MSc in Techno-Anthropology

Epistemologies of AI

A techno-anthropological study of researchers' experience of differences in epistemic cultures between the fields of Civil Engineering and Artificial Intelligence in an interdisciplinary project at Aalborg University's research center 'AI for the People'

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SYNOPSIS:
To gain an understanding of the complexities that constitute the field of AI, primarily seen in relation to interdisciplinary research projects with other fields, this study set out with the scope presented in the following problem statement: ***How are differences in epistemic cultures and milieu experienced by researchers participating in the practice of knowledge production within an interdisciplinary project involving AI?*** The thesis is based on a qualitative case study of an interdisciplinary research project between two departments at Aalborg University, "Built Environment" and "Architecture, Design and Media Technology", concerning the application of AI in the optimisation of indoor visual comfort. The knowledge and empirical data was gained through participation in meetings, conduct of interviews, and access to personal and official communication related to the case. The empirical data was analysed through the perspective of a theoretical framework build from several literature reviews, focused on interdisciplinary knowledge production and the notion of epistemic cultures, among others. With no tensions present in the immediate collaboration of the case, focus turned towards tendencies affecting the relationship between the fields of Civil Engineering and Artificial Intelligence. Through this, approaches towards a diffusion and demystification of AI were identified in relation to applicability of Computer Vision in the field of Built Environment.

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We call ourselves Homo sapiens—man the wise—because our intelligence is so important to us. For thousands of years, we have tried to understand how we think; that is, how a mere handful of matter can perceive, understand, predict, and manipulate a world far larger and more complicated than itself. The field of artificial intelligence, or AI, goes further still: it attempts not just to understand but also to build intelligent entities.

Russel and Norvig, 2016 (p.1)

Preface

The present report is the result of the thesis conducted as part of the fourth semester of the Master programme in Techno-Anthropology at Aalborg University. The project was conducted in the spring of 2021 and handed in April 30th.

I would like to extend my gratitude to my thesis supervisor Maurizio Teli for providing excellent guidance throughout the project period. Secondly, I would like to give thanks to the team members of the research project "*AI for optimizing indoor visual comfort from facial analysis*" at Aalborg University, for enlightening me with insights into their work, and a special thanks to Hicham Johra and Rikke Gade for taking the time to participate as key informants of this thesis. Finally, I wish to thank my family and friends for providing unconditional and much appreciated support during this period.

Clarifications

The report takes its point of departure in a study of an interdisciplinary research project involving AI, conducted in relation to my master thesis, with a focus on experienced epistemic cultures and milieux. The case connected to the study is named SCODYF1: A project combining the fields of Civil Engineering (Built Environment) and Artificial Intelligence (Computer Vision) in the interest of optimising indoor visual comfort from facial analysis through the use of AI.

The report consist of 11 chapters, to which it is recommended that the first 10 are read chronologically to attain maximum understanding of the information contained within each and their relation to each other.

The standards of Chicago 17$^{\text{th}}$ edition (author-date) are applied as reference style for sources. Chapter 11 presents an alphabetised list of all sources used in this report.
References to an appendix will appear as (App.X) and the following presents a brief overview of the appendices attached to this report:

Appendix A	Overview of the five literature reviews conducted in relation to this thesis. Both purpose, approach, and results are presented, but separated into five sub-appendices.
Appendix B	Overview of all pie-charts used in relation to the project.
Appendix C	The interview guides for the two interviews conducted.
Appendix D	Notes from the introductory meeting with the informants Hicham Johra and Rikke Gade from the research project used as the case of this thesis.
Appendix E	Transcription of the interview with Rikke Gade.
Appendix F	Transcription of the interview with Hicham Johra.
Appendix G	Field notes from a meeting in the project group concerning results from their prototype.
Appendix H	Coding procedure providing an overview of the analytical approach along with results and related qualitative mappings.

References to an appendix will appear as (App.X), while references for quotations will appear as (App.X, p.X, l.X). Seeing as some empirical data related to this thesis contains confidential information (email correspondences and work notes from informants) these will not be included in the appendices. Consequently, some sections will be referenced as *personal communication* and abbreviated as *P.C.*, with the following references when quoting (name, P.C.).

Figures and tables utilised in this report are numbered and an overview will be available succeeding the table of contents.

Clarification of Concepts or Abbreviations

The following listing presents some explanations of abbreviations and concepts used frequently in this report.

AAU	Aalborg University
AI	An abbreviation of Artificial Intelligence, which in this thesis is used to encompass the broad umbrella field that constitutes artificial intelligence.
AI expert	Used both when mentioning experts in Artificial Intelligence in general, as well as some to indicate some of the informants, primarily Rikke Gade. When referencing to the work of Forsythe (2001), these are referred to as "*Knowledge Engineers*", but I have chosen to use them as equivalents, as the knowledge engineers in Forsythes work refer to people developing AI solutions.
BE	An abbreviation of "Built Environment", a subfield to civil engineering, and the one which the key informant Hicham Johra works within.
BUILD	Used when referring to the department of "Built Environment" at AAU in relation to the case of the thesis: SCODYF1.
CE	Abbreviation of Civil Engineering or Civil Engineers when written as CE's.
CNN	Convolutional Neural Network
CV	An abbreviation of "Computer Vision", a subfield of artificial intelligence which constitutes the overall field of research of the key informant Rikke Gade.
Epistemic culture	"*[...] amalgams of arrangements and mechanisms-bonded through affinity, necessity, and historical coincidence [...]*" (Cetina, 1999, p. 1). Thus, epipstemic cultures both create and warrant knowledge in the world of science (Cetina, 1999).
MediaTech	Used when referring to the department of "Architecture, Design and Media Technology" at AAU in relation to the case of the thesis: SCODYF1.
Milieu	In relation to this thesis, milieu refers to the social and sociocultural environment and context. It is thus often used in the report as a reference to the social setting of the case or their respective fields.
SCODYF1	Abbreviation used in the report when referring to the case of this study: Part one of the Smart COntrol of DYnamic Façades project, an AAU bridging project named "AI for optimizing indoor visual comfort from facial analysis".
STS	The interdisciplinary field of Science, Technology, Society.

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Part I

Introduction

1 Introduction

Since the first industrialisation, academia has been through extensive disciplinary developments, shifting both the foci and content of fields, and in some cases affecting their approaches toward knowledge production and collaborative efforts to reach higher levels of innovation. This has pushed the agenda of interdisciplinary collaborations, which presents its own benefits and issues, depending on the contextual reality in which they take place.

Having previously worked with the way epistemic cultures affect implementations of digital technologies in a hospital environment, I find it interesting to explore the different academic and epistemic cultures existent in other academic fields. Seeing as my attention has been drawn to Artificial Intelligence for numerous years, I finally decided that now was the time to shift my focus onto the field of Artificial Intelligence. As an interdisciplinary field, it has many interfaces with other academic fields and, by extension, the field and the researchers who are part of it, are naturally at risk of encountering boundaries or tensions between epistemic cultures. Knowing how much epistemic cultures and tensions can affect a progress, artificial intelligence thus provide an interesting context for studying these factors, among others.

As it concerns humans and their socio-epistemic practices which are riddled with social and cultural factors, it is something that cannot and should not be studied as a purely theoretical concept or problem, but something that is intricately rooted in the practices of knowledge production and thus must be treated accordingly.

In the context of Artificial Intelligence, the research project "*AI for optimizing indoor visual comfort from facial analysis*" based at Aalborg University presents an interesting case for studying the aforementioned. Especially, considering the both highly similar and yet different characterisations of knowledge related view and practices that manifest in the two participating fields: Civil Engineering in the Built Environment and Artificial Intelligence in the form of Computer Vision.

