explicitly criminal motives). MPs thus often perceived themselves as negotiator between a

principle of *precautionary security*, achieved mainly by control-favouring regulation—the thought that people have to be saved from chaos and unruly spaces—and the idea of *precautionary freedom,* achieved by self-regulation of (online) cultures and architectures—the thought that useful regulations will to a much larger part grow organically.

I propose that the combination of the narratives that I described above lead to a kind of security-spiral that the MPs oftentimes feel obliged to keep running down in a perpetual pursuit of just enough order in a space—the digital—that they perceive as naturally chaotic. The ensuing narratives often convey an image of the Bundestag considering its role as that of the metaphorical person whose only tool is a hammer (here: laws calling for more control/order) and who is hence tempted to treat everything (here: various digital contexts) as if it were a nail.

The question now arises, what this means for political actors. Is politics doomed to be a negative sum game? I want to look at it differently. As I have mentioned before: The ordering of chaos, the desire to replace chance with strategies, and the trailing calls for both more freedom and security, are part of human history. To me, thus, there simply is no 'problem to be solved' definitely, at least not by politics. Lessig in his account, however, did somewhat criticise inconsequential or simplistic regulatory solutions offered by the (US American) government (Lessig, 1999, p.59). This concern may well be transferred to the German context, past and present.

4.2. Discussion: A call for new narratives

The 'solution' to me thus appears to be more of a change of thought rather than a specific action; politics may benefit from more refined and value-conscious debates around what is at stake at a given time and debate. Assumptions, values, and rationales underlying certain political decisions should thus always be precisely nameable by politicians and made transparent to publics on a conceptually richer level than it is at times, as seen in the examples; confounding digital and analogue environments, ideas of European sovereignty being achieved through a chip in ID cards, or that any digital endeavours by industrial companies will be 'null and void' without strong state regulation may be unpacked and scrutinised more. Because ultimately, it is both code and law that create digital realities together. Here I want to circle back to the works of Lessig and Jasanoff and Kim, and one of the things they repeatedly mention: that every seemingly technical decision is in the end one that is based on values, which get expressed via various narratives. One key takeaway that I had during my work on this contribution is that this part of the discussion is very often either cut short or left entirely implicit.

However, in politics, and particularly in liberal democracies, political work happens in a heavily contextualised environment and more often than not, long-acting measures are

more difficult to introduce to public discourses. Here, a dilemma of expectations appears. As the incorporation of digital technology has become and is still becoming more and more a standard in a manyfold of things, it is only logical that the state too is by many people expected to build up digital competences and enable more 'digitality'. It is not only that economical players craved security in the digital space, people, too, now expect the state to be digitally responsive. The already quoted former minister of the Interior Thomas de Maizière said that "People in Germany trust that they live in a safe country. They know that there is no such thing as absolute security. They demand and expect us to do what we can to protect them. This is just as true in normal life as it is on the internet" (Deutscher Bundestag, 2024, Federal Minister of the Interior Dr. Thomas de Maizière, 12 June 2015). MPs have made similar points numerously and I do think that this assumption is not very far-fetched, as the idea of Germany as a traditionally safe and secure country is a central figure of argumentation not only in parliamentary debates (see Hummelsheim-Doss, 2017).

Further problematising my own argumentation for more complex public debates to some extent, I am convinced the point can be made to urge MPs to revisit the conceptual 'code' they are running on without having to be pressed for that by external influence. Put differently, (lay) experts observing the discourse and the structures around digitalisation practices may be more careful in framing increased external engagement to be the one key solution for a more balanced governing of the digital. It shifts the discursive power to the actors currently central to the shaping of digital architectures and their decision to listen to other perspectives or not. While diverse engagement is undoubtedly useful, MPs and other decision makers may take more seriously the responsibility and power some positions come with by continually reflecting their underlying narratives and imaginaries.

Why is this important for this revisiting of Code? The debates Lessig sought to initiate continued over the past 25 years, and they largely did so in in ways Lessig expected (Lessig, 1999, p.205ff.), and it is well possible for them to continue in a similar manner. Those participating in these upcoming discourses should not aim to 'find a solution' but—as Lessig implied—enable open debates and transparently weigh different stakes and interests. Employing a more open-ended thought processes means for German politicians to increasingly allow narratives to be considered in law-making around digital innovation that do not align with traditional understandings of state, progress and orderliness. Openness to unusual narratives and ideas should not only be possible in times of public outcries or overt crises. It is only then that the code written that becomes 'law' in digital environments may reflect and balance out various needs and wants, societal, political and commercial.

It is in our hands—yet some hands more than others—to let another look back 25 years from now not be all too disillusioning by normalising more meaningful and reflective discourses as we keep 'muddling through' (Lindblom, 1959) our so-called digital age.

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Towards a method for exploring meaningful explanations of algorithmic processes

Igor ter Halle[1], Pascal de Vries[1]

[1]Research group Digital Business & Society, Windesheim University of Applied Sciences, The Netherlands

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Abstract. In an era where algorithmic processes increasingly influence our daily lives, the need for comprehensible explanations of these processes is growing. This paper introduces the development of a methodological approach to explore the possibilities for meaningful explanations of algorithmic processes. Utilizing both theoretical frameworks and empirical case studies, this study aims to bridge the gap between algorithmic complexity and user understanding. The proposed method emphasizes transparency and accessibility, supporting policymakers and technology designers in creating more insightful and accountable technological applications. Key findings from this research highlight the critical role of interdisciplinary approaches in shaping effective explanation mechanisms, which are essential for fostering an ethically responsible integration of technology into society.

Introduction

This paper presents the first findings of a project. In this project, a methodology is developed to help governments to make algorithm use more explainable. In this paper, we first describe the Dutch context, then provide a brief overview of the existing literature and then describe the method used to arrive at a methodology that can be used to discuss explainability in concrete use cases around automated decision making.

1. Context

Dutch citizens generally exhibit moderate trust in their government. The Dutch are conservative in their confidence in political institutions, assigning on average a grade of six out of ten (Grimmelikhuijsen 2018). The average political trust in the Netherlands fluctuates over time, yet there is no discernible long-term downward or upward trend.

Political trust tends to correlate with major national developments such as economic crises or viral outbreaks, subsequently returning to its original level.

It is noteworthy that the variance in political trust has structurally increased over the past fifteen years, indicating a greater divergence in trust levels among the Dutch populace. Furthermore, disparities exist between different levels of political institutions; local political bodies tend to inspire greater trust than national (and international) counterparts. Recent investigations by the Dutch newspaper Trouw have also revealed a high level of trust in the police and judicial system within the Netherlands. However, when it comes to specific aspects of governance, such as the government's fulfillment of promises, transparency in policy formation, and equitable treatment of all citizens, the Dutch are significantly more critical and pessimistic. Process satisfaction emerges as a vital contributor to political trust.

Grimmelikhuijsen (2018) posits that many assume transparency to be beneficial for governmental trust. Nevertheless, his research suggests that while transparency serves multiple purposes well, it does not inherently enhance trust, particularly concerning political decision-making. The less politically oriented an organization is, the more trust it engenders through transparent operations. This is evidenced by studies on the judiciary and regulatory bodies, where transparency has been shown to positively influence trust (Grimmelikhuijsen, 2018).

The underlying premise of a transparent government is the notion that if governmental organizations demonstrate to citizens (and other stakeholders) the decision-making processes, including how decisions are made and their outcomes, trust in the government will naturally increase (Grimmelikhuijsen, 2012). Thus, transparency is employed in practice as a standard tool to elevate trust (Grimmelikhuijsen, 2013).

2. The introduction of an algorithm register

To enhance transparency concerning algorithms used by the government, an online Algorithm Register has been available since December 2022. Government agencies publish information about the algorithms they employ within this register. An Algorithm Register is a public database that provides detailed information about the algorithms utilized by an organization. The content of the register may vary, but it typically includes the objectives of the algorithm, the data it processes, its operational mechanisms, and its impact on decision-making processes. The register offers information on the purpose and impact of the algorithm, any conducted Data Protection Impact Assessment (DPIA), or an Impact Assessment on Human Rights and Algorithms (IAMA), along with the data sources used.

Currently, the filling of the Algorithm Register is voluntary, hence it has not yet gained significant traction among the intended audience. However, according to the Action Agenda for Value-Driven Digitalization, by 2025 all algorithms relevant to citizens are required to be included in the Algorithm Register, deviating only when explicitly permitted by law or justified considerations.

In essence, government organizations will be responsible for providing insight into algorithms, thereby establishing and managing an Algorithm Register. The Data Protection Authority (DPA), as the algorithmic regulator, generally oversees the use of algorithms. This oversight applies not only to government bodies but naturally extends to businesses and other organizations as well.

A notable aspect of this initiative, wherein algorithms are published in a register, is the expectation that online publication of written documentation serves as an appropriate form of transparency. In the Netherlands, this is achieved by publishing a written description of the algorithm in the register, which may be available as a downloadable document. In other cases, such as in France, proactive efforts have been made to reach less language-proficient individuals through videos and audio presentations (Lovelace Institute, 2021).

3. Technical transparency versus explainability

Within the realm of algorithmic transparency, the Ministry of Justice and Security distinguishes between 'technical transparency' and 'explainability'.

Technical transparency pertains to disclosing all technical details of an algorithm, including the source code. Explainability refers to elucidating the operation of the algorithm to the concerned citizen.

3.1. Technical Transparency

Technical transparency primarily aims to facilitate the auditing of algorithms (Court of Audit, 2021). Algorithmic auditing can take various forms (gov.uk, 2022), such as verifying documentation, testing algorithmic outcomes, or examining internal operations. Audits may be conducted by external entities, regulatory bodies, researchers, or other parties initiating an audit independently. Auditing serves to ensure internal assurance or verify compliance with legal standards. The scope and depth of audits will vary based on the risks, the context of algorithm use, and existing legal requirements.

3.2. Explainability

A common critique of decision-making algorithms is their resemblance to inscrutable black boxes (Selbst, 2018). Users, citizens, and even designers often do not comprehend how algorithms make decisions, making it impossible to trace their decision-making processes (Lima et al., 2022). The widespread deployment of influential decision-making algorithms has necessitated an understanding of their operation. Explainable artificial intelligence (XAI) is an academic field dedicated to enhancing people's understanding of decision-making algorithms, emerging from this necessity. Although XAI seems concerned with artificial intelligence (AI), much of its literature is also applicable to less complex algorithms, such as those currently published in the Algorithm Register.

As defined by Arrieta et al. (2020), an explainable system is "one that produces details or reasons to make its functioning clear or easy to understand" for a specific audience, whether they be users, designers, patients, citizens, or policymakers.

Many XAI papers view explainability primarily in terms of clarifying the (technical) system to make it less opaque. However, following de Bruijn et al. (2020), we consider explainability more as a socio-technical challenge that addresses both technology and social aspects together. The focus should be on the impact and building trust, not solely on overcoming opacity. Here, it is helpful to consider explainability in terms of mutual intelligibility, a concept from linguistics (Bloomfield, 1926). Languages are mutually intelligible if speakers of one language can understand speakers of another without significant difficulty or study. Mutual intelligibility is a continuum; there are degrees of intelligibility, not a stark division between intelligible and unintelligible.

4. Meaningful explanation

At the Dutch Ministry of the Interior, a standard has been established for the publication of algorithms in the algorithm register, differentiating between experts and citizens. However, the exact identity of these experts and the precise information they require is not entirely clear. Are they policy staff, developers, or others? Given the difficulty in defining this target audience, there is a risk that the register could become so comprehensive as to be less accessible to the citizens for whom it was initially intended, especially as citizens themselves are not a exactly a homogeneous group.

Therefore, with such a variety of target groups that the register could serve, different modes of explanation may be necessary. The nature of the explanation might depend on the complexity of the context in which (complex) algorithms will be used, the type of data involved, the intention and purpose of its use, and, consequently, to whom it should be explained.

In addition to the complexity of target groups, according to de Bruijn et al. (2020), the context in which the algorithm is explained should also be considered. De Bruijn et al. distinguish two axes (figure 1): the degree of politicization and the impact of the algorithm on the life of the citizen. If the algorithm to be explained relates to a politically sensitive topic, then trust in the explanation of the algorithm will likely be low. If the impact of an algorithmic decision on citizens is significant, it may lead to the politicization of the decision and challenges to the explanation. Thus, explaining algorithms in complex situations will not always enhance trust.

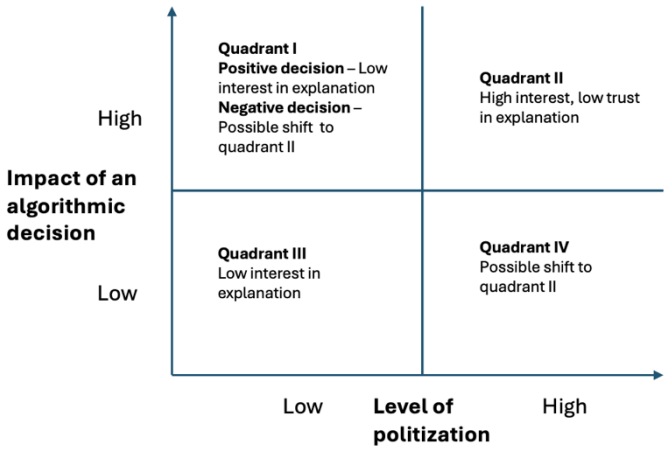

Figure 5. - Adapted from de Bruyn et al (2020)

Consequently, explaining the operation of an algorithm does not invariably lead to increased trust by citizens in the government or the deciding authority. It is therefore valuable to explore how to explain algorithms that have a high impact on the lives of citizens and a low to moderate degree of politicization to them.

A starting point for exploring potential strategies for explaining algorithms is the list of explanation strategies outlined by de Bruijn et al. (2020), based on the quadrant. These strategies include shifts from 1) explaining algorithms to explaining decisions, 2) from designing algorithms to co-creating/negotiating algorithms, 3) from explainable algorithms to explainable processes, 4) from an instrumental to an institutional approach, 5) from monopolistic algorithms and datasets to competing algorithms and datasets, 6) explaining the sensitivity to values of algorithms and how they have been addressed, particularly regarding gender, ethnicity, age, etc., and 7) from algorithms that replace professional decision-making to professionals who challenge algorithmic decision-making. As the challenges mentioned above are interconnected, a combination of strategies will typically be necessary.

5. Towards an approach for exploring meaningful explanations

To gain insight into how to meaningfully explain algorithms in practice, an approach is being developed to co-create actionable alternatives with professionals (to whom it may concerns). This approach looks for handles that professionals can use to provide contextual explanations about the algorithm and the context in which it has been used.

In the development of this approach, inspiration was sought from two methods that appear to be potentially suitable:

- Human-Centered Design (HCD)

- Guidance Ethics Approach (GEA)

HCD is frequently mentioned in the literature surrounding explainable artificial intelligence and is part of the approach (see, for example, Schoonderwoerd et al., 2021, Hall et al., 2019). The Guidance Ethics Approach is used within our Digital Business & Society research group to find concrete handles to apply technology in an ethically responsible manner (see https://ecp.nl/publicatie/guidance-ethics-approach for a full description of the approach).

5.1. Human centered design

Figure 2 presents a process flow diagram for a human-centered explanation design. In Human-Centered Design (HCD), three components are distinguished as crucial within the design process (see Schoonderwoerd et al., 2021, among others): domain analysis, requirements elicitation, and interaction design. Each component produces outcomes that serve as input for the next part.

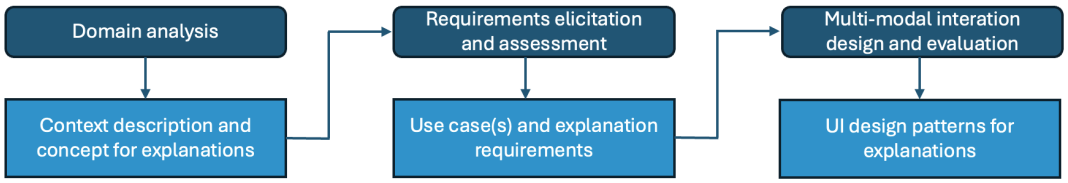

Figure 6. Flowchart explainable AI (Adapted from Schoonderwoerd et al., 2021)

5.1.1. Domain Analysis

A fundamental premise of all human-centered design approaches is to gain an understanding of the context of use (see, for example, Hall et al., 2019). The purpose of this insight is to determine whether and why explanations are needed and which information could be considered relevant in the context under examination.

The outcome of domain analysis is a description of the context in which a user seeks an explanation and an initial concept for the explanations based on the information that is relevant to end-users.

5.1.2. Requirements Elicitation

The objective here is to ascertain what kinds of explanations the system should be capable of providing. This process aims to outline a rich context (i.e., a use case or scenario) from which the target group's requirements can be identified (Maguire and Bevan, 2002). Wolf (2019) targets the development of usage scenarios where explanations are likely to be relevant (i.e., explanation scenarios).

5.1.3. Interaction Design

This phase's goal is to discover how the developed explanations can be effectively communicated. This includes selecting suitable modalities for presenting the information, typically involving a multimodal combination of visual and textual content (Holzinger et al., 2021).

6. Guidance ethics approach

The Guidance Ethics Approach (GEA) develops concrete action options for handling technology through structured dialogue with stakeholders within a sector or organization. From various user perspectives, the technological innovation under analysis is explored. The approach is employed to develop alternatives for AI applications.

It is also utilized in the development and usage of digital healthcare solutions. The method was developed in collaboration with Professor Peter-Paul Verbeek by the Platform for the Information Society and is described on the website begeleidingsethiek.nl (see https://ecp.nl/wp-content/uploads/2020/11/Guidance-ethics-approach.pdf for a summary in English).

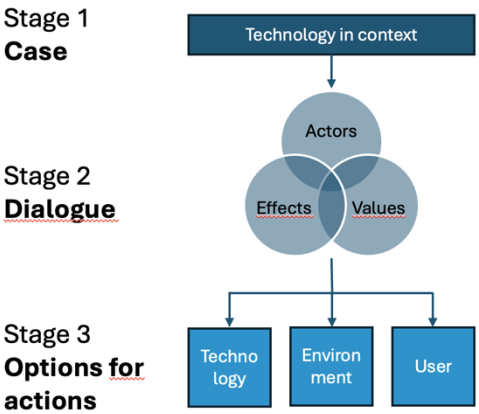

Figure 7. Guidance ethics approach (adapted from begeleidingsethiek.nl)

The approach involves a workshop where different stakeholders within an organization or sector engage in dialogue about the application of a specific technology within a specific context. The goal of the workshop is to jointly arrive at concrete action alternatives, ensuring that the technology discussed is embedded in the day-to-day operations within the organization or sector.

The workshop comprises three phases (see Figure 3). It begins with describing the technology and the concrete context in which it operates, focusing on a clear and comprehensible description without excessive jargon or technical details, making it understandable for an interested outsider.

In the second phase, the potential effects of deploying a technology in that context are explored. We seek to understand who is involved with the technology and which values are pertinent in daily practice. Ideally, the actual stakeholders would contribute to the dialogue. If not, all stakeholders can participate, representatives may think from their perspective. Distinguishing various effects can aid in acquiring a rich and realistic view of technology use. There are always multiple values associated with technology; in most cases, various values are significant. Like the effects, the process begins with an open inventory, followed by determining which values are deemed most relevant.

In the final phase, action options are formulated. Three types of action options are distinguished: from the technology ('ethics by design'), from the context ('ethics in context'), and from the user ('ethics in use').

7. Towards the meaningful explanation approach

After exploring both approaches through brainstorming, it has been decided to divide the workshop into two phases. The first phase explores the case from the participants' perspectives. In this exploration, the participants examine the algorithm to be explained from the perspectives of the actors involved with the algorithm. All these actors have expectations, and the outcome of the algorithm (such as whether or not a housing allowance is granted) has implications for the involved actor. Thus, the first phase explores the case and the various perspectives of the actors. Questions to be addressed in the first phase include:

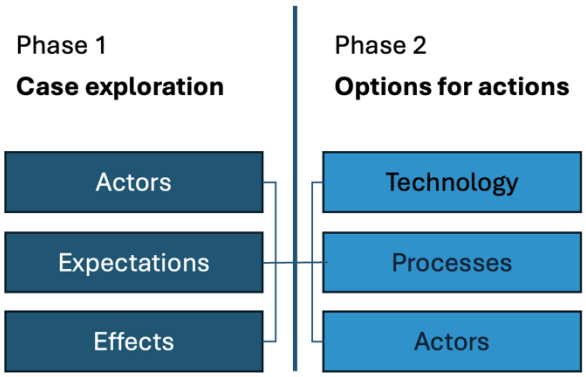

Figure 8. Meaningful explanation approach (1st version)

- Which actors play a role in explaining algorithms and procedures?
- What role do these actors play? What are their expectations?
- To whom should what be explained?
- What are the consequences of (in)comprehensible explanations for these actors?
- When is an actor satisfied?

Building on this exploration, the second phase investigates action alternatives from the perspective of technology ('transparency by design'). This includes personalized explanations, the use of multimedia, etc. Possibilities are also explored from the perspective of the process in which the algorithm is implemented ('transparency in process'). Consider, for example, the role a helpdesk might play or relevant parties in the process (such as housing associations, advocacy groups, etc.). Finally, the workshop explores ways to improve explanations from the various actors' viewpoints ('transparency in use').

Working with the meaningful explanation approach clarifies where meaning resides in the process of explanation. Following this, alternatives for action can be explored to achieve that meaning.

7.1. Testing the method

The method was first tested in a round table dialogue with participants from a department of the Dutch tax authorities. Six participants who are involved in an algorithm on the allocation of a rent allowance. Each participant had a different roles in the discussed algorithm (developers, policy advisors, helpdesk etc.). In the first fase of the dialogue the participants started from the perspective of different stakeholders such as users,

developers, policy makers and decision makers. After the dialogue, the participants generated options for action.

In order to prevent the dialogue from becoming mainly a theoretical exploration, we used one concrete algorithm to discuss the practical use of an algorithm: what is it? what does it do? who has anything to do with it? and what are the experiences with regard to explainability and transparency. A lot was discussed during the dialogue session. Entering into the dialogue in itself is already an exercise in transparency and explainability among colleagues.

Conducting a dialogue is not that easy. The participants were all personally invited by a colleague based on their specific areas of contact with the subject. Care was taken to ensure a mixed group of participants (in terms of expertise, gender, age, etc.)

A conclusion emerged from that process; participants indicated that it is good to talk to each other (from different practices) about a concrete algortihm. The structure of the dialogue session was used very loosely. The dialogue touched on all subjects and therefore it became a very natural dialogue. This does cause some difficulties for the reporting because the content can no longer be placed so well within the original framework.

After first test of the method, it is evident that the exchange of values around meaning has not yet been given a place, although there is a need for it. In the Guidance Ethics Approach (GEA), values are explored and identified in the dialogue between different perspectives of actors as represented by the participants. In the meaningful explanation approach, values are named from the perspective of the explainer. This clarifies what is alive among the participants and which values are recognized. The approach, therefore, works with different perspectives, but these are introduced by the explainer. Whether this aligns with the perspective of the explainees has not been definitively established.

Participation in an GEA-dialogue shows that introducing different perspectives of ownership provides the opportunity to discuss the process of the case study. We have not actively questioned the process of the algorithm, and it did not emerge organically, even though the selection of speakers took into account the constructivist nature of an algorithm (Seaver, 2018). Explaining should, after all, be part of the algorithmic process. This deserves attention next time to become part of the approach.

In the future, we aim to further employ this instrument in discussions about meaningful explainability within government organizations and refine it so that it becomes a tool to discern which alternatives for action contribute to a meaningful explanation of algorithmic processes.

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Thematic Field C:

Towards Low-Carbon Energy Systems and Fighting Climate Change

Navigating Time, Scale and Identities in Facilitation of Regional Development

Magnus Fredricson[1,2]

[1]University of Skövde, Sweden; [2]Skaraborgs kommunalförbund, Sweden

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Abstract. Facilitating regional development becomes increasingly demanding as complexity grows and multi-level and multi actor governance is required to achieve transformational change moving away from fossil dependence and enabling neo-industrialisation. Meta governance is a “practice by (mainly) public authorities that entails the coordination of one or more governance modes by using different instruments, methods, and strategies to overcome governance failures” (Gjaltema et al., 2020).

In Skaraborg, a sub-region of Region Västra Götaland in West Sweden a common energy supply plan is being established through a joint decision of 15 municipalities. The municipalities are also establishing energy plans as mandated by law, and some are developing plans for wind power. The more than 20 energy companies serving the region are also driving parts of the transition. This multi-actor, multi-level context is understood as complex and non-linear (Mowles, 2016) where relations of power and negotiation is central.

As an industrial PhD-candidate the question of what I am trying to do is multi-layered. On the one hand I am trying to prevent the loss of jobs in Skaraborg, and even enable new ones being added by addressing lack of electricity. This, in turn, supposedly safeguards tax income for the municipalities ensuring funding for schools, nursery homes and more. On the other hand my hope is that the contributions of the article will impact, and speed up, regional development and transition in other places.

The purpose of the research is to enable more productive planning and decision making through a widened discourse. This article presents initial interpretations of the transition of energy systems in Skaraborg and West Sweden. Strategies based in existential sustainability are then employed to enhance the productivity of the facilitation, including re-scaling, temporal aspects and a deepened understanding of identities.

1. Introduction

The endeavour to reduce, and indeed end, emission of greenhouse gases is global, based in the UN system: the International Panel on Climate Change and the Agenda 2030. The summary of the synthesis report from 2023 clearly states that there is progress, but nearly not enough (Calvin et al., 2023). This is true also on other levels, including the national level in Sweden where the Swedish Climate Policy Council clearly states that Sweden's achievement are non-sufficient (*Klimatpolitiska rådets rapport 2023*, 2023). The 2024 report of the council reiterates this, presenting comprehensive criticism (*Klimatpolitiska rådets rapport 2024*, 2024). This obviously calls for action, and to be more precise more productive action.

Regions are central actors in driving sustainable development, in Sweden even mandated by law to establish regional policy, strategies, for regional development. Region Västra Götaland is Sweden's largest region, encompassing 49 municipalities. To enable cocreation of regional development four intermediaries, regional associations of municipalities, are established. Spatial planning, a crucial tool for sustainable development, is in the Swedish context performed by municipalities. Regions and sub-regions have no formal power over municipalities, leaving different kinds of soft power options such as facilitation, political agreement and more.

Driving sustainable development entails balancing conflicts of interest (Kates et al., 2005) in ever increasing complexity (Norberg and Cumming, 2008). Sharpened tools and enhanced capacity for regional development is then paramount.

One current focus with regards to eliminating emissions is electrification. This creates high demand for electricity globally and also in West Sweden where demand is expected to at least double in upcoming years (Ackeby et al., 2024). Replacing non-visible emissions with visible energy infra structure (production sites, grids) produce local resistance, and the need for presenting holistic arguments to mitigate this is clear. Current arguments building on green growth and regional competitiveness are likely not sufficient. Existential sustainability paired with advanced facilitation of regional development is a possible contribution. Meta-governance is an established practice aimed at facilitating multi-stakeholder and multi-actor development (Gjaltema et al., 2020; Hooge et al., 2022; Jessop, 2011; Sundqvist, 2021).

New challenges demand a governance approach that acknowledges uncertainties, interconnectedness and potential consequences of decisions both intended and unintended. Traditional policymaking, reliant on public actors gathering expertise and implementing regulatory solutions, struggles to address modern societal complexities (Grothmann and Pütz, 2009). Policymakers express powerlessness with regards to this. Historically, regional policy focused on economic growth, but evolving strategies require

a more integrated approach. Productive regional policy necessitates collaboration across organizational boundaries, involving actors in decision-making processes (Hummelbrunner and Lukesch, 2002). Development is now viewed as transformative, emphasizing holistic behaviour and feedback mechanisms to avoid ineffective policymaking (Hummelbrunner and Lukesch, 2002).

Björling (2016) introduces fragility: lack of mandate, resources and competencies as something preventing a sustainable development. Mowles (2016) argues that people, while co-creating, enable or constrain each other in relationships of power. Furthermore Mowles argues that actions have both intended an unintended consequences and proposes complexity sciences, the sciences of uncertainty, as well as social sciences might prove productive when understanding and promoting co-creation. This article proposes the existence of systems of powerlessness, based in observations. Perceived, and expressed, powerlessness appears with reference to a multitude of complex and interrelated phenomena such as regulatory challenges, high demand on investment (combined with scarcity of resources), lack of clarity around roles, responsibilities and more. This also appears in Rosas thinking, where policymaking is described as futile. *"It seems that … it has become politically impossible to plan and shape society over time; the time of political projects, it seems, is also over"* (Rosa, 2003, pp. 21–22). According to Rosa the *"structural problem at the heart of this disappearance of politics is the political system's fundamental inability to accelerate"* (Rosa, 2003, p. 22). The conclusion becomes: *"As a result, the future opens up to almost unlimited contingency and society experiences time in the form of perpetual change and acceleration"* (Rosa, 2003, p. 14).

Picchi et al. (2023) point out that the sustainability of the energy transition implementation process is affected by a lack of social-ecological systems thinking and that future development of sustainable energy landscapes requires informed decision-making.

The scope of the research is regional development, and the current case of regional development is transitioning of the energy systems, specifically electrification. The board of the (sub-)regional association of municipalities has decided that a (sub-)regional plan for energy supply is to be established.

The sub-region has 15 municipalities and there are no less than 21 grid owners operating in the area. About half of them are owned by municipalities, a common solution in Sweden. Apart from a couple that are privately owned, the rest are cooperatively owned. This too is a common thing in Sweden. Incentives vary between these different types of companies. Municipally owned companies might be expected by their owners to contribute to the transition where the cooperatively or privately owned might fear large investments needed for that.

2. Contributions

The contribution of the research is enabling more productive facilitation of regional development through faster and more productive planning, decision making and implementation where multiple actors integrate their efforts to achieve impact on speed and quality of the transition through a transdisciplinary approach combining technology and social sciences. This includes establishing or further developing existing methods and constructs, where the term *method* is interpreted a bit wider than the definition posed by March and Smith: *"a set of steps (an algorithm or guideline) used to perform a task"* (1995, p. 257). It also includes possibilities to adapt to ever changing contexts and changes in policy. According to March and Smith *"constructs or concepts form the vocabulary of a domain"* (1995, p. 256).

This particular article presents initial interpretations of the transition of energy systems in Skaraborg and West Sweden through the lenses of the theory identified.

As an industrial PhD-candidate the question of what I am trying to do is multi-layered. On the one hand I am trying to prevent the loss of jobs in Skaraborg, and even enable new ones being added by addressing lack of electricity. This, in turn, supposedly safeguards tax income for the municipalities ensuring funding for schools, nursery homes and more. On the other hand my hope is that the contributions outlined above will impact, and speed up, regional development and transition in other places.

3. Case in point: Electrification Governance Skaraborg

Figure 1. Skaraborg is a sub-region within Region Västra Götaland.

Electrification Governance Skaraborg consists of several initiatives. It is based in my work as a strategist for sustainable development at Skaraborgs kommunalförbund, one of four sub-regional intermediaries mentioned above. It is an organization facilitating regional development together with its members, the 15 municipalities in the former county of Skaraborg, now a sub-region of Region Västra Götaland.

Based on a political decision a (sub-)regional plan for energy supply is currently being established, to mitigate lack of electricity in Skaraborg, both power and energy. Within the project SUES-Digit, financed by the national research agency Formas, research on governing the transition and development of the energy system also utilizing digital models is ongoing.

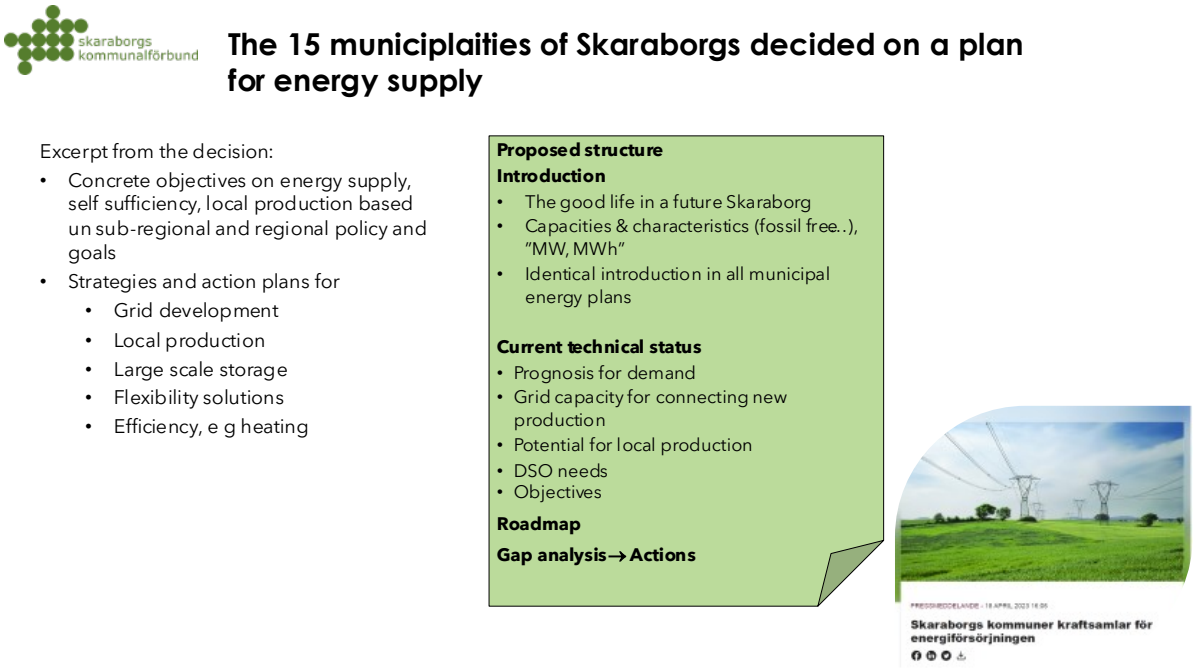

Figure 2. The decision on a regional plan and proposed headlines of the plan.

Skaraborgs kommunalförbund is a politically governed organization, where the board comprises of the mayors of the 15 municipalities. A multi actor and complex situation is at hand where there are 15 municipalities and no less than 21 energy companies, where some are only grid owners and other conglomerates with both grids, production, district heating etc. The board has adapted the role of meta-governor through the above mentioned decision and more.

The work as a strategist is aimed at regional development and regional transition, guided by (sub-)regional and regional policy. Several years of experience shapes a background for the research where one hypothesis is that there are systems of powerlessness preventing necessary decisions being made, and actions being taken. Hypothesis here being understood in the classical way, as a statement that can be tested through experimentation. (Park et al., 2020) In Björling (2016) fragility, described as scarcity of

resources, competencies and mandate is used to denote this. Another hypothesis, directed at mitigating identified challenges is that informatics, visualization using digital models, is a way to support decision making / policy making in complex contexts.

4. Theory: connecting existential sustainability with regional planning and development

Widening the discourse: sustainable existentialism

Kates et al. (2005) propose sustainable development as a process rather than a state that can be attained. Noting that values have a central role in sustainable development they also conclude: *"Finally - and in many ways, most importantly - sustainable development is defined in practice. The practice includes the many efforts at defining the concept, establishing goals, creating indicators, and asserting values. But additionally, it includes developing social movements, organizing institutions, crafting sustainability science and technology, and negotiating the grand compromise among those who are principally concerned with nature and environment, those who value economic development, and those who are dedicated to improving the human condition"* (2005, pp. 17–18).

This article proposes that existential sustainability ("Existential Sustainability," n.d.) adds several perspectives building on the foundations of general sustainable development, including:

On the scope of sustainability, and existential perspectives

1. Widening the scope of sustainability from only climate crisis to include loss of biodiversity where the first impacts all aspects of human life and the latter might even pose a real existential threat to human life, as pointed out by intergovernmental science-policy platform for biodiversity and ecosystem services, IPBES ("IPBES," n.d.).
2. Connecting the tangible with the intangible, the invisible and visible. One concrete example of this, proposed by Åsa Elmqvist at Energiforsk, is that mankind currently needs to replace invisible carbon dioxide with visible infrastructure (2023).
3. Realising the innate capacity for spirituality or interrelatedness within man.

Decision making and impacts on and by identities

4. Widening the understanding of human nature, and human decision making, from homo economicus, implying rationality, to downplaying sheer rationality (Mowles, 2010).

5. Widening the scope of sustainability even further to include the role of identities and impact on identities.
6. Realising that decision making evokes anxiety.

Temporal aspects, acceleration and powerlessness

7. Exploring systems of perceived power and powerlessness.

Possibilities associated with scale and re-scaling

8. Expanded sense of place, from local to global adding a connectedness.

The three later groups are presented below with the first group of perspectives interwoven. They are then combined in synthesised proposals on how governance can be enhanced.

Integrating perspectives: meta-governance

Gjaltema et al. (2020, p. 1771) define meta-governance as ”a practice by (mainly) public authorities that entails the coordination of one or more governance modes by using different instruments, methods, and strategies to overcome governance failures”. They explore the “who, what, why and how” of meta-governance where combining the who and what lead to four ideal types of meta-governance illustrated below: network meta-governance, multilevel meta-governance, meta-governance of multiplicity and meta-governance of modes (2020).

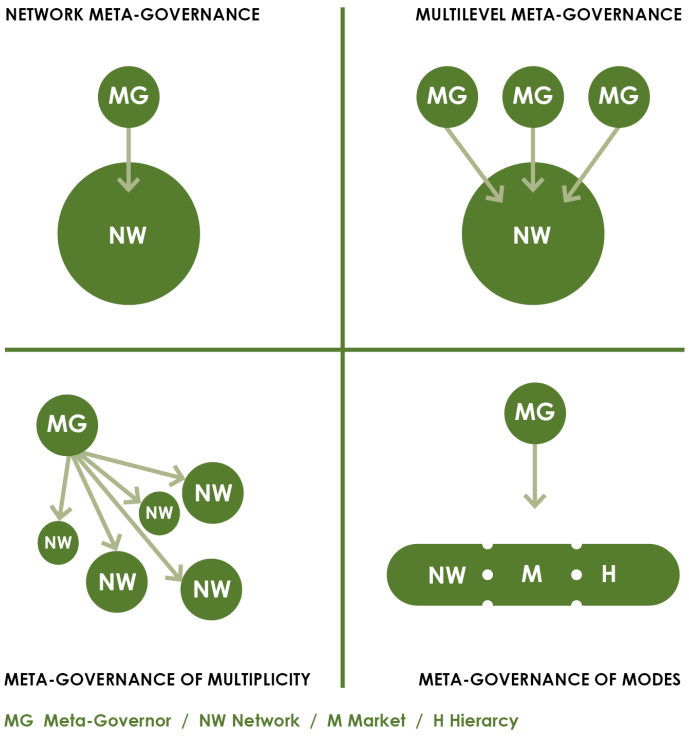

Figure 3. Different types of meta-governance, from Gjaltema et al. (2020).

> *"Thus, the meta-governance literature demonstrates a dialectical development in the debates on the shift from government to governance. The thesis of hierarchical steering by the sovereign state was followed by the anti-thesis of the hollow state in the new networked reality. Meta-governance can be perceived as its synthesis: it often implicitly tries to reconcile the government versus governance debate by looking into the new role of the state in the networked society. Meta-governance is "government plus governance" and can be constraining as well as enabling, as it "combines control and facilitation""* (Damgaard and Torfing, 2010, p. 260).