When regarding the expectations to researchers and the pressure to posed by societal developments and demands from the industry, it both seems relevant to study the context of knowledge production and how it is affected. Additionally, it prompts discussions about how to keep up with the fast-paced society we live in today, and which permeates the world of academia as well. In that sense, a key informant of this thesis expressed: "*[...] I think you should always be open for new ideas.*" (App.F, p.2).

But what does this actually entail when commencing a collaboration between disciplines with potentially disparate disciplinary worldviews, epistemic cultures, and approaches to knowledge production in interdisciplinary research milieux?

Problem Analysis 2

For many years I have kept a peripheral interest in the topic of Artificial Intelligence (AI), even though I have not pursued this through my previous projects for various reasons. Nevertheless, I have during both my bachelor and master's degree completed various courses on ethics, in which AI has been discussed, although these have naturally fixated on the ethical concerns regarding AI technologies' impact on society and its individuals. Yet, this is only part of what intrigues me about AI, the other part lies in the field's vast size and complex nature making it difficult for actors to navigate, without knowing the specifics.

Now, knowing that I needed a better understanding of AI's complete history as a research field, I chose to start off with what I believe is perceived by many as the universal tome of AI: "Artificial Intelligence - A Modern Approach" (Russell and Norvig, 2016c). Not being particularly trained in the technical areas that surround AI, I chose to focus most of my readings of this book on the history of the field, disciplinary contributions, conceptual understandings and ethics, which are outlined at the outset of this problem analysis. However, my initial read through brought a lot of questions to the forefront of my mind regarding the disciplines contributing to the development of the field, leading to a series of literature reviews (App.A) and the second part of this analysis.

2.1 Artificial Intelligence through Time

As quoted in the epigraph, humans have always been interested in what makes up our intelligence. With the emergence of advanced technology, this naturally lead to the interest of simulating it; a field that is now acknowledged as Artificial Intelligence or AI in its abbreviated form.

The 1940s and early 1950s presented many examples that might be characterised as AI, such as the development of neural networks which was swiftly abandoned though. However, Alan Turing's vision might be considered one of the most influential, introducing both the "*[...] Turing test, machine learning, genetic algorithms, and reinforcement learning.*" (Russell and Norvig, 2016a, p. 17).

The term *Artificial Intelligence* was officially conceived in 1956 during a two-month workshop at Dartmouth College initiated by John McCarthy; at the time working as an assistant professor with a PhD in mathematics acquired five years prior. The workshop proposed a study based on the notion that all aspects of intelligence, including e.g. creativity and self-improvement, could, in principle, be simulated by a machine. This study soon became the official beginning of the new field of AI focusing on both theoretical work and the attempt to program machines corresponding to the theories.

The field's early enthusiasm rapidly lead to small successes proving what machines could do, e.g. with the General Problem Solver (GPS) which was "*[...] designed from the start to imitate* *human problem-solving protocols [...] Thus, GPS was probably the first program to embody the "thinking humanly" approach.*" (Russell and Norvig, 2016a, p. 18). These accomplishments led to many tremendous expectations to further advancements. However, this proved to be hubris based on the success of early AI systems working in limited and simple environments which were vastly unsuccessfully when applied to wider contexts and more complex problems, due to e.g. a lack of background knowledge or intractability[1]. Therefore, these early AI research results, focusing on general-purpose search mechanisms, have been called *weak methods* of problem solving (Russell and Norvig, 2016a).

In the 70s, a shift was thus deemed necessary. The focus was now on using "*[...] more powerful, domain-specific knowledge that allows larger reasoning steps and can more easily handle typically occurring cases in narrow areas of expertise.*" (Russell and Norvig, 2016a, p. 22). This new methodology of *Expert Systems* lead to an increase in applications to real-world problems. Medical diagnosis quickly became a popular field of application, with the first system being MYCIN: Developed to diagnose blood infections based on extensive expert interviews (Russell and Norvig, 2016a). However groundbreaking MYCIN was, it was also the prime example of a knowledge-related failure stemming from the developers' tacit assumptions of what is obvious and common knowledge affecting the information and workings of the system[2] (Forsythe and Hess, 2001). Nonetheless, incorporating domain specific knowledge had a substantial importance in the understanding of natural language, overcoming ambiguity in early translation machines and focusing efforts on the problems of representing necessary knowledge to understand language (Russell and Norvig, 2016a).

Everything seemed to go well for the field of AI in the 80s where it grew, with impressive speed, into a multi billion dollar industry. However, the *AI Winter* was coming, and "*[...] many companies fell by the wayside as they failed to deliver on extravagant promises.*" (Russell and Norvig, 2016a, p. 24). Despite these unfortunate ordeals, the early work on neural networks was resumed and reinvented, diverging modern neural network research into two fields concentrating on creating mathematically effective networks or modelling actual neurons (Russell and Norvig, 2016a).

With a relatively robust field of AI, the adoption of the scientific method[3] from 1987 and onward, allowed it to grow further, withdrawing previous disassociation with existing fields, such as statistics and information theory, and embracing some of the early abandoned notions and theories. Building on early models with improved methodological and theoretical frameworks resulted in many improvements within the field, one of them being the *Bayesian network*, overcoming many of the previous problems with uncertain knowledge, e.g. being able to learn from experience (Russell and Norvig, 2016a).

[1] "*Roughly speaking, a problem is called intractable if the time required to solve instances of the problem grows exponentially with the size of the instances.*" (Russell and Norvig, 2016a, p. 8).

[2] In the case of a male with a bacterial infection MYCIN pointed to amniocentesis, a procedure carried out on pregnant women. The system simply did not contain the basic information that men cannot get pregnant (Forsythe and Hess, 2001, p. 19).

[3] "*[...] systematic observation, measurement, and experiment, and the formulation, testing, and modification of hypotheses.*" (Lexico, 2020).

The subproblems of AI was then solved with great progress, creating well-working AIs that could solve smaller well-defined tasks excellently. The successes of the more limited AIs, or so-called *Rational Agents*, lead back to the notion of a complete agent again in 1995 with the emergence of so-called *Intelligent Agents*. These are more complete agent architectures, based on the notion that "*[...] the concept of rationality can be applied to a wide variety of agents operating in any imaginable environment.*" (Russell and Norvig, 2016a, p. 34).

The internet soon became a vast environment for a variety of AI technologies, ever improving web-based applications. However, a few of AIs founders wanted to turn focus away from improving these single-minded applications and back to the notion of creating a machine, able to think, learn, and create: *Human-level AI*. A related effort is the subfield of *Artificial General Intelligence* which "*[...] looks for a universal algorithm for learning and acting in any environment.*" (Russell and Norvig, 2016a, p. 27). With the increasing availability of large data sets from 2001 and on, it became clear that the amount of data the system can learn from meant more than the specific algorithms applied. And from then on, thousands of AI applications have been created and embedded in the infrastructure of our society (Russell and Norvig, 2016a).

2.1.1 Approaches towards defining Artificial Intelligence

The different theoretical and practical approaches towards AI can be organised into four categories with varying dimensions (see table 2.1).

	Human Performance	Ideal Performance
Reasoning	*Thinking Humanly* Cognitive modelling: Theory of the mind based on introspection, psychological experiments and brain imaging	*Thinking Rationally* Laws of thought: Building logical programs to create systems with irrefutable reasoning processes
Behaviour	*Acting Humanly* The Turing Test approach: Imitation of human behaviour through varying capabilities programmed into a computer	*Acting Rationally* The rational agent: Focus on achieving the best (expected) outcome, based on logic and effectiveness etc.

Table 2.1: A matrix presenting four approaches to AI comprised of different dimensions, based on the work of Russell and Norvig, 2016a.

These categories encompass many facets of AI and are all important to the field. However, Russel and Norvig have chosen to focus mostly on the bottom-right entry of the matrix, providing a rather broad definition of AI:

> "*We define AI as the study of agents that receive percepts from the environment and perform actions. Each such agent implements a function that maps percept sequences*[4] *to actions [...]*" (Russell and Norvig, 2016d, p. viii).

Though this definition seems partial to a focus on rationality, it leaves relative freedom to the imagination of what can be counted as AI, which resonates considerably with my own views of AI.

2.2 The Academic Arena of AI

Despite the term AI being coined in 1956, the automation of computation can be traced back to the philosophical conjectures of Aristotle (384-322 B.C) concerning a system of syllogisms for rationality. These ideas were further developed in the 14th and late 16th to early 17th century by Ramon Llull and Thomas Hobbes respectively. The 1600s brought more to the table with the invention of calculating machines which furthered the speculation that machines might be able to "*[...] think and act on their own.*" (Russell and Norvig, 2016a, p. 6).

The idea that the mind operates according to logical rules and reasoning is related to the philosophy of *Rationalism*. However, these hypothesis also imply that the mind is a physical conception, governed by physical laws, which contradicts the idea of free will akin to the philosophy of *Materialism*. An opposing view of the mind exists in *Dualism* where part of the mind is considered outside the laws of nature, a differentiation between mind and matter first articulated by René Descartes (Russell and Norvig, 2016a).

Additional contributions from philosophy encompass thoughts about the origin of knowledge, which pose many theories including: *Empiricism*, *Induction*, *Logical positivism*, and *Confirmation theory*. But what is most crucial to AI is the question of how knowledge leads to action, because "*[...] only by understanding how actions are justified can we understand how to build an agent whose actions are justifiable (or rational)*." (Russell and Norvig, 2016a, p. 7). In the discipline of philosophy, and especially metaphysics, there are multiple theories or *isms* concerning what lead humans to actions, i.e. *Action Theory*, *Determinism*, *Libertarinism*, *Interactionism*, and *Kantianism* to name a few I have become acquainted with during my studies. This shows just a fragment of the complexities of human action, and what a difficult task it is to understand and possibly replicate it, and that is not even accounting for various other disciplines' contributions to this debate. But what Russel and Norvig (2016) choose to focus on, is purely the logic of reasoning. Stemming from Aristotle's argument that "*[...] actions are justified by a logical connection between goals and knowledge of the action's outcome [...]*"

[4] "*[...] the complete history of everything the agent has ever perceived.*" (Russell and Norvig, 2016b, p. 34).

(Russell and Norvig, 2016a, p. 7), the focus lies on quantitative formulas and formal theories for decisions, moving away from philosophical pondering (Russell and Norvig, 2016a).

2.2.1 Prominent Disciplines in AI

Although the philosophers presented fundamental ideas for AI, it required more than that to make it a *formal science*. And despite clearly being a branch of computer science, numerous disciplines had prominent parts to play: Mathematics, economics, neuroscience, computer engineering, control theory, (scientific) psychology, as well as linguistics (Russell and Norvig, 2016a). Narrating all these disciplines' contributions would undoubtedly take up most of this report. Instead I will present some central aspects from each disciplines that are important to understand the field of AI:

- As a fundamental aspect, Mathematics contributed with formal mathematical reasoning, such as the *Boolean (propositional) logic* and *first-order logic*, based on algorithms. Discerning as well as expanding what is computable with the existing technologies through careful use of resources is furthermore considered vital, along with developing the *theory of probability*.
- The field of Economics brought insight into human decision-making, with special focus on the mathematical treatment of utility by Léon Walras. Combined with the probability theory it constitutes a "*[...] complete framework for decisions [...] made under uncertainty [...]*" (Russell and Norvig, 2016a, p. 9) named *Decision theory*.
- Neuroscience has, through advanced images and mapping of the brain, proved that it consists of neurons which communicate through electrochemical reactions providing signals that control brain activity. Even with vast knowledge of this there is little understanding of how cognitive processes work and how memory is stored.
- Computer engineering has brought two things; the physical artifact (the modern computer) and a way to process information.
- Control theory presented notions of the self-controlling machine whose purposive behaviour stemmed from an attempt to minimise the difference between current and goal state through a regulatory mechanism.
- The areas of Behaviourism and Cognitive psychology both contributed with notions from the field of (scientific) psychology in the first half of the 20th century. The former focusing on how *percepts* leads to *action*, with the latter expanding this notion into three steps a knowledge-based agent must go through: "*(1) the stimulus must be translated into an internal representation, (2) the representation is manipulated by cognitive processes to derive new internal representations, and (3) these are in turn retranslated back into action.*" (Russell and Norvig, 2016a, p. 13). In the United States the field of *cognitive science* emerged in 1956 and demonstrated the use of computer models to elucidate psychological notions such as logical thinking.
- Linguistics focused on the relation between language and thought, presenting formal syntactic structures like Chomsky's theory explaining creativity. A hybrid field, Compu-

tational Linguistics, was founded to explore how knowledge should be represented in order for computers to use it (Russell and Norvig, 2016a).

These are merely the disciplines highlighted by Russel and Norvig (2016), but they compare relatively well with the academic areas that can be considered significant contributors to AI according to published research articles (see figure 2.1). Especially, granted that some of the aforementioned disciplines can be considered parts of the areas displayed in the chart.

The 'other' 9.3% of the chart consist of 17 different subject areas, as well as some contributions being undefined or under the area *Multidisciplinary*. Despite the more technical scientific disciplines being preponderant (computer science, mathematics, and engineering), the contributing disciplines are associated with quite divergent and even contrasting research paradigms, and thus, bring an amalgam of ontologies, methodologies, and epistemologies to the table creating a complex research and development environment.

However, these complexities concerning the development of new technologies are in fact not that surprising with the rising of the *fourth industrial revolution* and *wicked problems*, requiring various different disciplines and sectors of society to work together, as a consequence of the new technologies' often massive (potential) impacts on different aspects of society. This also applies to the AI field (Bruun, 2019).

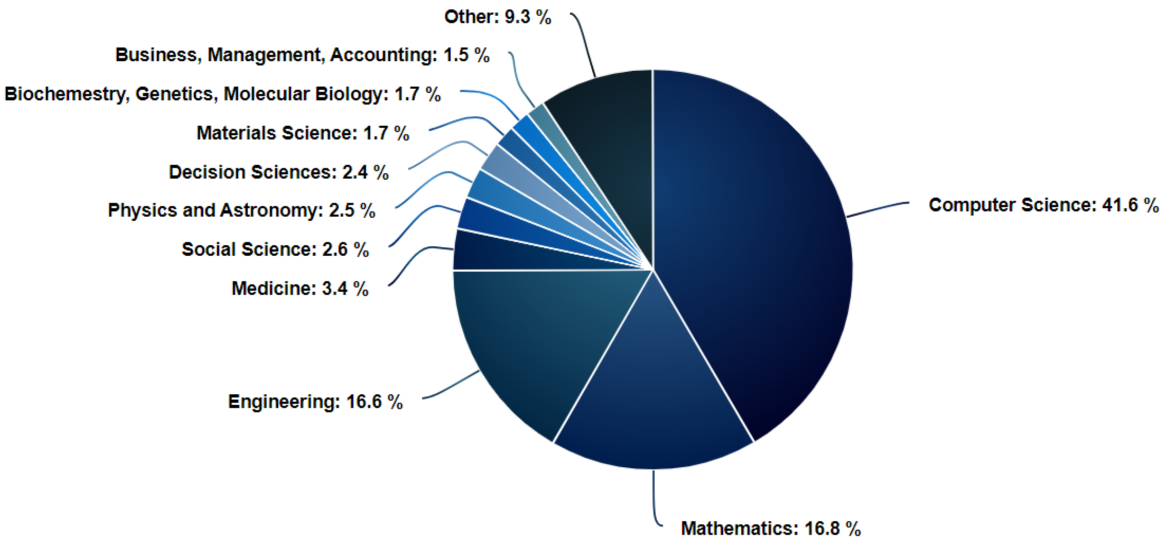

Figure 2.1: Pie chart based on SCOPUS' document analysis feature showing a division of documents by subject area from the 378,072 results of the search string (artificial AND intelligence) with occurrences in titles, abstracts, or keywords (App.B).