Hooge et al. (2022, p. 1594) present an institutional design approach where three types of meta-governance strategies are introduced: 1) network design strategies entails shaping and structuring networks, with in- and exclusion of actors and policy. 2) Network framing strategies focuses on formulation of goals to pursue, influencing the perception and sensemaking of actors creating a connection with identities. 3) Different kinds of participation by the meta-governor is the third type. However, it is understood that increasing complexity challenges a too mechanistic approach to governance (Mowles, 2010).

Examples of these strategies are presented in a heuristic analytical framework, from Hooge et al. (2022, p. 1595).

Table 1. Meta-governance strategies from Hooge et al. (2022).

Network design strategies	Influence the composition of the policy network. (1) Establish new actors (2) Re-arrange and shift positions of actors (3) Influence actors' roles
Resourcing strategies	Influence the activities undertaken by actors. (1) Provide/withhold actors with funds for specific purposes (2) Enable/disable activities by actors through provisions such as regulations and fiscal law (3) Grant/retract actors with knowledge and authority
Framing strategies	Influence the perception and sensemaking of actors regarding. (1) The (content of the) policy issue (2) The urgency of the policy issue (3) The purpose of the policy (4) The scope and/or specifics of policy goals by setting indicators, standards and targets

Emphasizing complexity, non-linearity and dialogue – Forum, Arena, Court

Several frameworks for understanding decision making in a complex setting with regards to strategic planning of society exist. Outlined by Fredriksson (2011), the Forum Arena Court framework proposes a widened understanding of strategic planning. *"Development discussions, strategic planning, and strategic decision-making, do not necessarily proceed in a linear chronology throughout forums-arenas-courts."* (2011, p. 83) Rather, strategic planning is described as messy and iterative. Capturing ideas and more, detecting emergent patterns and assisting them in taking shape in a more complex process than the legal system suggests (2011).

"…strategic planning becomes not a matter of designing rational processes to make logical decisions … but rather a matter of convincing other actors in a situation of multiple realities and multiple truths. It is about forming a story of what could/should be done based on the own mental image of reality and of using this as a base to strategically 'experiment' throughout the three forms of strategy construction sites, and in the struggle between discourses" (2011, p. 82).

However, forum arena court does not seem to directly address issues of power, or powerlessness.

Decision making and impacts on and by identities

Decision making involves moving from understanding to action, and it is the underlying assumption of this paper that understanding supports action, but in and of itself is not enough. *"Well-informed actions (i.e., those based on true beliefs) are more likely to achieve desired ends. Information is valuable insofar as it helps individuals form true beliefs which, in turn, promote effective, goal achieving action"* (March and Smith, 1995, p. 251). Decisions are, so far, mostly made by humans. Despite rather prevalent, neo liberal, ideas of homo economicus that imply rationality it is obvious that many things apart from objective, science based, material conditions impact decisions being made regarding sustainable development (Calvin et al., 2023).

A transition from a modern to a post-modern context has taken place during recent years. This impacts decision making and processes supporting decision making. Foucault essentially argued that where modern democratic and bureaucratic institutions see themselves as rational, almost scientific, this is not the case (Bevir, 1999). Rüsen (2005, p. 136) surveys the transition from modernity, bringing about the notion of the history to postmodernity where the idea of *"anything like one single … historical process of the development of humankind"* is *"radically rejected"*. (2005, p. 137)

An existentialist understanding of this, based in Kierkegaard and Sartre, is that the freedom that humans are condemned to, produces anxiety. Sartre distinguishes two types of existentialist anxiety where vertigo is a response not to external factors but freedom. Vertigo is therefore directed towards the future, and focuses on the consequences, intended or unintended, of decisions (Cox, 2021). Hence decision making, being about the future, is closely linked to the existentialist dilemma and vertigo.

One of the implications of this, regarding relations between civil servants and politicians, is that complexity, uncertainty and the possibilities of unexpected, specifically negative, outcomes of decisions now are a part of these relations. This, in turn, proposes that civil servants repeatedly place politicians in a state of anxiety. Obviously, this poses risks to the relationship and indeed the working environment of both parties, as they quite frankly make up big parts of each other's work lives.

As in any social context, strategies emerge to mitigate states and processes. Among them are requests for reduction (simplicity) often phrased as a demand for more concrete presentations and alternative solutions. This has consistently been the case within Skaraborg while working to create coherent and relevant strategies for the transition of the energy systems. Demand for simplification and visualisation is always high.

Decision making involves choosing between alternatives, prioritising and more. Making decisions also entails wielding power, where power is a notion that this paper does not seek to explain further. The opposite of power, powerlessness, is also not described. It is, however, an underlying assumption of this paper that systems of powerlessness exist and often come into play when (trying to) establish and implements decisions driving a sustainable development, especially in a multi-actor context of meta governance.

Identity, Alcoff points out *"is also a way of inhabiting, interpreting, and working through, both collectively and individually, an objective social location and group history"* (2006, p. 43). Wielding of power and living with the consequences is integrated into both individual and group history. Alcoff concludes: *"We might, then, more insightfully define identities as positioned or located lived experiences in which both individuals and groups work to construct meaning in relation to historical experience and historical narratives. Given this view, one might hold that when I am identified, it is my horizon of agency that is identified"* (2006, p. 43). Agency being the capacity for decision making implies that identities impact, and are impacted by, decision making.

Temporal aspects, acceleration and powerlessness

The German sociologist Hartmut Rosa grapples with modernization and presents the temporal dimension and specifically acceleration as a prerequisite for understanding the process of modernization. Acceleration, according to Rosa (2003), takes place in three forms: 1) Technological acceleration in goal directed processes speeding up communications, production and more. 2) Acceleration of social change where rates of change in society themselves are changing, increasing. 3) Acceleration of the pace of life

Rosa moreover identifies three drivers of acceleration: the economic, cultural and structural motors: 1) The economical motor where acceleration in short is driven by capitalism. *"The most obvious source of social acceleration in Western societies is, of course, capitalism. Within a capitalist economy, labor time figures as a crucial factor of production such that saving time is equivalent to making (relative) profit, as expressed in Benjamin Franklin's famous equation of time and money. Also, 'time leads' over competitors in the introduction of new technologies or products is a key element of market competition because it allows for crucial 'extra-profits' before the competitors catch up. Finally, the accelerated reproduction of invested capital is crucial with respect to what Marx called the 'moral consumption' of technology and to the credit system. As a consequence, the circle of production, distribution, and consumption constantly accelerates"* (2003, p. 11). 2) The cultural motor where acceleration is presented as a strategy to mitigate expectations of a fulfilled life, filled with realising as many options as possible, and the fact that time is limited. *"Now, on this cultural logic, if we keep increasing the speed of life, we could eventually live a multiplicity of lives within a single lifetime by taking up all the options that would define them. Acceleration serves as a strategy to erase the difference between the time of the world and the time of our life"* (2003, p. 13). 3) The structural motor where the principle of functional differentiation drives acceleration: *"In a society that is not primarily segregated in hierarchical classes but rather structured along the lines of functional 'systems,' like politics, science, art, the economy, law, etc., complexity increases immensely. As a result, the future opens up to almost unlimited contingency and society experiences time in the form of perpetual change and acceleration"* (2003, p. 14).

All of this impacts decision making and politics. Rosa points out: *"As a result, politics, too, has become 'situationalist': it confines itself to reacting to pressures instead of developing progressive visions of its own. Very often, political decisions no longer aspire to actively steer (acceleratory) social developments, but are defensive and decelerator"* (Rosa, 2003, p. 21).

Rüsen connects time and values where history *"clothes values in temporal experience"*. (2005, p. 25) One might argue that Rüsen connects temporality and identity, where values and identity are inter-related.

Possibilities associated with scale and re-scaling

Extension of scale might follow from sense of interrelatedness. This also correlates to the Judaeo-Christian notion of shalom – a state of oneness and peace for instance outlined by Harry Månsus, in what is described as the first instance of eco theology in Sweden (Månsus, 1983). Månsus continues to expand his themes, venturing again into the cosmic cathedral, stating: *"Surely, even life itself has an existential, religious dimension. Life provides overwhelming moments in awe and large gratitude"* (Månsus, 2021). (Translation by the author.)

Places, one type of scale, are hard to define but apparently socially constructed. *"While place is clearly central to human geography as well as to everyday life, it is equally clearly a changing and contested concept. Places range in scale from the corner of a room to the whole planet. They are, in the broadest sense, locations imbued with meaning that are sites of everyday practice"* (Cresswell and Holloway, 2009, p. 9).

Kärrholm et al. (2023) propose a "rudimentary vocabulary of modalities" to enable a discussion of rescaling. Referring to Caniggia and Maffei (2001) they expand the understanding of scale from geographical taking place, "big or small" to "different level of complexity of the components internally arranged to construct a whole". It is my understanding/proposal that this definition enables an understanding in part disconnected from the most basic notion of space, and that different systems of multiple actors and dynamics between them can be included in different scales.

The proposed modalities include:

- **Extension and compression** – whereby the importance of a specific scale is either extended or compressed by for instance adding actors from elsewhere.
- **Sidestepping** – whereby parallel situations are produced.
- **Multiple-scalar orders** – whereby the very idea of a single vertical scalar order is challenged.
- **Upscaling and downscaling** – whereby a vertical movement on existing scale relations take place.

Elaborating Kärrholm et al. note, highlighting the role of power: "This also means that scaling is often closely related to issues of power and the ways in which power is embodied, exercised and distributed" (2023, p. 273).

The efforts on regional development in Skaraborg builds on The Structural Image and is mainly perceived as an effort based in spatial planning. The Structural Image for Skaraborg is one of the empirical bases of Nils Björling's dissertation. Björling addresses scale in several ways: "Through architectural thinking assemblage thereby becomes useful, because it is open for a continuous rearrangement of components and processes and have the capacity to combine transformations and conditions from different scales" (Björling, 2016, p. 303).

The current work on developing the energy systems in Skaraborg involves (at least) one region (Region Västra Götaland), one sub-region (Skaraborgs kommunalförbund), 15 municipalities and 21 grid owners leaving the national level, industry and many relevant stakeholders out of this text.

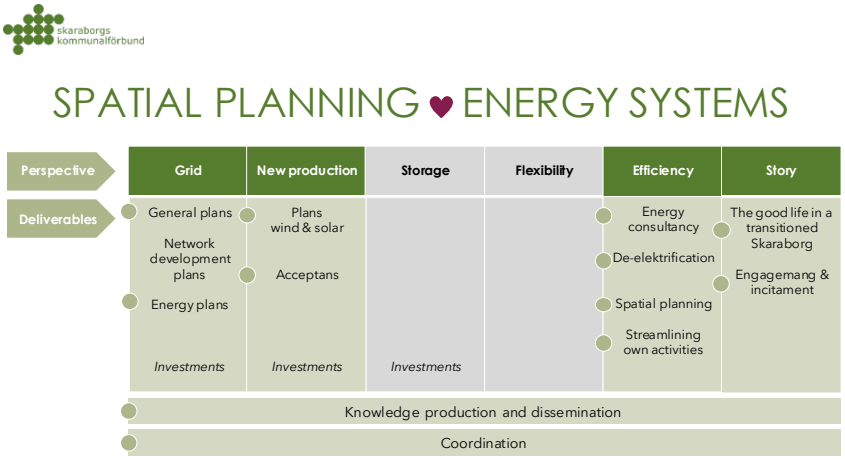

Figure 4. Connecting spatial planning with the development of local and regional energy systems, describing roles between municipalities and energy companies.

A rather obvious application of up- and downscaling is facilitating efforts on multiple scales such as only the grid owners, only the publicly owned grid owners, the municipalities and the grid owners and more. This modality has been tested, and the result is a proposed structure for co-creation of the desired transition depicted above. The grey columns are the sole responsibility of the energy companies, activities with a green dot are the sole responsibility of the municipalities.

The diversity with regards to legal structure and ownership of the grid owners in Skaraborg ranging from private to publicly owned via co-opted poses challenges for co-creation and indeed financing. In short, municipally owned companies are expected to contribute to regional development where the transitioning of the energy systems is a part, where privately owned and co-opted owners of grid lack incentives for that. Bringing in another financier, in this case the locally owned insurance company, for the facilitation of the cooperation between energy companies is an example of sidestepping.

Models and visualisation

Decision making in complex, multi stakeholder, contexts demand reduction to enable conversations and learning. One plausible way of facilitating this is the use of models and tools for visualisation.

Design of models that on the one hand enables decision making and on the other hand do not limit assessment of relevant outcomes or even relevant outcomes is then key. (Norberg and Cumming, 2008)

Visualisation is a pedagogical tool with capacity to present complex systems, enabling learning with regards to understanding consequences of decisions (Sterman, 2000). However, visualisation builds on reduction, and a perceived understanding might be false (Norberg and Cumming, 2008). Whether visualisation has a capacity to reduce actual anxiety is unclear.

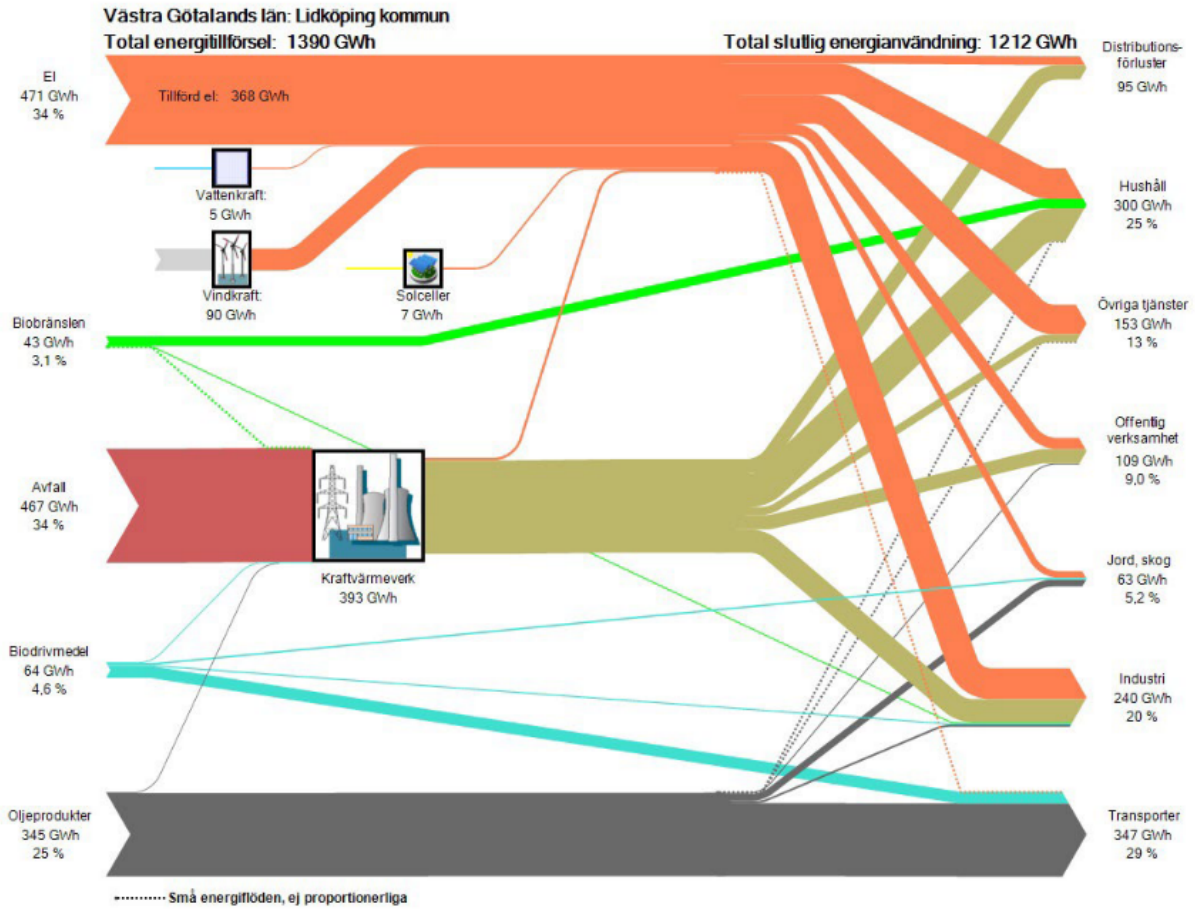

Figure 5. Includes as an example: a Sankey diagram of energy added and consumed in one of the municipalities. (Länsstyrelserna, 2023)

As a part of the aforementioned project SUES-Digit pilot testing of digital models and visualisation have been performed. Through open data, provided by several agencies, different scenarios based on for instance different levels of adaption of electrical vehicles,

introduction of local solar- or windbased production of electricity and others can be compared via Sankey-diagrams. These diagrams, or more specifically the differences between them, are then used as a basis for facilitating conversations and decision making. Models have been established for at least two municipalities. This work is presented in an article that is currently under peer review. (Fredricson et al., n.d.)The next step is to build a geographical model of the entire sub-region with enhanced visualisation capabilities of more perspectives than energy systems, for instance mobility, road infra structure and housing. This work is already in progress.

5. Contributions by Existential Sustainability within facilitation of regional development

Finding and implementing strategies enabling productive facilitation of regional development is challenging. The introduction of meta governance helps analyse and develop structures enabling governance and co-creation. Different parts or approaches of existential sustainability could be utilised to enhance the performative capacity of such facilitation.

Different approaches to re-scaling, enabling connectedness – stated above as one perspective of existential sustainability - are outlined above and have proven meaningful. Changing perspectives from invisible emission of greenhouse gases to visible energy infra structures often times faces NIMBY-based resistance from local communities. Offering a narrative including different scales might be a way to change the local discourse. Connecting local production of energy with the global scale and a sense of awe for the interconnectedness of biodiversity, threatened ecosystems and one's life and context is a path built on a widened scope of sustainability worth exploring. This is the case in upcoming efforts to establish several wind farms in Skaraborg. Connecting local and regional development in the shape of more job opportunities providing taxes financing schools and nursing homes is fairly common strategy. It might be the case that this strategy can be further developed and combined with the one above – connecting the global, human and local scales.

Appointing, or at least identifying (sic!) meta governors with an awareness of how identities are impacted by and impact wielding of power or performing of governance is a possibility. As Alcoff points out identity impacts "horizon of agency", which in turn would impact capacity for decision making (2006, p. 43). Both network design and framing strategies impact identities of actors. Framing strategies contain formulating meaning and objectives both related to formulation of identities. Being a part of or being excluded from an effort also influences self-image and identity. Wielding power, in this case being the meta governor, also impacts identity. One obvious strategy would be to spend time

aligning narratives around common ground with regards to vision and objectives. Another way of phrasing this, related to Rüsen (2005) is connecting narration and interpretation thus creating history is another. However, there are no guarantees that such common ground even exists or is large enough to enable co-creation. This is, in part, one of the challenges in Skaraborg with the different kinds of energy companies and other actors.

A more untried strategy would be to reflect on current and desired identities of the meta governor. “Circularity, along with hypothesizing, is a technique nurtured by curiosity” (Cecchin, 1987, p. 5). Circular questions or assumptions are an established way to support reflection. “Circular assumptions tend to be associated with holism, interactional principles, structure determinism, neutral attitudes, and systemic approaches” (Tomm, 1988, p. 3). Circular questions supporting this reflection might include: how does our identity promote or hinder our efficacy as meta governor? How are identities impacted by accepting the role of meta governor, and what are the risks associated with that? Productive questions are probably ones related to the notion of a “hard look at yourself in the mirror”. These types of questions will be explored in upcoming research. Interviews with mayors and other policy makers will survey perceived powerlessness and power driving transitional change, indeed relating to identity.

Adding a more holistic approach on existential sustainability, integrating identity, place and time, a question worth reflecting upon is: what are productive identities of a meta governor or other actors enabling different types of re-scaling and enabling decision making to become less ‘situationalist’ and hence less powerless? (Rosa, 2003, p. 21)

6. Poetical postscript

Know thyself echoes the inscription from Delphi.

This seems to include both “you” and “I”.

Together we are narrating history through time and space,

unavoidably in human scale, as the human race.

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Urban Labyrinth: Accessibility and 15-Minute Cities

Asier Divasson Jaureguibarria[1], Armando Aguayo[1], Ana M. Macarulla[1], J. Ignacio Garcia[1], Cruz E. Borges[1]

[1]Deusto Institute of Technology, Faculty of Engineering, University of Deusto, Spain

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Abstract. The "15-minute city" concept aims to enhance urban sustainability by ensuring that residents can access essential services, employment, and recreational opportunities within a 15-minute walk or bike ride from their homes. While this model offers numerous benefits, such as improved accessibility and reduced car dependency, it has faced criticisms regarding potential marginalization of individuals with reduced mobility and those in less densely populated areas. Concerns have also been raised about the variables used to define the concept and potential exclusions based on walking speed. Despite these challenges, the 15-minute city model is gaining global traction, with significant support from urban leaders, planners, and the European Union, which is funding initiatives to implement this model across Europe. This study investigates the practical application of 15-minute city principles in various urban environments within the Basque Country, revealing that denser cities exhibit greater disparities in service access based on demographic factors like gender and age. The findings suggest that while the concept holds transformative potential, it may necessitate redefinition to address issues of exclusion and inclusivity, highlighting the importance of incorporating alternative transport modes and adapting the model to diverse urban contexts.

1. Introduction

The concept of "15-minute cities" has emerged as a promising solution to address urban challenges in the context of rapid urbanization and sustainability concerns. These cities aim to provide residents with access to essential services, employment, and recreation within a 15-minute walking or biking radius from their homes (Moreno et al., 2021).

By creating compact and diversified neighborhoods, 15-minute cities promote accessibility, reduce car dependency, and encourage healthier lifestyles (Nieuwenhuijsen, 2021). Concentrating activities in smaller areas can also mitigate traffic congestion, lower carbon emissions, and decrease the ecological footprint of urban areas (Nieuwenhuijsen, 2021).

While the 15-minute city concept offers numerous benefits, critics raise valid concerns. Some worry that this approach may marginalize individuals with reduced mobility or those in less densely populated areas (Pozoukidou & Chatziyiannaki, 2021). Questions about the variables considered in defining a 15-minute city and potential exclusions based on walking speed have also been raised (Pozoukidou & Chatziyiannaki, 2021). These criticisms highlight the importance of addressing biases and ensuring inclusivity in the development of 15-minute cities, understood 'bias' as inequality in access to essential services within a 15-minute walking radius, influenced by factors such as population density, gender and age.

Given the growing interest in the 15-minute city model as a sustainable urban planning solution, this study seeks to answer the following research question: How does the implementation of the 15-minute city model impact accessibility to essential services among different demographic groups in diverse urban settings? This question is crucial to understanding the inclusivity and practical feasibility of the model, especially in diverse urban settings with different population densities and socio-economic conditions. In this concern, the European Union has recognized the transformative potential of this approach and is supporting initiatives to implement 15-minute city principles in cities across Europe (European Commission, 2023).

Through funding programs, research, and policies, the EU aims to foster the creation of sustainable, inclusive, and resilient neighborhoods aligned with the ethos of 15-minute cities. Research examining the practical implementation of 15-minute city principles in real urban environments provides valuable insights into designing cities that are equitable, sustainable, and people-centered (Moreno et al., 2021). By studying how these principles materialize on the ground, urban planners and policymakers can better understand how to create urban spaces that enhance quality of life, promote sustainability, and prioritize the well-being of residents.

2. Methodology

This study focuses on the assessment of accessibility to essential services within a 15-minute walking radius in several cities of the Basque Country, using geospatial data obtained from OpenStreetMap (OSM).

OpenStreetMap was selected as the primary data source due to its detailed and up-to-date mapping of urban environments, as well as its open access nature, which allows for extensive customisation and integration into GIS-based models.

Although OpenStreetMap has a label to characterise the main use of each building (residential, commercial...), there are a large number of buildings that are under the

standard "yes" label. This can be seen in figure. 1, where the buildings are shown under the labels "residential" (blue) and "yes" (green).

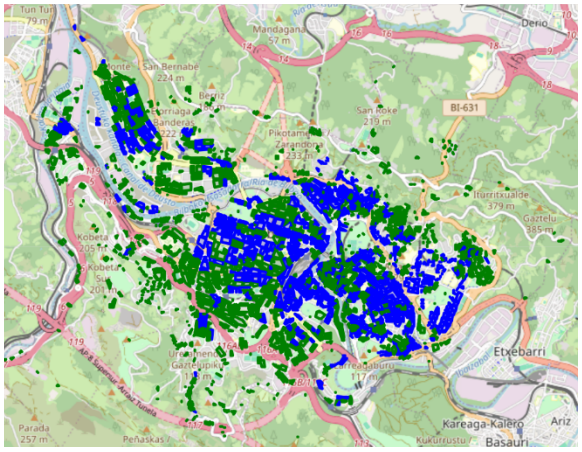

Figure 1. Analysis of the buildings under the labels "residential" (blue) and "yes" (green) on the Bilbao area.

The model developed for this analysis, defined as an algorithm that calculates access to services within a 15-minute walking radius, takes into account different demographic profiles. A ‘profile’ in this context refers to a group of people defined by characteristics such as gender, age and mobility.

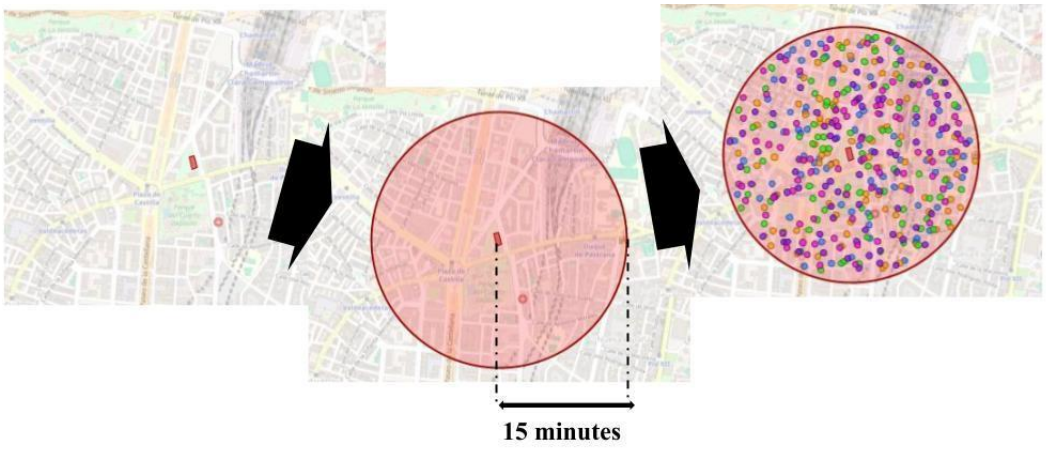

Figure 2. Visual representation of how the algorithm works.

As depicted in Figure 2, we start by taking a building as a reference and then create an area equal to all possible destinations that can be reached within a 15-minute walk. After this, a call is made to OSM to collect all the services (amenity) of the given area and work with this data. This process is repeated for each building and for each profile, i.e. a building is taken and the available services are evaluated for each of the 12 profiles to be considered. The following figure 3 shows this operation in the form of a pseudocode.

```
Determinate all buildings from an area
for = 1 : building all buildings:
     Assign a building to evaluate
     for = 1 : agent all types_of_agents:
          Create a 15min area based on the centre of building
          Gather all service data on the area from OSM
     end for agent
     Services clustering
end for building
Data printing
```

Figure 3. Pseudo code of the algorithm.

The validation of the model was carried out by visualising the results generated by the algorithm and the researchers' in situ knowledge of the territories. Using their experience in the urban areas of the Basque Country, the researchers compared the model's predictions with actual observations, adjusting it to accurately reflect local conditions. Although no comprehensive quantitative validation was carried out, this qualitative approach provided an adequate level of confidence with what was considered necessary for the study.

3. Results

This study has been carried out considering three large cities, three medium-sized cities and three towns in the Basque Country region of Spain. The main reason for focusing on such a small geographical space is to be able to compare infrastructures. As we collect our first data, we are not yet sure about the impact of differences in culture, policies, types of urbanisation, etc. Therefore, comparing areas in close proximity allows us to do so in a more confident and informed way, as it is the territory where we are located. This Figure 4 shows, in order of highest to lowest population, a total of nine urbanised areas.

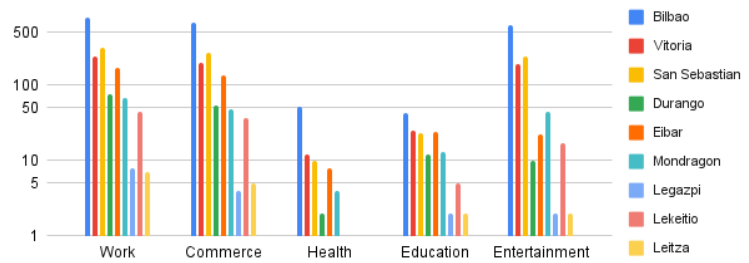

Figure 4. Services offered on 15 minute-area.

This figure shows that the higher the population, the higher the density of services available within a 15-minute radius.

We can also compare the data by gender, as shown in Figure 5, which reveals another interesting aspect. The percentage showing the reduction in access to services by gender indicates that, for example, in the case of Bilbao, women have 7% less access to services in each category. It can be seen how the more populated areas have a more pronounced bias than the others.

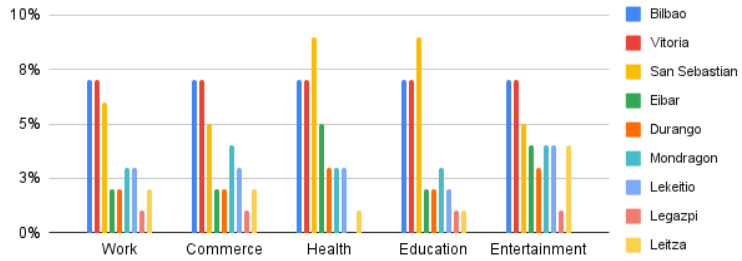

Figure 5. Gender inequality between analyzed areas.

This difference becomes more evident when comparing by age group. The following figure compares access for people aged 70-80 with that of people aged 20-30. This comparison allows us to draw other conclusions, such as that densely populated areas tend to marginalise those with a lower capacity for speed of travel or mobility.

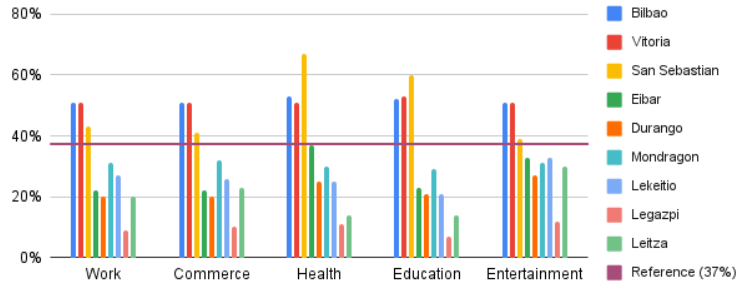

Figure 6. Age inequality between analyzed areas (70-80 compared to 20-30).

This phenomenon is accentuated when considering the reference line shown in the graph. Since, as mentioned above, travel speed varies according to gender and age, reference indicates the bias that we should consider only by taking into account the speed of travel. So, results show how big cities tend to have worse results than they should, based on walking speed decrease due to age, while small towns and villages act better than supposed to.

It can also be seen that, at the level of type of service, large cities also have more marked differences, with up to a 10% difference between the service with the least bias (entertainment) and the one with the most (health). These biases can be seen in the following table.

Table 1. Age inequality between analyzed areas (70-80 compared to 20-30).

		Work	Commerce	Health	Education	Entertainment
70-80	Big City	48%	48%	57%	55%	47%
	City	24%	25%	31%	24%	30%
	Town	23%	24%	22%	20%	28%

Table 1 shows how large cities are more biased in health and education, cities in health and entertainment and towns mostly in entertainment.

4. Conclusions

The results indicate that more densely populated cities exhibit a more pronounced bias compared to what might be expected based on certain criteria. This "bias" refers to the inequality in access to services within a 15-minute walking radius, with less populated areas showing a lower degree of inequality. However, these conclusions should be interpreted with caution, as the methodology used may not fully capture the complexity of factors influencing service accessibility.

This suggests that in contemporary cities, it is essential to consider the integration of other modes of transport, beyond walking or cycling, to fulfill Carlos Moreno's original definition of the 15-minute city. This definition should be expanded to include access to services via public transport, especially in areas where service density is insufficient to meet citizens' needs within walking distance. In these cases, regions with a high level of services in a small area, such as some tourist cities, may function as 15-minute cities without having been planned as such.

For instance, in the case of Lekeitio, we observe that the density of services, especially in the work and commercial sectors, is notably higher than in other areas with a similar population. We hypothesize that this peculiarity is due to the fact that the town's main economic activity is tourism, suggesting that tourism could improve access to jobs and other services.

5. Future Research Lines

Our current main focus is on adapting the model to a more realistic environment, considering more complex technical and social aspects. A key technical aspect will be the analysis of accessibility through isochrone maps, rather than using a simple radius around each building. This will provide a more accurate picture of service accessibility.

In the social sphere, we are highly interested in applying demographic factors specific to each region to understand the real needs of the population. Similarly, after objectively evaluating accessibility, we will integrate this data with social aspects to justify the 15-minute city concept, assessing accessibility in contrast to the real needs of residents.

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Thematic Field D:

Gender, Science and Technology

From Lived Bodies to Inclusive Interfaces. Plessner, Feminist Standpoint Theory, and Gender Inclusive Design Synergies

Charlotte Reinhardt

Chair for Sociotechnical Systems, University of Wuppertal, Germany

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Abstract. This article displays the potential of the combination of Helmuth Plessner's Philosophical Anthropology and Donna Haraway's concept of Situated Knowledges for Feminist Product Design processes. It is shown that Haraway can be used to argue for a product design, that takes materiality into account to prevent the reproduction of a male dominated technology design. By following this line of argument, the role of the body in a product design process is being strengthened. To maximise the analytical acuity Helmuth Plessner's Philosophical Anthropology is being introduced, for it allows the distinction of three spheres of the human being: Leib (lived body), Körper (body) and Person (persona). It is shown, that during the process of subjectivation every sphere is being gendered in a different way. The article finishes by analysing each of them in terms of their significance for human-technology interaction.

1. Introduction

Every day, we encounter technical artefacts (ta). But are these tas actually built for all of us? Nelly Oudshoorn, Els Rommes and Marcelle Stienstra (2004) were able to show that this is mostly not the case and that product design is primarily done for a masculine norm. Feminist Product Design (FPD), which is a branch of Feminist Science and Technology Studies (FSTS), has already produced some approaches in response to this problem. However, the problems begin where a category, that is as complex and difficult to define as sex/gender[1] is to be practically applied.

[1] Due to the interdependence of the phenomena of gender and sex, I use the terms in the form used above with a slash. This is to emphasise that when talking about the phenomenon of gender, it is impossible to separate sex and gender. For a detailed argument: Annie Duchesne and Anelis Kaiser Trujillo (2021, p. 2).

In this article, I will explore how Donna Haraway's (1988) concept of Situated Knowledges can be fruitfully combined with Helmuth Plessner's (1975) Philosophical Anthropology to conceptualise sex/gender in a way that can be applied to product development processes.

In the following, I will first present various views on the relationship between technology and society in order to derive the relationship between technology and sex/gender that is assumed for this article. I will work out that a so-called co-emergent approach is advocated in this article (Allhutter, 2014, p. 18), as it is the only one that is able to counter the body-mind dualism and its implications, by emphasising the materiality of technology and society. I will show that existing concepts of FPD do not sufficiently recognise this materiality.

Following this, Donna Haraway's (1988) critique of science will be roughly outlined. It will be shown that an FPD presupposes the adoption of a Feminist Standpoint (FS). Using the concept of Situated Knowledges, it will then become clear that for Haraway a FS is closely intertwined with corporeality. It follows from this that FPD in a Harawayian line of argument is only possible if we also think about the body in socio-technical systems.

The question of what it might look like to think about the body in socio-technical systems is explored in the fourth chapter. I will show that, for Helmuth Plessner (1975), the Körper (body) must be analytically distinguished from the Leib (lived body) and that these two, together with the Person (persona), form the three spheres of being from which the human being is constituted. I will show that sex/gender has a different effect on each of these three levels, which has different consequences for the interaction with tas.

In the future, this finding will enable a more precise analysis of sex/gender-relevant aspects in design processes. It also has the advantage that it does not fall prey to either social determinism or technological determinism and does justice to both the cultural and physical aspects of sex/gender and technology.

I would now like to mention a few assumptions that give this work its motivation: I follow the radical feminist line of argument that sex/gender is the central analytical category of (post-)modernity. I reject a perspective that understands sex/gender as a pure product of social norms. Instead, I am convinced of material evidence of sex/gender. Similarly, I reject the biologisation of the sex/gender debate and am convinced that sex/gender is to a considerable extent a cultural achievement. This work is to be understood as normative in the sense that I believe that women are still socially disadvantaged and I see it as the task of science in general and technology research in particular to work against these inequalities (Chapter 2). The statements I will make below, come from the perspective of a white woman from Germany who has been spared many levels of (social) discrimination. The limitations of this approach to the world have to be emphasised at this point.

2. Gender Inclusive Design

In the 1970s the first sociological research on the social construction of artifacts occurred (Paulitz, 2008, p. 780). According to Doris Allhutter (2014, pp. 17–18) there are three different ways to conceptualise the relation between society and technology: 1) the social constructivist approach; 2) the co-constructivist approach; and 3) the co-emergent approach.

The social constructivist approach holds the view, that the usage of a technological artifact forms it socially, in a way that the users' configuration of a ta leads to an inscription of norms and ideas into said artifact. Such perspectives have become known under names such as Social Construction of Technology (SCOT) or Social Shaping of Technology (SHOT) (Allhutter, 2014, p. 17). In contrast to this, co-constructivist approaches assume that technology and society are mutually constitutive. Here, questions come to the fore that deal with how technology shapes sex/gender perceptions and how the development and use of technology genderizes areas of life. In these approaches, sex/gender difference is perceived as performative and overcoming the sex/gender binary presupposes an understanding of development practices as socio-technical and showing the gendered character of technical paradigms by dissolving dualisms such as objectivity/subjectivity and/or technology/society (Allhutter, 2014, p. 18). These approaches can be found among »classical« Feminist Science and Technology (FSTS) theories such as Judy Wajcman's (2010).

In this article, I would like to highlight the third approach: the co-emergent one. In its understanding of the interdependence of technology and society it resembles the co-constructivist approach, yet it argues less discursively and more materially. Sociotechnical practices are not only understood in a way that social structures and norms play an active role but so do the physical bodies of both human beings and technological artifacts as well as »material realities« as codes or programs (Allhutter, 2014, p. 18). This concept of the relation between society and technology enables us to avoid the reproach of a technological determinism just as much as the one of a social determinism. Instead, we are provided with a concept that tries to mediate the dualism of society/technology, of culture/nature and of mind/body.

Those three dualisms are intimately intertwined with major questions of feminism (Klinger, 2019). Since sex/gender is the result of a natural-cultural process, the co-construction of society and technology also means the co-construction of sex/gender and technology.

Ingo Schulz-Schaeffer (2019, p. 17) conceptualises the process of the construction of a technological artifact as the objectivation of a "sinnhafte Intention" (causal intention). Therefore, the designer of an artifact of any sort has to decide what form of causal

intention shall be objectified in an artifact. Oudshoorn et al. (2004) showed that designers usually design for a male dominated norm. This critique grounds the demand for FDP2.

By facing the daily practice of designing for a masculine norm, we are looking for a sociotechnical solution for a sociotechnical problem which fits Paulitz' and Prietls (2019, p. 3) definition of a social innovation. By fitting this definition, the project of the development of heuristics on how to implement the sex/gender category must be a normative one.

The demand for sex/gender-inclusive design has already been formulated by others: Stanford University's Gendered Innovations (no date), Lucy Suchman's Human Machine Reconfigurations (2007) or Claude Draude, Susanne Maß' and Kamila Wajda's GERD-Modell (2014) all provide different solutions for sex/gender sensitive design. But neither of them starts with what we introduced to be a co-emergent approach towards the relation between sex/gender and society and hence take the sphere of the material fully into account. Corina Bath's De-Gendering Informatischer Artefakte (2009) is an exception from this. In her work she combines Karen Barad, Lucy Suchman and Donna Haraway to constitute a conception of the relation of society and technology which she calls a "Ko-Materialisierung" (Bath, 2009, p. 97) (co-materialisation) and which is structurally identical to what we call the co-emergent approach. Alas, in spite of a highly lucid and holistic theorisation of the relation of society and technology (Bath, 2009, chap. 3) in addition to an impressively extensive analysis of the dimensions and mechanists in which artifacts are being gendered (Bath, 2009, chap. 4), she falls short of providing a well-founded theory of sex/gender. Allhutter and Hofmann (2014) show, that there is no way to generalise the relation of sex/gender and technology but that sex/gender exists in relation to an artifact in a temporary and situated way. We therefore need a concept of sex/gender that is both definite enough to actually implement into heuristics for gender sensitive software design, and flexible enough to remain open towards the shifts that it undergoes during its production in a sociotechnical system. Furthermore, it has to take material aspect of the co-emergence into account.

To achieve this, we need to realise, what it means, to design for women; therefore, what it means to consider a FS in design processes. To this end, Donna Haraway's (1988) concept of Situated Knowledge will now be presented and its implications elaborated.

[2] The division along the line of sex/gender difference as such is indeed questionable (Allhutter, 2014, p. 15). But in the radical feminist tradition of thought (Jaggar, 2004, p. 59), I would like to understand sex/gender difference as "the fundamental structure of the symbolic world" (Kuster, 2019, p. 4 translated from German original).

3. Feminist Standpoint Theory

Feminist Standpoint Theory (FST) arose from the view that the 20th century women's movement, as Sandra Harding (2004a, p. 4) put it, “needed knowledge that was *for* women”. For a long time, science had produced knowledge that was – according to feminists – disadvantageous for women (Haraway, 1988, p. 575). One of the main points of criticism lies in the supposed objectivity proclaimed by science (Harding, 2004c, p. 20). Feminists argue that this objectivity does not merit the name, since it is not objective at all. Instead, the production of knowledge underlies the historical and spatial localisation of the individual that produces it and therefore just as much the individual’s social background (Jaggar, 2004, p. 55). That way, knowledge is per definitionem subjective. An epistemology that subordinates knowledge to the historical-material environment of an individual finds its origin in Marxian thinking (Harding, 2004a, p. 2)[3]. Socialist feminists emphasise that what is considered »knowledge« must always be a representation of the dominating class’ thought (Jaggar, 2004, p. 55). This makes (scientific) knowledge not only not objective, but also political.

Donna Haraway (1988, p. 581) calls the practice of hiding the scientist’s position in space and time “the god trick”. Different bodies mean different material situations that influence the acquisition of knowledge. By dethematising the spacio-temporal situatedness of a knowledge-producing individual, the context in which a scientific finding becomes a fact and consequently a possible truth is also obstructed (Haraway, 1988, p. 580; Harding, 2004b, p. 129). This removes it from scrutiny by the scientific community: possible blind spots cannot be assessed (Haraway, 1988, p. 583).

The result is the universality of knowledge, which in reality is mostly male, white, Western and precisely localised in space and time. Groups of people who do not belong to this leading class – in the socialist feminist sense – cannot easily shed their physicality and are excluded from the process of knowledge production[4]. Technology development always involves science; either in the form of prior research or at least in the form of scientific core assumptions, on the basis of which product development can only be possible. Consequently, this means that technology development is also indirectly male, white, Western and precisely localised in time.

[3] The ways in which this understanding of the origin of knowledge is played out differs between different Feminist Standpoint Currents. In this article I will mostly primarily refer to socialist Feminist Standpoint Theories, as presented by Alison Jaggar (2004).

[4] An explanation on why e.g. women can never have no body is being provided by: Klinger (2019).

If technology development is to become more inclusive, FST must be given space in terms of the situatedness of knowledge. If the FS is to be given space, the materiality and consequently the spatio-temporal situatedness of knowledge has to be taken into account. For Haraway, this means tying knowledge back to the body (Haraway, 1988, p. 581).

By pointing out their physically based spatio-temporal situatedness, scientists enable other scientists to judge their work. Objectivity is then not created through a single work, but through a network of complementary, recognisably subjective works (Haraway, 1988, p. 588).

Implementing a FS in a product development process must therefore, if we want to follow Haraway, tie technology back to the body.

For this aim, it is worth taking a closer look at what exactly is meant by the body and how it relates to the human being. Western philosophy alone can look back on over 2000 years of history in which the question of the relationship between humans, their »reason« and their physicality has been raised time and again. In the following, I would like to present Helmuth Plessner's answer to the mind-body problem. It will be shown that, for Plessner, the human being is divided into three spheres. These will be outlined below. In addition, I would like to sketch their respective significance for the process of gendering in broad strokes and work out what this process of gendering means in relation to a co-emergent approach.

4. Helmuth Plessner’s Philosophical Anthropology and its Potential for the Analysis of Sociotechnical Systems

In 1928, Helmuth Plessner (1975) published his opus magnus: Die Stufen des Organischen und der Mensch. In it, he develops a theory of the human being that attempts to do justice to the cultural diversity of humanity just as much as its individual diversity. With the help of his phenomenological-hermeneutic method, he works out three types of life fulfilment: the azentrische (acentric), the zentrische (centric) and the exzentrische Positionalität (eccentric positionality)5 (Lüdtke and Fritz-Hoffmann, 2012, p. 93).

The minimum requirement for a phenomenon to be considered alive is the independent realisation of its own boundary (skin, membrane, etc.). A phenomenon that »merely«

[5] At this point, I would like to point out, that only a few works of Plessner have been translated to languages other than German. In the following, I will work with the German terminology after roughly translating them into English. The translations might differ from the original ones, to which, at this point I do not have access.

realises its own boundary exhibits a zentrische Positionalität. As a plant grows, it independently constitutes an outside and an inside and thus places itself in a relationship to its environment. Once removed from this environment (withdrawn from the light, or uprooted, etc.) it must perish. An animal also realises its own boundary, but it is also forced to move its body and relate it to its environment. In addition to the physical constitution of inside and outside, this opens up a metaphysical inside-outside distinction: the animal has a physical body that is relatively located in the environment. This is what Plessner calls the Körper (body). In addition to that the animal has a perceived body that represents its absolute spatio-temporal location (here and now): This is what Plessner calls the Leib (lived-body). “The location is therefore a double one […] yet it is one, for the distance to its body is only made possible by its complete oneness with it alone” (Plessner, 1975, p. 237 translated from German original). Since there is no difference between Leib-Sein (being-a-lived-body) and Körper-Haben (having-a-body) for an animal, its being oneself remains hidden (Plessner, 1975, p. 288). The „absolutes Hier-Jetzt“ (Plessner, 1975, p. 289) (absolute here-and-now), that had acted as an existential category for the animal, is now lost to the human being in their exzentrische Positionalität.

As a moving organism, humans also possess the Leib-Körper duality. However, their environment does not appear to them as directly given, but as a Sachstruktur (structure of things) (Plessner, 2019, p. 97) from which individual objects can be detached at any time and made the object of reflection: a brightly shining star just as much as a grammatical structure. As an independent object that can be removed from its immediate context, a pen is not only suitable for writing things down, but also for putting your hair up. Plessner describes this as the loss of Unmittelbarkeit (immediacy) (Plessner, 1975, p. 327).

This ability to abstract has two consequences: 1) it means that a human being is forced to organise their environment. Since Unmittelbarkeit and, as a consequence, cultural achievement are existential, for Plessner (1975, p. 309) culture is the nature of man. 2) The ability to abstract objects from the Sachstruktur also means that a human being can reflect on their own physical presence and thus make it their object. In short: nothing is immediate to man any more, but everything, including their own corporeality, has become dubious.

For Plessner, this dubiousness leads to the disintegration of the human being into a triad:

1) The human being senses their Leib. The Leib is the sphere of the absolute Here-Jetzt, which creates a metaphysical inner to the human being (Plessner, 1975, p. 295). It is also the sphere from which in a complex interdependence with the Mitwelt, the Ego arises.

2) A human being is able to turn their corporality into an object: One's own Körper is no longer just an experienced Leib, but also an object that can be viewed and studied as such from the outside. To be able to look at something from the outside requires an external vanishing point. A life form that can observe itself from the outside without leaving their Leib-Körper requires an entity that can cognitively create a distance to themselves (Plessner, 1975, p. 290). Plessner describes this instance as a
3) Person. It is personified culture and a result of what Plessner calls the Mitwelt (Joint-World) (Krüger, 2012, pp. 40–41). This Mitwelt is – roughly said – close to what is generally called society. A society of embodied human beings, that are constantly in a social relationship.

In the course of their life, a human being is faced with the task of mediating this triad at every moment in such a way that a unity, a human being, is created and at the same time interacting with the world around them from these three levels (Plessner, 1975, p. 325). All three spheres structure each other and are subject to each other.

Gesa Lindemann (2011) can be credited with applying Plessner's theory to the sex/gender question for the first time. Building on Lindemann, I could establish that gendering is produced differently on all three spheres, and that it signifies a different reality in each case (Reinhardt, 2022).

In the following, these three levels will be briefly analysed. The aim is to illustrate the extent to which they are relevant for technology research.

4.1. Gendering at the Sphere of the Körper

The Körper is the sphere of the outside. It is the object to which other people can relate and with which the human being is bound in a relative spatio-temporal sphere.

A human being is being gendered by the world into which they are born, either before or at the latest at the moment of birth. The newborn is assigned a sex/gender based on the shape of their genitals. From this moment on, the Leib-Körper functions as a gendered Leib-Körper. What such a gendered Körper should look like socially is a question of the respective social institution.

For Foucault (1992) the Körper is the central point of reference for power. In addition, he understands sex/gender as the central category of power for establishing a society (Siebenpfeiffer, 2014, p. 269). This leads to sex/gender being applied to the Körper as a category of power.

Lindemann was able to show that the relationship of sign, in which a certain Körper shape suggests a sex/gender affiliation that is so strong that the Körper as a sign carrier does not refer to a sex/gender affiliation, but that it is synonymous with it. In other words, the

Körper *is* sex/gender (Lindemann, 1995, p. 78). Due to this relationship – in which the Körper *is* sex/gender – it is a synthesis of gendered Körper and gendered Leiber (gendered Leib-Körper) that is moving in a society.

Since, for Plessner, humans have a Körper, this means that they have a physical sex/gender.

As the external sphere of human beings, spatially seen human beings are physical bodies that move within a society. The Körper is therefore an element of society. If society and technology are co-emergent, then this means that Körper and technology are also co-emergent. Since, socially, Körper are always gendered Körper, we can conclude that gendered Körper and technology are co-emergent.

Analytically, in the interaction between technology and humans, a gendered Körper, which *is* a sex/gender, meets a technical object, which at first glance is a-gendered. They produce each other in this encounter.

4.2. Gendering at the Sphere of the Leib

Lindemann (2011, p. 56) shows that at the sphere of the Leib, sex/gender is structured via so-called Leib-Inseln (Islands of the lived body).

Once conceived as a gendered Körper, the human being is placed into the world in a gendered way. Children of different physical sexes are exposed to different stimuli shortly after and even before birth, which leads to different developments in the structure of the brain (Imhoff and Hoffmann, 2023). These changes not only lead to a demonstrable change in the body, but also to different environmental relationships.

For Plessner, the Leib is the sphere of environmental intentionality. It is the sphere of sensing that locates people in space and time absolutely here and now and from which they experience their environment, its effect on them and their effect on them. By establishing different neuronal connections between the sexes in early childhood, the physical experience of a person changes qua genderedness. As elements of socialisation meet biological presence, the result is a sensed perception of the world that becomes an experienced truth via the Körper and society. Therefore, a human being is their sex/gender. Since a human being has to realise their own life in every moment, they also do their sex/gender. They are it by doing (Reinhardt, 2022, p. 73).

When human beings and technology meet, two bodies come together on the one hand, and a Leib and an inanimate object on the other.

As a sentient Leib, the human being encounters the ta as a gendered Leib: Humans, who according to Plessner must realise their relationship to their environment at all times, do so from the sphere of the Leib, which means that they do so in a gendered way.

The sentient Leib with which a human interacts with a ta is – if we remain in a binary sex/gender system – different for women than for men: Statistically, tas are mostly produced by men. Oudshoorn et al. (2004) showed, that in most of the cases they are also produced for men. Schulz-Schaeffer (2019, p. 17) conceptualised the development of a ta as the objectification of a sinnhafte Intention. In the interpretation proposed here, this means that tas are objectifications of an environmental intentionality. Since every environmental intentionality happens in a gendered way, it follows that the process of action that is materialised in the ta is a gendered process, too.

In this way, a sentient and gendered Leib on the one hand and an inanimate, but in its »environmental intentionality«, if one can speak of it, gendered object on the other, meet in the interaction.

This finding is remarkable in that technology development is usually preceded by a significant amount of research.

If the prevailing research practice is, as Haraway criticises, disembodied, then this means first of all that it is also supposedly free of a Leib. However, since an individual in research reaches out to their environment and interacts with it, science is of course not free of a Leib. By banning the body from science in favour of objectivity, the inevitably necessary sphere of the Leib of research is obstructed. Thus, firstly, there is a male environmental intentionality in the research preceding technology development and, secondly, the objectification of a male meaningful intention.

So if we ask ourselves again why tas are used differently by different sex/genders or are accessible to sex/genders differently, then this reading of Plessner offers a promising perspective.

For the co-emergence of technology and society, this means that qua the androcentrism of the world, people who are not men (have to) realise their relationship to the environment by dealing with tas that were not developed for them. Since sex/gender is realised in relation to the environment, for all sex/genders that are not men this means that they perform their sex/gender in demarcation to a world that is not made for them. Lindemann (2011, p. 202) has already made this finding in a different way and without reference to technology.

Since men build disembodied technology, but said technology presupposes emerges from a constituted ego that arises from the Leib, for the interaction with the ta a Leib is considered that does not correspond to the Leib of a woman: the result is an irritation in the action. However, since the interaction is co-emergent, the Leib shifts. Due to the androcentric use of technology, women's processes of becoming a Leib, shift in contrast to those of men.

4.3. Gendering at the Sphere of the Person

The third sphere of which Plessner speaks is the Person. This sphere binds the human being into a common frame of reference among other Körper. Here, the human being becomes a relatum in social relationships. For Plessner, this social space is the so-called Mitwelt. From it, a human being subjectivises themselves (Krüger, 2012, pp. 40–41). No matter what happens to a human being in their life, they are included in a social relationship between people. As children, humans experience themselves as the absolute here and now. By interacting with other entities, that happen to be other Leiber, that appear to them from birth, the young human being positions themselves in this structure, whereby they subjectivise themselves. In this respect, in Plessner's Philosophical Anthropology, the ego of a human being arises from the Mitwelt. This environment is always shaped in some way against the backdrop of the cultural achievement that humans must always achieve in their environmental relationships. How, depends on the culture into which an individual is born. All cultures have rules and norms that structure their Mitwelt. As the subject grows up in a Mitwelt that is structured by rules and norms in a specific way, an individual is not only characterised by the values and norms of a society, but it also arises from them as a subject. If we now understand the Mitwelt as a place of lived sociality, and in its form as that which for Plessner comes closest to a society, we must understand technology and the Mitwelt as co-emergent.

If society and technology are co-emergent and technology is primarily produced by men, then this form of technology design produces a Mitwelt that is itself structured by men. For the subject emerging from the Mitwelt, this means that, regardless of which sex/gender they have at the sphere of the Körper and which sex/gender they do by being, they must shape their personhood within the patriarchal framework, i.e. they must carry it out in some way in differentiation from the general male.

Subjectivation from a Mitwelt that is co-emergent with technology leads to the finding that people always subjectivise themselves from the technological design of a particular epoch. The instance of the Person, which can thus refer to its Körper and its Leib, is always already gendered and technicised. By implementing the technological into the Körper-Leib, the human being becomes what one might call a Cyborg[6]. In terms of interaction, this means that the ta interacts with a Person who is always already partly technical, but whose technicality depends on their sex/gender.

[6] The cyborg is a metaphorical figure, that was initially introduced by Haraway to exceed western dualisms (Haraway, 1995). Due to this article’s limitations this connection cannot be displayed in more detail.

5. Conclusion and Outlook

Throughout this article it has been illustrated how Donna Haraway's (1988) concept of Situated Knowledges can be fruitfully combined with Helmuth Plessner's (1975) Philosophical Anthropology to conceptualise sex/gender in such a way that it can be applied to product development processes. To this end, after an introduction to FSTS, I introduced Donna Haraway's concept of Situated Knowledge. This made it possible to demonstrate the necessity of thinking about the body in socio-technical systems in two ways: 1) this must be done to counter body-mind dualism and its implications and 2) this must be done because FPD must maintain a FS and from Haraway's perspective, a FS cannot be conceived without the body.

Subsequently, I was able to show that a human being is gendered in different ways in each of their three spheres of being. I was also able to show that interaction with a ta takes place differently in each of the three spheres of being:

1) On the sphere of the Körper, a gendered Körper, which is sex/gender, and a supposedly a-sexual ta meet and produce each other in the encounter.
2) At the sphere of the Leib, a sensual gendered Leib meets a lifeless objectification of a doubly masculine sinnhafte Intention. Women relate to their environment differently than men, which leads to a shift in the processes of becoming a Leib in the interaction.
3) The co-emergence of society and technology means that the technologised world is structured in a masculine way. As the subject in Plessner's work emerges from this technicised Mitwelt, it arises a male-structured technicised Mitwelt, whereby they become a cyborg. Depending on their sex/gender, subjects are cyborgs in different ways.

For FPD from a perspective that wants to take materiality into account, this means that corporality has to be considered in three ways and cannot be thought of in a non-gendered way.

Plessner's division of the human being into a triad of Körper, Leib and Person, makes it possible to refine the analytical grid for the gendered factors in product development processes. It can be worked out more precisely which aspects of sex/gender are actually relevant in product development processes and on which levels they are effective. The fact that the three spheres are mutually dependent means that materiality is always taken into account, and the fact that a human being is embedded in a cultural framework means that their cultural framework is also taken into account.

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Gender+ in nanotechnology. A practical experience.

Rita Bencivenga[1], Diego Colombara[1], Cinzia Leone[2]

[1]University of Genoa, Italy

[2]Italian Institute of Technology, Italy

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Abstract. The experience described refers to an EU-funded research and innovation project on nanotechnology, REusable MAsk Patterning, (REMAP), financed by the European Commission PathFinder Open programme and aimed at formulating a novel class of bifunctional composite fluids called magnetorheological electrolytes. The inclusion of a gender+ perspective in the research project is not obvious given the research areas investigated in the project and the hypotheses to be tested. However, even if the initial technological readiness level (TRL) of the research is low, this research is ultimately expected to have a disruptive impact on society. It is therefore crucial that the relevant hypotheses and methods are free of gender bias from the outset. The inclusive Gender Equality Plan of the University of Genoa, Italy, implements a group of activities at project level, the Project Gender+ Action Plan (P-GAP), which integrates gender+ in the work plan of R&I projects and tries to fulfil the EU requirement to include a gender+ perspective in all phases of research. Therefore, REMAP foresees the implementation of several micro-actions that also relate to the project's dissemination and outreach activities.
The initiative aims to overcome the resistance to the implementation of a gender+ perspective in STEM disciplines and to create a fruitful and positive cross-fertilisation between STEM and social sciences, especially gender and diversity studies.
The next step is to consolidate this initiative at local level and through collaboration with other EU-funded projects.

1. Introduction

In 2021, Horizon Europe (HE) made gender equality plans (GEP) or equivalent strategies mandatory for public organisations to apply for funding. However, the 2022 HE calls for proposals recognised the heterogeneity in the implementation of GEPs across the EU and the persisting structural barriers in research and innovation institutions (i.e. HE

Framework Programme, WIDERA call, 2022) requiring the Higher Education Institutions (HEI) to adopt an inclusive perspective in their GEPs. This paper is firmly based on the idea that, in order to address these challenges, HEIs should propose inclusive GEPs that are in line with the priorities of the new European Research Area (ERA) and gender equality objectives (Addabbo *et al.,* 2021).

The GEP of the University of Genoa, Italy, is implementing three transversal pilot actions, at department, project, and curriculum levels, focused on promoting inclusivity in research and teaching activities. In our contribution, we focus on the action at project level, the Gender+ Action Plan (P-GAP), which is based on the requirements of the EU FP6 (2002-2006) (Kalpazidou Schmidt *et al.,* 2020) and integrates gender+ into the work plan of R&I projects to fulfil the EU requirement to include a gender+ perspective in all phases of research, i.e. problem identification, conceptualisation, research, data collection and analysis, dissemination and follow-up (Bencivenga *et al*., 2022).

It is perhaps not superfluous to clarify that by adopting a Gender+ strategy, the interactions of gender with other sources of inequality and grounds of discrimination are taken into account. The term “gender+” (gender plus) was first used in the European research project Quality in Gender+ Equality Policies in Europe, QUING, 2006-2011 (Krizsan *et al.*, 2012). It was originally coined by Mieke Verloo, the scientific director of the project, and has become established in many areas.

The experience described here relates to an EU-funded research and innovation project on nanotechnology, REusable MAsk Patterning, (REMAP), which was funded by the European Commission's Pathfinder Open programme under grant agreement No. 101046909. Among the researchers working for the project coordinator, those working on organic, physical and inorganic chemistry will be supported and advised in their activities by a team of experts in Gender+ and Equality, Diversity and Inclusion (EDI) studies, with the aim of integrating strategies and activities related to Gender+ into the project and adding a transdisciplinary dimension.

The paper is organised as follows: we start describing the societal readiness level (SRL), a scale that assesses the degree of societal adaptation for a given social project, technology, product, process, intervention or innovation (social or technical) to be integrated into society. SRL is one of the concepts chosen as the basis for the REMAP pilot initiative. Next, we summarise the current state of the art in relation to Gender+ and EDI in chemistry, particularly in nanotechnology. We then describe the process that led to the activities carried out within the REMAP project and give a brief description of the activities related to the dissemination and outreach aspects of the proposal. Finally, we summarise the theoretical and empirical implications, outline the limitations of the approach and suggest further ways to formalise the content in the project methodology and in a consistent manner throughout the proposal.

2. Societal Readiness Level

In planning the Project Gender Action plan and the actions to be implemented in projects like REMAP, we were guided by a theoretical reflection on the concept of Societal Readiness Level ((Innovation Fund Denmark, 2019; Leone *et al*., 2024). As the SRL is strictly related to the Technology Readiness Level, we will describe both scales.

When considering the maturity level of a research result or an innovation product, we are asked to place it on a fixed scale of values, also used by the European Commission, which aims to measure the maturity level of a technology, particularly in comparison to its introduction into the production system and ultimately into the market.

One of the first introductions of this concept was its use in National Aeronautics and Space Administration planning (Mankins, 1995), where the scale was first established and then further developed in its terminology so that it extended to other technological areas. The Technology Readiness Level (TRL) now ranges from 1 to 9 and depends on how far research has progressed in relation to our subject matter and how complete the path to market and large-scale production is.

This scale is used today by the European Commission for example in the Horizon Europe calls for proposals for research and innovation projects. It asks applicants to position the research and/or their product in a specific TRL range that meets the Commission's expectations.

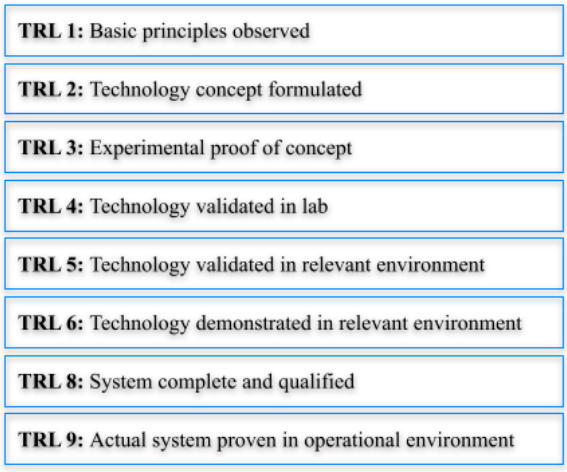

Figure 9. The EC Technology Readiness Levels (TRL) scale (Yfanti, Sakkas, 2024, p. 2).

In the case of an innovation that uses the TRL scale as a reference, it is crucial to ensure that the corresponding hypotheses and methods are free of gender+ biases from the outset and that the technological product/object we are dealing with is socially acceptable and accepted (Sella *et al*., 2024), i.e. it is also “ready” in social terms. This denotes that technology cannot function as the sole means of introducing innovation into our societies. Rather, consideration must be given to how technology can be reconciled with, for

example, ethical judgements, societal values, expectations of special needs, gender+ approaches, inclusivity and others (Bernstein *et al.*, 2022).

While the TRL model provides a valuable basis for assessing technological maturity, it may need to be adapted and supplemented to fully capture the complexity of innovation developments and to guide effective innovation and its application. We also aim to overcome the limitations of the TRL model while improving its application by exploring new avenues of innovation and social innovation (Leone *et al*.,, 2024).

In order to fulfil the requirements of social acceptance and compliance with the social values of innovation, a new scale has recently been introduced to measure the level of readiness. It is the Societal Readiness Level (SRL), a scale that reverses the so-called classical approach to technology and offers a completely different measurement of the technology object being observed.

The SRL scale was originally introduced by the Innovation Fund Denmark, the main public fund for low-interest financing of research and innovation projects by private companies and public knowledge institutions. The fund also invests in research and development projects aimed at solving societal problems. The scale is meant to assess the degree of social acceptance of a particular technology, product, process or measure. The underlying concept is that any innovation, whether technical or social, must be integrated into the social environment. In fact, the results of Innovation Fund Denmark must also be evaluated in terms of improving social well-being, increasing societal welfare, creating jobs, reducing CO2 emissions, a cleaner environment, etc. Thus, a higher SRL value indicates better integration both in terms of societal structures and social interactions, reducing the need for ad hoc measures to achieve a real and convincing shift at both levels (Innovation Fund Denmark, 2019). It is a paradigm shift that calls on scientists, researchers and innovators to shift their perspective from the purely technological and technical levels to embedding the societal and social values of the object of study or innovation. This can be applied to all areas and domains, as also defined by the Danish government:

> Societal Readiness Level (SRL) is a way of assessing the level of societal adaptation of, for instance, a particular social project, a technology, a product, a process, an intervention, or an innovation (whether social or technical) to be integrated into society. If the societal readiness for the social or technical solution is expected to be low, suggestions for a realistic transition towards societal adaptation are required. Naturally, the lower the societal adaptation is, the better the plan for transition must be. (Innovation Fund Denmark, 2019, p.1)

Parallel to the TRL scale, the SRL scale is divided into 9 different levels:

MATURITY LEVEL	DESCRIPTION
SRL1	Identification of the generic societal need and associated readiness aspects
SRL2	Formulation of proposed solution concept and potential impacts; appraisal of societal readiness issues; identification of relevant stakeholders for the development of the solution
SRL3	Initial sharing of the proposed solution with relevant stakeholders (e.g. through visual mock-ups): a limited group of the society knows the solution or similar initiatives
SRL4	Solution validated through pilot testing in controlled environments to substantiate proposed impacts and societal readiness: a limited group of the society tests the solution or similar initiatives
SRL5	Solution validated through pilot testing in real or realistic environments and by relevant stakeholders: the society knows the solution or similar initiatives but is not aware of their benefits
SRL6	Solution demonstrated in real world environments and in co-operation with relevant stakeholders to gain feedback on potential impacts: the society knows the solution or similar initiatives and awareness of their benefits increases
SRL7	Refinement of the solution and, if needed, retesting in real world environments with relevant stakeholders: the society is completely aware of the solution's benefits, a part of the society starts to adopt similar solutions
SRL8	Targeted solution, as well as a plan for societal adaptation, complete and qualified; society is ready to adopt the solution and have used similar solutions on the market
SRL9	Actual solution proven in relevant societal environments after launch on the market; the society is using the solution available on the market

Figure 2. SRL scale (Bruno et al., 2020 p. 5, adapted from Innovation Fund Denmark)

Regarding our specific focus on gender+, it should be noted that gender bias can manifest as unintentional errors in research conceptualisation and design, execution, understanding and validation of research findings, from theory to experiment (European Commission, 2020). Aside from the ethical implications, by adopting the SRL scale, eliminating these biases can 1) bring long-term economic benefits by improving the market base and commercial attractiveness of the technology developed; 2) lead to more integral and complete research and scientific results; 3) help develop better products that are more acceptable to end users.

This unbiased approach to innovation would also avoid production errors in which new products or innovations are brought to market without taking into account the actual needs or expectations of end consumers or simply ignoring them (Coughlin, 2017). While gender discrimination remains an important issue, the neglect of other forms of discrimination in the context of innovation reveals a significant gap in our understanding of inclusivity. For example, there are clear examples of how ageing is not adequately considered in discussions about innovation, despite older adults being a rapidly growing population group in Western societies. In a market where older adults are often portrayed

as unsympathetic and overly stereotyped, this omission highlights the importance of addressing ageism alongside gender discrimination. As a matter of fact, nowadays “just 31 percent of companies take global ageing into account in their market sales plans”, in a market where “older adults […] find their contemporaries’ portrayal unappealing and overly stereotypical” (Coughlin, 2017, p. 9).

Other typical examples of how research and scientific innovation should be inclusive to avoid mistakes are some examples given in the first edition of the report Gendered Innovations (European Commission, 2013). They show how wrong hypotheses have led to wrong treatments or interventions that have been corrected by recent research from a gender perspective. For instance, knee replacements should not be determined by gender, but by weight and height differences; ischaemic heart disease is not a predominantly male disease; osteoporosis is not a disease that only affects women, and so on. The more recent edition of Gendered Innovations (Schiebinger and Klinge, 2020) also shows how different inclusive approaches in the same areas can lead to broader outcomes, improvements or efficiencies, for example in transport, energy use and efficiency, chronic pain management and others.

As for the gender dimension in particular,

> Technology is an extremely significant site of gender negotiations in relation to occupations, symbols, and identities, and gender in all these areas has an extremely significant shaping influence on the design and use of technologies (Lohan and Faulkner, 2004, p. 319).

Without due consideration of gender in the conception and design phases, the societal adoption of R&I results would ultimately fail. A very well-known case of failure due to gender aspects being misjudged or underestimated is, for example, the failure of Dell, which tried to launch a pink laptop in 2009 because it thought women would like it – but they did not. A similar failure was that of Honda in 2013, who tried to launch a car solely intended for women, thus repeating the analogous failure of the US company Dodge some sixty years earlier (Coughlin, 2017, p. 109).

To avoid biases and make progress towards inclusion, SRL and TRL should engage in dialogue. Indeed, the impact that the tenacious and fruitful dialogue between SSH and STEM disciplines can have at scientific, economic, and societal levels has been recognised by the European Commission since Horizon 2020, and demanded to all applicants. Multi- and interdisciplinary approaches have become mandatory in recent years, and therefore all researchers and scientists should be interested in such cross-fertilisation and constant dialogue, which has ancient roots (Snow, 1969).

In summary, by refocusing scientific activity in research and innovation on a technological and societal readiness level approach, we can better develop the idea of democratising innovation that was born at the beginning of this century (von Hippel, 2005), when

innovation was overwhelming our societies and it seemed to many that it was no longer people-centred. So if we use TRL and SRL together, we can truly claim that “innovator and consumer are one and the same” (Coughlin, 2017, p. 120) and that great progress can emerge from the dialogue between different disciplines.

3. Gender+ in chemistry and nanotechnology

As the REMAP project relates to nanotechnology, it is important to give a brief overview of the progress that has been made within the discipline with regard to the integration of gender+ perspectives. Nanotechnologies represent an area where the implementation of the gender+ dimension may seem particularly difficult, resulting in a high risk of "nano-divide" that reinforces inequalities (Cozzens, 2010; The Royal Society, 2004). The potential economic and social benefits of nanotechnologies could be compromised if these technologies contribute negatively to stigmatisation and discrimination (UNESCO, 2014).

In general, EU initiatives that promote gender equality and progressively integrate inclusion as a pervasive dimension have adopted three analytical approaches to issues in science and technology research, focussing on i) balanced representation, ii) institutional change and iii) the adoption of gendered perspectives in the research process. These analytical approaches have been applied in successive phases, but all three remain important as the results obtained for each separate approach may be considered conclusive (Schiebinger, 2000, 2014). This is all the more true when considering, in addition to gender imbalances, imbalances in relation to other groups that are underrepresented in the scientific community due to their ethnicity, sexual orientation, the presence of disabilities or other factors.

The first analytical approach, known as "Fixing the Numbers"," focuses on the inclusion of women and other underrepresented groups in research and innovation and in decision-making positions. This includes, for example, introducing gender quotas for evaluation committees and expert groups and setting a target of 40% for the underrepresented gender in advisory groups and committees (Caprile *et al.*, 2022).

The second analytical approach, which Schiebinger defines as “Fixing the Institutions”, promotes inclusive gender equality in research and innovation careers by stimulating changes in policies, practises and, more broadly, in the culture of research institutions. This approach focuses on increasing the participation of women and underrepresented groups in research at all levels, including career development.

The literature in the chemistry field has been addressing the need to "fix the numbers" and "fix the institutions" by reflecting on possible discrepancies in individual performance (Reinhold, 2007) or by highlighting positive results achieved by female scientists (Meng, 2018).

More recently, research targeting the application of nanomaterials has developed an awareness of the importance of adding a gender dimension to innovation (Yang *et al*., 2021). This is leading to the third analytical approach, referred to as "Fix the Knowledge", which addresses the need to eliminate gender bias in the production and dissemination of scientific knowledge and to promote excellence in science and technology by integrating gender and intersectional analyses into research. Originally, this included recognising the contributions of women scientists to science and the need to develop gender-sensitive research methods and practices (Tannenbaum *et al.*, 2019), but this requirement now also extends to other underrepresented groups.

Although some progress is made, there is still a lack of good practice that should be followed when conducting EU-funded research. However, progress is made thanks to the EC initiatives. Horizon Europe emphasises how important it has become to take the gender+ dimension into account in all scientific fields and in the production of innovation. To better implement these requirements, the European Union recommends utilising the resources available through the Gendered Innovations initiative (Schiebinger, 2008), such as the website www.genderedinnovations.eu and the associated reports and articles. Gendered Innovations provides the research community with tools and guidelines to integrate the analysis of sex and gender into their research. The policy review “Gendered Innovations: How Inclusive Analysis Contributes to Research and Innovation” published by the European Commission (EC) (European Commission, 2020), which has resulted in a series of actions to promote equality, diversity, inclusion and gender+ in all projects funded by the European Commission, clearly states that:

> Integrating sex and gender analysis into research and innovation adds value to research and is therefore crucial to secure Europe’s leadership in science and technology, and to support its inclusive growth (European Commission, 2020, p.7).

Notwithstanding the fact that there is still a long way to go, it can be said from the authors' experience that the European Commission tends to take better account of the gender+ dimension in research. In fact, all scientific fields should take gender and inclusion into account when preparing a project proposal for the EU (unless explicitly mentioned in the call). For example, in Criterion 1 (Excellence), reviewers assessing projects submitted to Horizon Europe calls also evaluate whether the consideration of the gender dimension in research and innovation is duly addressed.

4. Gender+ in a fundamental research project: the REMAP project

We now describe some of the experiences made within the framework of REMAP, a R&I project funded by a call to foster bottom-up avant-garde disruptive innovations, the Pathfinder Open funding scheme of the European Innovation Council (EIC). The scheme is part of the Ninth European Framework Programme for Research and Innovation (Horizon Europe) and aims to support deep-tech projects with a high level of scientific and technological ambition and risk with grants of up to four million euros.

The EIC Pathfinder Open supports research teams seeking the scientific basis to underpin breakthrough technologies. It supports the early stages of scientific research to explore deeply innovative directions with a technological impact that can transform sectors and markets or create new opportunities. Indeed, the programme focuses on the implementation of innovative technological solutions to identify, develop and support breakthrough innovations across Europe.

The inclusion of a gender+ perspective in the research project is not easy in view of the research areas investigated in the project (magnetism, click-chemistry, electrodeposition, photovoltaic devices) and the hypotheses to be tested. It is well known that the gender dimension has been neglected for many years in some specific areas of interest here (Pollitzer, 2021). Nevertheless, even if the initial technology readiness level (TRL) (Mankins, 1995) of the research is low, a disruptive impact on society is ultimately expected from this kind of actions when they elapse. Therefore, it is crucial to ensure that the relevant hypotheses and methods are gender unbiased from the very outset.

Gender bias may include unintentional flaws in the research design, implementation, interpretation of the results, and validation of prototypes all the way from theory to experiments, or it can relate to the knowledge production cycle, where “consequently, ‘male’ as the norm came to dominate science knowledge-making, explicitly by excluding females as research subjects, and implicitly by not analysing and not reporting results disaggregated by sex, where male are dominating the knowledge-production” (Pollitzer, 2021, p.656).

Besides the most obvious ethical implications, careful assessments can bring longterm economic benefits through the value added in terms of expanded market base and commercial appeal of the sought technology. In order to prevent the emergence of gender bias in the research content, it is necessary to reflect on the perspective that has emerged since the 2000s in Gender and Technology studies, which views technology and gender as socially co-constructed in a reciprocal shaping process (Lohan and Faulkner, 2004).

The P-GAP initiative, a pilot experience in the GEP of the University of (UniGE), Italy, allowed to establish a positive interdisciplinary co-operation between the researchers writing the proposal and experts in gender and EDI studies. The evaluation included the "right-to-react procedure", that follows directly after the individual evaluation executed by experts. The applicants get a limited amount of time to respond to the comments drafted by the experts during the individual evaluation phase. The aim is to provide a more detailed feedback to the applicants in an early phase of the evaluation procedure to increase accountability. The coordinator of the REMAP proposal, who is co-author of this article, received a list of comments from the evaluation panel covering different topics related to the scientific premises, the foreseen technological and societal impact, and the methodologies, including the gender approach. The response to the evaluators' comments had to be submitted within five days from the receipt of the comments and could not exceed two pages.