2.2.1.1 AI as an Interdisciplinary Field

By and large, the field of AI is far from homogeneous and neither are the disciplines contributing to it the field. And even though the field might still be considered relatively new compared to other more traditional fields of science (mathematics, physics, chemistry etc.) it has already gone through several *revolutions* and, thus, grown very complex. Furthermore, the interdisciplinary character of AI results in people bringing their own practices, institutions, understandings, biases, and presumptions, potentially resulting in discordance and tensions (Ekbia, 2003). In fact, from a certain point of view, AI might be described as a behemoth with all its multitudinous facets leading to potential and significant difficulties with epistemological boundaries, making it difficult for practitioners to navigate.

Even though the field of AI has naturally matured during the 21^{st} century, late anthropologist Diana Forsythe's argument, that the field is interesting for social science studies due to its struggles with defining its own identity and the boundaries to adjacent disciplines, still appears valid today. However, she also stated that "*[...] relatively little attention has been devoted to examining the fact that scientific processes are culturally contingent as well.*" (Forsythe and Hess, 2001, p. 2), and to my knowledge, brought forward by this study, the effect differences in academic or epistemic cultures has on AI research has not been studied explicitly or from an interdisciplinary point of view.

Coming from an inherently transgressive interdisciplinary education (Bruun, 2019), I not only find it interesting but crucial to consider disciplinary differences and boundaries as well as how we can transcend these in new technological development.

3 Problem Statement

The behemoth that is the field of artificial intelligence has experienced a substantial expansion in different fields during its existence, touching from computer science to engineering to social science etc., with many different practices. The problem is how professionals navigate in this jungle of research and collaborate with professionals from other disciplines with both similar and disparate epistemologies of practice, leading to a multiplicity of perspectives and competences which need bridging or considerations. Thus, this study is grounded in the problem statement presented below:

> *How are differences in epistemic cultures and milieu experienced by researchers participating in the practice of knowledge production within an interdisciplinary project involving AI?*

3.1 Limitations and Delimitations

There exist a multitude of interesting avenues to explore within the world of AI and its inherent epistemologies and related challenges but these would require a project with considerable resources in terms of time and labour. Due to resource constraints, this thesis represents only a fragment of collaborative AI research and their experiences with epistemological differences among other factors. The time constraints of prevents the examination of the case project from its start to finish, seeing as it is concluded two months after the deadline of this thesis.

Thus, this thesis offers no generalised conclusions but claims about context-dependant tendencies which are not declared as universally true but *real*; claims which might be beneficial when applied in other similar contexts.

Some of the more technically educated might view this thesis as employing a rather simplistic approach to the technical properties of AI as a field, and perceiving it as a sign of a lack of knowledge and understanding. While this might be true to some extent, the omitted focus on technical AI components and theories is a conscious delimitation on my part. The aim of this thesis is not to examine specifically what is being developed in the research project that constitutes the case of this thesis, but rather the work practices and epistemologies of the researchers.

Part II

Research Design and Framework

4 Theory

In order to examine the aforementioned problem statement, awareness of the theoretical perspective one applies is of great importance. There are many ways to go about a relational and reflexive study such as this thesis, especially when predominantly conducted as an inductive study. Thus, the following chapter merely constitutes the theoretical framework which has been selected as one way of identifying and understanding different tendencies in the case, in accordance with the objective of addressing the problem statement.

4.1 Science, Technology, Society

> "*Science is inherently social, and therefore its organisation plays an important role that must also be analysed from the perspective of the philosophy of science.*"
> (Rehbein *et al.*, 2020, p. 3).

The field of Science, Technology, and Society (STS) presents the view of knowledge production and science as a social process and a culturally contingent system: They are dependant on both the social and organisational context of science, and research practices differ in relation to the cognitive qualities within a research field. These are views which has been brought forth by visible figures from different fields, though some in an implicit manner, and are reflected in notions such as *Tacit Knowledge* (Polanyi and Sen, 2009), *Denkstil* and *Denkkollektive* (Fleck *et al.*, 1979), *Epistemic Culture* (Cetina, 1999), and *Communities of Practice* (Lave and Wenger, 1991) among others. Arguably, science and knowledge production, along with technology, cannot be seen as value-neutral, as it is implicitly or explicitly influenced by those performing it and the milieu in which it is conducted (Forsythe and Hess, 2001; Rehbein *et al.*, 2020; Klausen, 2009; Lengwiler, 2006). Science can thus be said to be a socially organised process controlled by multifarious factors, including:

> "*[...] written and unwritten rules and embossed by power relations and interests. There are initiation rites and learning processes, role models and scare stories, authorities (experts), authorative texts, priviliges, pecking order, competition and not least a high degree of division of labour.*"[Translation] (Klausen, 2009, p. 86).

The notion that science is a *socio-epistemic* practice[1], seen from a socio-technical and constructivist perspective, promotes the value of studying the organisation of knowledge production in emergent scientific fields such as AI.

[1] "*[...] practices which simultaneously produce new knowledge and enable new social arrangements in different socio-technical constellations.*" (Ferrari and Lösch, 2017, p. 76).

4.1.1 Knowledge Production and Tech Development

One aspect that increases the importance of studying and seeking improvement of the knowledge production processes in certain fields, can be attributed to the importance the outcome of knowledge production have in our society, namely the technological contributions. In relation hereto, when considering the great role science and technologies play in contemporary society, it is important to think about not only who uses the technology and how, but also who creates it and how they do it as well as how they view the world.

Furthermore, it is no secret that *Big Tech* companies[2] affect how we think and act in the world through their technologies. But as a consequence of the move towards *academic capitalism* (Jamison *et al.*, 2011, p. 2), Big Tech also have a lot of power in the scientific community, promoting certain agendas over others. These power structures can in some cases lead to a hierarchical structure of different areas of research within a field or a company that incites a sort of internal disenfranchisement of certain areas; akin to what happened with Ethical AI researcher Timnit Gebru's work at Google[3] (Tiku, 2021; Foer, 2018).

In the same manner, it can be considered that the dominant disciplines within a research field might constitute the overall way of thinking and lead to the disenfrachisement of marginalised perspectives. By virtue of their presence in the field of AI, computer scientists, mathematicians, and engineers etc. have undoubtedly and will inevitably affect the different AI technologies, but also determine which ontologies, epistemologies, and methodologies are appropriate or considered the norm within the field.

Seen from a techno-anthropological point of view, this further substantiates the relevance of studying different aspects of the philosophy of science in the field of AI, especially those that have a great impact on the work practices; and often seem to be taken for granted or deemed irrelevant (Forsythe and Hess, 2001).

4.2 AI as a Research Field

There are several researchers arguing for the inclusion of social science in science and engineering fields (Sørensen, 2009; Subrahmanian *et al.*, 2018; Nascimento and Pólvora, 2011) as well as the development of AI, and not just as a descriptive contribution, but having an active role in the development of AI (Forsythe and Hess, 2001; Mutzner, 2020; Royer, 2020). However, what I find highly interesting is not only AI as a technology or concept, but as a complex research field with many disciplinary interfaces, which has hitherto only received little to no attention (see section 2.2.1.1).

What occurred to me early on in my readings is the nature of the disciplines that make up the core of AI research according to Russel *et al.* (2016) (see section 2.2.1), which can be

[2] E.g. Amazon, Google, Facebook etc..

[3] Timnit Gebru's work on identifying problems with AI at Google was publically celebrated, but at the same time it was kept hiararchically distinct from other initiatives and their were no incentives created to heed her advice and put the findings into practice. When expressing discontent concerning this, Gebru essentially ended up being fired for doing the job she was hired to perform (Tiku, 2021).

considered to belong more to what is known as *realism*. On the other hand, there seem to be an apparent lack of more *constructivist* (social) science. Admittedly, economics is considered a social science discipline, but with it is mathematical focus on decision making in AI, it seems a highly positivist one. Similarly, linguistics is an inherently interdisciplinary field, lying at the cross-road between social science and humanities, but it is application in the field of AI seems rather positivist, with computational linguistics being even more so (Forsythe and Hess, 2001; Russell and Norvig, 2016a).

Thus, it seems that what is most visible in the AI field is the more positivist epistemology. But, how could you go about defining such a wide-ranging field?

4.2.1 AI and Social Science

As a start we might look at the differences between knowledge production in AI and social sciences, to enlighten some of the peculiarities of *technical work* and more specifically the dominant notions of and approaches towards knowledge production in AI.

When anthropologist Diana E. Forsythe (2001) studied the world of AI through several years of fieldwork, she gained many insights and identified many cultural tendencies among what she termed *knowledge engineers* who worked in the expert systems[4] community, primarily within medical informatics. This is perhaps the most prominent work focusing on the culture of AI and how an anthropologist fit into this world, and brings forth many interesting difference between AI experts (knowledge engineers) and social scientists (primarily anthropologists) (Forsythe and Hess, 2001).

The present section will thus aim to describe AI through a comparison with social science, based on primarily Forsythe's work combined with the view of Techno-Anthropology and other figures who have further contributed to the debate.

At the very foundation, we have the perhaps obvious, yet slightly generalised, differences in philosophical traditions (realism versus constructivism). One might also equate it to the division of engineering and anthropology as prescriptive and descriptive disciplines respectively (Bruun, 2019); although this may be a quite simplistic view especially when considering the complexities of AI as a research field. Nevertheless, despite its multiplicity in disciplines and perspectives resulting in a certain heterogeneity, AI seems to have constructed this collective identity as a "*hard*" science, which "*[...] reflects the fact that the knowledge engineers universally view their work as technical in nature.*" (Forsythe and Hess, 2001, p. 80). This view has also affected their notions on what knowledge is, which are quite antithetical to what can be considered the social scientific notion of knowledge (see table 4.1).

[4] "*Each expert system is intended to automate decision-making processes normally undertaken by a human expert by capturing and coding in machine-readable form the background knowledge and rules of thumb ("heuristics") used by the expert to make decisions in a particular subject area ("domain")*" (Forsythe and Hess, 2001, p. 18).

AI Experts' Assumptions of Knowledge	Social Scientific Notion of Knowledge
Knowledge as unproblematic	Knowledge as complex and problematic
Knowledge as *"[...] an either/or proposition: it is either present or absent, right or wrong."*. It is absolute.	Knowledge as situational and relational to perspective and cultural background
Reasoning is *"[...] a matter of following formal rules."*	Terms of meaning and reason is relational to social and cultural context.
Knowledge as a purely cognitive phenomenon.	Knowledge as a *"[...] social and cultural phenomenon as well as a cognitive one."*
Knowledge is conscious and explicit.	Knowledge as both conscious and tacit.
Thought and action are isomorphic.	The relation of belief and action is complex.
Knowledge as universal.	Knowledge as both local, situational, and global.

Table 4.1: A table based on Forsythe's (2001) distillation of knowledge engineers' assumptions about knowledge, which is largely tacit, as opposed to a social scientific notion of knowledge viewed from her own perspective as an anthropologist (Forsythe and Hess, 2001, pp. 52–53).

In brief, this indicates an apparent divergence in *disciplinary worldview* (Forsythe and Hess, 2001) with AI experts and social scientists acting from basic premises and values that differ from each other. Relying on the institutionalised or universal absolute facts, AI experts present a view of knowledge and practice embedded with an insistence on "*[...] formal rules, procedures, facts, and relations [...]*" (Forsythe and Hess, 2001, p. 10), which impedes or disregards a focus on that which is culturally contingent. This tenet is quite contrary from the view of an anthropologist, often sharing the view that "*[...] all scientific processes are culturally contingent [...] representing interests and perspectives.*" (Royer, 2020, p. 17). Human or expert knowledge is thus seen as a concrete, structured, and bounded entity which is even stable and consistent over time. It is something that can simply be acquired through the route of *just asking* and then transferred to a system. There is no process of constructing or translating knowledge, taking the complex relation between verbal representation and visible action into account, or even the fact that informants' representations can scarcely be considered impartial: All views and practices that are common or even expected among most anthropologists.

Knowledge, thus, seems to have been redefined as what can be read and manipulated by a computer program, which in turn requires it to be "*[...] explicit, globally applicable rules whose relation to each other and to implied action is straightforward.*" (Forsythe and Hess, 2001, p. 53). In light of these points, it has been argued that computer scientists (and by extension AI experts) tend to *delete the social* as well as *delete the cultural* through their automation of the concept of knowledge itself (Forsythe and Hess, 2001).

This concept of knowledge has formerly been visible in how AI systems are viewed as neutral and objective agents, with rational reasoning free of "*[...] the unpredictable social and cultural contingencies of everyday life.*" (Forsythe and Hess, 2001, p. 94), although this view might not necessarily be dominant today with the development of engineering practices (Bruun, 2019). In comparison, anthropologists tend to view technologies in a socio-technical perspective, placing emphasis on the designers' own world(view) and the embodiment or inscription of cultural values in the design of systems (Forsythe and Hess, 2001).

Subsequently, the preeminence of formal and quantifiable factors in the field of AI is similarly present in the evaluation of systems. Systems are judged in relation to technical requirements and not whether potential users find them useful in the real world as "*[...] usefulness is not quantifiable.*" (Forsythe and Hess, 2001, p. 7), although this has changed since the time of Forsythe's study. In contrast, a social scientist would stress the importance of considering situational or contextual factors in relation to the future real-life users (Forsythe and Hess, 2001).

These views may also stem from the assumptions regarding the relative importance of different kinds of work practice, where what might be characterised as epistemological work is marginalised or perceived as unimportant by AI experts seeing as it is not deemed technical, and therefore not immediately productive. The division of different types of work, among other factors, has further resulted in what might be viewed as a bias towards social scientists from the point of view of engineers or AI experts, which in turn reflect their own worldview (Forsythe and Hess, 2001; Bruun, 2019). And, as has been argued in the discussion of the role of social science in engineering:

> "*[...] social scientists are often perceived by engineers to be critical conversationalists engaging in 'philosophy', a thing that is not appreciated in a profession which values, above all else, hands-on problem-solving engagement.*" (Sørensen, 2009, p. 96).

A view which is not foreign among AI experts, according to other studies. They might even go as far as to scoff at the qualitative nature of anthropological analysis and its emphasis on the subjective experience, deeming it no actual research method due to the lack of deductive reasoning and controllable or quantifiable experiments. And yet, for some it might not be due to any negative opinions of such inductive or qualitative work, but simply because the view of knowledge and the practices among social scientist are too abstract and less comprehensible for AI experts, seeing as they can be difficult to implement into a world of technical thought and considerations (Forsythe and Hess, 2001; Mutzner, 2020).