A question related to gender was about the planned research activities and their gender-specific dimension from a biological, social and cultural perspective. The reviewers found that the gender dimension considered in the proposal was not related to the planned research activities but, on the contrary, lagged behind them and asked for further clarifications. With the support of gender studies experts at the university, who are co-authors of this article, the coordinator prepared an answer that was accepted and contributed to the funding of the project. The reply stated that the research topics of REMAP, which concern ferrofluid, magnetorheology, etc., cannot include a sex/gender approach. On the other hand, REMAP would produce a policy report paper (in the form of a deliverable) addressed to the European Commission, among others, as a result of communication activities at science festivals and other communication and dissemination events, where the gender dimension could be observed and influenced. In this context, the project would carry out surveys in accordance with the EIC Work Programme 2021, taking into account gender-specific and other variables among participants. Furthermore, the coordinator reiterated that the gender dimension would be closely linked to REMAP research activities: in line with EU best practices for inclusive innovation, the dedicated gender studies experts would support the partnership in promoting gender+ balance and equal opportunities during activities and events, gender-neutral language in dissemination and communication. Foremost, the REMAP consortium would address the gender dimension as a moral obligation in line with the United Nations SDG No. 5, Gender Equality.

Another comment from the reviewers pointed to specialists in fields traditionally distant from STEM disciplines, such as economics, politics, gender studies, as not strictly required to achieve the proposed breakthrough, even though such specialists were included in the teams since its start. Also in this case, the answer was deemed satisfactory, and confirmed that – with a holistic approach - the REMAP breakthrough

would only succeed if the technology would have a major impact on science, economy and society – the project's goal no. 4 - in the long term. Whereas the scientific breakthrough can be achieved without the disciplines of social sciences and humanities (SSH), the involvement of SSH experts (which accounted for about 8% of person-months) was deemed crucial to achieve the targeted economic and societal impact as included in criterion 2 (Impact) of the project proposal. Indeed, the implementation of REMAP would include specific programmes to accelerate training. In this case, the proposed actions would empower young or early-stage researchers with a high potential for translating research into innovation.

An assessment of the economic sustainability of commercial exploitation was also envisaged, thus integrating competences in the economic, business and political fields. Furthermore, it was evidenced that the participation of research experts in gender studies would show that REMAP's attention to the gender dimension is not mere "purple and/or pink washing", but on the contrary a commitment to excellence, creativity and entrepreneurship.

5. Dissemination and outreach activities

In order to promote a gender+ perspective, REMAP foresees the implementation of several micro-actions, of which we will focus in this presentation on the communication, dissemination and outreach activities of the project.

Communication, dissemination and outreach activities are particularly important as they can be an important catalyst for promoting an inclusive culture and introducing relatively new concepts such as the gender+ perspective. Below, we present some of the strategies and suggestions made in the first phases of the project.

5.1. Dissemination activities

REMAP included lists of journals and conferences identified for the scientific dissemination of the project, as well as the list of resources for communication (from the website to various social media and networks), which helped identify a series of suggestions for the partners.

A bibliographic search in various scientific journals related to chemistry and nanotechnologies mentioned in the proposal allowed the identification of a number of articles published in the last three years that are in some way related to gender. This activity aims to provide partners with up-to-date references that can serve as a basis for knowledge acquisition and the expansion of the project network to include individuals and research groups that pay attention to gender balance, diversity and the adoption of

a gender perspective. For example, based on the editorial by Lojou et al. (2021), access was provided to a special issue on the presence of women in chemistry.

Another valuable resource was the EU's CORDIS database, where it was possible to identify projects related to nanotechnologies that contained specific references to gender and/or diversity. Again, for reasons of space, we will limit ourselves to mentioning only one source. Three white papers, published a few years ago but still considered valid, offer suggestions for the implementation of RRI (Responsible Research and Innovation) conditions in nanotechnology research and innovation (Bechtold, Fuchs and Borrmann, 2020).

White Paper 1 explores the opportunities and drawbacks of using co-creation as a tool to enhance the responsiveness of nanotechnology research and innovation to societal needs and values. The first white paper highlights the findings from the GoNano co-creation process and suggests five rules of thumb for prospective co-creation practitioners. It is mainly targeted at researchers, engineers and other stakeholders involved in research and innovation.

White Paper 2 provides insights on how to implement co-creation, considering research as well as the innovation ecosystem. It addresses industrial and business partners, research institutions, and policy makers involved in research and innovation.

White Paper 3 provides guidance on how to realise co-creation in the light of a gender and diversity perspective in order to better integrate these perspectives into nano-related research and innovation. The main addressees of the third paper are process organisers and/or researchers in a position to put co-creation into practice.

Regarding the communication of the project activities, some recommendations were included in the communication, dissemination and exploitation plan presented in the third month of the project. In particular, the importance of adopting the following suggestions as far as possible was emphasised.

- Remind in the deliverables and outputs that EU funding can also contribute to promoting equality, diversity and inclusion and gendering the research pathway in a gender+ perspective, mentioning EU strategies where appropriate.

- To ensure gender+ balance, it is important to monitor the composition of advisory boards, committees and working groups involved in the project. This includes determining the inclusion of scientists of all genders and emphasising the benefits of research for individuals regardless of their gender.

- Training on gender+ and aspects of equality, diversity and inclusion relevant to project activities should be included to raise awareness and promote an inclusive research environment.

- To evaluate the effectiveness of gender equality measures, it is also important to select and introduce key performance indicators (KPIs). These KPIs should be tailored to track and evaluate the impact of gender equality measures within the project in order to measure progress and identify areas for improvement.

5.2. Participation in science festivals

For outreach activities, given the partners' participation in a number of science festivals in different partner countries of the project, a special training session was organised to illustrate a range of strategies to promote accessibility and inclusion from the planning phase to participation and data collection. Partners can adapt the list to their specific circumstances by deleting inapplicable suggestions and adding others, thanks to the appropriation of general principles applicable to different social, geographical and cultural contexts. Note that these suggestions do not include elements already formally adopted by project partners, such as accessibility criteria for visually impaired individuals or physical accessibility of spaces where events are held.

As a first step, it is recommended to establish a code of conduct that promotes respect, inclusivity and non-discrimination. Publish it at all stages, from initial planning to all advisors and organisers with whom researchers interact and collaborate, and distribute it to participants. It is important to provide clear and easily accessible information to enable feedback to be submitted.

A list of recommendations on various aspects that are typical of science festivals and other initiatives aimed at the general public has been discussed with the researchers. The different aspects were divided into the following macro-areas: a) contents, also paying attention to the diversity of speakers, including in terms of background; b) venue and organisation, provision of accessible venues from different points of view, for people with different disabilities or other needs, e.g. left-spot childcare; c) language(s) so that inclusion, accessibility and different cultural backgrounds are welcome; d) inclusion of underrepresented communities and potential stakeholders; e) the last but perhaps most important advice is to publicise all of the above in traditional media, social media, networks, project and university websites, etc.

The above mentioned initiatives and others related to other workpackages have been at the centre of information and training events since the project's kick-off event and are updated at each regular meeting. The aim is to help researchers create roadmaps that integrate the theoretical aspects of the project, the technologies developed and their future applications into a narrative that takes into account the gender+ dimension at all stages of the project, including impact and future technological uptake.

We are aware that embedding the gender+ dimension in research planning and implementation remains an open question, especially in the scientific fields analysed here, although such a dimension is crucial in all phases of scientific production from the very outset (Soldin *et al.*, 2011) or when the gender perspective is necessary for a better research outcome (Romero-Perales *et al.*, 2023).

6. Conclusions

Despite the limited space that prevents a comprehensive overview of the numerous activities organised within the project REMAP — most of which are transferable to other EU-funded research activities — we hope that the above illustrates how the initiative described aims to overcome resistance to the implementation of a gender+ perspective in STEM disciplines and to create a fruitful and positive cross-fertilisation between STEM and social sciences, in particular gender and diversity studies.

The concept of SRL was the most relevant framework for considering how to promote gender+ in a fundamental research and innovation project. Whereas STEM scientists are used to considering the TRL of their research activities, integrating a social perspective can prove difficult without the support of experts in SSH. The aim is to provide researchers with medium- to long-term perspectives, resources and strategies that will be useful in the future to implement the gender+ perspective in all phases of research, as required by Horizon Europe.

Indeed, it can be observed that SSH are often far from an application-oriented field, and it is difficult to involve such disciplines in research projects dealing with technology or technical progress. In the case of the initiative we are presenting, the P-GAP and its application to the REMAP project, it is becoming increasingly clear how helpful positive collaboration and exchange between different disciplines can be, and that this makes the result leading to innovation completer and more comprehensive. At the same time, SSH scientists can take inspiration from this successful example and unleash an open dialogue with the STEM fields.

The limitations of the initiative are that it is not yet widespread and, therefore, it needs fine-tuning to become applicable on a larger scale. Other ways to formalise the experience are related to the importance of the ground-up approach. This approach consists of providing information, training and support material to a number of researchers who are part of a consortium, which they can apply in the development of other proposals, from the concept phase, in which the problem is identified, through the design of the research, collection and analysis of data, to the communication, dissemination and exploitation phasesanalysis of data, to the communication, dissemination and exploitation phase.

The next steps are to consolidate the P-GAP through co-operation with other EU-funded projects and to extend it to all scientific fields. A useful resource in this sense is the possibility of disseminating the competences acquired in the Ulysseus University Alliance, to which the coordinating partner belongs. Within Ulysseus, the eight partners are working on a work package dedicated to the promotion of EDI in the activities of the alliance. This includes a comparison and harmonisation of the partners' GEPs, where UniGe's idea of a P-GAP can be tested and implemented in other universities.

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Co-creating a 3D Printed Prosthesis Design using an Intersectionality Lens

Anita Thaler[1], Sascha Fink[2], Daniela Krainer[2], Peter Schubert[2], Rosmarie Heim[2], Julian Bosch[2], Thomas Rockenbauer[3], Michael Sauer[4], Matthias Sepin[5]

[1]Interdisciplinary Research Centre for Technology, Work and Culture, Austria

[2]FH Kärnten gemeinnützige Gesellschaft mbH, Austria

[3]Luxinergy GmbH, Austria

[4]Magna Powertrain GmbH & Co KG, Austria

[5]Sepin Orthopädietechnik Sanitätshaus Ges.m.b.h., Austria

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Abstract. The ongoing project PROTEA1 aims to improve the fit and acceptance of lower leg prostheses by optimizing the prosthetic design using 3D printing and integrating sensors to monitor pressure distribution of the residual limb to identify and localize potential problems, such as pressure or chafing points, in advance. This goal is pursued since 2022 with a human-centred, gender- and diversity-sensitive, participatory technology design. For this, a transdisciplinary team comprising engineering, physical therapy, orthopaedic technology, psychology, movement sciences and gender studies regularly meets and co-creates knowledge in online and face-to-face settings. The gender-sensitive, continuous and iterative involvement of stakeholders and potential users is the base for technology development and influences decisions regarding specific designs. The intersectional perspective of the gender approach of PROTEA became most visible in a use case decision workshop, where the team decided on which user group they would like to focus on. For this co-creation workshop, empirical results of user and stakeholder interviews and focus groups as well as literature analysis were translated into diverse conditions and challenges of respective target groups, and questions around potential ethical and societal consequences were raised.
In this paper we will present the sociotechnical framework of PROTEA, comprising a detailed requirement analysis which led to the development of personas and a set of

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technical and user-driven requirements. These results are being used by engineers who are currently working on a 3D-printed outer and inner socket of a lower leg prosthesis and the placing of pressure sensors within the inner shaft.

1. Introduction

The prostheses research project follows a human-centered design approach, which supports the development of appropriate technologies in an iterative process with relevant stakeholders by using qualitative methods (e.g. focus groups, interviews and personas) to put human needs, abilities and behaviour at the heart of developments and results in user-friendly technologies (Norman 2013). The first step of this approach is to develop a general understanding of the context of use of the application to be developed, and in the second step, the specific requirements of the users are specified. Since the project received funding for specifically integrating gender knowledge and expertise into the research (Thaler 2022), the entire process of PROTEA is gender- and diversity-sensitive, building on theories of mutual shaping of technology and use (van Oost 2003; Rohracher 2005).

The understanding of sex and gender in the project is intersectional, which means that relevant social and identity markers are used along with experiences of inequity and (potential) discrimination in order to analyse usage contexts and prepare them for technology development (Winker 2009, Winker & Degele 2011, Walgenbach 2012).

The integration of gender researchers and their knowledge already started at the proposal writing phase and led to a project design, in which scientific gender knowledge (Wetterer 2009) was included as crosscutting issue in all phases and all work packages of the project. At the kick-off meeting a first workshop was held for the transdisciplinary project team about gendered innovations (Schiebinger et al. 2011) and especially raising awareness on the concept of “configuring the user as ‘everybody’ and the use of the ‘I-methodology‘” (Oudshoorn et al. 2004, p.30). I-methodology is a technology design practice without any involvement of actual users, in which designers and engineers construct a general idea of a user (an ‘everybody’) and try to answer research questions by putting themselves in the role of the users (Thaler 2022). This problem was addressed by PROTEA’s approach of a human-centred design approach, deriving user requirements and needs from empirical data and not those of the designers.

Already during the kick-off meeting beside gender and intersectionality, also responsible research and innovation (RRI) was seen as highly relevant, including not only ethical, wider societal and environmental aspects, but also process values of reflexivity, responsiveness, anticipation and deliberation (Stilgoe et al. 2013).

2. Methodology

The methodology of PROTEA has two levels. The first one is the immediate level of gender-sensitive human-centered technology design, using stakeholder mapping, focus groups, interviews, personas, user workshops etc. The second – or meta-level – comprises methods of knowledge co-creation within the transdisciplinary project team and advisors. The motivation to co-create knowledge respectively co-design technology within the transdisciplinary team comprising engineering, physical therapy, orthopaedic technology, psychology, movement sciences and gender studies was that: "… scientific knowledge, in particular, is not a transcendent mirror of reality. It both embeds and is embedded in social practices, identities, norms, conventions, discourses, instruments and institutions – in short, in all the building blocks of what we term the social. The same can be said even more forcefully of technology." (Jasanoff 2004, S. 3)

The co-creation and co-design approach need flexibility, systemic thinking and good facilitation (Greenhalgh et al. 2016), and a "shared understanding of others experience is key in the early stages of building trust between diverse stakeholders and helps banish myths that constrain contextually sensitive solutions being developed." (Langley et al. 2018, p. 5).

In PROTEA the knowledge co-creation is not only aiming at the prostheses design but also at gender knowledge (Thaler et al. 2022). In **Fig. 1** the methods and co-creation process is presented in a timeline from July 2022 to June 2024.

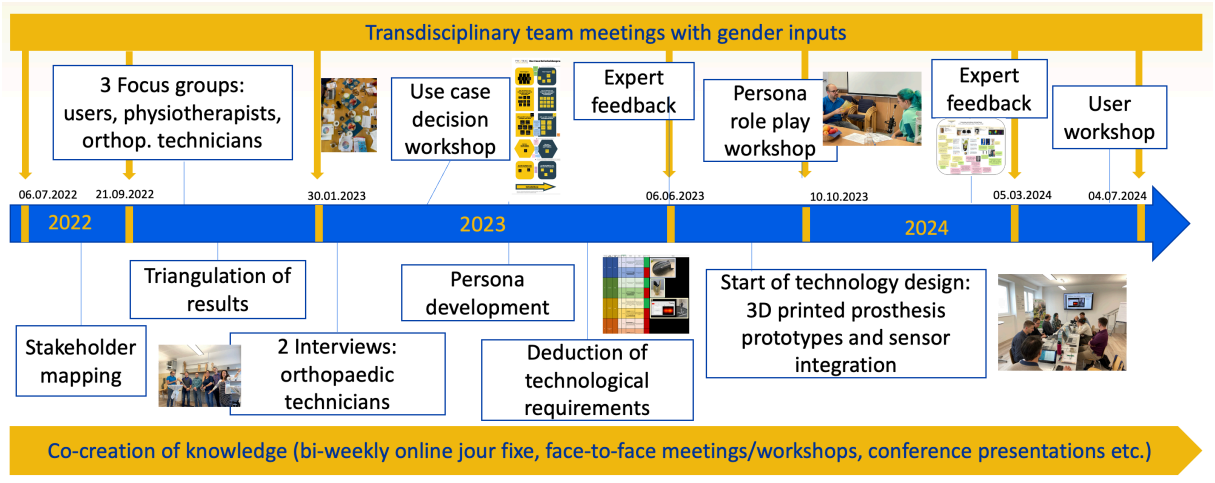

Figure 1. Overview of the context of use and requirements analysis in PROTEA

In the initial project year, a total of three focus groups and two interviews were conducted with three relevant stakeholder groups, namely users with prostheses (contacted via a self-help group), orthopaedic technicians, and physical therapists. The focus was on analysing the problem areas of using prostheses in everyday life and the solutions proposed by different stakeholders from their specific expertise and perspective. In order

to ensure the saturation of the results, two interviews were conducted with prosthetists and orthotists based on the results of the focus groups.

As part of the co-creation process, team-internal meetings (including gender inputs) and a workshop were held to triangulate the results, define the target group and develop personas. The results were further consolidated by involving advisors with orthopaedic and healthcare expertise, and with co-creation workshops at three consortium meetings between September 2022 and June 2023. The knowledge co-creation always took place within the whole transdisciplinary team, in order to generate a corresponding common understanding on the one hand and to create a robust catalogue of requirements for the human-centered technology design.

The integration of gender and intersectionality in PROTEA's human-centered technology development (the first level of methodology) took place firstly, in the gender-balanced selection of interview and focus group participants and the use of gender-balanced teams on the part of the interviewers and evaluators; secondly, gender-sensitive addressing of participants and design of guidelines (e.g. using gender-sensitive language and avoiding gender stereotyping), and thirdly, in the evaluation and interpretation of the results, as well as presentation and dissemination of preliminary results within and outside the PROTEA team. The necessary gender competences were introduced in the context of consortium meetings through the implementation of specific gender workshops, using inputs and interactive methods, such as the wheel of privileges exercise (Thaler & Karner 2023).

One key method and moment of knowledge co-creation was the team-internal use case decision workshop, which was conducted online using a virtual whiteboard. The workshop began with an input including background literature (Greitemann et al. 2016) and results from PROTEA's focus groups and interviews. All team members contributed to a discussion on different usage contexts and discussed potential users and use cases in an interactive setting. Two fundamentally distinct user groups were initially identified (based on amputation history and activity level of those affected) and their specific needs were substantiated with data from literature and empirical results. Subsequently, the respective technical solution concepts and design ideas for each user group were outlined, and the respective user-specific challenges and problems were defined. Finally, social and ethical considerations for the respective user group were added, and both use cases were discussed.

From the engineers' perspective in the team, the workshop was a necessary step, as it became clear that there are sometimes major differences within the group of the affected people and the resulting requirements. The different mobility classes and a closer look at the everyday situation showed that not all needs can be met universally and that the

adaptations to the prosthesis need to be designed more specifically. The decision was essential for the technical concepts, which could be defined more precisely.

Consequently, the joint decision in the team for a specific user group (“the user as somebody”) instead of “configuring the user as everybody” (Thaler 2022, p. 5) was made, and led to the derivation of personas. Personas are not actual users, but hypothetical archetypes (Hartson and Pyla op. 2012). Personas are an effective method for placing the wishes and needs of users at the centre of development and for developing scenarios that are as close to reality as possible. The advantages of this method are an understanding of the (primary) users for the whole transdisciplinary team, with their needs and behaviours, which can counteract stereotypes based from the personal environment (“I-Methodology”), lead to more empathy with users, and puts needs and goals of these users in the centre of all decision-making. In reflection meetings, the gender-sensitive design of the personas was discussed in particular in order to avoid gender stereotypes (Marsden et al. 2015).

In the second year the knowledge co-creation process was employed to transfer the identified user problems, as well as the needs and requirements of various stakeholders into technological tasks. The first technical concepts and developments comprised various elastic 3D printing materials, which were tested for their suitability for the soft socket and compared with material samples from conventional production. Simplified geometries were then created to test the sensor placement on a curved surface. A method had to be found for integrating the sensors into the soft socket, therefore a door system was integrated into the geometry into which the sensors were inserted. The next step was to implement these concepts into the real geometry. The entire process was continuously evaluated and adapted through regular exchanges with the whole project team. This exchange with colleagues as well as interviews with stakeholders and experts and their feedback were an important factor in the technical conceptualization and implementation. Through this knowledge co-creation, PROTEA’s engineers were able to very quickly supplement the existing design with the new findings.

This process involved several meetings and the ongoing exchange of empirical results. A key method of knowledge co-creation used role play as an intervention. Based on the developed personas, engineers of the project team received distinct items and basic instructions to “try walking in my shoes”, as the exercise was called. The role plays always included two active players, one personating a specific user based on the developed personas, the other playing themselves as engineers explaining their 3D printed prosthesis prototype asking for feedback.

Furthermore, technical solution ideas and sketches were constantly discussed in bi-weekly online meetings, and through team-internal existing expertise, including that pertaining to orthopaedic technology, physiotherapy, and so forth. Initial technical

concepts were discussed in face-to-face meetings, including one with advisors from medicine and physiotherapy, as well as an affected person with expertise in orthopaedic technology.

During another face-to-face meeting two users were invited to assess their needs for an upcoming user workshop, which took place at the end of year two. In this workshop with four users the newest 3D printed prototypes were presented, and potential sensor integration and data issues discussed.

At the time of the submission of this paper another face-to-face meeting is planned, including advisors to specifically address arisen gender-specific and medical questions concerning the implementation of sensor technology. The further development of the technology and answering of gender related question will be in the focus of the third project year.

3. Results

The main focus of PROTEA activities – of the first methodological level – was the empirically sound conduction of the context of use and requirements analysis based on the verbalized wishes and needs of relevant users and involved stakeholders. Affected persons reported that it is crucial to put the prosthesis on properly in the morning. Otherwise pressure and friction points may occur or walking and standing on the prosthesis may become unsafe. From the therapists' perspective, a primary objective of the therapy is to develop the independence of those affected and to achieve safe handling of the prosthesis in the respective living environment. For the therapists, the possibility of a before-and-after comparison would be particularly helpful for future prostheses in order to better map the therapy process. Relevant data for this would be parameters of the gait pattern, movement behaviour in everyday life and prosthesis use. Biofeedback for patients using pressure sensors in the soles or on the residual limb would also be useful, possibly with live data transmission to a tablet.

In the perception of orthopaedic technicians, they mostly work with people who suffer from peripheral arterial occlusive disease (PAD) and belong to a lower social class. From their point of view, it would be beneficial if sensors could be positioned between the liner and socket and the sensors could focus on pressure (tibia, popliteal fossa), temperature (popliteal fossa, end of residual limb) and blood flow (circular on the residual limb). It would also be important that the sensors are suitable for documentation and also function as a biofeedback system so that users of the system can be shown what the actual pressure situation looks like, for example. With regard to the visualization of the data, it was noted that valid threshold values are needed in order to be able to handle the data accordingly.

On the second or meta-level of knowledge co-creation within the transdisciplinary team, one important event was the use case decision workshop, which was held in order to determine the characteristics, problems, needs and proposed solutions based on the aforementioned requirements. Based on roughly two different reasons for amputation (trauma vs. disease-related; see Greitemann et al. 2016) and the different age and activity structure of those affected, two user groups were distinguished, supplemented by the different needs from a social, (physio)therapeutic and (orthopaedic) technical perspective based on the empirical results. The engineering teams described technical solutions for the two use cases complemented by social and ethical dimensions. Finally, a decision was made in favour of focusing on users with multiple morbidities and health impairments who tend to have a low socio-economic status. This group of people tends to be inactive and moves mainly indoors and to a limited extent outdoors. In accordance with the classification of mobility classes after amputation (Greitemann et al. 2002) this corresponds with mobility class 1 (indoor walker) and mobility class 2 (limited outdoor walker). This group of people is also characterized by muscular weaknesses and advanced age. The issues that arise for this target group include poor stability when walking, difficulties with rolling while walking, problems when putting on and taking off the prosthesis to limited mobility in general or a severely impaired 'healthy' foot.

The final decision on the user group paved the path for further steps, and based on the description of the user group three personas were set up. The personas include a description of the living situation, social environment, their health status, aids, background of the amputation, medical care, their daily challenges and their personal requirements for the prosthesis.

In the second year, the focus was transferring this knowledge into the development of prototypes. In a first step, the prototypes developed to this date were discussed in the form of a moderated role play. PROTEA’s engineers assumed the role of the personas created and attempted to comprehend the daily challenges from the perspective of those affected and to reflect on the prototypes created to this date. As a consequence, the technicians gained an understanding of the situation of those affected and user-centred questions such as “Is the material easy to clean?” came to mind. In addition to the moderated discussion, two interviews were conducted with orthopaedic technicians to answer gained questions like “Do you need markings on the outer and inner socket to put the prosthesis on quickly and easily?” and to gain a better understanding of state-of-the-art prosthesis production. The results of these iterative discussions led to the identification of three objectives for the further development of the prototypes:

- Development of a breathable prosthesis
- Reduction of the number of parts where possible
- Determination of the ideal sensor positioning

To address these issues in detail a fabric structure should be investigated for the 3D-printed prosthesis that allows temperature regulation and offers appropriate comfort in order to avoid pressure points. With regard to the sensor technology, a pressure point detection and monitoring system is desired. Furthermore, a solution that allows for quick and easy donning would be desirable. The sensor technology, outer wall, and inner wall were developed as prototypes, which were discussed together with users in a workshop. In this workshop, four retired males with amputated lower legs (due to chronical diseases) – generally assessed the current prototype very positively. They regarded the optics as satisfying, the perforations in the prosthesis prototype for air ventilation as clever, but the weight as too heavy for now. About integrating pressure sensors, the group had diverse attitudes for various reasons, reaching from a general technology aversion (which led to a principal refusal of all digital solutions) to a hope for exactly this sensor technology to avoid undetected pressure wounds. The perception of three users was that pressure points can be detected easily by themselves, and a sensor technology would not be needed for them. But if sensors would be integrated and then send data, they all agreed that their orthopaedic technicians were their most trusted experts, which they would feel comfortable sharing their personal sensor data with.

Now, the next engineering steps towards a sensor integration were taken. Different elastic printing materials got tested for their behaviour and properties. First simplified geometric parts were produced to test the sensor behaviour on a curved surface. Therefore, a system was created being both a sensorized prosthesis demonstrator and a test bench for the soft socket. This system is a mechanical part simulating the interaction between patients and their prostheses. It is able to display a real-time mapping of the forces within a soft 3D-printed half sphere representing the soft socket. A mobile mass consisting of a steel cylinder with a handle mimics the movement while walking. Flexiforce[2] sensors and an Arduino Nano[3] are used, the data is read out via an USB interface. The visualization is done in real time through a Matlab[4] interface by using a colour map and two graphs for force and voltage monitoring. Furthermore, a first prototype of the soft socket was printed. It includes a door system for the sensor integration and is perforated to improve the temperature of the residual limb. In the third and final project year the sensors will be implemented and tested on the printed socket.

[2] https://www.tekscan.com/force-sensors

[3] https://www.arduino.cc/

[4] https://www.mathworks.com/products/matlab.html

4. Discussion and outlook

The gender-sensitive human-centered design approach applied in PROTEA focuses on the participatory development of 3D-printed prostheses with sensor technology. This process is carried out iteratively as co-creation of knowledge and co-design of technology with the project team, users and relevant stakeholders. The human needs, abilities and behaviours from a diversity perspective are at the centre of the developments and the result are user-friendly technologies according to the ‘Gendered Innovations’ concept (Schiebinger et al. 2011) and the avoidance of the so-called 'I-Methodology' (Oudshoorn et al. 2004).

The gender-sensitive knowledge co-creation was conducted in coordination with the entire transdisciplinary team in order to generate a corresponding shared understanding on the one hand and to create the broadest possible catalogue of requirements on the other (Thaler 2022). A use case decision workshop was held in the overall consortium in order to arrive at personas and requirements based on the empirical results. Starting with two user groups, the different needs of the respective target groups were first described from a social, (physio)therapeutic and (orthopaedic) technical perspective based on the empirical results and technical solution approaches for the two use cases. Possible problems and challenges as well as social and ethical dimensions were then discussed for both user groups. Finally, a consensus was reached focussing on multimorbid and health-impaired users with a rather low socio-economic status. In accordance with the classification of mobility classes after amputation (Greitemann et al. 2002), this group can be categorised as mobility class 1 and mobility class 2. People in mobility class 1 tend to be inactive and move mainly indoors. In contrast, mobility class 2 is characterised by greater mobility and a tendency to move around in limited outdoor areas This group of people is also characterized by muscular weaknesses and advanced age.

The aspect of gender sensitivity of PROTEA was firstly evident in the gender-balanced selection of interview and focus group participants and the use of gender-balanced teams of interviewers and evaluators; secondly, it was evident in the manner in which the participants were addressed and the design of the guidelines; thirdly, it was evident in the evaluation and interpretation of the results, as well as their presentation in joint knowledge production settings within and outside the PROTEA team (e.g. with advisors). The fourth step involved the translation of empirical results into the previously mentioned use case decision workshop, which was guided by the concept of intersectionality (Winker & Degele 2011; Walgenbach 2012; consideration of gender, age, socio-economic status). This requirements analysis derived from the empirical surveys, co-creative processes and the use case decision workshop led to the development of gender-sensitive personas (Marsden et al. 2005), which were later used for a role play

‘try walking in my shoes’, one of the interventions aiming at gender-reflexive knowledge co-creation and technology co-design.

At the end of the second year, the project is well on track, the results from human-centred design and gender research methods are well integrated in technology development of PROTEA, the bi-weekly online meetings, and regular face-to-face-meetings as well as gender workshops and meetings with advisors and users can be seen as successful instruments of a transdisciplinary knowledge co-creation.

For the last and third project year two major tasks lie ahead, on the technology design level the integration of sensors and the algorithmic model to make use of gained data. And from an intersectional perspective – which connects to the technology design – more data are needed to answer questions, which arose from the latest user workshop: Did we invite the right target group, and if so, are they really not needing sensors or may they not be aware of the benefits of sensor technology like orthopaedic technicians suggested? And finally, how can we better include under-represented users potentially facing discrimination because of intersecting identity markers (elder women, less mobile users, multi-morbid users living in care facilities, etc.)?

Co-creation and co-design are no guarantee that we will get everything right from the start, but they help us to detect conceptual errors in early stages and lead us to designs and technologies, which are robust, because they are more likely to be accepted by our target group.

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Gender Relations in Sociotechnical Energy Transition: Heating System Change Motivations and Negotiations among Couples in Single Homes

Andrea Wolffram[1]

[1] Institute of Sociology, RWTH Aachen University, Germany

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Abstract. The energy transition as one of the most challenging sociotechnical transformations processes of our time is lacking gender sensitive reflection and shaping. In a qualitative pilot study about the reasons behind the decision to install renewable energy systems in the home and the impact on household-related practices of homeowners, the couple dynamics and positioning strategies towards renewable technologies are analysed. The study shows that, on the one hand, positioning strategies enable 'doing gender' and, on the other hand, that these strategies differ according to the different technology-related action resources and competence attributions among homeowner couples. The results are reflected in the theoretical framework of an actor-centred sociotechnical transformation. The article concludes with considerations for the resulting implications for practice and for further research informed by gender theory.

1. Introduction

The future energy supply has become a key issue of the 21st century. There is a broad consensus, at least in large parts of Europe, that it is impossible to maintain a fossil fuel-based energy supply due to the already advanced stage of climate change. In many respects, the conversion of the energy system to regenerative and climate-neutral technologies has moved from the political agenda to regulation through legislation, into the investment strategies of industries and business, and finally into the everyday lives of citizens. (cf. Kaufmann-Hayoz et al. 2011: 130ff). The German and European energy transition is therefore one of the most challenging sociotechnical transformation processes of our time. The fundamental and especially social changes associated with it involve all areas of life. However, in technology and innovation research, the focus is often on the technical and economic components of the energy transition. From the STS

perspective, in contrast, the social side of the energy transition takes centre stage. Linked to this is the question of how society deals with economic, technical and ecological changes. Nonetheless, mainstream STS research is (once again) largely blind to gender-relevant effects (cf. Walk 2024, Wolfram & Kienesberger 2023).

It is to the credit of STS research to show that technology is always embedded in social contexts as expressed, for example, in the concept of the seamless web (Hughes, 1986) and that transformations - especially major ones - will not succeed if the social conditions in which the technical transformations are embedded are ignored. Especially with such a perspective on technology and innovation, the relevance of gender and diversity relations in technology research is often obvious and offers a variety of methodological approaches for social science analysis.

I would like to illustrate this using the example of the use of renewable energy systems in existing private buildings. This involves considerable investment decisions about when energy-saving technologies or renewable energy technologies are to be purchased and installed. A closer look at how these decisions are made and implemented suggests, on the one hand, traditional gender orders. On the other hand, a research design, that takes into account other relevant social categories in the context of these decisions, such as professional background, socio-economic status, socio-cultural orientation, introduces a more complex and well-founded analysis.

2. Problem Background

The relevance of owners of private buildings for supporting the energy transition can be illustrated by looking at CO2 emissions of the private building sector. The building sector is the area in which the most CO2 emissions are produced in Germany. The building sector takes up about 40% of total emissions if not only the energy consumption for hot water and heating but also the so-called grey emissions for construction and possible dismantling are taken into account. (dena 2021) In 2018, 30% of the 41.4 million households in Germany were single-family homes. Around two-thirds of the energy required by houses is used for space heating. And here, single-family homes account for the largest share of energy consumption for space heating by far at 47.5 % (ebd.). Moreover, this number is especially high considering that only 30% of households live in single-family homes.

One lever in the building sector for reducing greenhouse gases is the integration of renewable energies for heat supply, i.e. for heating and hot water. This can be achieved, for example, by installing heat pumps and photovoltaics as well as solar thermal systems. As owners of owner-occupied single-family homes have autonomy of decision and action here, it can be concluded that they have a relevant influence on the design of energy emissions in the building sector and thus also on the energy transition.

The available statistics (Statistisches Bundesamt 2019: 30) differentiate between the following household types: single people living alone, differentiated by gender, single parents, couples differentiated by "without child" or "with child(ren)" and other households. As expected, single-family homes are predominantly occupied by couples (46.7 %) with children (52,7 %) and without children (43,7 %). However, the largest group among single-family homeowners is the "other households" group at 53.6%. These include households with children over the age of 18, multi-generational households, shared living arrangements, etc. However, no further information is available on how these other familial and non-familial household constellations. Decisions regarding larger investments, such as those required for energy-efficient building renovations and measures, are likely to be far more complex in these cases.

3. Literature Overview: Gender and Technology in Energy Transition

Research into the social dimensions of the energy transition that specifically takes gender perspectives into account is still in its infancy, as Kannig and colleagues explain in their literature review. (Kannig et al. 2016) International gender research focussing on climate and energy issues primarily concentrates on ecological problems in the Global South. (ibid.) In the European context, there are a few studies that address spatial and planning science issues and, among other things, analyse space in its socially relevant dimensions (Mölders et al. 2025). There are also studies that include questions of gender equality in the transformation process of the energy system (Bauriedl/Wichterrich 2014, Fraune 2015) and studies that focus on the consumers of energy (Weller 2013, Offenburger 2016). However, especially from a feminist STS-informed perspective, there is still a lack of work focussing on the sociotechnical transformation of the energy sector. Feminist STS (Faulkner 2001, Wajcman 2003, Suchman 2007) understands gender and technology equally as socially constructed and therefore does not take either for granted, but rather emphasises their mutual co-construction. This means that transformation processes such as the energy transition can only be adequately understood and at best governed as socio-technical transformation processes. In these processes, everyday power and domination relationships also come into play, and these are structured by the category of gender and other effective social categories which can also have complex interdependencies. This pilot study addresses this research gap and builds on some few

studies who deal with the question in recent years, how visions, relationships, and practices with emerging energy technologies are gendered in the context of home relations. (Strengers et al. 2022, Mechlenborg & Gram-Hanssen 2022) Especially Ursula Offenburger (2016) investigates how the emergence of a 'home' is created through the gender-differentiated division of labour around housing. Part of this ongoing process is the establishment and maintenance of living space and therefore also the processes of construction and renovation. The supply and consumption of thermal energy is of central importance in this respect. Offenburger's concern is to make clear how these aspects of creating a home are integrated into overarching, historically developed standards that structure the practices of creating a home. The fully automated heating system, developed after the Second World War, has represented an unquestioned expectation that has been taken for granted for decades1, and this is carried over to the installation of heating systems with renewable energy sources. Interaction with the heating system is reduced to the actuation of thermostats during unobstructed operation. While the focus of the analysis is on individual fireplaces and stoves in living rooms and central heating systems in functional rooms that are operated with biomass (logs, woodchips or pellets), my focus is on solar and solar thermal systems, with the latter becoming increasingly relevant and strong in the market, especially in combination with heavily subsidized heat pumps in private homes. With regard to the individual fireplaces, Offenburger finds that the location of the individual fireplace and the associated specific design suggest strongly gender-differentiated meanings and typical patterns of family division of labour. (ibid.: 99) Under the concept of knowledge orders, Offenburger also focuses her attention on the interactions of central actors in connection with the acquisition and use of heating technologies and the associated negotiation content. She shows that "technical knowledge" and "technical competence" are both negotiated in these interactions. Gender acts here as a resource for the creation of analogies and the drawing of boundaries and channels technical expertise and knowledge to the actors involved. (ibid.: 101)

These findings refer to another instructive study by Elisabeth K. Kelan (2007), who works out how gendered positions are discursively produced in the context of technologies. Based on a social constructivist understanding of gender, in which gender is the result of a continual and perpetual performance. Kelan argues that the tendency of women to distance themselves from technology while men's tendency to appropriate technology as subject positioning fulfil the function of 'doing gender'. (Kelan 2007: 359) She investigates how far these relative positions regarding technology are enacted in ICT work and identifies four strategies of positioning through which a hegemonic gender order is

[1] These expectations are comparable with the automotive based individual mobility as Katrin Manderscheid has worked out and called these expectations as "Automobility in the Head" (Manderscheid 2019)

reproduced either in a conformist or in a non-conformist way. While her study examines the positioning strategies of professionals in the ICT sector, decision-makers in single-family homes generally have no relevant technical expertise, if any at all. In this respect, it can be asked how men and women with different levels of technical competence position themselves in retrospect regarding the decision process to install renewable energy systems. What strategies do they use and how do these strategies relate to the subject positioning of their partners? What are expectable and what are not expectable strategies and how are these positioning strategies communicated?

4. Research Design of the Pilot Study, Methodological Approach, Data Collection and Sample

In the pilot study "Gender arrangements of sustainable energy behaviour in everyday life" the focus was on the question of how the energy transition is implemented in everyday life. What are the (sustainable) energy practices in households and in people's everyday lives? What gender and diversity-relevant insights can be generated with regard to positioning strategies in relation to technology? What conclusions can be drawn from this with regard to the question of how sustainable energy practices can find a broader entrance into society and thus serve the implementation of the energy transition?