Despite all these differences, there are indeed some aspects that engineering shares with anthropology which I believe can be attributed to the field of AI as well. Whether expressed transparently within the disciplines or not, both are constituted by applied approaches of a diverse range of theories based on intellectual scientific knowledge, which is primarily used as tools. Thus, they are also considered practical disciplines, with the aim of either understanding complexities in the world or developing solutions applicable in the real world, which all necessitate other forms of knowledge to be present, whether explicitly or implicitly; e.g. intuition, improvisation, language, and tacit knowledge (Bruun, 2019).

Nevertheless, the dichotomy between AIs emphasis on the controllable, technical knowledge and the more social, cultural, and somewhat abstract view of knowledge in social science is as interesting as it is troublesome for any potential cooperation between the two fields (Mutzner, 2020). For the time being, however, the purpose of this chapter will remain on unfolding the academic field of AI.

4.3 The Complexities of Disciplinarity

As previously stated in section 2.2.1.1, AI is an inherently interdisciplinary field. But what does this mean?

Firstly, an essential component to consider is the concept of a *discipline*, which is largely referred to as the organisational structure of knowledge production and modern science in a *horizontal strata*[5] (Rasmussen *et al.*, 2007, p. 23). Through disciplines, science and knowledge production is controlled by means of two elements: One nominal concerned with identity and the other related to exchanges in the real world. The former simply convey the notion of having an agreed upon name for the discipline. The latter is the need for jobs and a market which can be related to the discipline and, thus, the chosen name. Through these elements "*[...] collectivities that include a large proportion of persons holding degrees with the same differentiating specialization name [...]*" (Turner, 2000, p. 47) are created. Here, collective identities are shared through common interests and knowledge production structures which are moderately fixed with the exclusion of internal divisions that are relative to the main identity. In the collectives, communicative competencies and tacit knowledge etc. are also established through practice, which enables people within a discipline to understand each other and partake in the daily activity of their discipline (Maasen *et al.*, 2006; Turner, 2000; Rasmussen *et al.*, 2007).

But what is interesting to consider in relation to disciplines is the way they are affected by development in the collective field of science in modern society. With globalisation and *industry 4.0*[6], we face development at impressive speeds and new problems to solve which challenges the rigidity of disciplines: They are at the risk of becoming archaic and loosing their relevance all the time, and either need to develop internally, merge with other, or breed new disciplines to stay relevant. In correlation to this need, globalisation can be said to breed hybridisation and the need to transcend the epistemological, metaphysical, and political constraints of disciplines and tightly structured knowledge production; although some disciplines are less rigid and homogeneous than others. Add to this, the idea of disciplines extending their horizons through encounters with other disciplines and discoveries being more likely to occur at the boundaries between these. Furthermore, some have argued this to be a way to make technologies more

[5] The disciplines exist alongside each other.
[6] Another term given to the fourth industrial revolution.

democratic, ethical, sustainable etc.. And a way to achieve what we could call this hybridisation of disciplines is through cross-disciplinarity in some form, although it might be temporary in some cases and in others more permanent (Jamison *et al.*, 2011; Bruun, 2019; Turner, 2000; Nascimento and Pólvora, 2011; Barry and Born, 2013; Verma, 2017).

The topic of cross-disciplinarity has received much attention the last several decades, achieving the status as a buzzword, resulting in a multitude of perspectives on the different forms of disciplinarity and, thus, making it difficult to provide a unified definition (Klein, 1996). The following paragraph will, therefore, bring forth relevant definitions seen from the perspective of techno-anthropology and the topic of this thesis.

The terms almost universally agreed upon to distinguish the traditional *Multidisciplinarity* from the different types of cross-disciplinarity are *Monodisciplinarity*, *Interdisciplinarity*, and *Transdisciplinarity*. The division between these are often somewhat simplified, but several factors are included when determining the type of cross-disciplinarity in a project or a discipline itself (see figure 4.1) (Rasmussen *et al.*, 2007).

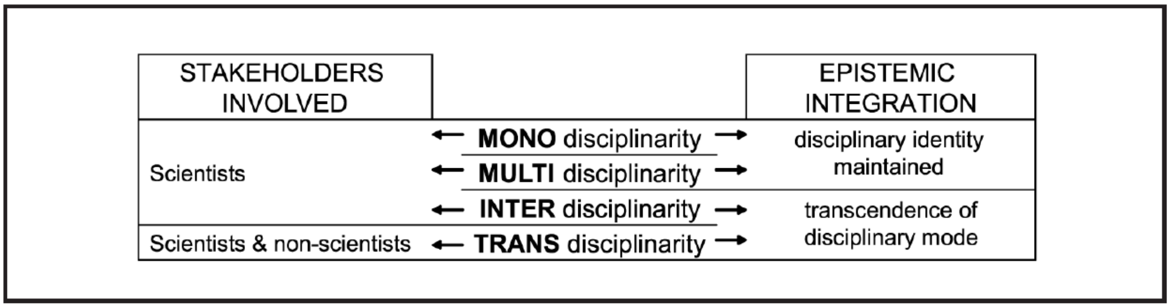

Figure 4.1: "*Degree of epistemic integration in cross-disciplinary research.*" (Rasmussen *et al.*, 2007, p. 24) portraying an understanding of cross-disciplinary research based on involved stakeholders and epistemic integration between disciplines.

Monodisciplinarity constitutes what has been described previously as simply a discipline. If we take it one step further we have the cooperation between disciplines, though with a low degree of interaction, in what is called multidisciplinarity. This means that participants keep their own disciplinary identity, framing, and mode of knowledge production intact while collaborating with people from other disciplines. It can be described as working in parallel towards the same goal, which might have different values for the participants depending on their home discipline (Rasmussen *et al.*, 2007; Barry and Born, 2013).

On the other hand, interdisciplinarity attempts to transcend monodisciplinary barriers and synthesise the knowledge production and perspectives of various disciplines. The, in most cases temporary, cooperation is often carried out in a formalised and structured manner to achieve both a high degree of organisation and *cognitive coupling* of divergent methods, theories, and concepts. However, this is a somewhat simple description of interdisciplinarity, as it should not necessarily only be characterised as the sum or synthesis of several disciplinary components, but should be regarded as more complex. Therefore, attempts have been made to further divide and expound interdisciplinarity, e.g. Barry and Born's (2013) three modes of interdisciplinarity presented below (Barry and Born, 2013; Rasmussen *et al.*, 2007).

1. **The integrative-synthesis mode:** "*[...] in which a given interdisciplinary practice proceeds through the integration of two or more 'antecedent disciplines' in relatively symmetrical form [...]*" (Barry and Born, 2013, p. 10), where interdisciplinarity is understood additively.
    - This mode is, thus, equivalent to the somewhat simple description of interdisciplinarity explained previously.
2. **The subordination-service mode:** "*[...] interdisciplinarity takes a form in which one or more disciplines occupy a subordinate or service role in relation to other component disciplines.*" (Barry and Born, 2013, p. 11).
    - The cooperation is still understood additively, though it takes on a clear hierarchical form.
3. **The agonistic-antagonistic mode:** "*Here, interdisciplinarity springs from a selfconscious dialogue with, criticism of or opposition to the limits of established disciplines, or the status of academic research or instrumental knowledge production in general.*" (Barry and Born, 2013, p. 12).
    - It is an attempt to contest and transcend the epistemological and ontological assumptions and practices of already established disciplines, consequently making the newly formed interdiscipline "*[...] irreducible to its 'antecedent disciplines'.*" (Barry and Born, 2013, p. 12).

Viewed in relation to the previous definitions of multidiscplinarity, the first two modes can be seen as such, from some point of views, due to their preservation of the disciplines as separate entities which are merely combined in various ways. However, the third mode can also be viewed as what Bruun (2019) has termed *transgressive interdisciplinarity* which necessitates an awareness of different modes of knowledge production and "*[...] has the explicit goal to transcend 'antecedent disciplines' and to contest their epistemological and ontological assumptions in order to create new think- and work-spaces.*" (Bruun, 2019, p. 38).