The aim of the pilot study was therefore to explore initial starting points as to how the energy transition can be implemented starting from the actor level and how actor behaviour is embedded in and interacts with the socio-technical energy system and interacts. I pursued these questions in a qualitative and therefore explorative research design. In the pilot study, seven interviews with homeowners where conducted, in detail three couple interviews, four individual interviews because the partner was unable or unwilling to participate at the time of the interview and one written interview because the interviewee requested this. The interviewees differed as much as possible in terms of their socio-demographic characteristics, i.e. in particular in terms of social class, lifestyles, gender, age, city/country, mobility needs, technical affinity and occupations. The interviews followed a structured guideline but were nevertheless open to support the narrative flow and the interviewees' own logic. The guidelines covered the above-mentioned questions. It was also focussed on the social negotiation and implementation processes involved in the installation of photovoltaic or solar thermal systems, including in combination with e-mobility as given, among the residents of single-family homes. And finally, it was also looked at their sustainability-related attitudes and behaviour.

Data collection took place between December 2020 and August 2021. Due to the COVID-19-pandemic, the interviews had to be conducted online, which meant that no personal impression of the homes could be gained and that observation of the interactions between the couples was also limited. The interviews lasted between 60 and 90 minutes. The data collection was carried out in the form of theoretical sampling, which aimed to cover the descriptive diversity contrasts in order to be able to analyse the various meaning structures of the respective motivations, resources and energy practices in terms of their origins and effects. All interviews were recorded and fully transcribed.[2]

To analyse the data material, thematic content analyses and discourse analyses where carried out. The qualitative data analysis used the data software MaxQDA. I relied on Braun & Clarke's (2006) approach to thematic analysis with multiple rounds of coding using an inductive approach. I began using an open coding process generating initial codes on a semantic level, coding based on common words or phrases in the comments. The data were then recoded for similarities in attitudes, beliefs, and ideas surrounding experiences (Braun & Clarke 2006). Furthermore, I relied on the Davies and Harré (1990) approach to discourse analysis. Different positions are created through discourse, but these are negotiated in interactions. By adopting and asserting certain positions for themselves, people establish themselves as certain subjects. Of interest here is how gender is performed through adopting or rejecting subject positions and thereby communicating and doing gender. (West & Zimmerman 1987)

These approaches opened the view for the individual case typology and for typical and generalisable characteristics across cases, as well as for the production practices of gender in the context of renewable energy technologies. During the analysis, no theoretical saturation became apparent in the present sample, meaning that the scope of the results has not yet been fully explored. In this respect, the results presented below only allow for the formulation of hypotheses that need to be examined and expanded in further interviews.

[2] I would like to take this opportunity to thank my student assistant at the time, Julia Neidhardt, for her collaboration on the interview study. In particular, she supported me in conducting the interviews, transcribing them using speech recognition software and helping with the thematic content analyses.

5. Findings

The interviewees are largely located in middle-class milieus, mostly with modernised attitudes towards an egalitarian gender order. But even in these milieus, gender-differentiating technical relationships are still predominantly handed down. This means that women tend to downplay their own technical competence and knowledge and leave responsibility for technology-based installations firmly in male hands. In focussing their responsibilities and sustainable behaviour largely on household management, men and women enact masculinity and femininity in suitable ways. Gender arrangements that deviated from this pattern also deviated from the ones of traditional couple relationships.[3]

Within the heteronormative couple relationships, the wives supported the cost-intensive projects of converting or upgrading the energy supply with PV systems and, in some cases, the associated automotive e-mobility, although they had to adapt their everyday organisation considerably in some cases. For example, hot water may not be available all day, or the reduced capacity of the PV system may be supplemented in winter by using a wood-burning stove that must be filled and lit in the morning. However, they also expressed their pride in switching to an alternative energy supply. The *motivation* of these couples was largely driven by climate protection. If, on the other hand, the motivation was of an economic nature, the installations and conversions were perceived more as a burden.[4]

In contrast to these patterns of behaviour and attitudes between women and men, which have been selected here as examples and are generally quite predictable, the further analysis of different masculinities and their positioning strategies towards (regenerative) technologies is of more in-depth interest, as it allows us to explore very different resources and patterns for these strategies and therefore of justification for the (non-)use of sustainable energy in housing and mobility.

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[3] In my sample, two study participants fall outside the heteronormative couple constellation. One is a female homeowner who lives in a same-sex marriage and the other is a middle-aged owner of a three-family house who lives in a weekend-only long-distance relationship. For both of these interviewees, the motivation for retrofitting or building a zero-emission home was primarily an ecologically conscious attitude with a corresponding lifestyle.

[4] It makes an important difference whether the renewable energy is fed into the electricity grid or is predominantly used by the homeowner. Feeding energy into the grid involves only minor adjustments to everyday organisation, while not feeding energy into the grid in conjunction with a lifestyle that is as energy self-sufficient as possible requires a major adjustment or change in the use of appliances and therefore energy consumption in the home. The degree of self-consumption of the energy generated varied considerably in some cases, but most couples endeavoured to consume as much of the energy generated as they possibly could.

The resources of homeowners can be derived, among other things, from their localisation in specific types of masculinity, which in turn are rooted in different lifestyles and ways of life. In my sample, there is the technology-informed, ecologically committed academic; the craftsman specialising in renewable energies; the economically motivated, conservative pensioner supported by a son; or the family man - who makes use of comprehensive advice - who is concerned about a viable future for his children.

Offenberger (2016) points out in her study that specialised knowledge relating to construction and renovation is not a monopoly of professionals. Rather, homeowners are able to acquire a considerable amount of their own knowledge and skills, which leads to an increase in 'consumer sovereignty' (Offenberger 2016: 106), especially when their own (technical) professional expertise can be activated (ibid.: 105). Offenberger uses this finding to explain the low consumer sovereignty of women:

> "Since technical professions are still numerically dominated by men, the statistical chance that male household members will assert their own professional expertise and involvement in professional networks is significantly higher than the chance that women will make their professions relevant in order to interact with experts in construction professions on an equal footing." (ibid.: 106)

Even the women with technical professional expertise in her sample would not use their professional knowledge for the transfer or acquisition of skills for construction and renovation matters. This finding points to Kelan's assumption that "positioning towards technology can be seen as doing - and indeed communicating - gender" (Kelan 2007:364) i.e. that technology-related subject positions are not equally accessible to all.

Based on these assumptions and findings, I would like to draw on the concept of consumer sovereignty to explore the resources for technology-related positioning strategies that may result from this, from which a differentiation of "energy technology-related masculinities" can be derived. I would like to do this by comparing two of the four types of masculinity initially defined above.

Mr. Green, a 58-year-old mechanical engineer, set up his own business in the field of renewable energy systems 25 years ago and used his circle of friends in the field of ecological construction to renovate the farmhouse he bought with his wife six years ago from the ground up in an ecological manner. With his relevant self-employment experience, he is at the upper level of a continuum of the concept of consumer sovereignty, insofar as he possesses comprehensive expert knowledge. At the same time, this leads to a partner-backed positioning as the sole expert for technology-based ecological construction. However, Ms. Green also presents herself as technically informed and therefore also interested.

> “... and I originally had no idea about all this stuff (meaning solar technology in particular and ecological building in general). (...) Yes, and I was actually always interested in nature and animal protection (...) and waste avoidance, that was always my focus, but that suits Gerd quite well. Ecological building and these energy-related things, I'm also learning about them now.”

In contrast, 65-year-old Mr. White, also a mechanical engineer, also presents himself as interested in technology, but his interest in and commitment to an ecologically sustainable lifestyle must also be economically justifiable. After the 15-year-old heating system in the detached house had to be replaced in 2015, Mr. and Ms. White opted for gas heating with condensing boiler technology and had a PV system installed at the same time. However, the electricity produced is fed into the grid in its entirety due to what they consider to be the high feed-in tariff. Mr. White cites his technical interest as the main motivation for installing the PV system.

> “That's perhaps a little disappointing. The motivation was not necessarily to do something good for the environment, but simply an interest in technology and the idea that the investment would pay for the system when we retire and, of course, to use renewable forms of energy.”

He informs himself about PV systems, but also makes use of advisory services, which he considers to be consistently competent. With a view to consumer sovereignty, he confidently positions himself as technically competent and on a par with solar technology experts.

> “Of course, I did my research before making the decision to put a system on the roof. But the advice was competent, not just from the company we chose, but in general. I didn't start studying the technical literature even a year beforehand.”

Mr. White positions himself as willing to take risks and open to new technologies. He does this in particular in contrast to his wife, who supports the decision after her concerns about the PV system had been allayed:

> “My wife was more concerned about electromagnetic fields and whatnot, and fire safety and things like that. She tends to be anxious. Of course we talked about it, but she didn't push for it (the installation of the PV system).”

In both cases, the men claim technological expertise for themselves alone, and this is accepted by their female partners. Nevertheless, women also succeed in positioning themselves as technically interested or informed by either increasingly acquiring technical knowledge in the process of use, as in the case studies presented, or by reflecting on and scrutinising the possible risks of new technologies.

6. Discussion and Theoretical Framing of the Results

The interview analyses have so far shown that in the context of the installation of renewable energy systems in private homes, these technologies are used to express masculinity in heteronormative gender arrangements in particular. In contrast, female subject positions are expressed in the form of a gradual orientation towards technology or in the form of a more negative attitude in the sense of risk reflections. In addition, the women in these gender arrangements are considerably affected by the negative implications of the new energy systems, such as the change in everyday routines or noise and dust nuisance when renovating their own home. (cf. also Fischer 2011)

Two case studies were used to illustrate how the homeowners indirectly communicate gender by communicating a certain relationship to technology. These still preliminary findings are less indicative of the fact that gender differences are actively produced via technology. Rather, they show how the genders and their unequal relationship to each other is achieved through communication.[5] It is also interesting to note the rejection of women's lack of interest in technology and their lack of technical expertise in traditional gender arrangements, which is reflected in their own approaches to renewable energy systems. This reveals new female subject positions that express new ways of dealing with new technologies.

In the following, I would like to discuss the results within the theoretical framework of an actor-centred sociotechnical transformation. Transformation research has long been working on analysing the interactions between socio-economic and technical aspects in systemic transformations (Geels and Schot 2007; Araújo 2022). Here, for example, new governance mechanisms or changing power structures associated with the transformation are analysed (Avelino and Rotmans 2009; Loorbach and Rotmans 2010).

With regard to the role of actors in socio-technical transitions, the conceptualisation and analysis at the actor level in socio-technical transitions has also become increasingly elaborate. In their literature analysis, Fischer and Newig (2016) provide a comprehensive overview of the different conceptualisations of actors. At the same time, they show that gender-theoretical perspectives are largely lacking here.

In order to situate agency of actors within the transformation process of the socio-technical energy system, I draw on the conceptualisation of Grin et al (2011). Here, the actor levels “government,” “market,” “science and technology,” and "civil society" are differentiated. In addition, Fischer and Newig (2016) categorise “civil society” as “NGO/s,”

[5] This pattern is also identified by Kelan /2007) in her study, which analyses the subject positions of women and men in the ICT sector and thus among equally qualified people.

“trade union/s,” “political party/ies,” “environmental group/s,” “interest group/s,” and “household/s.” According to her literature review, if the research is strongly underrepresented in the area of “civil society” compared to the other actor levels, this applies even more to the subgroup of households. However, it is precisely in the subgroup of households that women in particular come into focus while existing power structures marginalise women in particular in all the other areas mentioned that can be assigned to the public sphere. Judy Wajcman (2003), among others, has already pointed this out when she emphasised that women in particular come into the focus of gender-technology relations when the lens is widened. Then the actors in STS analyses are not just the male heroes, the big projects, and important organisations, but the work of women as production workers, marketing and sales staff, and as end users of technologies comes into focus. Here, regarding the use of new renewable energy systems, it is clear that these once again have ambivalent implications for women.

If the perspective is directed to the household level in the context of sociotechnical transformations, however, the focus is not only on women as users of household technologies, but also on gender relations. The more traditional the gender relations are, the more consumer sovereignty shifts to the male side of the relationship, through which ‘doing masculinity’ is effectively (re-)produced. In contrast, justified questioning of new technologies, e.g. with regard to their risks or usefulness, is devalued as a lack of technical expertise and as female emotionality. At the same time, however, this denies women relevant agency as actors in the energy-related socio-technical transformation.

7. Research Perspective

This article has set itself the goal of expanding energy-related sociotechnical transformation research to include perspectives informed by gender theory that have been largely lacking to date. This was done on the basis of a pilot study that investigates the motivations behind the installation of renewable energy systems in owner-occupied homes and the subject-related positioning strategies in relation to these technologies of homeowners in their respective gender arrangements.

With the qualitative design of maximum contrasts, the initial aim was to identify and make sense of the gender-differentiated motivations and resources that transform owner-occupiers into change agents in the energy transition. An important finding that emerged was that women are relegated to marginal subject positions in this process, especially when they are living in heteronormative relationships, which at the same time deny them appropriate agency. Of course, the pilot study does not exhaustively capture this. In the future, further qualitative case studies will be needed to identify the full range of subject positions and the motivations and resources associated with them. It will be particularly

instructive here to identify those subject positions that are produced outside of heteronormative life contexts. In addition, the interweaving of these positionings with other categories of social inequality must be substantiated by making a decidedly intersectional-theoretical approach fruitful for this purpose. Subsequently, a quantitative design can build on a sound knowledge of the motivations and resources of sustainable energy practices in order to be able to make statements about the relevance of motivations and resource correlations.

In contrast to the expected patterns of behaviour and attitudes between women and men in heteronormative gender arrangements, the further analysis of further subject positions in terms of masculinities and femininities in connection with a intersectional approach is of particular interest here, as this can also be used to explore very different patterns of justification for the use and non-use of sustainable energy in the area of housing and mobility.

With regard to an actors-centered understanding of the energy transformation, a gender-sensitive framework is required und very useful. On the one hand, this must take into account the constitution of gender-differentiated actor behaviour, i.e. the different factors influencing actor behaviour, such as individual practices, goals, perception and learning processes. And secondly, the embedding of this diversified actor behaviour and interactions or lack of interactions with the sociotechnical system must be taken into account, insofar as questions of power also become relevant here.

The article therefore locates itself in the field of multi- and transdisciplinary energy research and expands it to include gender perspectives, which were previously in their infancy. The study builds on the ground-breaking work of Ursula Offenberger, whose work expands current behaviourist-oriented theoretical approaches to include practice and action-theoretical approaches. Regenerative energy supply and sustainable energy use can thus be examined beyond individual attitudes and behaviours and can instead highlight collective patterns and dynamics of sociotechnical transformations without losing sight of interaction-based, situational negotiation processes. (Offenberger 2016: 5) Combined with a critical feminist perspective, the structures and results of current knowledge production - here in the context of the sociotechnical energy transformation - can also be questioned and criticised with regard to their epistemic premises or (natural) scientific models of objectivity, universality and neutrality and their interweaving with a positivist understanding of science. (Hofmeister et al. 2013: 348f). How such an understanding is reflected in the practices and attitudes of homeowners who will be confronted with the installation of renewable energy systems in the near future due to current European and national legislation and how this reconfigures or reconfigures gender orders will be of great interest.

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Thematic Field E:

Mobility and Logistics: A Socio-Technical System on the Way to Sustainability

Navigating Complexity: Managing Multi-faceted Changes in India's Transport Sector

Dwarkeshwar Dutt[1]

[1]School of Public Policy, Indian Institute of Technology Delhi, India

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Abstract. In roughly the last two decades, new policy objectives like net-zero, developing industrial competence in emerging green technologies, and reducing fuel import dependence have been added over already existing ones like meeting growing fuel demand and air quality improvement to India's transport sector policy mix. To realize these multiple objectives, several alternative fuels and powertrains (AF&P) are being promoted. However, weaving multiple policy goals in a single coherent vision can create tensions between technological trajectories and pose governance challenges (especially in the short- to medium-term). This study takes a brief stock of the variegated AF&P landscape of India and through wide stakeholder interviews identifies three significant governance challenges. It is argued that addressing these would require shifting from the governance paradigm based on linear management of clearly structured problems towards a more reflexive approach. Based on the principles of reflexive governance and transition management, a reiterative governance framework is proposed.

1. Introduction

Traditionally, energy security objective i.e., fulfilling energy demand cost-effectively has been the fulcrum of national fuel policies. However, over the years, environmental concerns like climate change and air pollution have layered new policy objectives such as emission reduction, net-zero goal, and air quality improvement. Moreover, novel alternative fuels and powertrains (AF&P) are being developed and deployed and therefore, developing industrial competence in these new technologies has also become an important policy goal. In India, for instance, ethanol blending program to reduce oil imports was initiated in 2002 and has lately gathered steam. To address the air pollution issue, the Supreme Court mandated the use of Compressed Natural Gas (CNG) in public transport in Delhi 2002 (Narain et al., 2005). Since then, CNG has become a prominent fuel technology and recently the Government of India (GoI) has begun to promote its greener version - bio-CNG (MoPNG, 2022). In 2010, the GoI launched its first policy

program to promote electric vehicles (EVs) (Talwar, 2021). It also came out with a methanol roadmap in 2017 and launched National Hydrogen Mission in 2022. A selective chronology of major policy pronouncements for different AF&P is given in figure 1.

However, weaving these multiple objectives into a coherent policy vision can pose governance challenges as objectives may conflict with each other, particularly in the short- to medium-term. In this study, a brief overview of five important AF&P – EV, ethanol, bio-CNG, green hydrogen, and methanol – is provided in section 3, after introduction (section 1) and method (section 2). The fuel technologies are chosen based on their current or near-term market penetration, sustainability potential, and importance in the government's energy transition plans. Based on semi-structured interviews with a variety of stakeholders, the governance implications of managing this diverse landscape are discussed in section 4, which is followed by the final section 5, conclusion.

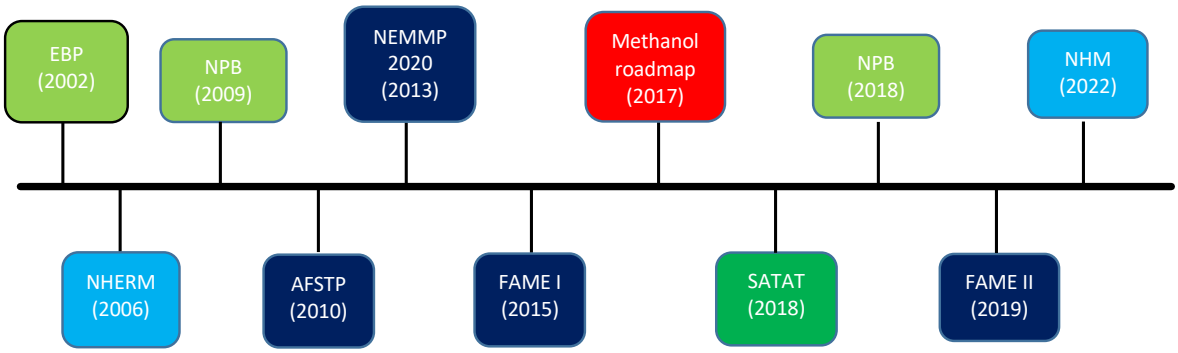

Figure 1. Timeline of major policy announcements (Colour codes for text boxes –electric vehicle: dark blue, ethanol: light green, bio-CNG: green, hydrogen: light blue, and methanol: red)

2. Method

The study employed documentary analysis and semi-structured interviews as methods for understanding India's AF&P landscape and its governance challenges. The documentary analysis consisted of newspaper and magazine articles, think tanks' and consultancy organizations' reports, government reports, and peer-reviewed articles. It provided a useful snapshot of the lay of the land and was supplemented with 21 semi-structured interviews from a variety of institutions such as government ministries, independent think-tanks, government associated organizations, public sector enterprises, and private automotive companies (see Table 1). Stakeholders were identified through a combination of internet search and snowball sampling. The interviews were electronically recorded with the respondents' prior permission.

The interviews were centred on certain themes like broad governance challenges in managing alternative fuels, policy-making processes, government's organizational structure, and conflict between different policy goals. The respondents are given

alphanumeric codes like I-1, I-2, etc. to maintain anonymity. The method of thematic analysis was employed to analyse the interview data. Thematic analysis basically involves examining data for prevalence of themes and is a common method for analysing interview or newspaper data (Joffe, 2012). It identifies and enables the researcher to analyse recurring patterns of expressions in her data (Braun and Clarke, 2006). Joffe (2012) argues that thematic analysis is a tool through which both manifest and underlying meaning of the data can be systematically analysed by capturing the nuances people bring to their expressions.

Table 1. List of respondents

S. No.	Position/Designation	Institution/Organization
1.	Director	Ministry of Heavy Industries
2.	Senior manager	Gas Authority of India Limited
3.	Research scholar (energy transition)	Council on Energy, Environment and Water
4.	Sr. deputy director	Automotive Research Association of India
5.	Deputy secretary	Ministry of Petroleum & Natural Gas
6.	Senior manager (project development)	Gas Authority of India Limited
7.	Chief manager	Gas Authority of India Limited
8	Senior Programme Lead	Council on Energy, Environment and Water
9	Distinguished Fellow	Observer Research Foundation
10	Head (Propulsion & Power System)	VegaPod Hyperloop
11.	Designer and technical advisor (automotive sector)	Self-employed
12.	Research analyst (mobility team)	Council on Energy, Environment and Water
13	Senior vice president	Ashok Leyland
14	Senior programme manager	World Resources Institute
15	Energy analyst	Institute for Energy Economics and Financial Analysis
16	Powertrain designer	Daimler Trucks Asia
17.	Manager	Euler Motors
18.	Energy consultant	Deloitte
19.	Senior manager	VOLVO Group India Private Limited
20.	Engineer	Bharat Petroleum Corporation Limited
21.	Senior officer	Gas Authority of India Limited

3. AF&P landscape in India

3.1. Electric vehicles

3.1.1. Policy initiatives and prospects

The first policy program to support EVs in India – Alternate Fuels for Surface Transportation Program (AFSTP) – was launched by the Ministry of New & Renewable Energy (MNRE) in 2010. Under AFSTP, INR 950 million was set aside for the period 2010-2012 for developing and promoting EVs (Talwar, 2021). The policy boosted the market of electric two-wheelers but sales declined sharply when it was terminated in 2012 (see figure 2) (Dutt, 2023; Tryti and Pareek, 2017). After that, the GoI introduced a more comprehensive National Electric Mobility Mission Plan (NEMMP) 2020 in 2013 (NEMMP, 2020). As part of NEMMP 2020, the government launched FAME (Faster Adoption and Manufacturing of Hybrid and Electric Vehicles) scheme (see Table 2). The first phase of the scheme lasted from 2015 to 2019 and the second phase begun in 2019 and will last till 2024 (FAME phase-I; FAME phase-II).

Table 2. Allocations under FAME schemes (Parihar and Urele, 2021).

FAME scheme phase-I		FAME scheme phase-II	
Component	Allocated fund (INR billion)	Component	Allocated fund (INR billion)
Technology platform	1.9	Demand incentives	89.56
Demand incentives	49.5	Charging infrastructure	10.00
Charging infrastructure	.30	Administrative expenditure	.38
Pilot projects	.70	Total for phase-II	96.34
IEC/operations	.10	Committed from phase-I	36.6

EV industry is a globally developing industry and a well-functioning self-sufficient EV supply chain would make countries less dependent on others for critical inputs. The GoI also launched National Mission on Transformative Mobility and Battery Storage in 2019 which is a phased manufacturing program to build domestic battery manufacturing capability (Parihar and Urele, 2021). NITI Aayog, a government think-tank, has also initiated National Programme on Advance Chemistry Cell Battery Storage which incentivizes setting up large battery production units with a capacity of at least 5 GWh (Gode et al., 2021). Finally, recent changes in the FAME scheme mandate domestic content requirement for EV producers for promoting domestic EV manufacturing (Dutt,

2023). A report by think-tank, Council on Energy, Environment and Water (CEEW), estimates that a strong policy push can lead to EV sales between 14 and 26 million units by 2030 (Singh et al., 2020).

3.1.2. Current market scenario, projects, and challenges

In India's automotive space, the electrification is expected to happen unevenly. Of the total EV sales, 79% is constituted by electric three-wheelers (including electric rickshaws), 17% by electric-two-wheelers, and merely 4% by electric four-wheelers (Parihar and Urele, 2021). The market for electric two-wheeler segment has expanded because of decreasing battery prices, government's policy push, and entry of vibrant start-ups like Ather (Dutt, 2023). In the high weight vehicle segments i.e., trucks and buses, the electrification is mostly happening at the level of public and private demonstration projects and small-scale pilot projects (PTI, 2022; HT Brand Studio, 2020). In the bus segment, for instance, the number of electric buses in India has increased from near zero in 2017 to more than 4000 in 2022 due to the government's procurement strategy (Wadhwa, 2022).

There are three significant issues pertaining to India's EV transition. First, India has to build a strong EV manufacturing capacity so that it does not lag behind other countries (Behuria, 2020). This would require a strategic policy framework, raw materials availability, and sufficient finance. A report estimates that building manufacturing capacity targeting 50% to 100% localization would need between INR 500 billion and 1 trillion (Singh et al., 2020). Also, the government has to secure supply of critical minerals such as lithium, nickel, graphite, and cobalt to build a complete supply chain and shield India from global fluctuations (Kumar and Thoopal, 2022; Parihar and Urele, 2021). Second, currently India has inadequate charging infrastructure which has to be expanded considerably to alleviate range anxiety of customers. According to an estimate, India would need close to 3,000,000 public charging stations by 2030 to support its EV targets (Gode et al., 2021). Further, due to unique factors like high number of electric two- and three-wheelers, hot and humid environment, and poor quality of grid electricity, India would need its own context specific solutions and can't adopt other countries' strategies (Lakshmi, 2022). Third, India's current EV penetration is very low and thus the market has to grow substantially to support its domestic manufacturing ambitions and encourage entry of new players. For this, India needs to adopt stronger EV policies along the lines of EV mandates adopted by California and China (Roychowdhury et al., N.D). Lack of clear policies also result in unwillingness of financial institutions to involve in extending debt to EVs and thus stifle the market (Singh et al., 2020).

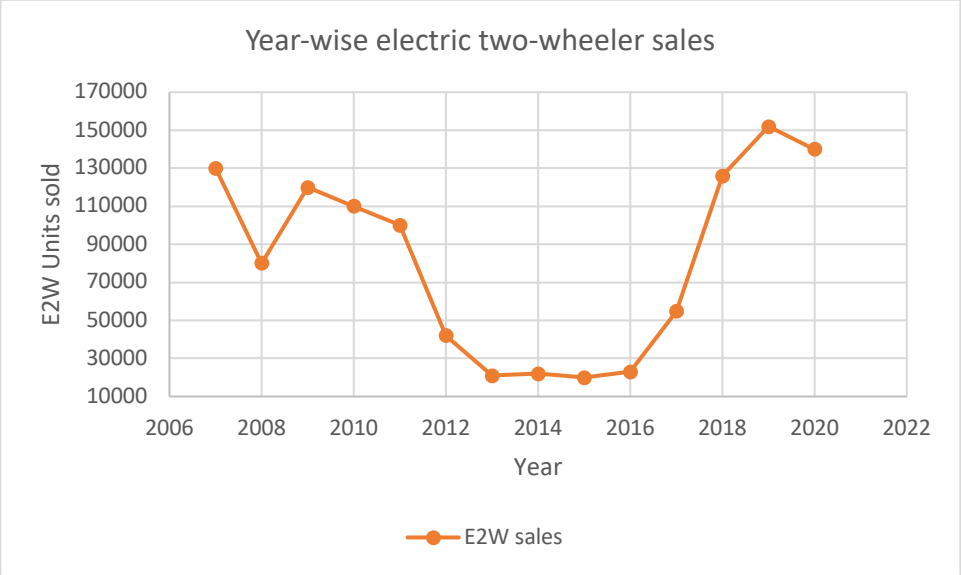

Figure 2. Electric two-wheeler sales in India. Source: Dutt (2023)

3.2. Ethanol

3.2.1. Policy initiatives and prospects

The initiatives to promote biofuels like ethanol began from early 2000's because of the rising oil imports (Saravanan et al., 2018). In 2001, a small 5% ethanol blending pilot programme was started, which was followed by India's first large scale ethanol initiative – Ethanol Blending Programme (EBP) – by the Ministry of Petroleum and Natural Gas (MoPNG) in 2002. It mandated 5% ethanol blending from 2003 in certain states and union territories (Aradhey, 2010). In 2009, National Policy on Biofuels (NPB, 2009) was adopted, which abandoned the mandatory aspect and adopted a target of 20% ethanol blending by 2017 (Chandel et al., 2017). In 2018, in the next iteration of biofuel policy – National Policy on Biofuel (NPB) 2018 – a target of 20% ethanol blending with petrol by 2030 was adopted (Das, 2020). Unlike earlier ethanol policies, NPB 2018 adopts a more holistic perspective and in addition to reducing oil import dependence, also focuses on augmenting farmers' income, generating rural employment, and promoting sustainability through judicious use of drylands (Prasad et al., 2020). It also provides a strong push to 2G ethanol that is produced from waste and doesn't conflict with food security. It adopts a Viability Gap Funding (VGF) scheme for infrastructure development under which a financial aid of INR 50 billion has been allocated for setting up of 2G bio refineries (CCEA, 2019). However, NPB 2018 also allows ethanol production from edible feedstock like sugarcane juice, sugar beet, sweet sorghum, and starch containing materials like corn (Mookherjee, 2022). Estimates show that 10% ethanol blending that India achieved recently has enabled it to save INR 410 million worth of fuel imports (Livemint, 2022).

India produces enormous quantities of agricultural waste which can be used for producing 2G ethanol. If such ethanol plants are set up, numerous rural job opportunities can be created in the areas of baling, hauling, transportation of biomass, and operation of plants (Singh et al., 2017).

3.2.2. Current market scenario, projects, and challenges

Most of the ethanol produced in India is utilized for the production of potable liquor and the surplus is used for fuel blending by Oil Marketing Companies (OMC) (Dey et al., 2023). In the last 5-6 years, India's ethanol production capacity has increased considerably (see figure 3). For instance, between 2010 and 2019, a 3700% increase in ethanol production for blending purposes has been seen (Roy et al., 2019). Recent estimates show that ethanol production capacity in India stands at around 9 billion litres of which 84% of ethanol is derived from sugarcane, 10% is accounted for by Food Corporation of India's rice stocks, and 5 per cent from maize/damaged food grains (Saini et al., 2023). Thus, most of the ethanol produced in India is 1G as more sustainable 2G technology is relatively underdeveloped. To develop 2G ethanol technology, the GoI has provided financial support for the period 2018–19 to 2023–24 for setting up of 12 commercial scale and 10 demonstration scale 2G ethanol projects using lignocellulosic biomass and other renewable feedstocks (Roy et al., 2019).

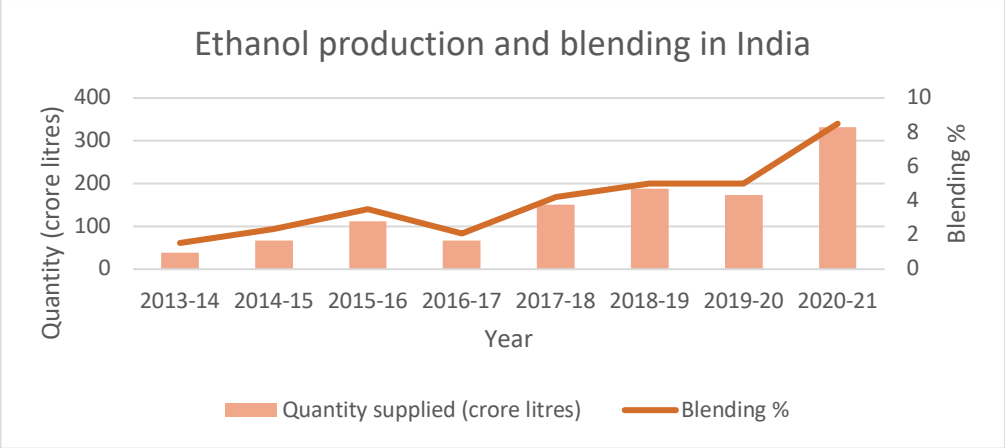

Figure 3. Ethanol production and blending in India (Source: MoPNG, 2022) (1 crore = 10 million)

The ethanol production in India faces several challenges. For 2G technology, the procurement window for agricultural waste feedstock is 15-20 days which makes it difficult to establish a sustainable biomass supply chain (Pandey et al., 2021). Sugarcane crop, which is a significant source of ethanol feedstock in India, is a very water intensive crop. One litre of ethanol from sugarcane requires about 3,000 litres of water. As India attempts to increase its ethanol production, groundwater depletion may get worse (Lee et al., 2020). Completion of all the stages of sugarcane cultivation takes a long time

rendering the land useless for cultivating other crops for about 4-6 years (Seth et al., 2021). Thus, increasing ethanol production may also interfere with India's food security.

3.3. Bio-CNG or compressed biogas (CBG)

3.3.1. Policy initiatives and prospects

CNG was introduced in India in early 2000's to improve air quality and has become an important part of the government's pollution control strategy since then (Bell et al., 2005). Further, the government wants to increase the share of gas in its energy mix from current 6.2% to 15% by 2030 (Nouni et al., 2021). A big part of this increase is expected to come from CNG deployment. However, increasing CNG production would adversely affect India's energy security as India imports around 50% of its natural gas. Further, although CNG produces less emissions than gasoline and diesel but it is still a fossil fuel. Bio-CNG on the other hand more sustainable than CNG as it is produced from agricultural, cattle, and urban wastes and can easily replace CNG (Munagala et al., 2022; Singhal et al., 2017).

The bio-CNG potential in India is estimated at 62 million metric tonnes (MMT). Therefore, the government launched the SATAT (Sustainable Alternative Towards Affordable Transportation) scheme in October 2018 to promote bio-CNG. SATAT policy plans to invest INR 2 trillion to set up 5000 bio-CNG plants across the country. This would result in production of 15 MMT of bio-CNG and 50 MMT of bio-manure as a by-product. Under the scheme, several incentives are provided such as assured offtake of the bio-CNG produced, long term agreements, priority sector lending, and financial assistance depending on the volume of bio-CNG produced with a cap of INR 100 million (MNRE, 2022).

3.3.2. Current market scenario, projects, and challenges

There are currently 17 bio-CNG plants operating in the country having an aggregate production capacity of 46,178 kg/day. Most of them are located in the western and northern parts of the country (Goyal, 2018). Governments trying to find a solution to the problem of rising waste are exploring bio-CNG plants as an option. For instance, Delhi government recently announced that it will set up 3 new biogas plants (Manupriya, 2018). India also has Asia's largest bio-CNG plant in the Sangrur district of the Punjab state and following setting up of this plant, the Punjab government is planning to set up 42 more plants that would cumulatively produce 492.58 tonnes of bio-CNG per day (Gulati, 2022, Kumar, 2022). It has also been reported that influential industrial houses such as Reliance Industries and Adani New Industries Limited are planning to make considerable investments in setting up of bio-CNG plants (Pathak, 2022).

A key challenge in the development of bio-CNG (and CNG as well) is the lack of pipeline infrastructure. Gas pipeline infrastructure is regionally skewed and its uniform expansion is necessary to boost demand (Corbeau et al., 2018). Also, the bio-CNG supply chain comprises different sectors like agriculture and urban waste and their co-ordination presents difficulties in efficient supply chain management. For instance, there is a lack of aggregation yards and formal aggregation models for collecting agricultural and livestock waste (Shrivastava, 2022). Similarly, many cities don't have adequate waste segregation facilities which are needed for bio-CNG plants' operation (Narayana, 2009).

3.4. Hydrogen

3.4.1. Policy initiatives and prospects

MNRE brought out India's first hydrogen and fuel cell roadmap called National Hydrogen Energy Roadmap (NHERM) in 2006 (Gupta et al., 2022). However, there has been a recent surge in the global attention to hydrogen. Therefore, the GoI launched a more holistic hydrogen initiative – National Hydrogen Mission – in 2022. The mission focuses on developing complete hydrogen value chain, catalyzing demonstration programs, development and deployment of hydrogen technologies, and addressing concerns pertaining to safety and standards (Qureshi et al., 2022). A national body called Indian National Hydrogen Energy Road Map (INHERM) has also been set up to promote hydrogen utilization in the power and automotive sectors (Greig and Sharma, 2022). The government has also launched an ambitious 'hydrogen 2-1-2' initiative which aims to decrease the cost of hydrogen fuel by two times compared to gasoline, reducing the cost of hydrogen storage, distribution, and refuelling to less than $1, and generate a favourable return on investment for hydrogen in less than two years (Kannah et al, 2021). India already is one of the cheapest producers of solar energy which can be leveraged to power production of green hydrogen (Bhardwaj, 2021). Green Hydrogen would help India in achieving its goals of energy independence by 2047 and net-zero by 2070.

3.4.2. Current market scenario, projects, and challenges

Hydrogen fuel is currently in the demonstration stage but can find commercial applications in the future in the heavy-duty vehicle segment where electrification is less feasible (Danielis, 2020). Several pilot projects have been initiated for testing hydrogen fuel's feasibility. Tata Motors in collaboration with Indian Oil Corporation Limited and Indian Space Research Organisation (ISRO) showcased India's first hydrogen fuel cell bus in 2018 (Express drives desk, 2018) and after evaluation of the trial run, Indian Oil Corporation Limited invited bids for 15 fuel cell buses in 2020 which was won by Tata Motors. The buses are expected to be on road in June 2024 (Anon. (2021). Two hydrogen refuelling stations have also been set up at Gurugram and Faridabad in the state of

Haryana by Indian Oil R&D Centre and National Institute of Solar Energy respectively (Sontakke and Jaju, 2021). Being a new and undeveloped technology, cost is the most significant barrier for hydrogen fuel. Green hydrogen production uses water electrolysis to produce hydrogen which is a very expensive process and until cost is considerably reduced, hydrogen take-off is unlikely to happen. In addition to the cost, other factors like lack of hydrogen fuelling infrastructure, safety concerns, and delicate powertrain system of hydrogen vehicles also inhibits its uptake (Das, 2021).

3.5. Methanol

3.5.1. Policy initiatives and prospects

Methanol, also known as wood alcohol, is an alternative biofuel that can be blended with gasoline and used in ICE vehicles. It can be produced from a variety of sources like natural gas, coal, and biomass (Saraswat and Bansal, 2021). It is a recent addition to the AF&P basket in India and as such planning is still in the early stages with no clear policy roadmap. However, some recent high-level initiatives regarding methanol fuel development indicates the government's seriousness in developing it.

In 2016, NITI Aayog organized an international conference on methanol economy to elicit perspectives from various stakeholders like industry, academia, policy makers, and government officials (Shih et al., 2018). Following this, a taskforce called Methanol Economy taskforce was set up which published a report in 2017 with the title 'India's Leapfrog to Methanol Economy'. The report highlighted methanol's potential in reducing oil and gas imports and argued for increasing use of methanol as transportation fuel, cooking fuel, and as a diesel substitute in power generators used in telecom towers (Saraswat and Bansal, N.D).

In December 2017, NITI Aayog announced that it is preparing a roadmap for India's methanol economy and proposed a plan to set up a Methanol Economy Fund of around INR 50 billion (Saraswat and Bansal, 2021). An important benefit of using methanol as an alternative fuel is that since it can be produced from coal gasification, it can allow for optimum usage of India's coal reserves. Coal usage for power generation is likely to decline in the future and India can divert its vast coal reserves for methanol generation. Moreover, coal gasification when combined with CCS technology produces very little emission and therefore can contribute to India's net-zero goal (Shih et al., 2018).

3.5.2. Current market scenario, projects, and challenges

India has very low methanol production capacity. In 2020-21, its methanol production capacity was 0.23 million tonnes (Mt) (Saraswat and Bansal, N.D). In contrast, China blended around 21 Mt of methanol with gasoline in 2016 (Anon., 2023). At present, there are no commercial scale methanol plants in India but the government has set up some pilot projects. A technology demonstration public-private partnership project has been initiated between a prominent Indian technological university and Thermax, an environmental solutions company. The aim of the project is to develop and refine indigenous technology for methanol production from high-ash Indian coal (Anon., 2020).

A pilot project to study the feasibility of 15% methanol blended petrol (M15) has been started in the state of Assam and would be extended to other areas if the outcomes are satisfactory (Ray et al., 2021). The main challenge in developing methanol fuel in India is lack of a clear policy roadmap or mission. Some visions and goals have been stated but a detailed roadmap is yet to be articulated by the government. Another obstacle is uncertainty regarding production cost. While Saraswat and Bansal (2021) argue that methanol would be cheaper than ethanol and petrol even when subjected to comparable tax regimes and other costs, however, in absence of commercial scale production, an accurate picture can't be provided.

4. Discussion

4.1. Governance challenges

The energy transition in India's transport sector is currently in a state of great flux. The government is trying to achieve multiple objectives and aggressively promoting many AF&P that are at different stages of maturity (see Table 3 for summary). The progress on ethanol blending and EV penetration is taking place gradually, though the ambitious targets are likely to be missed. Bio-CNG has the advantage of a ready market but has not taken off as expected. Methanol and green hydrogen are at very early stages of development and would require sustained support for years to mature as viable fuels.

Ethanol and methanol blending will help in reducing oil imports and save foreign exchange, bio-CNG deployment can be very effective in reducing vehicular air pollution in cities and reduce gas imports to some extent, and EVs and green hydrogen fuel are expected to support long term net-zero and industrial development goals. Different technological options, thus, are underpinned and justified, to different degrees, by different values such as long-term environmental sustainability, industrial competence, energy security etc. and currently all desirable values don't converge into any single option (see Table 4). These different objectives are likely to be achieved at different time

scales, require different technologies, different kind of policy support, massive investments and may compete for resources.

Table 3. Summary table for different AF&P

Fuel/Technology	Policy goals and visions	Market status	Main objective(s)	Challenges	Magnitude of Investment
EV	Sales target of 30% for private cars, 70% for commercial vehicles, and 80% for two-and three-wheelers by 2030	Subsidy driven Little market penetration in two- and three-wheelers Procurement driven uptake in public sector city buses Pilot projects in other vehicle segments	Developing industrial competence in EV Net-zero goal	Lack of battery manufacturing capacity Challenges of grid integration Upfront cost of EVs	INR 148 trillion by 2030 to achieve policy targets
Bio-CNG	SATAT scheme envisages 5000 CBG plants with production capacity of 15 MMT of CBG and 50 MMT of bio-manure per annum by 2023-24	Ready market as a percentage of three-wheelers, buses, and cars run on natural gas Slow progress of SATAT scheme with only 38 commissioned plants	Cutting natural gas import dependence Addressing poor city air quality	Supply chain management issues pertaining to aggregating and segregating waste Lack of uptake of bio-manure Shortage of skilled professionals and lack of standards for the waste-to-energy segment Lack of inter-departmental co-ordination	INR 2 trillion to set up 5000 bio-CNG plants by 2024
Ethanol	Blending target of 20% by 2025	Blending target of 9.45% achieved recently Most bioethanol produced through 1g and 2g technology relatively underdeveloped	Cutting down oil imports	Sugarcane farming for bioethanol production leads to groundwater depletion Using food grains can lead to food vs. fuel dilemma Lack of inter-departmental co-ordination	INR 454 billion to achieve 20% blending by 2025
Green Hydrogen	National Green Hydrogen Mission envisages production of 5 MMT of green hydrogen per annum by 2030	Limited to pilot projects for buses and trucks	Developing industrial competence in green hydrogen Net-zero goal	Production processes still expensive Hydrogen production from coal is an emission intensive	INR 197.44 billion approved for National Green Hydrogen Mission
Methanol	No specific targets	Limited to few blending pilot projects	Cutting down oil imports	Nascent technology so considerable ambiguities regarding cost and regulatory structure	Methanol Economy Fund of around INR 50 billion is planned

Table 4. Matrix table of AF&P against policy objectives

	Objectives (Values)	Reducing import dependence (energy security)	Industrial competence	Air quality (short-term sustainability)	Net-zero (long-term sustainability)
Alternative fuel or powertrain					
Electric vehicles		*	***	*	***
Ethanol		***		***	
Bio-CNG		***		***	*
Hydrogen		*	***		***
Methanol		***			

4.1.1. Inter-sectoral co-ordination

A primary challenge in managing simultaneous transitions involving multiple technologies is to forge a strong inter-sectoral co-ordination, which has to be realized at two levels – systemic level and technology supply chain level. At the systemic level, there is a need to co-ordinate the visions and transition trajectories of different fuel options. The governance structure of the fuel options considered in the study is dispersed among different ministries and departments. Therefore, individualistic visions and goals of these organizations have to be woven into a coherent, long-term, unified, and strategic vision. In general, climate policy governance processes in India have been considered as fragmented and lacking a clear vision (Kumar and Naik, 2019). Similar shortcoming was also observed during the interviews with respect to the energy transition governance. A respondent from a public sector enterprise stated:

We [different ministries and departments] apparently have different objectives and aims which can sometimes seem to be not in tune….better co-ordination will surely help in making good policies….hmm….but it's not easy' (I-4)

Another public sector enterprise respondent, I-12, recalled attending an energy conference attended by officials from different ministries and observing 'a general sense of confusion with respect to long-term goals'. Currently, there doesn't seem to be an effective platform where different stakeholders can come together to share their visions and discuss issues regarding the transport sector's energy transition. On being asked if such a platform exists or is currently being planned, a high-ranking ministry official succinctly pointed out that s/he was not aware of any such platform (I-8).

At the level of individual options too, co-ordination between different ministries and departments is needed to establish a robust a supply chain. The supply chain of fuel technologies considered in the study span across different sectors with different organizational and institutional structures. Markard (2018) argues that in the next phase of energy transitions, where focus would be on accelerated deployment, such cross-sectoral linkages would be crucial. For instance, for bio-CNG and ethanol, co-ordination is needed between agriculture, urban waste-management, fuel production, and transport sectors. Similarly, for EVs, co-ordination with electricity sector is imperative for large scale deployment. Respondent I-3, who has been involved in managing ethanol supply chain, stated:

'It is a challenge to maintain biofuel supply chain. There is such a diversity of actors….farmers, biomass aggregators, fuel producers and fuel buyers. Different domains are involved [in the supply chain] and you need people who can bind these domains together'.

4.1.2. Balancing policy neutrality and specificity

In multiple technology options, the question of technology neutral vs. technology specific policy support often arises. Conventionally, popular opinion usually favours a technology neutral hands-off approach, by offering a level playing field with minimum common technological standards and allowing the market factors to play dominant role (Sandén, and Hillman, 2021). This approach is based on the argument that the state is often not in a good position to pick winners (Sandén and Azar, 2005). The automobile lobby organization Society of Indian Automobile Manufacturers (SIAM) has also advised the Indian government to adopt a technology neutral approach (SIAM, 2019). However, some scholars argue that in the context of sustainability transitions, the role of the state should not be limited to providing passive support but rather adopting a more proactive approach (Sandén and Azar, 2005). According to them, sustainability transition is an inherently political process and a hands-off approach may result in sub-optimal outcomes (Azar and Sandén, 2011).

Although by and large, the respondents understood and even accepted the government's obligation to simultaneously promote several fuel options enthusiastically, still, some of them indicated a lack of strategic long-term vision in the current approach. As one think-tank respondent commented:

'It seems that the government's strategy is to throw everything at the wall and see what sticks….they [policy makers] have their reasons for doing so....i know….but a more detailed and strategic approach is required' (I-6).

A respondent from a prominent automobile company also shared a similar sentiment:

'More clarity from the government on the technology direction would be welcome….surely….but we don't know when we would get it….so, what we are doing is that we are working on multiple technologies so regardless of where markets or government goes….we would be ready (I-11).

A strategic approach going beyond simultaneous promotion doesn't mean picking winners or promoting some selected technologies but aligning the different technological trajectories in a coherent fashion with respect to the long-term sustainability goal.

4.1.3. Articulating the role of gas in the transition

A concrete case of the above ambiguity involves articulating the role of gas in transport sector's energy transition, which was pointed out as a prominent issue by several respondents. A recent official document of the GoI - Long-Term Low Emission Development Strategy identifies gas as a 'transition fuel', however the strategy of employing it as a transition fuel is not clear. Lobby organizations like SIAM and other gas supporters want more incentives for promoting gas deployment and are wary of the government's aggressive EV push (SIAM, 2019). However, as the government expands gas infrastructure with the massive investments, the fear of sunk investments is likely to aggravate concerns over institutional and infrastructural lock-in into gas.

Unfortunately, there has been very little discussion in India's low-carbon transport policy discourse on the possibility of gas lock-in, its implications for India's energy transition, and ways to address it. A report by a think tank, CEEW, did highlight gas lock-in and argued for capping gas penetration in India's energy mix at 18% (Malyan et al., 2021). However, lock-in by its very nature resists such an easy escape at a specified point. A think-tank respondent did recognize the problem as a 'tricky one' but also mentioned that 'the government should be more concerned about meeting India's growing demand' (I-13). On the other hand, a ministry respondent relatively openly acknowledged the governments' ambiguity regarding gas' role:

Yes…it [gas' role] is something we have still not figured out completely….specifically, the CNG vs. electric is a bit of a problematic area for us as of now (I-2)

4.2. Governance paradigm for India's low-carbon transport transition

The traditional governance paradigms were formulated and developed for contexts where problems are clear and structured and policy process is a linear exercise. However, this paradigm falls short in a situation which involves long-term objectives, uncertainties, and potential value conflicts. The governance challenges engendered by such situations are inherently political. Therefore, addressing them would need a governance paradigm suited for long-term policy making, underpinned by consultation and reflexivity.

A significant aspect of this governance paradigm is to understand the interlinkages between technology, values, and policy objectives. Energy technologies are underpinned by different values like affordability, sustainability, industrial competence, feasibility, and efficiency. Among these, the values of sustainability and industrial competence have acquired a prominent place in the energy policy discourse in the last few years. A given technological option may help in realizing some objectives but not others and thus, while promoting a technology, clash between different values (and objectives) is not uncommon (Milchram et al., 2019). However, the connection between values, visions, and technologies in energy systems is often not scrutinized adequately (Trutnevyte, 2014).

According to Busch et al. (2014) a low-carbon strategic vision is constituted by strategic objectives, which are a combination of environmental and economic goals and a strategic framework, which articulates problem framing, desired solutions, and governance processes. Aligning economic and environmental goals is a daunting task and thus the vision has to be developed through an extensive stakeholder consultation. The process is likely to involve negotiations and compromise. In other words, the vision would be political in nature (Azar and Sandén, 2011). Understanding the connection between technology, values, and policy objectives would shed light on the conflicts and complementarities between different visions. Considering the political nature of consultation, identifying these conflicts and complementarities is not likely to eliminate former completely but it can help provide points of deliberation for developing a shared transition vision through wide stakeholder consultation.

During the course of long-term transition, social, political, and economic contexts change. Also, as technologies develop, the complementarities and trade-offs between them are also likely to change. All this would cause a concurrent shift in the dynamics between technology, values, and objectives. Thus, in a rapidly evolving state, any shared vision arrived at has to be periodically revisited and recalibrated. This would require incorporating reflexivity in the governance. In essence, this would require embracing the multi-dimensionality of problem framings and keeping the policy processes and goals open ended. Instead of providing one right solution to the problem, policy making in this

case must be a reiterative exercise of experimentation, learning, and knowledge integration (Voß and Bornemann, 2011) (see figure 4).

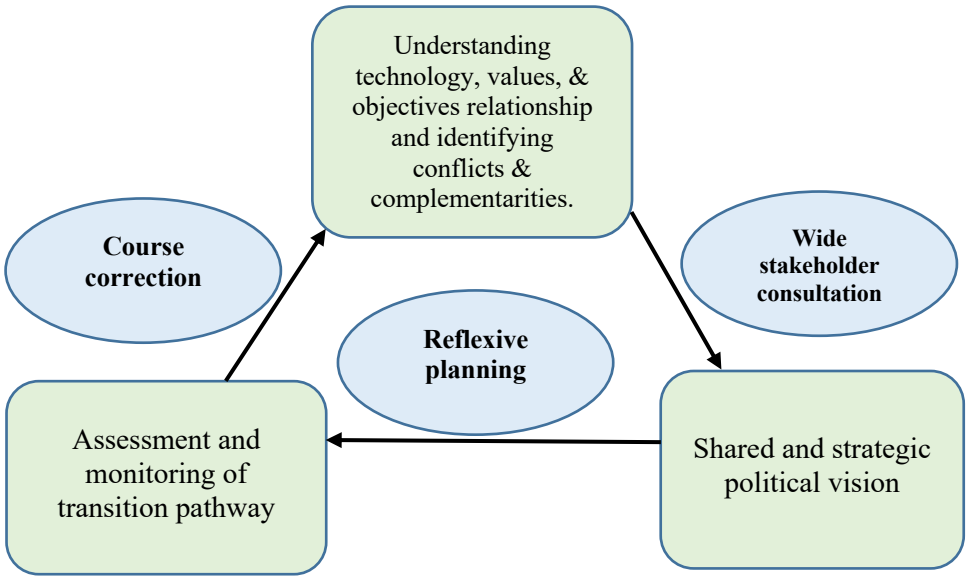

Figure 4. Iterative governance paradigm for development of India's low-carbon transport

5. Conclusion

India's alternative fuels landscape has undergone substantial changes in the last two decades. From being dominated predominantly by a single fuel (gasoline/diesel), it looks much more variegated as the government simultaneously pushes for multiple options to realize its different objectives. This simultaneous development of multiple fuels poses some significant governance challenges that can't be addressed through conventional linear policy making. In this study, we highlighted the governance challenges associated with promotion of multiple technologies at the same time and suggested an iterative governance approach based on the principles of reflexive governance and transition management as an alternative. The approach consists of understanding the sources of conflicts between different objectives, develop a shared vision through wide stakeholder consultation, and periodically calibrating the vision in the wake of changing external conditions.

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Investigating Autonomous Vehicle Readiness of Cities: a Structured Text and Content Analysis

Miklós Lukovics[1]

[1]Faculty of Economics and Business Administration, University of Szeged, Hungary

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Abstract. The process of urban integration of autonomous vehicles is posing increasing challenges for many cities today. Based on the growing number of autonomous vehicle tests on urban roads, it seems that the urban presence of these vehicles requires only minimal preparation from cities. However, their widespread adoption, integration, and effective and safe operation at the urban level require substantial preparation. Various studies have explored the key factors influencing AV readiness using different methods such as backcasting, online surveys, and expert interviews. However, the added value of our work lies in synthesizing these individual findings through software-supported structured text and content analysis using MaxQDA 2023 software. Based on the results, nine main factors and twenty-seven key elements that could be crucial in supporting the future mass adoption of autonomous vehicles in urban areas are identified. The paper seeks to contribute to a deeper understanding of urban autonomous vehicle readiness and the identification of measures necessary to achieve it[1]. Representing the 27 key determinants with indicators offers a great opportunity for further research, thereby urban autonomous vehicle readiness could be measured based on this synthesized framework.

1. Introduction

The question today is not if autonomous vehicle-driven urban mobility will become a reality, but when (Threlfall, 2018). (Threlfall, 2018). There are various estimations about it, nevertheless, the technological developments related to AVs have accelerated by now (Grindsted et al, 2022). The number of involved cities and companies with road test permit is increasing; In July 2024, California issued road test permits to 7 companies

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without safety drivers, granted deployment permits to 3 companies, and allowed 36 additional companies to test with safety drivers.[2].

One of the companies has already travelled 20 million kilometers with over 600 vehicles accident-free throughout the USA, completing over 2 million paid rider-only trips[3]. There is a major expansion in the urban robotaxi services functioning without a safety driver in developed countries; the number of both the issued permits and the areas covered by the service is dynamically growing (Zou – Xu 2023, Tavor – Raviv 2023).

The potential benefits of the autonomous vehicle revolution have significant potential for well-prepared cities. Some authors highlight the benefits of traffic reduction claiming that sharing-based AV fleets will be able to move the same amount of traffic by using fewer vehicles compared to privately owned vehicles (Liljamo et al., 2021, Kesselring et al., 2020, Spurling – McMeekin, 2014, Fagnant – Kockelman, 2016, Alazzawi et al., 2018, Martinez – Viegas, 2017, Overtoom et al., 2020), thus the new mobility system may substantially reduce the number of vehicles in urban traffic (Alazzawi et al, 2018; Martinez and Viegas, 2017; Overtoom et al, 2020). Autonomous vehicles can represent a new urban mobility paradigm, where private car ownership is replaced by autonomous fleet usage and integrated transport system, active urban mobility, and sustainability play an important role (Medina-Tapia – Robusté, 2018, Kovacic et al 2022, Zardini et al 2022). Based on other scenarios, autonomous vehicles can become counterproductive (especially if they are privately owned), and, contrary to expectations, they may slow down urban mobility (Overtoom et al, 2020; Alam and Habib, 2018).

Other authors emphasize that the mass adoption of autonomous vehicles entails economic and social benefits (Threlfall, 2018, Lipson – Kurman, 2016, Litman, 2017, Bezai et al., 2021): the hours spent driving can be converted to productive time, the number of road accidents caused by human error can be reduced, safety and comfort can increase, environmental pollution and fuel consumption can decrease, and the movement of disabled and elderly people can become easier (Litman, 2017, Bezai et al., 2021).

However, several urban challenges are associated with autonomous technologies (Threlfall, 2018, Bezai et al., 2021), including the potential vulnerability of the transport system (Alfonso et al., 2018, Atzori et al., 2018), traffic management (Straub Schaefer, 2019), and urban budget (Smahó 2021). Narayanan et al. (2020), DuPuis et al. (2015), Chapin et al. (2016) and Fraedrich et al. (2019) found that urban land use is one of the major areas where autonomous technology and lifestyle tendencies collectively give rise to substantial changes.

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[2] Currently available on https://www.dmv.ca.gov/.

[3] www.waymo.com

As a result, the concept of urban autonomous vehicle readiness becomes more significant, which highlights that the success of autonomous vehicle adoption does not only depend on the advancement of the technology but also on the characteristics of the receiving environment; cities must take proactive steps for the safe introduction of AVs (Khan et al., 2019). Autonomous vehicles require special urban development interventions for the safe operation of the technology. AV-specific urban development is key in the realization of benefits and avoidance of drawbacks expected of from autonomous vehicles. Without it, autonomous vehicles may even increase the mobility problems which road authorities currently face (Duarte–Ratti, 2018).

The present research investigates what is required for the mass adoption and effective and safe operation of autonomous vehicles in future cities. The methodology of the research is software-supported structured text and content analysis, in which the factors and key determinants of the autonomous vehicle readiness of cities is determined by coding and analyzing 223 key factors identified in the international literature. The results can provide important assistance for urban policy makers and professionals to understand the logic of the new urban mobility paradigm and the preparation required in their city to support the mass adoption of autonomous vehicles.

To achieve the research goal, we review the literature on the topic and then present the analysis methodology and the database. Following this, we discuss our findings, focusing on the factors and the 27 key determinants, which we introduce individually. Finally, we conclude the study with our conclusions.

2. Literature Review

In terms of capturing AV readiness, the widely referenced AV Readiness Index of KPMG must be highlighted, which defines autonomous vehicle readiness with the help of four pillars (technology, policy and legislation, infrastructure, social acceptance) (Threlfall, 2018). As the critical mass and spatial concentration of autonomous vehicles which represents an issue requiring the most comprehensive planning and preparation will affect cities, the present study focuses on capturing AV readiness on urban level. Nevertheless, the national framework is considered an important cornerstone which the interventions of urban autonomous vehicle readiness must match.

Studies on urban AV readiness generally focus on a few specific areas in many cases (e.g. legislation, infrastructure, land use, governance, and social aspects). Several studies emphasize the prominent role of infrastructure when examining the factors of AV readiness.

Riggs et al. (2020) tested how AVs can appear on city streets to increase urban liveability with a focus group including car manufacturers, engineers, and planning and policy professionals. They emphasize that road infrastructure becoming AV-friendly is key, but it is a long and gradual transformation process. Manivasakan et al. (2021) focused on developing, evaluating, and testing urban infrastructure supporting AVs. They defined three factors to evaluate the readiness of AV-compatible infrastructure: safety, efficiency, and availability. Based on the results of Chajka-Cadin et al. (2020), the first step of the adoption of connected and autonomous vehicle technology is the development of physical and telecommunications infrastructure. Dale-Johnson (2019) studied the issue of urban AV readiness with a focus on legislation and property market, identifying the following related factors: safety of AVs, their integration into the transport ecosystem, land use, infrastructure, and municipal revenues.

Lau and van Ameijde (2021) consider the topic of AV readiness an urban planning task. They ran several simulations with an animation software to explore how the use of AVs can lead to more open urban spaces, dynamically changing flexible zones, and progressive social processes. Aoyama and Leon (2021) examined the urban appearance of AVs in terms of governance, suggesting that cities must implement four complementary functions for successful AV deployment: regulator, mediator, data catalyst, and promoter. In a similar approach, Zhou et al. (2021) highlighted the impact of the transformation of mobility on land use and urban development. Grindsted et al. (2022) also apply the governance aspect of AV readiness, analyzing 39 planning documents of 10 European capitals according to the objectives related to sustainable cities and communities defined by the UN. They found that municipalities must make specific interventions if they would like autonomous technology to contribute to the objectives targeted at sustainable development.

Campisi et al. (2021) approach AV readiness from the aspect of smart cities and identify the criteria of urban mobility optimization, paying special attention to the future development of AVs. Seuwou et al. (2020) also study AV readiness from the aspect of the mobility of future smart cities, identifying six factors: consumer acceptance, cost of vehicles, legislation and issue of responsibility, social and ethical problems, cyber and data security and data protection concerns, and infrastructure. Milakis and Müller (2021) focus on the societal dimension of the deployment of autonomous vehicles in terms of AV readiness, and identify three related key areas: societal acceptance, societal implication, and the governance of autonomous vehicles (Table 1).

Table 1. Studies capturing the key topics of urban autonomous vehicle readiness

Author(s)	Focus	Characteristic
Aoyama and Leon (2021)	Governance	They describe various types of roles of cities on a conceptual level from four aspects: city as regulator, mediator, data catalyst, and promoter. Two examples are presented based on Pittsburgh, Pennsylvania, and Boston, Massachusetts.
Campisi et al. (2021)	Smart city	They review the development of smart cities, defining a methodology which enables identifying the criteria for determining the optimization of urban mobility, paying special attention to the development of future autonomous mobility.
Chajka-Cadin, et al. (2020)	Infrastructure	Autonomous vehicles and connected autonomous vehicles. Their work is based on the experience and opinion of representatives and professionals. Questionnaire survey is conducted.
Dale-Johnson (2019)	Legislation	Interviews with well-informed professionals. Comprehensive description of the pillars of readiness. Questionnaire survey is conducted.
Grindsted et al. (2022)	Governance	Apart from the impacts of shared autonomous vehicles, the impacts of privately owned autonomous vehicles. They compare plans with the objectives of UN related to sustainable cities.
Lau and van Ameijde (2021)	Urban planning	It breaks with car-based planning practice. Wide-ranging applications of autonomous vehicles.
Manivasakan et al (2021)	Infrastructure	Readiness is quantifiable. Readiness is considered in general, covering the entire autonomous vehicle phenomenon.
Milakis and Müller (2021)	Society	Backcasting approach. It covers a wide spectrum of the pillars of preparing for autonomous vehicles.
Riggs (2020)	Infrastructure	Level of awareness ensured through education. Involving different stakeholders.
Seuwou et al. (2020)	Smart city	Autonomous vehicles are presented as a necessary instrument for achieving the aims of cities. It describes obstacles and makes proposals.
Zhou et al. (2021)	Governance	It studies short-, medium-, and long-term effects. Making a distinction between socio-economic groups.
Zomarev and Rozhenko (2020)	Governance	Comprehensive review of the emergence of autonomous vehicles. They differentiate the set-out measures according to 4 potential future scenarios.

The international literature contains examples where researchers applied a comprehensive holistic approach, these served as the basis for our qualitative research. Fraedrich et al. (2019), Freemark et al. (2020), Brovarone et al. (2021), Jiang et al. (2022), CEG (2019), Fagan et al. (2021), NSW (2022), Zali et al. (2022), KPMG (2018),

define the main groups and areas which determine the autonomous vehicle readiness of cities (Table 2). Beyond that, Khan et al. (2019) define the index of urban autonomous vehicle readiness. Numerous studies have examined the critical determinants of AV readiness through a variety of methodologies, including backcasting, online surveys, and expert interviews, case studies. What distinguishes our research is its focus on integrating these diverse findings into a cohesive synthesis, utilizing structured text and content analysis supported by MaxQDA 2023 software. The empirical survey of the present research relies on the factors defined by these studies.

Table 2. Studies comprehensively capturing urban autonomous vehicle readiness

Author(s)	Main groups	Methodology	Number of factors
Fraedrich et al. (2019)	Transport planning, Traffic management, Infrastructure planning, Urban planning, Participation Other aspects	interviews	18
Sperling et al. (2018)	National level, Local level	narratives	11
Freemark et al. (2020)	Land use, Environmental protection and equity / fairness, Transport system	online survey	12
Brovarone et al. (2021)	Mobility, Innovation, Telecommunications, Physical infrastructure	backcasting	37
Jiang et al. (2022)	Infrastructure, Directives, legislation and policy, Population	online survey	19
CEG (2019)	Infrastructure, Policy	narratives	12
Fagan et al. (2021)	Promotion of MaaS, Land use, Managing and reducing congestions, Data sharing, Income repositioning	case studies	22
NSW (2022)	Law and safety, Infrastructure and planning Transport services, Data, Consumer acceptance	narratives	12
Zali et al. (2022)	Social acceptance, Infrastructure, Directives and legislation, Technology and innovation	fuzzy Delphi	48
Khan et al. (2019)	Directives and legislation, Physical infrastructure, Cyber infrastructure	online survey	16
KPMG (2018)	Directives and legislation, Technology and innovation, Infrastructure, Social acceptance	questionnaire	16
Total			**223**

3. Method and Data

To achieve the research objective, qualitative research was conducted in the form of software-supported structured text and content analysis. The literature analysis included the identification of research findings which interpret urban autonomous vehicle readiness in a comprehensive holistic approach and define its key factors. The present research aims to synthesize these factors with structured text and content analysis. 223 factors in total listed in Table 2 were involved in the analysis. The factors were processed with MaxQDA 2023 software, which conducts qualitative data analysis and derives quantitative information through different metrics (Kuckartz – Rädiker 2019). In order to achieve these objectives, the first step was coding (Fig. 1).

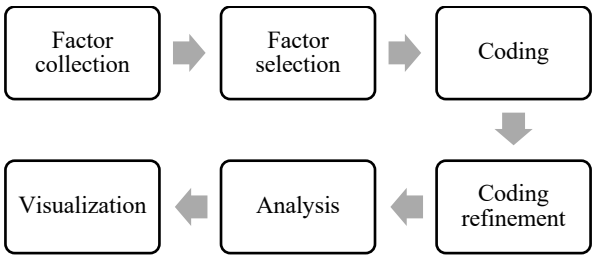

Figure 1. Framework of the primary research

In the coding process, patterns were searched during the text analysis of factors, based on which the original raw data were standardized with a predefined framework (Creswell 2013, Babbie 2016, Brait 2020). In qualitative research, codes serve as attributes, briefly summarizing the content, whether it is linguistic or visual (Saldaña 2013). By assigning the codes to the textual description of the factors, the contents described in the factors can be evaluated in a standard framework. The coding process enabled arranging the factors of urban autonomous vehicle readiness into a single structure, which contributed to exploring the patterns underlying the contents of factors. Often several codes were assigned to a coding unit by applying simultaneous coding (Saldaña 2013).

When defining the codes, it was important to minimize the analyst's subjectivity, therefore, a framework which is accepted in wide professional circles was chosen. The research relied on the areas defined in the reviewed literature. The coding process was carried out manually in two steps, in MAXQDA software. First, all main groups defined in the literature were put in the code list, resulting in 13 codes (Table 3).

Table 3. Codes definable based on the reviewed studies

Code / study	Fraedrich et al. (2019)	Freemark et al. (2020)	Brovarone et al. (2021)	Jiang et al. (2022)	CEG (2019)	Fagan et al. (2021)	NSW (2022)	Zali et al. (2022)	Khan et al. (2019)	KPMG (2018)
Policy and legislation				X	X		X	X	X	X
Technology			X					X		X
Physical infrastructure	X		X	X	X		X	X	X	X
Public readiness	X			X			X	X		X
Integration	X	X				X	X			
Data						X	X			
Safety							X			
Vehicle communication		X								
Business model						X				
Virtual infrastructure			X					X		
Planning	X						X			
Land use		X				X				
Urban mobility	X	X	X			X				

The second step is the fine tuning of codes, where the codes can be complemented with new codes and subcodes created during a deeper analysis of the texts (Saldaña 2013). In this case, a deeper analysis of the 223 factors required the inclusion of a new code, the code of vehicle communication, and the code system ultimately consisted of 14 codes:

1. Policy and legislation
2. Technology
3. Physical infrastructure
4. Public readiness
5. Integration
6. Data
7. Safety
8. Environmental protection
9. Business model
10. Virtual infrastructure
11. Planning
12. Land use
13. Urban mobility
14. Vehicle communication

4. Results

In the coding process, 446 codes in total were placed in the text system formed by the 223 analyzed factors of urban autonomous vehicle readiness. Their number and relative frequency of occurrence in the code system can be monitored and it is found that the *urban mobility* code was placed in the text system most frequently, 65 times, while the less frequent was the *environmental protection* code, only 5 times (Table 4). The variation of the occurrence of the codes is relatively high, the range is 58. Among the fourteen codes, four codes, *urban mobility*, *policy and legislation*, *technology,* and *physical infrastructure* cover over 50% of the total number of codes. In contrast, the total occurrence of the four least frequent codes (*environmental protection, integration, safety, land use*) is lower than the most frequent urban mobility code.

Table 4. The occurrence and proportion of each code in the text system

Code name	Number of placed codes (pcs)	Relative occurrence of codes (%)
Urban mobility	63	14.13
Policy and legislation	61	13.68
Technology	52	11.66
Physical infrastructure	51	11.43
Business model	36	8.07
Virtual infrastructure	36	8.07
Public readiness	29	6.50
Vehicle communication	26	5.83
Planning	21	4.71
Data	19	4.26
Land use	18	4.04
Safety	17	3.81
Integration	12	2.69
Environmental protection	5	1.12
Total	**446**	**100.00**

The code relations browser shows which code pairs co-occur frequently within the same factor (maximum distance=0) to understand the complex relation of code pair occurrences. A scale of the added heat map ranging from blue to red indicates which code pair is frequent or less frequent in the system. *Urban mobility* and *policy and legislation* codes occur most frequently within the same factor (Table 5), but there is a strong relation between the code pairs of *technology* and *virtual infrastructure*, *physical infrastructure* and *urban mobility*, and *integration* and *urban mobility*.

Table 5. Code relations browser (maximum distance=0)

Code system	Integration	Vehicle communication	Data	Safety	Environmental protection	Business model	Virtual infrastructure	Planning	Land use	Urban mobility	Policy and legislation	Technology	Physical infrastructure
Integration	0	4	0	0	0	0	0	2	0	22	8	2	2
Vehicle communication	4	0	2	4	2	0	22	6	0	12	12	18	8
Data	0	2	0	6	0	2	13	2	0	2	13	2	4
Safety	0	4	6	0	0	2	6	2	0	8	9	3	6
Environmental protection	0	2	0	0	0	4	0	0	0	10	8	2	0
Business model	0	0	2	2	4	0	0	4	0	20	28	18	3
Virtual infrastructure	0	22	13	6	0	0	0	4	0	2	6	32	18
Planning	2	6	2	2	0	4	4	0	8	12	2	2	6
Land use	0	0	0	0	0	0	0	8	0	10	6	0	14
Urban mobility	22	12	2	8	10	20	2	12	10	0	47	14	23
Public readiness	0	10	0	2	0	9	0	0	2	17	4	8	0
Policy and legislation	8	12	13	9	8	28	6	2	6	47	0	16	10
Technology	2	18	2	3	2	18	32	2	0	14	16	0	14
Physical infrastructure	2	8	4	6	0	3	18	6	14	23	10	14	0

If a visualization of the code relations browser presented in Table 5 is created, the model of the text system composed from the 223 factors of urban autonomous vehicle readiness is obtained (Figure 2). The model demonstrates the frequency of the co-occurrence of each code in the textual data. If two codes co-occur frequently, it indicates that the two codes are probably linked to each other or the same topic.

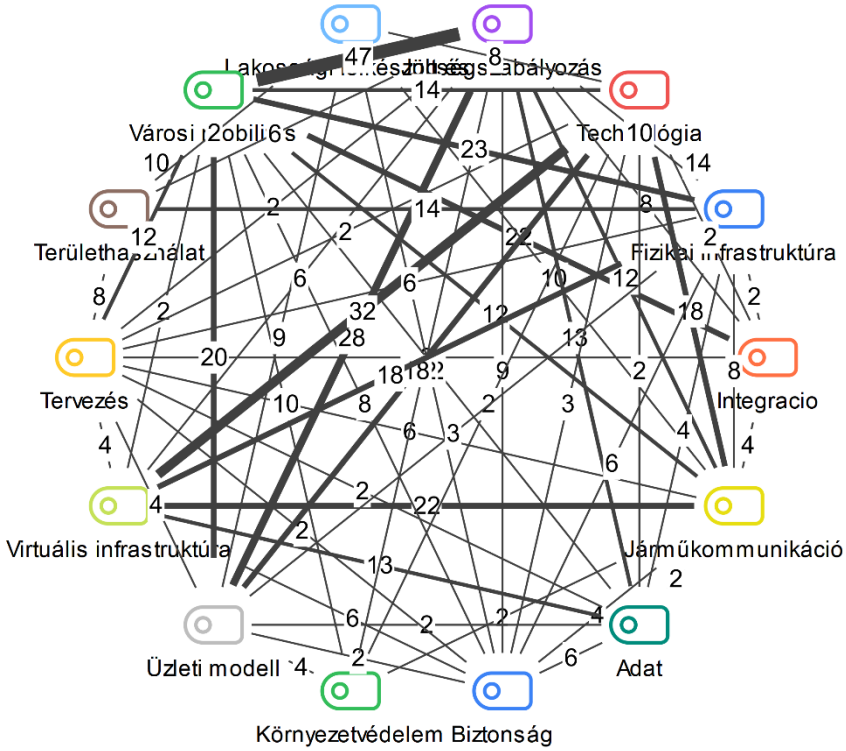

Figure 2. Code co-occurrence model

Further connections can be revealed about the text system created from the 223 factors of urban autonomous vehicle readiness based on the code map (Figure 3). The different codes are represented by circles, whose diameter is determined by the frequency of the occurrence of a given code. The line joining two codes demonstrates the frequency of the co-occurrence of the two given codes. The various colors of the code map show the clusters formed based on the distances, indicating the most significant co-movement of codes within the entire text system created from the 223 factors of urban autonomous vehicle readiness. It results in 4 clusters with the following codes:

- Cluster 1: virtual infrastructure, technology, vehicle communication codes
- Cluster 2: planning, land use codes
- Cluster 3: business model, policy and legislation, urban mobility codes
- Cluster 4: Physical infrastructure, data, safety, environmental protection, public readiness, integration codes

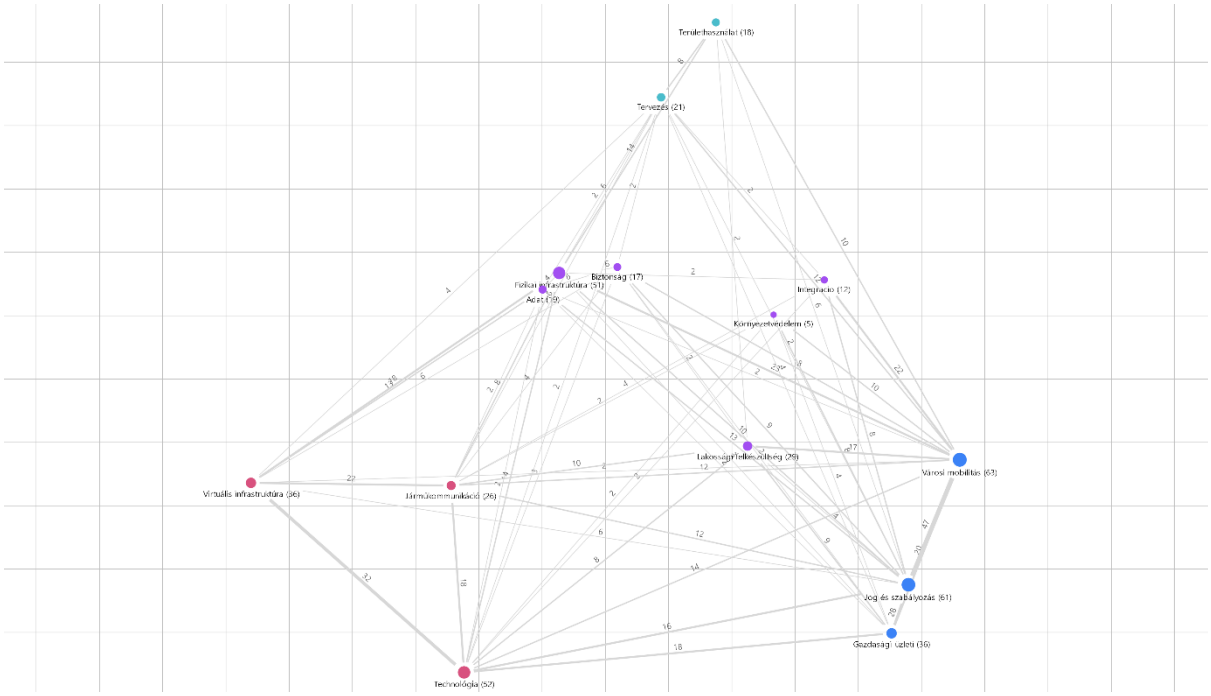

Figure 3. Code map and clusters of AV Readiness of Cities

The model, code map, clusters, and the overlaps of the factor codes of the text system enable defining the factors and key determinants of urban autonomous vehicle readiness. It is not sufficient to consider the outputs of the text system, the 223 factors must be analyzed one by one to interpret the overlap of each code. With simultaneous coding several codes can be assigned to a more complex factor based on its content. Urban autonomous vehicle readiness is an extensive topic, thus the 223 analyzed factors included one with 5 codes. It can also lead to a situation where a code itself cannot be associated with any factors despite the fact that it was completely justified to be included in the code system based on the literature review. As a result, two codes could not be connected to any factors separately: integration and environmental protection. The latter was removed from the code system. In the case of the integration code, all factors which had an integration code also got an urban mobility code, creating the “Integration and urban mobility” factor.