The transgressive interdisciplinarity, though, is incredibly similar to what is normally considered transdisciplinarity. A reason for this, might be the less clear distinctions between interdisciplinary and transdisciplinarity, seeing as they are often intertwined in practice. One distinction though, seems to be partly agreed upon: It does not simply transcend disciplines but the margins of science with the inclusion of non-scientist actors and problem-framings derived from societal challenges or markets and not only academic interests (Barry and Born, 2013; Maasen *et al.*, 2006).

4.3.1 AI and Disciplinary Complexities

The presentation of the history of AI and its approaches in section 2.1 and 2.1.1 illustrates the complex nature of AI and why there has been extensive debates about the characterisation of the most fundamental notions of AI such as *intelligence* and *artificial intelligence* among others. The purpose of AI cannot be viewed as homogeneous and has, thus, been an ongoing negotiations both in scientific literature, public discourse, and the everyday practice of AI experts. Furthermore, there have been discussions about the very foundations of work practices in the fields, concerning whether it should be considered *Science* or *Engineering* (Forsythe and Hess, 2001; Ekbia, 2003).

On one hand, AI is viewed as a science with the (positivist) aims of discovering the truth of intelligence through AI; whether it be the nature of human intelligence or a more abstract notion. In order to explain the human mind, along with human behavior, controlled experiments of systems are used to test theories, but not with the aim of future implementation as science is more about ideas and not implementation. On the other hand, AI is regarded as more of an applied science, as it is argued not to be a scientific discipline separate from others, but an engineering field. From this view, AI seeks to build precise working systems, which can be applied in the real world. However, it is highly related to the engineering principle of "*[...] understanding by building [...]*" (Ekbia, 2003, p. 22). Yet, trying to distinguish between whether a discipline should be considered science or engineering assumes a dichotomy between the two, dictating that one cannot be both. However, this view is not as common, seeing as engineering can be considered applied science, and thus inherently contingent on science fields and vice versa in order to produce knowledge or products of relevance in relation to society. And I believe this is the crux of it all. The interconnectedness between science and engineering in AI is readily apparent from the dissenting views presented here (Forsythe and Hess, 2001; Ekbia, 2003).

Based on all of this, along with the descriptions of AI's history in section 2.1, I believe it is fair to agree with Ekbia (2003) and say that "*[...] AI, as a way of* knowing *and a way of* doing*, straddles the boundary between science and engineering.*" (Ekbia, 2003, p. 22), creating this hybrid identity.

Proceeding with the understanding that AI research is constituted both by science and engineering, along with its tangential focus on ethical and societal consequences, I would regard it as a *Technoscience* (Jamison *et al.*, 2011). Through its hybridisation of many different disciplines and subdisciplines as well as its relation to the real world, AI as an emergent field has transcended traditional academic disciplines and thus, also professional identities. It is by many regarded as an inherently interdisciplinary domain (Mutzner, 2020; Verma, 2017; Ekbia, 2003), but I would argue it can also be viewed as transdisciplinary depending on the circumstances.

4.3.2 Interdisciplinarity in Practice

With the previous sections characterising the notion of disciplinarity in its complexity, this section will bring attention to the practice of interdisciplinary (or transdisciplinary) work in relation to how it is experienced by participants.

As mentioned in section 2.2.1.1, interdisciplinary cooperation naturally brings many differences in knowledge production to the table, including specialised practices and jargon, sometimes impeding any outsiders' ability to even understand what they are saying and doing. Additionally, working outside of ones own familiar epistemology, ontology, or methodology and crossing the disciplinary boundaries, has the risk of resulting in discomfort and insecurity. This can lead to researchers "*[...] retreating to their disciplinary safety zones [...]*" (Levitt *et al.*, 2018, p. 7); resorting to what can be likened to multidisciplinary collaboration instead. It is, thus, quite important to acknowledge that interdisciplinarity is not about dismissing ones own disciplinarity, but rather being adequately aware of its strength and limitations in order to uncover new disciplinary territory and engage in interdisciplinary dialogue and practice with the antagonistic discipline(s). This can be achieved through a collaborative disciplinary problem framing, establishing common goals, language, and approach for knowledge production (Levitt *et al.*, 2018; Defila and Giulio, 2017). However, it is never as simple as that. Seeing as knowledge production is also constituted by tacit knowledge, which is customarily non-transferable, researchers collaborating in cross-disciplinary projects, cannot necessarily verify the validity of each others results and statements. Consequently, working with people from other disciplines and/or different branches of science, it also requires trust: The researchers must acknowledge and accept that the other part has expert knowledge which cannot be communicated or reconstructed in a simple manner (Polanyi and Sen, 2009).

What all these factors of interdisciplinarity in practice have in common is that they can be considered social and cultural, the importance of which will be expounded in the subsequent section(s).

4.4 Views on Culture in Knowledge Production

With science and knowledge production being described as socially and culturally contingent (see section 4.1), it seems only relevant to expound the meaning of culture. Culture is a permanent feature that permeates many aspects of human life. Being such a vast notion, it is no surprise that culture has received much attention through time, especially in the fields of sociology and anthropology, more specifically STS "*[...] with an interest in the reproduction, the practices and the identities of epistemic communities.*" (Baus, 2009, p. 97). Nonetheless, culture still has no universal definition, but is presented through numerous, sometimes dissenting, views. The social scientific depiction of culture selected and presented in this section is what comprise my own views of the notion, with emphasis on elements and themes that are relevant in relation to the focal point of this thesis.

Leaning on interpretive anthropology, culture can be defined as "*[...] what we take for granted, including explicit, formal truths of the sort embodied in scientific paradigms*[7]*; the tacit values and assumptions that underlie formal theory; and the common sense truths that "everybody knows" within a given setting (or type of setting).*" (Forsythe and Hess, 2001, p. 1). It is the fundamental

[7] "*[...] basic beliefs (or metaphysics) that deals with ultimates or first principles. It represents a worldview that defines, for its holder, the nature of the "world", the individual's place in it and the range of possible relationships to that world and its parts [...]*" (Guba and Lincoln, 1994, p. 107).

categories through which we perceive and make sense of the world and determine preferable action (Forsythe and Hess, 2001).

In relation to taking things for granted, an important part of culture is tacit knowledge; especially in relation to knowledge production. Tacit knowledge is constituted by a multitude of factors, but can be described in smaller terms as knowledge which is sedimented in the body. It is something our practices rely on, but which cannot be readily explained. Additionally in our perception of things lies projections of internal processes in the form of tacit knowledge. One interesting aspect of tacit knowledge is the process of *interiorisation* which creates a tacit framework through which we act. As part of our disciplinary backgrounds, we either intentionally or unintentionally interiorise and identify ourselves with ways of knowing and doing, using it as a specific way to view and approach things. However, we might be able to move tacit knowledge from distal parts of our awareness to more proximal parts by dwelling on these interiorisations (Polanyi and Sen, 2009).

In relation to the practice of researchers and knowledge production, culture can then be described as "*[...] aggregate patterns and dynamics that are on display in expert practice and that vary in different settings of expertise. Culture, then, refers back to practice, in a specific way.*" (Cetina, 1999, p. 8). From this perspective culture is adding some understanding to the notion of practice: Culture can be understood as disruptions of the uniformities of practice, suggesting the existence of diverse ways of knowing and doing, and that these serve different ends; culture also adds a certain richness to knowledge, and practice of knowledge production; "*[...] if knowledge is constructed it is deeply and intricately constructed, involving multiple instrumental, linguistic, theoretical, organizational, and many other frameworks.*" (Cetina, 1999, p. 10); culture is associated with the symbols-and-meanings conception, noting that perceptions and meanings are embodied in symbols through which we communicate with each other and evolve our knowledge and perceptions of the world. No matter the amount of divergent and muddled understandings of *symbolic things*, one perspective is shared: "*[...] culture as a concept that sensitizes us to the symbolic components of social life [...]*" (Cetina, 1999, p. 10), a view which adds to the understanding of shared epistemologies in the practice of disciplinary collectives (Cetina, 1999).