In the following step, the codes were examined within the clusters based on the cluster recommendations of the software. There was a large overlap among the codes proposed in cluster 1 and 2 during double-checking, thus the factors were defined on cluster level for the codes in these clusters as follows:

- 3 codes included in cluster 1, virtual infrastructure, technology, and vehicle communication codes were considered as a cluster-level factor named as *CAV technology and virtual infrastructure;*
- 2 codes included in cluster 2, planning and land use codes were considered as a cluster-level factor named as *Urban planning and land use*.

The contents of the factors under the codes within cluster 3 and 4 are so different that combinations are not justified; therefore, the codes of these clusters can be interpreted as separate factors. If the content of the factors and their connections to other codes is analyzed systematically, the key determinants which are the most important in terms of urban autonomous vehicle readiness can be given by factor (Table 6).

Table 6. Factors and key determinants of AV readiness in cities

Factors	Key determinants	Reference
A. Urban planning and land use	1. Updating transport plans 2. Adjusting infrastructural plan 3. Replanning land use	Narayanan et al. (2020), DuPuis et al. (2015), Chapin et al. (2016), Fraedrich et al. (2019), Fayyaz et al. (2022), Rahman–Thill (2023), Silva et al. (2021)
B. Physical infrastructure	4. Providing and transforming road infrastructure 5. Maintaining road network 6. Establishing P+R facilities	Duvall et al. (2019); Khan et al., 2019; KPMG, 2020; Oliver et al. (2018), Johnson (2017); Khan et al., 2019; NACTO, 2019; Saeed (2019)
C. CAV technology and virtual infrastructure	7. Installing V2I technology in roads 8. Establishing CAV-compatible crossings 9. Providing server technologies	Khan et al., 2019, Sheehan et al. (2019), Duvall et al. (2019); Johnson (2017); Saeed (2019)
D. Data	10. Data management, data analysis 11. Private data protection 12. Sharing socially useful data	Cui et al., 2018; Khan et al., 2019; Lin et al., 2018, Fagan et al 2021
E. Safety	13. High-level cyber security 14. Managing vehicle safety risks 15. Latest vehicle safety technologies	Khan et al., 2019; KPMG, 2020; Sheehan et al. (2019), Alfonso et al., 2018, Atzori et al., 2018
F. Urban mobility and integration	16. Integrating AVs into transport system 17. MaaS integration of transport system 18. Promoting the use of MaaS system	Alazzawi et al, 2018; Martinez and Viegas, 2017; Overtoom et al, 2020, Straub Schaefer, 2019
G. Legislation	19. Local rules encouraging autonomous fleet use 20. Local rules discouraging private car use 21. Local policy interventions	Barnes et al. (2017); , Duvall et al. (2019); Khan et al., 2019; Kimley-Horn (2016); KPMG, 2020
H. Business model	22. Local support encouraging autonomous fleet use 23. Local taxes and fees adding to the cost of private car use 24. Rethinking urban budget	Smahó 2021, Mares et al., 2018, Maciag, 2017, Clark et al., 2017, Fagan et al 2021
I. Public readiness	25. Informing the public about AV technologies and their urban impacts 26. Public involvement in urban AV-related decisions 27. Public involvement in new land use-related decisions	Golbabaei et al. (2020); INRIX, 2017; KPMG, 2020, Kacperski et al. (2021); Mathis et al. (2020), Threlfall, 2018, Lipson – Kurman, 2016, Litman, 2017, Bezai et al., 2021

The next section elaborates on the content of each key determinant in terms of urban development. It must be noted that most key determinants have a state-level connection, but it is not described during the presentation of key determinants due to the urban focus. Nevertheless, national-level frameworks (legislation, policy, etc.) must be regarded as an important base for planning urban interventions which specific actions must be adapted to.

A. Urban planning and land use

1. *Updating urban mobility plan*: it is particularly important to plan what role the city designates to AVS in its own urban mobility. Fitting AVs into the urban mobility fabric ensures that autonomous technology is an integral part of urban transport system, facilitating optimal and safe transport.
2. *Adjusting infrastructural plan*: the city must be prepared for the special infrastructural requirements of AVs. Roads, crossings, signs, signals, etc. may require developments to ensure the effective and safe operation of AVs.
3. *Replanning land use*: it includes reconstructing parking places, replanning streets, establishing embarkation and disembarkation zones, etc. The adjustment of land use plan allows cities to completely exploit the benefits offered by AVs, for example, more efficient traffic and increased public spaces.

B. Physical infrastructure

4. *Providing and transforming road infrastructure*: providing, transforming, and certifying road infrastructure for AVs, which refers to the implementation of the infrastructural plan. The physical infrastructure of the city is adapted to the requirements of autonomous technology.
5. *Maintaining road network*: more frequent maintenance of the elements of road infrastructure, such as signs, lights, lane markings, and potholes to make them easily detectable and perceivable for the sensors of vehicles. It is essential for the safe operation of AVs.
6. *Establishing P+R facilities*: appropriate establishment of parking places and transfer points simplifies the change from AVs to other means of transport, contributing to the efficiency of urban mobility.

C. CAV technology and virtual infrastructure

7. *Installing V2I technology in roads*: Vehicle-to-Infrastructure technology enables AVs to communicate with the infrastructure. It requires the instalment of special sensors and communication equipment in the road and other infrastructures.
8. *Establishing CAV-compatible crossings*: the aim of the crossings developed for connected and autonomous vehicles (CAVs) is to enable AVs to communicate with their environment, as well as coordinated crossing. It increases transport efficiency, minimizes the risk of collision, and contributes to the safer and smoother transport of the city.

9. *Providing server technologies*: AVs rely on advanced server technologies, such as 5G, optics, cloud solutions. The access to server technologies must be provided in cities to ensure that AVs remain in contact and make decisions based on the most recent data.

D. Data

10. *Data management, data analysis*: it is important for the city to conclude agreements to access the huge amount of data recorded by AVs (or at least a part of it) to monitor the road network in real time and make an informed decision on transport, urban development, and other urban planning matters.
11. *Private data protection*: regarding the data collected by AVs available to the city, it must be ensured that the personal information of the public is protected. Such vehicles use several sensors, cameras, and other data collecting devices, which can also record personal information.
12. *Sharing socially useful data*: data collected or generated by AVs about transport processes (congestions, accidents), environmental indicators, and other important factors can contribute to increasing the efficiency of urban mobility, the safe transport of classical and autonomous vehicles, and providing information for the public.

E. Safety

13. *High-level cyber security*: preventing attacks against vehicles and related infrastructure is a priority public security matter. The city must integrate these measures into daily processes to protect its inhabitants and the infrastructure from the repercussions of cyber risks for urban safety.
14. *Managing vehicle safety risks*: to manage the specific safety risks of AVs efficiently, the city must take an active part in risk management processes. It includes cooperation with urban police, fire brigades, and emergency services to be able to respond to emergencies promptly and capacities are not absorbed by false automatic alerts. Efficient communication and cooperation are important, including informing the public about potential risks and measures.
15. *Latest vehicle safety technologies*: V2X (Vehicle-to-Everything) technologies, establishing a data connection between the vehicle and its environment, can help increase the safety of AV passengers and the safety of people in its environment, such as pedestrians and cyclists. With the instalment of these technologies, the city can take major steps to increase the safety of mobility.

F. Urban mobility and integration

16. *Integrating AVs into transport system*: AVs must be integrated into the urban transport system in coordination with the urban mobility plan and transport infrastructure. Integration improves the efficiency of transport, decreases traffic and parking problems, and contributes to the sustainability of urban mobility.

17. *MaaS integration of transport system*: Mobility-as-a-Service (Maas) enables simple and coordinated use of various modes of urban mobility with a single mobile application. It increases the comfort of passengers and optimizes the urban transport system.
18. *Promoting the use of MaaS system*: the MaaS system can increase the efficiency of urban mobility only if the public uses it actively. Thus, the promotion of the system is key in the paradigm shift of urban transport.

G. Legislation

19. *Local rules encouraging autonomous fleet use*: the city can encourage autonomous fleet use targeted at decreasing urban mobility issues with municipality regulations and rules. Ridesharing is of special importance in the paradigm shift of urban transport.
20. *Local rules discouraging private car use*: the city can discourage private vehicle use with municipality regulations and rules. These interventions can encourage alternative mobility modes, helping the city develop environmentally friendly and efficient transport systems.
21. *Local policy interventions*: local policy can take several measures which are not exclusively regulatory but also facilitating the paradigm shift of urban transport. The city can give policy guidelines to exploit the benefits of autonomous fleets and can elaborate financial incentives in the form of a business model.

H. Business model

22. *Local support encouraging autonomous fleet use*: in terms of efficient and sustainable urban mobility, it is beneficial if autonomous fleets can be used by the public with substantial cost benefits as a part of the urban mobility mix compared to private car use. The specific forms of support must be accurately planned and introduced by the city.
23. *Local taxes and fees adding to the cost of private car use*: it is an instrument for cities to decrease private car use and encourage other modes of transport. For example, with high parking fees and zone fees the cities can decrease private vehicle use and make urban mobility more sustainable.
24. *Rethinking urban budget*: the mass adoption of AVs will affect the budget of cities negatively both directly (parking fees, fees from vehicle ownership, taxes), and indirectly (local tax revenues). It requires preparations for loss minimalization and the sustainability of management.

I. Public readiness

25. *Informing the public about AV technologies and their urban impacts*: an important condition for the widespread deployment of AVs is public acceptance, which can be facilitated if urban residents understand the operation and impacts of AV technology and receive satisfactory responses to their concerns.

26. *Public involvement in urban AV-related decisions*: it is important in the introduction of AVs that urban residents participate in decision-making processes. Considering public opinions and experience increases the acceptance of Avs and helps the city establish systems which indeed satisfy the needs and requirements of the public.
27. *Public involvement in new land use-related decisions*: the mass adoption of AVs can change the common and beloved streetscape. Public involvement can promote that the needs, expectations, and esthetic considerations of the public are reflected by the land use decisions related to AVs.

5. Discussion

Our study identified and analyzed key factors influencing the adoption and integration of autonomous vehicles (AVs) in urban environments. Our findings are consistent with previous research results, aligning well with the established literature on the adoption and integration of autonomous vehicles.

Our findings align with multiple studies emphasizing the importance of robust policy and legislation frameworks for AV deployment. For instance, CEG (2019), NSW (2022), and KPMG (2018) all highlight the necessity of clear regulations to ensure safety, public acceptance, and seamless integration into current transportation systems. Technology advancements are crucial for AV development, as supported by studies such as those by Freemark et al. (2020) and Khan et al. (2019). Continuous innovation in sensor technology, machine learning, and AI is needed to enhance vehicle performance and safety. Consistent with numerous studies, our research underscores the importance of upgrading physical infrastructure to accommodate AVs. Studies by Fraedrich et al. (2019), Jiang et al. (2022), and Zali et al. (2022) emphasize that investments in infrastructure, such as roads and traffic signals, are crucial for the successful integration of AVs into urban environments.

Public readiness is a recurring theme in the literature. Educating the public about AV benefits and addressing safety concerns are critical for acceptance. Studies by Fraedrich et al. (2019) and Fagan et al. (2021) emphasize the need for effective communication strategies to improve public perception. Integration into existing transportation systems is essential for the successful deployment of AVs. This factor is supported by studies like those by Freemark et al. (2020) and NSW (2022), which discuss the challenges and solutions for integrating AVs into urban mobility frameworks.

Our research, in line with NSW (2022) and Zali et al. (2022), identifies data management as a key factor. Efficient data collection, storage, and analysis are vital for the operational success of AVs. Safety remains a paramount concern, as noted by Zali et al. (2022). Our

study reaffirms that safety protocols and rigorous testing are essential to gain public trust and regulatory approval. Brovarone et al. (2021) and Zali et al. (2022) discuss vehicle communication, which is pivotal for AV coordination and accident prevention. Our findings suggest that developing robust vehicle-to-everything (V2X) communication systems can significantly improve traffic efficiency. Zali et al. (2022) highlight the importance of sustainable business models for AV deployment. Our study supports this, emphasizing that viable economic models are necessary for widespread AV adoption. Brovarone et al. (2021) and Zali et al. (2022) emphasize virtual infrastructure. Our findings indicate that digital infrastructure, such as high-definition maps and simulation environments, is crucial for AV operation.

Our study, consistent with Fraedrich et al. (2019) and Fagan et al. (2021), underscores the need for meticulous planning. Strategic urban planning can facilitate the integration of AVs and improve urban mobility. Freemark et al. (2020) and Fagan et al. (2021) discuss land use changes due to AVs. Our study supports this, noting that AVs can transform urban landscapes by reducing the need for parking spaces and potentially repurposing land for other uses. Finally, our study aligns with Freemark et al. (2020), Brovarone et al. (2021), and CEG (2019) regarding urban mobility. AVs have the potential to revolutionize urban transport, making it more efficient and accessible.

By comparing our findings with previous research, we highlight the multifaceted approach needed to address the challenges and leverage the opportunities presented by AVs. Effective policy, technological advancements, infrastructure upgrades, public readiness, and integration strategies are all critical components for the successful adoption of autonomous vehicles in urban environments.

A potential and highly significant future research direction could involve assigning indicators to the identified key determinants, thereby making it possible to measure AV readiness at the urban level. Future research could examine case studies of cities that have successfully integrated AVs into their transport systems. Future research should investigate the long-term urban planning implications of widespread AV adoption.

6. Conclusions

The present study addressed what is required for the mass adoption of AVs in future cities and for their effective and safe operation. The question was approached by synthesizing 223 urban AV readiness factors defined in the international literature with software-supported structured text and content analysis. As a result, the factors and key determinants of urban AV readiness were defined following several iterations.

It is to be emphasized that the identified factors and key determinants are required for the widespread adoption of AVs rather than their introduction. The increasing number of available urban road test results show that the urban appearance of AVs in a small number entails a minimum task for cities, however, their appearance in an increasing volume raises more serious issues (for example, in San Francisco). Therefore, proactivity is necessary on an urban level, the first step of which should be defining the aim of the city with AVs, as it determines the necessity of further steps.

It is important to see that AV technology offers a real theoretical opportunity to address the major challenges of urban mobility (traffic jams, noise, air pollution, congestion), nevertheless, it has essential conditions. An important condition is that AV technology can be counterproductive if its business model is private ownership. In this case, the AV owner, making a rational decision, will not pay for parking but use the car in traffic (ceteris paribus), thereby increasing urban traffic.

Therefore, promoting and getting the public to accept and use autonomous fleets for ridesharing is crucial, even though it seems challenging. If we also integrate connected vehicle technology into this system, sensors in vehicles, roads, and intersections will enable much more efficient traffic management and significantly improve road capacity.

Extending sensors to cyclists, pedestrians, and other road users considerably increases urban mobility safety. Their conditions and server technologies (e.g. 5G) are given but their instalment requires strategic decision making at urban level due to their time and cost claim. It does not only apply to technology, but also to the existing physical infrastructure, moreover, it raises safety and data management issues which require significant interventions in the case of the mass adoption of autonomous vehicles.

In the case of the mass adoption of autonomous vehicles, it is recommended that the city should find the place of this new mobility form in the urban mobility system and designate its specific role. Autonomous vehicles must be integrated into the existing public transport system and if possible, it is expedient to implement the entire urban mobility in the MaaS system.

Nevertheless, the effective operation of the new urban mobility paradigm requires the decision of the urban population to reduce private car ownership and increase autonomous fleet use. It must be supported in terms of both legislation and finances, facilitating fleet use and making private car ownership more costly. Involving the public into urban-level decision making related to autonomous vehicles is essential based on the experience of test cities. This will be important if the new urban model reduces the number of vehicles on city roads and transforms asphalt areas, changing the urban landscape.

Representing the 27 key determinants with indicators offers a great opportunity for further research, thereby urban autonomous vehicle readiness could be measured based on this synthesized framework.

It is evident that the urban-level mass adoption of autonomous vehicles offers significant, at first reading maybe futuristic opportunities, which also requires considerable preparation. It is to be emphasized that these preparations are not for some autonomous vehicles to appear and travel on urban streets but for the critical mass of AVs to provide benefits rather than drawbacks for cities.

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Thematic Field F:

Sustainable Food Systems

Integrating strategies for Budapest and Lisbon's sustainable, healthy, and resilient food systems. Lessons learned and steps forward

Vanda Pózner[1], Bálint Balázs[1], Éva Bánsági[1], Rosário Oliveira[3], Carolina Capitão[2], Rodrigo Feteira-Santos[2], Osvaldo Santos[2]

[1]Environmental Social Science Research Group (ESSRG), Hungary

[2]Environmental Health Behavior Laboratory, Institute of Environmental Health, Lisbon School of Medicine, University of Lisbon (EnviHeB Lab, FMUL), Portugal

[3]Institute of Social Sciences, University of Lisbon (ICS–UL), Portugal

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Abstract. This work relies on the experiences gathered from urban food planning policy design in two European city regions, Lisbon and Budapest, considering urban and peri-urban food production landscapes as the basis for systemic approaches. Data analysis comprised four complementary approaches: 1, a desk research phase (narrative literature review and historical analysis of food policies affecting the city regions); 2, qualitative interviewing with different groups of stakeholders (including, for instance, city administration representatives); 3, city-regional and district-level food environment mapping activities with representative stakeholders, with a considerable proportion of vulnerable groups from two neighbourhoods; and 4, two workshops extending to a visioning, system understanding and a strategic planning phase. Results suggest different ways and derives to integrate local food policy measures into current planning policies. Although food policies and planning are best done through integrated approaches holistically addressing multiple purposes and potentially conflicting urban planning agendas and strategies, they are a rarity for many reasons. Nevertheless, it will be pointed out how currently available urban planning practices can enable a food planning policy and strategy that integrates social, economic, cultural, climate, and biodiversity-related policies. Current good practices for innovative urban planning policy measures will be discussed using the FoodCLIC project's assessment framework, proposing an integrated approach to transform urban food systems and environments in the European food transition framework.

1. Introduction

Urban food planning has emerged as a critical area of focus for cities worldwide in the quest for sustainable, healthy, and resilient food systems. This study explores the integration of food policy measures into urban planning in two European cities, Budapest and Lisbon. These city regions provide contrasting yet informative case studies on how urban and peri-urban food production landscapes can serve as foundational elements for systemic approaches to food system planning.

Our current global food systems are characterised by complex production, distribution, and consumption networks that have evolved significantly over the past century (Clapp, 2020). Driven by complex interactions between environmental, social, economic, and political factors, the food system now faces several critical challenges. Innovation in food systems is imperative to address these challenges, requiring a re-evaluation of land use practices. This includes prioritising the enhancement of plant production, reducing reliance on animal husbandry, and preserving soil health and biodiversity (Tilman and Clark, 2014).

Drawing on extensive experiences from urban food planning policy design, this study examines the specific strategies employed in Budapest and Lisbon. It leverages a multi-faceted data analysis approach, encompassing four complementary methods: a desk research phase, qualitative interviews with city administration representatives, city-regional and district-level food environment mapping activities, and two workshops focused on visioning, system understanding, and strategic planning.

The findings highlight diverse methods and pathways for integrating local food policy measures into urban planning policies. Despite the recognised need for holistic and integrated approaches that address multiple and potentially conflicting urban planning agendas, such strategies still need to be discovered (Morgan, 2009; Sonnino, 2016). Therefore, this study illustrates how current urban planning practices can be harnessed to develop food planning policies and strategies encompassing social, economic, cultural, climate, and biodiversity-related objectives.

Adopting systemic approaches to urban and peri-urban food production landscapes involves recognising and leveraging the interdependencies between urban development, food systems, and environmental sustainability. This integrated approach is essential for building resilient cities that can effectively meet the food needs of growing urban populations while safeguarding biodiversity and enhancing the overall well-being of both human and non-human actors.

Using the FoodCLIC project's assessment framework, this work discusses current best practices and proposes an integrated approach to transforming urban food systems. The lessons learned from Budapest and Lisbon provide valuable insights into the European

food transition framework, showcasing innovative urban planning policy measures that can drive the future of sustainable urban food environments. This study will compare the use of the FoodCLIC framework in two cities, and describe lessons learned during these processes, taking stock of specificities, needs, and resources mapped in each context.

2. The FoodCLIC Project and Assessment Framework

FoodCLIC1 is an EU-funded Horizon Innovation Action Project that started in 2022 and runs until 2027. The project's primary goal is to create resilient urban food environments across Europe. It takes action in 8 city regions, where municipalities and local research institutions work together to transform urban food environments and food systems to be environmentally sustainable, healthy, just, and accessible.

The framework's foundation is the CLIC concept, grounded in systems thinking and transformational learning. This concept was developed by Sonnino and Milbourne (2022) and presents an innovative and integrated framework designed to guide interventions in urban food environments that deliver sustainability Co-benefits, strengthen rural-urban Linkages, enhance social Inclusion, and foster new Connections between food and other complex systems. Therefore, it is a normative framework emphasising four key dimensions: social, environmental, spatial, and sectoral integration.

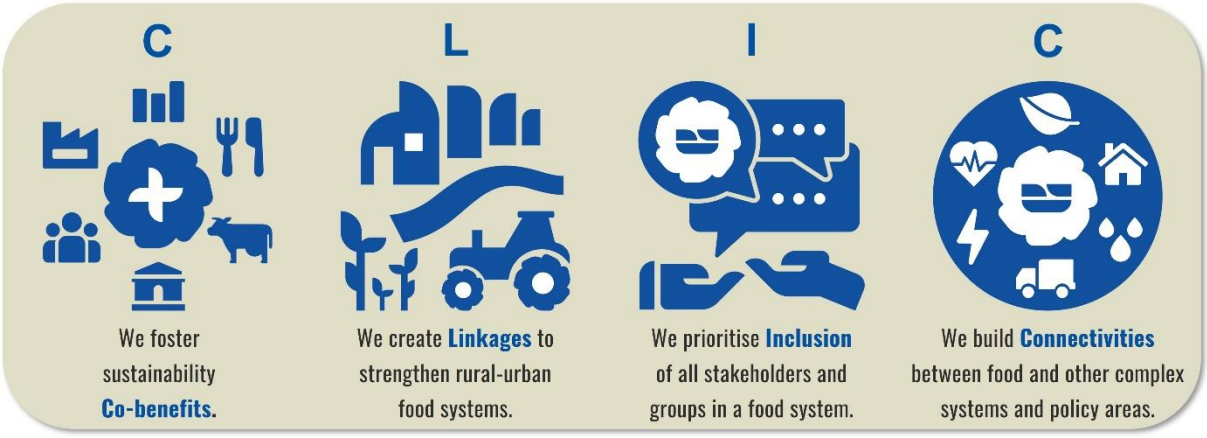

Figure 1. CLIC framework @FoodCLIC Project

I.

[1] FoodCLIC EU Horizon Innovation Action Project: https://foodclic.eu/ (accessed at 15.05. 2024)

In the subsequent section, we will introduce the four pillars of integration based on the project's proposal[2].

Co-benefits. The concept of ‘co-benefits’ acknowledges that sustainability strategies aimed at particular economic, social, or environmental objectives can positively or negatively impact other aspects of a system, leading to synergies or trade-offs. Considering co-benefits helps us to identify and address conflicts of interest among stakeholders with diverse viewpoints, fostering collaboration and alignment toward shared goals.

Linkages. Linkages encompass systems' dynamic flows, connections, and interactions, emphasising fluidity over rigid boundaries. This concept introduces a territorial dimension to co-benefits, highlighting the importance of (re)establishing or enhancing positive spatial, socio-cultural, economic, and environmental relations between communities and localities and bridging urban-rural divides. Viewing linkages underscores the interconnectedness between urban and rural areas, reframing the rural landscape as an integral and valuable component of urban spaces that requires protection rather than exploitation.

Inclusion. The concept of inclusion emphasises empowering diverse communities through increased participation, local leadership, and ownership of initiatives while highlighting the significance of knowledge pluralism. Knowledge pluralism involves leveraging diverse knowledge sources and their underlying values, providing valuable insights into transformative possibilities.

Connectivities. Connectivities refer to the physical and virtual relationships between our food consumption practices and broader public goods such as health, well-being, the environment, and the welfare system, all governed at various levels. Recognising the significance of these connectivities is crucial for addressing the rigidities, divisions, and gaps within the current system that hinder the development of integrated food policies. This awareness sheds light on the fragmentation of responsibilities across multiple departments, ministries, and state agencies and the power imbalances among actors within the food system and across governance levels.

This methodological framework behind the entire FoodCLIC project has guided research activities.

[2] FoodCLIC Project Grant Agreement No.101060717 - HORIZON-CL6-2021-COMMUNITIES-01

3. Methods

In this study, our primary goal was to compare the use of the FoodCLIC framework, which aims to create integrated strategies, in two different cities. We also described lessons learned during the process, taking into account the specificities, needs, and resources mapped in each context.

To achieve this objective, we adopted a comprehensive, multi-phase design that allowed us to analyse and understand urban food policies and environments thoroughly. Our methods were chosen to capture a holistic view of the urban food landscape, considering various dimensions and stakeholders involved. For that purpose, we used four complementary approaches, which are detailed below. While our approach encompassed multiple research methods, including desk research, food environment mapping, and workshops, we recognise the need to streamline our findings to effectively grasp the specific area of integration possibilities. Therefore, after a short introduction to the methods, this report will primarily delve into the outcomes focused on each case study.

3.1. Desk Research Phase

The first phase involved extensive desk research, including a narrative literature review and a historical analysis of food policies of the target city regions. This step aimed to gather existing knowledge and contextualise the current food policy landscape. The narrative literature review provided a broad overview of the academic and policy discourse surrounding urban food systems, while the historical analysis traced the evolution of food policies over time. This phase set the groundwork by identifying key themes, policy shifts, and historical influences that have shaped food environments in urban areas.

3.2. Qualitative Interviewing

In the second phase, qualitative interviews were conducted with representatives from city administrations. These semi-structured interviews aimed to gain in-depth insights into the perspectives and experiences of policymakers and administrators directly and indirectly involved in designing and implementing food policies. The interviews focused on understanding city administrations' challenges, successes, and future aspirations in managing urban food systems. This qualitative data enriched the study by providing nuanced, insider viewpoints on the practicalities of policymaking and implementation.

3.3. City-Level and District-Level Food Environment Mapping

The third phase involved city-regional and district-level food environment mapping activities. These mapping activities were conducted in two neighbourhoods per city region, characterised by a significant proportion of vulnerable societal groups. Representative stakeholders, including residents, community leaders, and food retailers, were engaged in mapping the local food environments. This participatory approach aimed to capture a detailed and localised understanding of food accessibility, availability, and quality within these neighbourhoods. The mapping activities highlighted spatial disparities and specific challenges vulnerable groups face, informing targeted policy recommendations.

3.4. Workshops: Visioning, System Understanding, and Strategic Planning

The final phase consisted of two workshops designed to extend the findings from the previous phases into actionable strategies. The workshops involved diverse participants, including policymakers, community representatives, researchers, practitioners, and other stakeholders. The first workshop focused on visioning and system understanding, where participants collaboratively developed a shared vision for the future of urban food systems and identified vital leverage points for change. The second workshop was dedicated to strategic planning, where concrete action plans were formulated based on the insights and visions generated. These workshops facilitated a collective approach to problem-solving and strategic thinking, ensuring that the proposed solutions were holistic and grounded in the realities of the local context.

The integration of these four complementary approaches provided a robust framework for analysing urban food policies and environments, leading to well-informed and contextually relevant recommendations.

4. Urban food planning policy in two European cities

Food policies and urban food planning are critical components of sustainable urban development. As cities grow and populations become more urbanised, ensuring food security, promoting healthy diets, and minimising the environmental impact of food systems are increasingly important. Effective urban food planning requires the integration of food policies into broader urban strategies, addressing issues such as food access, sustainability, and community engagement (Moragues-Faus and Battersby, 2021; Janin, Nzossié and Racaud, 2023).

This short comparative analysis examines the implementation of the FoodCLIC framework in two European city regions: Budapest and Lisbon. While both cities are

working towards improving their urban food systems, each context's characteristics imply differences and adaptations in their approaches, level of integration in food policies and urban food planning efforts, and community engagement strategies. By exploring these differences, this analysis aims to highlight the strengths and challenges of each city's approach, providing insights that could inform future urban food policy developments.

Budapest

Budapest's food policies are primarily shaped by national regulations, with local initiatives playing a supplementary role. The city has traditionally focused on agricultural policies due to Hungary's strong agrarian history. Budapest's urban food policy is less developed than other European cities, with limited strategic integration of food systems into broader urban planning frameworks. Budapest promotes and is recognised for its local farmers' markets, and city dwellers find it essential to support small-scale farmers and increase access to fresh, local produce. However, the impact of these markets is often limited to specific neighbourhoods, not fully addressing the needs of the entire urban population.

The city faces challenges related to food security, particularly for vulnerable groups. While there are initiatives to support low-income residents, such as food banks and social grocery stores, these efforts are often fragmented and need comprehensive policy backing. Environmental sustainability is an emerging focus, with efforts to reduce food waste and promote organic farming. However, the integration of sustainability goals into urban food policies remains in its nascent stages.

Budapest's urban planning has yet to fully incorporate food systems thinking. Limited coordination between urban planners and food policy stakeholders results in missed opportunities to create synergies between food production, distribution, and consumption within the city's spatial planning strategies.

Lisbon

The city of Lisbon has historically been fed by its hinterland, which supplied fresh food to the urban population until half of the 20th century. For this reason, when urban food planning started to be researched, it was done at the metropolitan scale (Oliveira and Morgado, 2016). In 2018, 38% of the land use of the Lisbon Metropolitan Area (LMA) was dedicated to agricultural, supplying 12% of Portugal's total food produced and consumed. However, the operation of this food system is not subject to any regulations in terms of spatial planning or land use management, and its impact on sustainability transition in the region still needs to be adequately known. How to drive food transition in the LMA, in which 18 municipalities are integrated, has thus arisen as a prominent question. In 2019, within a living lab context, the first steps were taken to this very challenging pathway, in which the definition of a food transition strategy was identified as

the priority to sow the seeds of a food planning process (Oliveira, 2022). In 2023, a Food Transition Strategy (FTS) was established to operate collaboratively and to co-define a set of long-term objectives according to a vision for 2030 and a collaborative action plan (Oliveira et al., 2023). The Lisbon Metropolitan Authority is part of several international networks, such as the Milan Urban Food Policy Pact, due to the influence of FoodLink. This food policy network was vital in influencing a strategic approach to urban food systems planning in which 40 public and private entities are currently involved and engaged in the FTS implementation.

This achievement in the regional context was also possible due to the influence of FoodLink in the regional strategic design, namely the Lisboa 2030 Regional Strategy, which has been in operation since 2020 as the primary guiding document for the regional food transition. It contributes to the objectives of cohesion and convergence in the country and Europe through the role that this system plays in economic growth, in reducing territorial and social asymmetries, and in pursuing governance solutions that actively involve strategic regional players, the public, private, and associative sectors in the metropolitan region.

Bearing in mind that the FTS pursues a multi-sector, multi-scale, and multi-actor approach, this policy tool should have a positive impact on restoring the dynamics of wealth creation and on internal and external regional cohesion, mainly through increasing dynamism between urban, peri-urban, and rural territories, in tandem with the blue economy. At the same time, the FTS is an opportunity to integrate sectoral policies such as those relating to the territory, the economy, health, agriculture, and the environment, creating opportunities and synergies with an effect on innovation and territorial competitiveness, particularly in the context of the 2021-2027 funding framework and the challenges set for 2030 - 2050, particularly within the framework of the European Green Deal.

Therefore, the planning of the metropolitan food system aligns with the productive specialisation observed in the LMA territory, specifically in business services, transport, logistics and distribution, energy, the environment, the agri-food industry, education, and health. Hence, it is understood that the increase of value chains from the production, processing, distribution, consumption, and treatment of food waste is an innovative approach to the territory where the dynamics of local and regional food systems take place, with a positive impact on the sustainability and resilience of the region in the context of climate change. In this context, the LMA will also play an important role in implementing the strategic framework of the Metropolitan Plan for Adaptation to Climate Change, particularly about the sectoral objectives of adapting the agricultural, forestry, and agri-food sectors, in plant and animal terms, and promoting proximity food supply circuits between producers and consumers, based on the conservation and sustainability of soil, water, biodiversity, and landscape resources. This plan also includes agendas to

which the implementation of the FTS is geared, such as the sectoral metropolitan agendas for economic adaptation, energy and energy security, water resources, human health, coastal zones, and the sea.

To sum up, food policies in Budapest are less integrated into urban planning and need to be more cohesive. While there are local initiatives to support food access and sustainability, these efforts need a cohesive policy framework and strategic direction. On the other hand, the Lisbon Metropolitan Area exhibits a more advanced and integrated approach to urban food policies, with comprehensive strategies that align with broader urban sustainability goals. The existence of a regional food policy network that participates in international networks and its commitment to innovative food solutions set it apart as a leader in urban food planning.

5. The case study of Budapest

For the Budapest case study, we focused on presenting the results of our qualitative interviews. This selective approach was adopted to provide a concentrated analysis of stakeholders' perspectives and insights on the potential integration of urban food planning and policy within the city administration, understanding their role, challenges, and opportunities in shaping urban food environments.

Through qualitative interviews, the Environmental Social Science Research Group (ESSRG) aimed to capture nuanced viewpoints, challenges, and opportunities perceived by city administrators, policymakers, and relevant actors in the urban development arena. We can present a concise yet comprehensive understanding of the landscape by focusing on these interview results. This enables a focused discussion on the feasibility and pathways for integrating food considerations within city governance frameworks.

We conducted 17 semi-structured interviews in the Mayor's Office, across various departments of the Municipality of Budapest, and within companies either partially or fully overseen by the Municipality; we sought to engage in dialogue with relevant stakeholders. Although we were open to discussions with a broad range of individuals, our primary focus was on those likely to influence food-related matters, particularly urban planners and those responsible for managing the city's green spaces. The stakeholders we interviewed are shown in this table.

Table 1. Interviews with city officials

Municipality of Budapest	**Mayor's Office Departments**	**Municipal Institutions**
Mayor	Climate and Environmental Affairs	Budapest Public Road Ltd.
Deputy Mayor	Urban Planning	Budapest Public Utilities/Division for Urban Park Management
Deputy Mayor for Urban Management	Social Policy	Centre for Budapest Transport
Deputy Mayor for Smart City and Participation	Landscape Architecture	Budapest Market Halls Ltd.
Senior Adviser on Housing and Social Policy		Budapest Wholesale Market Ltd.
Senior Health Adviser		InDeRe Food Research and Innovation Institute
		Budapest City Construction Design Ltd.

During these interviews, we inquired about the challenges they perceive within Budapest's food system, the necessary changes, and their perceived roles in this transformation. We evaluated their capacities, barriers, and gaps to gain insight into their connection to the food system and their potential roles in developing a healthy, just, inclusive, and sustainable food strategy for the capital.

By "capacity," we refer to the ability to effect change within the food system. This ability is contingent upon three factors: 1) the actor's knowledge of food-related issues, 2) their awareness of available means of action, and 3) the potential impact of the instruments they possess or could possess on the food system. The figure below shows the results of these discussions.

Figure 2. Actors of Budapest's food system and perceived roles' relevance

Our focal point is the transformation of Budapest's food system. Each shape's size and darkness represent each actor's perceived role based on their feedback and perceptions. At the apex, we find the Mayor and Deputy Mayor, who have expressed a strong interest in food issues and to be committed to elevating these concerns within the Mayor's office and the Municipality. The Mayor endorses an integrated approach, believing that the Municipality's engagement can yield positive outcomes. The Deputy Mayor is crucial in advocating for these issues within the General Assembly, making their support indispensable for any significant change.

The Climate and Environment Department is recognised for its influential role, particularly as a project partner responsible for implementing FoodCLIC within the Mayor’s Office. This department's involvement extends beyond this project, as it is integral to the city's climate strategy and energy transition initiatives. Consequently, the department perceives a direct connection to food-related issues and is motivated to incorporate this perspective into daily operations.

Several key entities are involved in the management of green spaces, including the Departments of Urban Planning and its Landscape Architecture Division. The Landscape Architecture Division oversees the Budapest Public Utilities/Division for Urban Park Management. At the same time, urban planning and implementation are handled by the Budapest City Construction Design Ltd. Presently, these agencies do not consider urban green areas as components of the food system, except for community gardens, which are in high public demand. Nevertheless, these agencies express openness to repurposing green spaces for food production or programs like the Orchard City Initiative, which envisions cultivating seedlings and saplings on city-owned land to be distributed to the suburbs for creating orchards and green areas.

The Budapest City Construction Design Ltd. identifies its transformative potential through its comprehensive knowledge of urban green spaces, capability to design strategies and planning frameworks, and capacity to execute these plans. However, before our discussions, they had not contemplated integrating food into their approach. Urban ecology is pivotal in urban space design, but food considerations have yet to be prioritised.

Lastly, Budapest Market Halls Ltd. occupies a foundational position. Market halls represent a critical and potentially transformative element of the food system. Almost each city district features a market, though not all are managed by the Municipality of Budapest; due to Budapest's dual administrative system, some fall under the jurisdiction of district governments. A rethinking of the role of markets is essential, as they could have a significant impact on citizens' food consumption patterns.

Based on our preliminary findings, we have identified three primary conclusions: information needs to be improved regarding food-related issues within the community, a widespread lack of understanding about the challenges facing Budapest's food system, and an insufficiency of capacity within the municipal departments. Although significant work remains, we are encouraged by the general openness and interest demonstrated by the various stakeholders. We plan to continue the co-design workshops and discussions at the city level to apply an integrated approach, as two of the FoodCLIC project's main objectives are to create an integrated food strategy for Budapest and establish a food policy network.

6. The case study of Lisbon

This section explores the application of the FoodCLIC framework within the Lisbon region, focusing on the municipality of Cascais as a pilot approach, visioning the subsequent sharing of experience and learnings with the other 17 municipalities within the Lisbon Metropolitan Area (LMA). While initial socioeconomic data positioned Cascais favourably compared to other LMA municipalities, for instance in terms of annual gross income per inhabitant and unemployment rate, a deeper analysis revealed significant internal disparities. Neighbourhoods like Adroana and Cabeço do Mouro exhibited stark inequalities, highlighting the complexities of achieving a city-region-wide healthy and inclusive food environment. This realisation underscored the need for a nuanced approach that considered the unique realities of each Cascais neighbourhood.

Following FoodCLIC methods, a needs assessment was conducted through three semi-structured group interviews with local stakeholders and residents from the targeted neighbourhoods. This process explored perceived food-system-related challenges, root causes, potential roles, and capacities within the food system. Identified key issues included limited access to essential food items, particularly fresh produce, leading to restricted dietary choices for residents. More fruit and vegetable consumption raised concerns about potential affordability or availability issues. The need for suitable venues for community gatherings further hindered the promotion of healthy food practices.

Beyond these immediate challenges, the in-depth analysis revealed broader concerns: food insecurity emerged as a significant issue for residents. Low food literacy levels limited knowledge about healthy food choices. Socio-economic barriers restricted access to healthy food options, while inadequate infrastructure, transportation limitations, and storage facilities presented additional challenges.

A Food Policy Network emerges as a crucial tool to tackle these challenges. By bringing together key stakeholders (local government, civil society, businesses, and academia), the Food Policy Network can foster collaboration and identify synergies to improve the food environment for vulnerable communities across the municipality.

The process evolved by identifying stakeholder capacities that can contribute to the FPN's success. Local government departments such as the Division of Social Solidarity and Life Quality and the Health Promotion and Well-being Division possess social services, health promotion, and community empowerment expertise. Cascais Food Lab offers resources for capacity building and promotes healthy and sustainable culinary practices. Terras de Cascais Strategy contributes through community production spaces and local food market development. Research partners from universities in Lisbon can provide valuable support in needs assessment, monitoring, and evaluation of FPN initiatives. Finally, representatives from food aid organisations, food education initiatives,

and private social solidarity institutions within civil society bring experience and willingness to contribute to positive change. However, engaging some key stakeholders, particularly representatives from local government and businesses, has proven challenging. Further efforts will be required to secure their participation in the FPN.

7. Conclusion

Developing integrated strategies for sustainable, healthy, and resilient food systems necessitates a context-specific approach that leverages the capacities and perspectives of the stakeholders involved in the city-region food system to position food system transformation as a central priority.

The Budapest case study identified several challenges in integrating food issues into urban planning. Not only is there a lack of information regarding urban food-related issues within the community, but we also recorded a widespread lack of understanding about the challenges facing Budapest's food system that the current capacities only insufficiently cater to. Budapest is seeking to join the Milan Urban Food Policy Pact and create a food policy network that will help to develop integrated strategies in the capital in the future.

The Lisbon case study highlights the importance of several vital learnings, starting with the benefit of a food transition strategy and a regional food policy network that provides guidance when planning the transformation of local food systems. On the other hand, the regional level can be enhanced and strengthened by local initiatives in permanent and interactive common learning. Looking into the case study in the municipality of Cascais, it becomes clear that urban planning and health policies still need to build up more integrated and integrative agendas when looking into local food strategies. Second, multi-layered analysis is crucial to effectively understanding disparities within municipalities and tailoring interventions. Third, community engagement is essential to involve residents in identifying challenges and shaping solutions effectively. Finally, a long-term stakeholder commitment is vital to harnessing diverse capacities within the FPN framework.

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Thematic Field H:

Teaching STS

Navigating Future Skills: The FOUNDING LAB Experience in Shaping the University of the Future

Maria Pfeifer[1], Regina Sipos[2], Anna Weiss[1]

[1] Ars Electronica Futurelab, Austria

[2] Technical University of Munich, Germany

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Abstract. This paper introduces the FOUNDING LAB, an interdisciplinary, futures-oriented educational initiative designed to enhance students' skills and competencies for addressing complex global challenges through art, social sciences and technology. It brought together students from various disciplines, backgrounds, and countries to collaborate on projects that blended artistic and technical elements, fostering critical thinking, empathy, and creativity. The program offered students opportunities to engage with experts and mentors from leading institutions in media art and innovation. The design, implementation, and evaluation of the program were based on participant feedback and project analysis. The paper aims to demonstrate how the program enhanced futures literacy, a crucial 21st-century skill, along with interdisciplinary knowledge, communication, collaboration, and ethical reflection. Additionally, the challenges and limitations of the program were identified. The FOUNDING LAB set a precedent for a higher education model prioritizing questioning, experimentation, and co-creation for transformative learning.

1. Introduction

The challenges of the Anthropocene–often referred to as a “polycrisis” (Lawrence et al., 2022)–require interdisciplinary approaches based on creativity and co-creation. The fast changes in science and society require skills that prepare for the unknown future. But there is no consensus on what these “future skills” are and how to teach them in science. STS literature has long discussed that scientific and technological literacy, problem-solving, and most importantly, responsible social action is core to STS education–yet, sweeping educational reforms are to be approached with caution and care (Waks and Prakash 1985). As we discuss the creation of a novel educational program in this paper,

we attempt to remain cautious, while also responding to recent calls for future-oriented skills and their integration into curricula (Ioannidou and Erduran 2022).

This paper discusses the so-called FOUNDING LAB. This experimental program was a collaborative prototype with which the newly funded IT:U–Interdisciplinary Transformation University located in Linz, Upper Austria (also known as IDSA–Institute of Digital Sciences Austria) and Ars Electronica wanted to identify and develop new methods and formats for shaping a pioneering university. This goal was based on the aim to “equip students with the 21st century skills needed to tackle global challenges.”, as Assoc. Prof. Dr. Martin Polaschek, Federal Minister of Education, Science & Research put it (Polaschek 2024). Within the experimental program, a strong emphasis was put on interdisciplinarity within the field of technical transformation: boundaries between disciplines and between art and science were to be overcome and a multitude of dimensions of digitization to be considered. Futures literacy played a central role in the FOUNDING LAB. The project served as a platform for exploring future scenarios of higher academic learning and research settings and preparing for the future challenges coming with digital transformation, emphasizing the importance of anticipatory thinking in an ever-changing world.

Although Science and Technology Studies (STS) was not explicitly referenced in the conceptual framework of the prototype presented here, several key elements of STS were inherently integrated and were central to the project’s design. From an educational perspective, STS and its critical contributions were, for a long time, not sufficiently included in higher education curricula (Zeidler et al. 2004). With the domain of socioscientific issues (SSI), students were inspired to at least consider the relationships between science-based issues and moral principles (ibid.). These include critical reflections on the relationship between society and technology and the challenge of how artistic and design methods could be integrated to explore and reflect on science and technology.

Additionally, our role evolved into providing the structural foundation for teaching such STS principles and implicitly strengthening futures literacy as a critical skill. The primary focus was on practical implementation rather than theoretical reflection. Notably, the perspectives shared here are predominantly informed by the authors' direct involvement in the on-site realization of the project, supplemented by questionnaires filled out by the participants.

The FOUNDING LAB took place from August 2023 to January 2024 in Linz, Upper Austria, and started with a three-week-long Summer School. At the Ars Electronica Festival 2023, the students’ visions for the future university were used as the kick-off for the following semester. Previously held Festival University Summer Schools are documented on the website of Ars Electronica and in Sipos et al. (2024). For this

FOUNDING LAB Fall Term, the Ars Electronica Futurelab, together with 21 international Fellows (this term refers to lecturers in the program) from different disciplines, designed a novel approach that was then tested for feasibility and practicability. The backgrounds of these Fellows included scientists, teaching professors, leading industry heads, artists, activists, entrepreneurs, journalists, UNESCO-Fellows, feminists and government advisors. 25 students from all over the world were selected to join program and–beside taking part in the classes, workshops and lectures, and the development of their own semester projects, share their visions of the needs and wants of a new university, a "university of the futures".

2. Methods: Building on and Developing "Future Skills"

What is the goal of a "university of the future"? To train the workforce of the future? To equip students with the skills, mindset and knowledge to face upcoming challenges and grasp opportunities ahead?

There has been quite some political to and fro surrounding the founding of the university project that is now named IT:U (Nimmervoll,2024, Klatzer, 2024, DerStandard, 2024). From an STS perspective, the landscape in which the new university was founded is quite an interesting one. It would be worth exploring this background in a separate paper, as a case study reflecting on the "messiness" of technoscience practices shaping and reproducing the social world (Law, 2017). Beyond the political complexities, in this paper we focus on the premise this new university was built on. Namely, one of the main goals from the beginning was "to achieve scientific excellence and to also capitalise on it with impactful contributions to society and industry, in terms of processes and start-ups that are going to change the world." (Austrian Federal Ministry of Education, Science and Research, 2022). Thus, with this paper, we aim to contribute to STS from an educational perspective, as there is an increase in policymakers urging the inclusion of so-called "future-oriented skills" to deal with pressing issues. In a similar vein, "twenty-first century skills" include foreseeing future scenarios, anticipating potential problems and critical engagement with problem-solving strategies (Ioannidou and Erduran, 2022).

In his Afterword to the Special Issue on "Politics by other means: STS and research in education", Decuypere (2018) highlights that one of the major strengths of STS in educational research is that it allows the researcher to trace how a particular practice is relationally unfolding at–and through–a particular moment in time. The paper at hand is an example of such ethnographic work, aiming to contribute to the body of knowledge rooted in "presentism". While a longitudinal follow-up study could uncover more complex insights into the stabilization and crystallization beyond what was originally intended (ibid.), this paper represents a snapshot of our times through an experiment. New

courses created by engaged lecturers are an excellent way to update the education of any discipline to address the present. One example for this is how the Technical University of Munich has been experimenting since 2023 with so-called project weeks to inspire moving away from theory and provide students with more practical skills in an interdisciplinary way, preparing them for the 21st century (TUM 2023). Such approaches to create change are widespread, as adapting whole educational systems to the rapidly changing needs of industry and businesses is a challenging task (Sipos and Kutschera, 2024). The first experimental semester of a new university however opens a unique window of opportunity to respond to those needs, experiment, and test novel formats.

The program described in this paper is situated firmly in the context painted above. The authors of this paper saw the opportunity to record their journey in re-making how we think about learning (Decuypere, 2018). In addition to recording the *how*, we also inquire about the *what* and the *who*: what competencies are necessary to face future challenges? And who identifies these demands?

2.1. Supporting Frameworks

When searching for supporting frameworks to assess our educational prototype for a selected group of international and interdisciplinary students, we turned to the Future Skills Framework, provided by an overlap of the key competencies according to UNESCO (UNESCO, 2018) and the Future of Jobs WEF reports (World Economic Forum, 2020 and World Economic Forum, 2023).

The authors of this paper selected the UNESCO and WEF frameworks for several reasons. Although–or rather because–UNESCO and the World Economic Forum (WEF) are non-scientific institutions with their own distinct cultures, values, and agendas, they wield significant influence in the non-academic world. What Ars Electronica brought to the table within the collaboration with the Founding Convent of IT:U is interdisciplinarity with the field of Art: We wanted to explore how artistic strategies, mindsets, and ways of working could enrich the interdisciplinary field of digital transformation. We also wanted to assess how our educational prototype would perform according to non-academic frameworks that influence the global economy and society. Therefore, we chose the UNESCO and WEF frameworks as references to evaluate our program's impact and relevance. We wanted to find out how a highly experimental prototype for higher education based on art science collaborations would perform against the background of these frameworks with their respective agendas outside the world of academia and art.

Also, this new higher education program was supposed to address two global trends in particular: One is that due to the climate crisis, there is an urgent need for people with the skills to sustainably transform the world. The other pertains to the changing landscape of work: as technology is rapidly adopted in the workplace, jobs are becoming obsolete,

and new jobs are being created that need new types of expertise. The FOUNDING LAB project took the chance to experiment with how higher education can concretely help address these issues.

Our decision also builds upon Kotsiou et al. (2022), who examined 99 future skills frameworks and used thematic analysis along with Social Network Analysis to create meta-categories of future skills identified by current research, observations which highlight a shift in recent times towards equipping learners for uncertainty, specifically citing UNESCO and WEF frameworks as examples (p. 182).

UNESCO, with its global mandate to promote education, science, and culture, is instrumental in shaping educational policies and fostering international collaboration. Its focus on sustainability and global citizenship aligns with the urgent need to equip individuals with the skills to address climate challenges. Some scholars argue that UNESCO's initiatives, particularly in education, can reflect a top-down, one-size-fits-all approach that may overlook local contexts and needs (McCowan, 2019). However, its emphasis on sustainability and global citizenship provides a benchmark for ensuring that our educational prototype aligns with international standards for addressing climate challenges. By integrating UNESCO's competencies, we aim to embed a global perspective on sustainability into our program.

On the other hand, the WEF, a forum where business, political, and societal leaders meet, is a critical player in forecasting the future of work. The WEF's Future of Jobs reports highlight the evolving skill sets required in an increasingly automated and digitized world. It has been criticized for its elitist nature and potential to prioritize corporate interests over broader societal needs (Fuchs, 2020). The WEF's Future of Jobs reports, while influential, have also been questioned for further blind spots, for example focusing exclusively on technological change and missing major shifts throughout entire private and public organizations (Ehlers 2020). Despite these critiques, the WEF's insights into emerging labor market trends are an interesting perspective on our program and can support the exploration of how well it would equip students with the skills demanded by an increasingly automated and digitized economy–as the WEF sees it.

While UNESCO tends to prioritize long-term societal well-being and global equity, the WEF is more concerned with immediate economic outcomes and the needs of the global market. Despite these differences, there is overlap in their focus on skills for the future—both institutions recognize the need for education and training to address emerging global challenges, such as technological disruption and sustainability. However, UNESCO approaches this from a humanistic perspective, advocating for education that supports inclusive and sustainable development, while the WEF's approach is more closely aligned with preparing the workforce for the demands of the global economy. In essence, UNESCO and WEF can be seen as complementary yet distinct forces:

UNESCO advocating for educational and cultural policies that promote equity and sustainability, and WEF driving economic and technological policies that prioritize efficiency and innovation. Juxtaposing the two reports, we attempt to balance those economic imperatives and the broader social goals necessary for sustainable global development. Their perspectives are particularly relevant when considering the program's potential impact from the vantage point of industry, entrepreneurship, and human resources, rather than purely through an academic lens.

By choosing these two frameworks, we not only examine perspectives that challenge academic conventions but also aim to evaluate our program's effectiveness in a broader, real-world context. This approach helps us bridge the gap between academia and the reported needs of the global economy, fostering a new generation of professionals capable of driving sustainable transformation.

This does not mean however, that academia has not considered similar skillsets valuable. In STS literature, specifically in the discourse on SSI, the need to achieve a practical degree of scientific literacy is highlighted. For example, a combination of practical and theoretical skills, such as scepticism, open-mindedness, critical thinking, an acceptance of ambiguity, multiple forms of inquiry, as well as a search for data-driven knowledge are considered (Zeidler et al. 2004). Similarly, but more recently, Hodson outlined the need for more radical change by building a curriculum for sociopolitical activism (Hodson 2020). Each element of this combined list of skills has a strong presence in the list of future skills we address below.

The 2023 WEF's Future of Jobs report highlights cognitive skills, particularly complex problem-solving, which are anticipated to experience the fastest growth in evolving significance of skills for their workforce for the upcoming five years. Creative thinking is projected to rise slightly more swiftly than analytical thinking, while technology literacy ranks as the third-fastest growing core skill. Notably, self-efficacy skills are reported to increase in importance at a higher rate than working with others. Businesses identify socio-emotional attitudes such as curiosity, lifelong learning, resilience, flexibility, agility, motivation, and self-awareness as rapidly growing in importance. This underscores the emphasis on cultivating resilient and reflective workers who embrace lifelong learning in an environment where skill lifecycles are diminishing. The top 10 also include systems thinking, AI and big data (World Economic Forum, 2023, p. 38).

The UNESCO's report "Issues and trends in education for sustainable development" (UNESCO, 2018) emphasizes crucial competencies essential for sustainability. These competencies include systems thinking, anticipatory, normative, strategic, collaboration, critical thinking, self-awareness, and integrated problem-solving. Each competency addresses specific aspects related to understanding relationships, anticipating multiple futures, negotiating values, collaborating effectively, and critically examining norms. The

integrated problem-solving competency is highlighted as particularly important, emphasizing the interconnectedness of these skills. With this strategy as base, the FOUNDING LAB program employed learner-centred, action-oriented, and transformative learning approaches. The program also prioritized interdisciplinary and transcultural collaboration, incorporating project-based and research-based learning. To be able to gauge the impact of the approach, the Fall Term program employed a feedback and evaluation process, enabling students to self-assess their development regarding future skills. For the student feedback and evaluation of this project, we subsumed anticipatory, and systems thinking under the term futures literacy and understood it as a crucial skill to face future challenges and lead transformation and innovation processes:

Interdisciplinarity: Highlighted by UNESCO and the WEF as one of the major future skills, interdisciplinarity involves the ability to integrate knowledge and perspectives from various fields, fostering a holistic understanding of complex issues. This skill is particularly crucial in research and education, where it plays a vital role in breaking down silos, promoting collaboration, and encouraging innovative solutions by working with people from diverse backgrounds. Effective communication is key in conveying complex ideas and encouraging the development of innovative solutions.

Collaboration: According to UNESCO, in education, this refers to the ability to learn from others; empathy: understanding and respecting the needs, perspectives and actions of others; to exercise empathetic leadership, meaning understand, relate to and be sensitive to others, and deal with conflicts in a group; and facilitate collaborative and participatory problem-solving. According to WEF, in the workforce this includes emotional intelligence, or the concern for others (being sensitive to others' needs and feelings and being understanding and helpful on the job); cooperation, or being pleasant with others and displaying a good-natured, cooperative attitude; social orientation, meaning that the job requires preferring to work with others rather than alone and being personally connected with others on the job; as well as social perceptiveness, or being aware of others' reactions and understanding why they react as they do.

Futures Literacy: UNESCO coined the term Futures Literacy to describe the skill of cultivating optimism and motivation for change amid global challenges. While literacy traditionally refers to basic reading and writing skills, in the context of the future, it involves training imagination to construct narratives that address and overcome challenges. This also encompasses anticipatory competency, involving the understanding and evaluation of multiple futures—possible, probable, and desirable. It includes creating personal visions, applying the precautionary principle, assessing consequences, and navigating risks and changes. Additionally, strategic competency plays a crucial role, emphasizing the collective development and implementation of innovative actions to promote sustainability locally and globally.

Critical Thinking: In UNESCO's summary, this means the ability to question norms, practices and opinions; reflect on one's values, perceptions and actions; and take a position in the sustainability discourse. According to WEF, this means critical thinking and analytical skills, e.g. using logic and reasoning to identify the strengths and weaknesses of alternative solutions, conclusions or approaches to problems. It also includes monitoring and assessing the performance of yourself, other individuals, or organizations to make improvements or take corrective action.

Problem Solving: In education, UNESCO highlights the overarching ability to apply different problem-solving frameworks to complex sustainability problems and develop viable, inclusive and equitable solutions that promote sustainable development. In the WEF Report, competencies include reasoning, problem-solving and ideation, which are abilities that influence the application and manipulation of information in problem- solving. It also includes quantitative abilities, in the case of problems involving mathematical relationships.

Anticipatory and Systems Thinking: According to UNESCO, this is summarized by the ability to recognize and understand relationships, to analyse complex systems, to perceive the ways in which systems are embedded within different domains and different scales, and to deal with uncertainty. In WEF's understanding, analytical thinking and innovation will be relevant in jobs that require analysing information and using logic to address work-related issues and problems. Furthermore, creativity and alternative thinking skills will be necessary to develop new ideas for and answers to work-related problems.

Self-Management: For UNESCO, self-management is the self-awareness competency: the ability to reflect on one's own role in the local community and (global) society, continually evaluate and further motivate one's actions, and deal with one's feelings and desires. In the Future of Jobs, this translates to resilience, stress tolerance and flexibility, as jobs require being open to change (positive or negative) and to considerable variety in the workplace. Jobs will also require maintaining composure, keeping emotions in check, controlling anger and avoiding aggressive behaviour, even in very difficult situations. Finally, self-management includes accepting criticism and dealing calmly and effectively with high stress situations.

Technology Use: In education Technology Use plays a role that becomes more and more important – from media competency to actual skills of using technology to learn, research and create results. Using technology with a critical awareness and basic understanding of the underlying rules and technical properties. For WEF, this means technology use, monitoring and control, being able to determine the kind of tools and equipment needed to do a job, including controlling operations of equipment or systems,

but also technology design and writing computer programs for various purposes, as well as generating or adapting equipment and technology to serve user needs.

2.2. Futures Literacy

The term futures literacy has been used and interpreted in different ways and is nowadays often seen more as a concept of UNESCO that is yet to be translated and applied in the educational field. We move away from this concept towards the understanding of the UNESCO Chair on Futures Literacy at Hanze University of Applied Sciences, who define futures literacy on their website as „*the capability of imagining diverse and multiple futures, and using futures as lenses through which we look at the present a new*“, also referring to Riel Miller (see https://futuresliteracy.net/). It is an ability that can be enhanced through practice, training, and experience, entailing ”*the capacity to decipher and categorize as well as produce (design, conduct and interpret) explicit (volitional and intentional) processes of anticipatory knowledge creation, as a necessary and ordinary skill. (...) Futures Literacy is the knowledge and skill of how to ‘use-the-future’, it is a familiarity with anticipatory systems and processes.”* (Miller, 2018, p. 58)

Moreover, it also involves the competence to critically examine existing and emerging narratives of futures and their implications for society. The analysis of such future narratives and their link to certain technologies enables to draw insights about society, its desires, its fears and its potential to transform. In the FOUNDING LAB program, we also followed the structured action learning process of the Futures Literacy Laboratories which Miller (2018) describes how participants develop their skills step by step, from an initial recognition of how their notions of the future influence their perceptions of the present, all the way to collaborative knowledge creation and capacity to design processes of collective intelligence. (Miller, 2018, pp 16-17).

Within the field of futures studies the concept of futures literacy has been critiqued for the framing of it as an individual competency that can be trained or "leveled up." This approach, so the argument, risks placing the responsibility for global change on personal skills, potentially overshadowing the need for deeper structural and systemic transformations (Slaughter, 2004; Inayatullah, 2007). Slaughter, for instance, has warned that focusing too heavily on individual foresight may oversimplify the complex and collective nature of global challenges, while Inayatullah has highlighted the importance of addressing broader societal and institutional dynamics in futures work. Despite these critiques, futures literacy remains a useful tool for empowering individuals to navigate within the systems they are a part of, influence their environments, and establish the individual mindset that can be shared with allies and is necessary for systemic change.

2.2.1. The Ars Electronica Futurelab Angle on Futures Literacy

One of the main research areas of Ars Electronica Futurelab's Art Science Research strategy is Futures Fluency. This terminology was introduced to express a capacity beyond the basic skill of futures literacy in its original meaning. According to this definition, a future-literate person could deconstruct existing future narratives, and a future-fluent one could create new, meaningful stories that convey a shared vision, which can express and reinforce collective values, emotions and norms. This research focuses on developing and applying future thinking processes such as Art Thinking (Ogawa, 2020) and Future Narratives (Pfeifer, 2021), which help to create and evaluate philosophical value systems and collaborative future prototypes in various domains, such as business, culture, and education. Narratives play a significant role in initiating and guiding change processes in the present. Here we take the notion of the individual skill of futures literacy to a shared vision that can be the driver for systemic changes, from individuals as "agents of change" to a collective "agency of change", also defined as "sociopolitical change" by Hodson (2020).

Art is one means to fabricate and reflect such narratives, as it is both a reflection and a projection of society. It depicts reality as it is and as it could be. Employing artistic strategies to materialize ideas can be a form of knowledge production that transcends the intellectual level and appeals to the emotional and sensory dimensions of human experience, as it provides an immediate emotional and sensual reaction. Recent studies in science and technology studies (STS) are increasingly focusing on art and design as key areas of inquiry and how "STS scholars can benefit from the ways artists and designers bring about new futures and work in speculative modes of inquiry that are not necessarily beholden to established epistemological frames, methods, conventions, and practice ", with an emphasis on the entanglement of bodily senses and knowledge (Salter et al. 2017).

The projects and research at the FOUNDING LAB involved cultivating such an artistic mindset introduced by the Ars Electronica Futurelab, and applying different artistic methods, such as prototype experimentation, artistic journalism, Art Thinking (Ogawa, 2020), and an overall creative and critical attitude towards future technologies with the aim to produce immersive and engaging experiences that encouraged dialogue and collective intelligence. For easier referencing, in the following, the term futures literacy is used, subsuming all previously described skills according to Miller (2018).

3. Training Futures Literacy at the FOUNDING LAB

The future skills framework was a key starting point. In addition to the skills presented in the previous section, we need to keep in mind that the group of diverse students who took part in the program, already had many of the key competencies, which we were able to build upon. Thus, Futures Literacy was applied in the FOUNDING LAB Fall Term using implicit as well as explicit methods.

Explicitly, we designed sessions on the university of the futures and workshops on future thinking methods. We also built anticipatory competency and the skill to comprehend and assess different futures through exercises, workshops and lectures. To give some concrete examples, the FOUNDING LAB Fall Term concept foresaw one online meeting before every program block in Austria. These so-called Zoom-in calls introduced the new chapter topics and set a common ground for the work on-site. During the Zoom-in calls, following the methodology of Art Thinking (Ogawa, 2020), the students were asked to concentrate the content input into creative questions that reach beyond the presented content. The curated art works inspired to see beyond their final form, to ask reflective, daring, visionary questions that open up new thinking possibilities for future scenarios. Also, they were asked to come up with imaginary future tasks and conceptualize a machine that responds to that urge. The students were challenged to render a proof-of-concept draft plus create an AI generated promo video for their current semester projects projected to our world in 2050. During the so-called Zoom-out calls after each program block on-site, the learning experiences were collectively contextualized within the bigger frame of the university of the future. These included, amongst others, workshops and discussions on possible future university concepts, as well as crucial skills to be taught in next generations.

Even more dominantly used were implicit methods for training futures literacy. The overall endeavour was conducted under the flag of envisioning and practicing a university course for future students. The FOUNDING LAB program served as experimental testbed for future university concept ideas. Digital transformation served as a recurring theme throughout the project. The Fellows and the Ars Electronica Futurelab team created interdisciplinary learning opportunities like the Dancing Drone Challenge. By forming interdisciplinary teams and given different learning context including a preselected technology like drones, the students built meaningful, tangible scenarios that opened up profound questions for future developments. Also, one of the major contexts for personal and professional growth were the students' semester projects. They provided hands-on experience in tackling future challenges.

4. Measuring Future Skills in the FOUNDING LAB Fall Term Program

To record the impact of our approaches, the Fall Term program employed a feedback and evaluation process, enabling students to self-assess their development regarding future skills. Due to the small number of 25 students participating, the assessment focused on collecting qualitative impressions to measure whether the program lived up to its promises regarding the development of future skills. One of the challenges we faced in the evaluation process was the small and heterogeneous sample size of 25 participants, who were involved in a one-time prototype program. We wanted to measure the development of future skills, which are not easy to quantify or standardize. Therefore, we used a mixed-methods approach that combined numerical ratings with open-ended questions and group interviews. We asked the students to self-assess their growth in each of the five skills, as well as to share their more general feedback and reflections on the program. We acknowledge that this method has some limitations, such as potential bias, subjectivity, and inconsistency in the responses. However, we also believe that it still provides valuable insights into the students' individual and collective learning experiences and outcomes. We also aimed to use the evaluation results as a formative tool for improving the program design and content delivery throughout the semester, rather than as a summative assessment of academic performance at the end. Therefore, we shared the feedback with the fellows who led the program, with the opportunity to discuss the strengths and areas for improvement. In this paper, we present some of the findings and implications of the evaluation process, while recognizing its exploratory nature and scope.

4.1. Rating Futures Literacy as a skill? An Exploration towards Quantitative Analysis

We evaluated the program with online surveys where the participants rated the contents and conducted self-assessments. For a streamlined approach, we concentrated on five key skills for the anonymous feedback process. In the online questionnaire, the students rated how the content chapters supported them in developing:

- critical thinking, including problem-solving, questioning norms, and creativity,
- technology use, including the use, design, and development of technology,
- self-management & self-awareness, including active learning, curiosity, and the ability to reflect on one's own development,
- interdisciplinarity, including collaboration and communication across disciplines,
- futures literacy, including anticipatory competency and the ability to understand and evaluate multiple futures.

The following graph (Figure 1) shows the students' rating on how well they felt, the six different program sections (1 Infrastructure, 2 Data & Code, 3 Machines & Robots, 4 Interfaces & Visualizations, 5 Media, 6 Digital Society & Policy.) supported their skill development of Futures Literacy. The survey used a six-point scale, with six being the highest. The definition of Futures Literacy was not explicitly discussed before the survey, but well understood in the line of 21st century skills within the group. The feedback was given directly at the end of each program section.

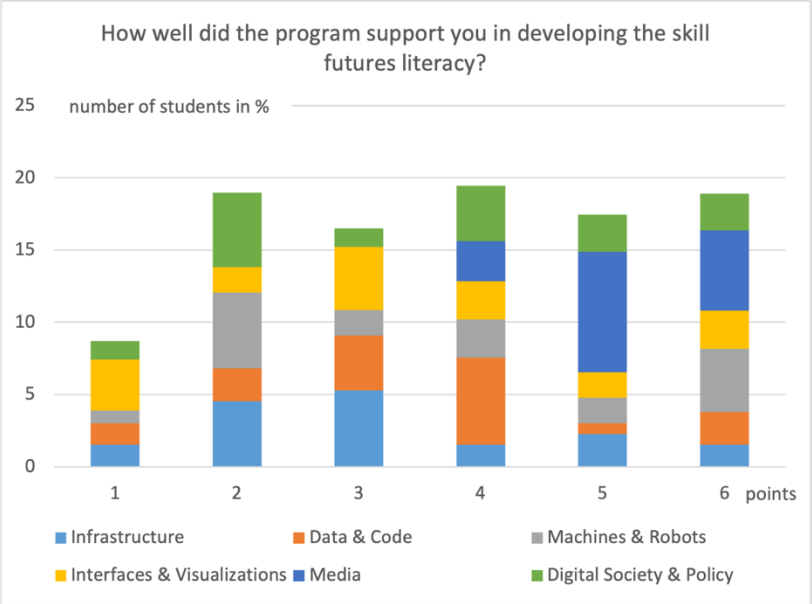

Figure 1. Quantitative evaluation of the explicit and implicit training methods of futures literacy in the six content blocks during the FOUNDING LAB Fall Term

The average scores for futures literacy skill development during each content block ranged from 3.18 to 5.6.

The survey results showed that the program section on media literacy had the highest rating for futures literacy skill development, while the one on infrastructure had the lowest. This could be due to the different approaches and tools used in each block, as well as the students' expectations and criteria for this skill. It is important to highlight that self-assessment is only one potential tool and might not completely accurately reflect the actual competence level. At the same time, other methods of assessment such as practical tests (improvement in the ability to complete a given task) or written tests might provide a more comprehensive picture. However, such examination tools were not foreseen for this program. The students were asked to write a reflexive summary of their semester projects for our archives and show their newfound knowledge and skills by exhibiting the outcomes of their semester projects. While speaking with the visitors of the exhibition, we could hypothesize that they improved e.g. science communication skills. In future programs, more accurate tools of skills development might be deployed. The fact that students had diverse backgrounds and expertise would also have complicated centralized skills measurement. The complexity arising from their diversity also becomes

visible in how their backgrounds influenced the personal ratings of different sessions. The degree of education varied from Bachelor's to PhD and students came from different universities and disciplines.

The key finding from these ratings is that the overall feedback on the program in total was positive. 80% of the students rating 5 or 6 out of 6, estimating how well the program prepared them for future challenges (see fig. 2).

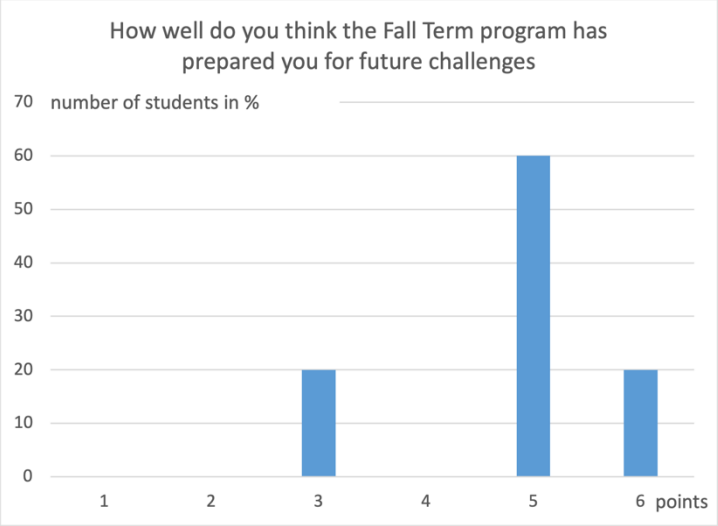

Figure 2. Quantitative student self-assessment of how well the FOUNDING LAB Fall Term prepared them for future challenges

4.2. Tackling Future Challenges? A Qualitative Assessment

We also collected qualitative data on the students' experiences, challenges, and outcomes of the project. We had regular check-in sessions after each program block for collecting verbal assessments in addition to the constant exchange between students and faculty. Continuous communication based on mutual trust between students and faculty allowed for constant feedback flow.

In anonymous, written feedback, participants shared in which aspects the Fall Term program prepared them for future challenges:

- Exposure to Game Changers: Participants felt that the program introduced them to individuals who are catalysts for change, expanding their perspectives significantly.
- Expanded Network and Career Insights: Many participants noted the value of expanding their network and gaining insights from the lived experiences of fellow participants, shaping their views on future career trajectories.
- Skills for Transdisciplinary Work and Collaboration: Participants highlighted the acquisition of skills and knowledge valuable for working in transdisciplinary groups and emphasized the significant improvement in collaboration and interdisciplinary skills because of the program.

- Equipped for Global Discussions and Increased Confidence in Addressing Societal Issues: The program enabled participants to engage in dialogues with global implications and to feel more confident in tackling societal challenges related to digital transformation, AI, and decolonization.
- Overcoming Personal Barriers: Some participants mentioned overcoming personal fears and gaining confidence to engage with the world outside of virtual environments, which was a significant personal takeaway.
- Strengthened Thinking: While acknowledging the program's positive impact on their thinking, participants recognized the need for personal effort to translate their learning into practical skills.

Overall, the responses reflect a diverse range of experiences and insights gained from the Fall Term program, highlighting its effectiveness in preparing participants for future challenges across various domains, including interdisciplinary collaboration, global discussions, and personal growth.

4.3. Comparison of the FOUNDING LAB and Home University Experiences

In this section, we report on the participants' perceptions of how the FOUNDING LAB program differed from their previous university courses. We asked them to compare the two types of learning environments in terms of various aspects, such as the teaching methods, the assessment criteria, the feedback mechanisms, the level of challenge, and the impact on their thinking and skills. The following themes emerged from the analysis of their responses:

- Participants mentioned several major differences between the FOUNDING LAB program and their home university courses, such as a highly personal learning environment, better communication with teachers and Fellows, and more flexible and intense activities. Participants appreciated the increased time spent with one another and the depth and length of conversations during the program. While courses at their home universities were similar in format, the intensity and range of disciplines available in the FOUNDING LAB program were noted as key differences, with unrestricted study being enjoyed.
- Participants stated that the FOUNDING LAB program helped them grow interdisciplinary skills and critical thinking more than their home university courses. Moreover, participants rated the time and effort spent on interacting and communicating with students much higher in the FOUNDING LAB program, and pointed out the advantages of wider networks, more knowledge, and a supportive team.

Given that such a survey reflects very individual experiences, this still reveals a noteworthy picture. The survey results reflect the diverse and heterogeneous nature of

the program, both in terms of its curriculum and its participants. The program, co-designed by a multidisciplinary team of fellows, offered educational methods and thematic inputs catering to different interests and needs. The participants also brought their own backgrounds and skills to the program, which resulted in a wide range of subjective responses and experiences.

5. Reflection and Conclusions

In conclusion we observed a reflection of the program's inherent heterogeneity. The curriculum, a result of interdisciplinary collaboration among a diverse cohort of Fellows, consisted of varied educational methods and individual thematic approaches. The students brought diverse backgrounds and skill levels too, so their individual responses exhibited a substantial range. While the average ratings were clearly favourable, there were always some students who could not relate to or gain competences during the various inputs.

According to the questionnaires, the FOUNDING LAB program has had a significant impact on participants' research and artistic practices, providing opportunities for collaboration, experimentation with new technologies, and a supportive environment to try without fear of failure. Key takeaways include the realization of the potential for art to catalyze change in thinking and to connect individuals with diverse lived experiences, the value of interdisciplinary collaboration in both artistic and technical projects, and the importance of mental health and balance in one's approach to work. Participants also highlighted the fruitful debates with peers and Fellows, expressing a desire for more dedicated time for such discussions. The program has led to the development of interdisciplinary projects, expanded networks for learning and collaboration, and newfound confidence in taking on complex projects that involve diverse skills and people. Overall, participants have gained new perspectives, critical thinking skills, and confidence, while also forming meaningful connections and friendships. The decision on and application of the quantitative feedback and the rating of skills on a scale was a deliberate choice to provide a simple and accessible tool for students and Fellows to evaluate their learning outcomes and competencies. However, we are aware of the limitations and criticisms of such a method, which can be seen as reductive, subjective, and biased. Therefore, we do not claim that the results are definitive or representative of the entire program or its participants. Rather, we see them as a quick check-in and an invitation for further dialogue and reflection on the complex and multifaceted nature of the program and its impact. The feedback we received suggest that the program is effectively enhancing students' skills to meet the challenges of the future. In the overall feedback we can also see a strong tendency in the development of one of the skills the World Economic Forum named as one of the “core skills top 10“ in their Future of Jobs

report 2023: “*empathy and active listening*” (World Economic Forum, 2023, p. 38) and, similarly to Hodson (2020), propose that it should also be added to the education of interdisciplinarity.

Also, this notion of “care” was extremely well received in the supporting programs, not provided by the different Fellows, that dropped in and out of classes. The team consisting of Ars Electronica Futurelab members and facilitators was able to connect with the students on a substantial level, due to the more long-term interaction and by giving support not only on intellectual challenges but by helping to overcome obstacles–from visa issues to accommodation and intercultural conflicts–so that the students were able to realize their envisioned projects at the end of a Fall Term. Here the students could develop the skill of futures literacy, by feeling empowered, by realizing their visions and creating tangible outcomes. Skills associated with futures literacy, including imagination and creativity, adaptability and resilience, interdisciplinary knowledge, communication and collaboration, ethical reflection, and learning agility were strengthened. Linked to the future-oriented topics at hand the whole program was very much about developing futures literacy – even though only some inputs were explicitly “futuring” or scenario-building exercises.

In the FOUNDING LAB program, we combined the idea of saying goodbye to one’s individual ideas and embracing change and collaboration for novel outcomes with UNESCO’s action-oriented learning for a transformative learning experience. All of this was only made possible by bringing together a diverse group of students: diverse in terms of age, gender, cultural background and nationality, and discipline. In a forthcoming book (Liebl et al. 2024), we present the project descriptions. These show that interdisciplinarity was not the result of different disciplines working alongside each other but by allowing different ideas to merge and emerge through collaboration. The FOUNDING LAB experience, marked by its diverse and collaborative nature, provides a valuable case study for designing futures-oriented, futures-literate and futures-fluent university curricula. By balancing the potentials and limitations of collective action and creating learning environments that prioritize questioning over knowledge transfer, the program aimed to inform precedents for the university of the future. By recording the findings in this paper, the authors hope to contribute to the recent re-uptake of STS’s interest in SSI by providing a practice-based, experimental perspective.

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