This brings us to the notion of "*collective identity*" as presented by Forsythe: "*[...] the sense that practitioners of AI have of themselves as members of a category by virtue of their work. Identity in this sense is collective, and defines itself in opposition to that of other disciplinary categories perceived as different.*" (Forsythe and Hess, 2001, p. 77). Culture is, in this sense, constituted by the values, meanings, assumptions, and practices that are shared within a community, which is not necessarily shared with others outside and thus distinguishes them (Forsythe and Hess, 2001). This ties well with the view presented by Karin Knorr Cetina (Cetina, 1999) where culture is linked to the notion of episteme[8]. Cetina implies that science can be culturally

[8] *Episteme*, or *epistemology*, refers to a theory about knowledge engaged with the *how* and *what* of knowledge: Our perceptions and recognition of knowledge within a scientific paradigm (although

divided, as cultures emerge when domains of social life are separated from each other and thrive in an internally referential system, identifying itself in comparison to others. Subsequently, disciplinary communities can be identified by the specific approaches to knowledge production that they relate to as well as through those they are antithetical to. Aiming attention at these factors with the appearance of culture as distinguishable entities displays contemporary science as fragmented and disunified. It brings out the diversity of science seen in relation to its *epistemic machinery*: "*[...] it displays different architectures of empirical approaches, specific constructions of the referent, particular ontologies of instruments, and different social machines.*" (Cetina, 1999, p. 3). And, thus, came Cetina's (1999) introduction of the term *epistemic cultures*. Wishing to go beyond the relatively simplistic divisions that the notion of separate and distinguishable disciplines provide, the notion of epistemic cultures amplifies the cluttered and intricate heterogeneity of *knowledge machineries* in contemporary science. Epistemic cultures, are thus introduced as one aspect of the phenomenon of the knowledge society: The cultures of knowledge settings which might appear structural, but are in fact much more complex. These settings are described as "*[...] amalgams of arrangements and mechanisms-bonded through affinity, necessity, and historical coincidence [...]*" (Cetina, 1999, p. 1), and through this, the cultures both create and warrant knowledge in the world of science (Cetina, 1999; Baus, 2009).

The division of academic practice in relation to epistemic cultures additionally indicate the presence of cultural boundaries, which are not clear-cut, especially seeing as one person can be part of many (epistemic) cultures that move across even geographical and disciplinary boundaries. Likewise disciplines are often characterised by epistemic pluralism where not everyone in a certain discipline shares identical sets of meaning and those shared do not necessarily determine the scientific practice: "*Rather, common values serve to frame the space within which accepted practices varies and allowable debate take place.*" (Forsythe and Hess, 2001, p. 12). In relation to this, a particularly strong commitment to a paradigm or scientific discipline's traditional practice can confer significant "*[...] conceptual power upon the values and assumptions it embodies.*" (Forsythe and Hess, 2001, p. 12). To challenge the values that underlie accepted practice is to run the risk of being marginalised, but with possible reward of achieving important developments within the field or discipline in question. Moreover, when strong cultural identities are established among disciplinary collectives, boundaries are set to distinguish themselves and these are defended against outsiders "*[...] through cultural elements such as traditions, customs, practices, transmitted knowledge, beliefs, morals and rules of conduct, and linguistic and symbolic forms of communication.*" (Baus, 2009, p. 97)(Forsythe and Hess, 2001; Baus, 2009).

Boundaries are a natural part of social life, and we are relatively used to more practical barriers that distinguishes between e.g. different physical objects, but these cultural boundaries

not limited to the concept of paradigms). It is, stated in a simplified manner, *how we know what we know* (Guba and Lincoln, 1994; Cetina, 1999).

are perceived as more challenging to recognise and understand, as they are immaterial, abstract, and intangible to those who are surrounded by or meet these barriers. And when encountering other epistemic cultures, academic communities, or knowledge practices, it can evoke some sort of *cultural shock*; and the incorporation of new or different epistemic practices with people belonging to other communities can in some cases be perceived as a threat that destabilises the established routines and collective identities. This kind of cultural commitment can results in a cultural resistance that impedes the merging of communities (Jouvenet, 2013; Baus, 2009). Whether intentional or not, the existence of different cultures, especially epistemic cultures, and the difficulties they pose for cross-collaborations can further be considered in the light of tacit knowledge and how we transfer knowledge from human to human. Even something as (in appearance) simple as defining an object or a concept can create misunderstandings if the two people communicating have different epistemic prerequisites for understanding the world and objects within it:

> "*Indeed, any definition of a word denoting an external thing must ultimately rely on pointing at such a thing. This naming-cum-pointing is called "an ostensive definition"; and this philosophic expression conceals a gap to be bridged by an intelligent effort on the part of the person to whom we want to tell what the word means. Our message has left something behind that we could not tell, and its reception must rely on it that the person addressed will discover that which we have not been able to communicate."*
> (Polanyi and Sen, 2009, pp. 5–6).

The unconscious way we fill-in the missing pieces to provide an understanding of an object or phenomenon based on our own, often tacit, assumptions, is something that can create tensions in collaboration, due to the difficulties it poses for communication across epistemic boundaries. (Polanyi and Sen, 2009).

Consequently, in order for interdisciplinary collaboration, with several different epistemic cultures present, to succeed or at to least be sufficient, the cultural shocks and conflicts need to occur as a way to incite a process of gaining mutual understanding. In a way this can bring forth some of the tacit knowledge and break with the idea of mutual control and consensus in science, assuming that the traditions of one or more dominant disciplines are true and common throughout all science. Especially seeing as the connection between different cultures cannot be perceived as seamless, because the boundaries are often maintained and not easily dissolved. Instead, the boundaries could/should be viewed as a way to negotiate new collective identities in collaborations through practices and discourse; constituting a cosmopolitan approach to cooperation with people from different academic disciplines and epistemic cultures (Jouvenet, 2013; Polanyi and Sen, 2009).

4.5 Closing Remarks

Even though AI can be viewed as one field, it is not exempt from the division of disciplinary collectives. AI can be characterised as a very complex interdisciplinary field, with many different aspects of knowledge production and epistemologies of practice simultaneously at play. This poses a risk of creating tensions between AI experts and experts from other fields when collaborating in research projects, not to mention the tensions that already exist within the field itself (Ekbia, 2003). However, AI and its boundaries to other fields, and how this is experienced is still understudied, even though it has been of relevance for quite some time (Forsythe and Hess, 2001).

Thus, questioning how these differences in perspectives on knowledge production, practice, and epistemic cultures are experienced by researchers from different academic backgrounds who are collaborating on AI research is highly relevant; it is arguably one of the first steps to understanding how to better align different work practices and create a greater basis for interdisciplinary work in the field of AI. Furthermore, it is highly relevant from my perspective, seeing as one of Techno-Anthropology's core interests is the incommensurability or conflicts between groups involved in technological processes, where cultural reflections is one of the ways this can be carried out (Børsen, 2013).

Therefore, this thesis intends to identify tendencies in the experience of the researchers from the "*AI for optimizing indoor visual comfort from facial analysis*" project who are working across disciplinary boundaries; primarily Civil Engineering and AI, specifically Computer Vision.

Naturally, just like everyone is influenced by their background and outlook, I conduct this study from my own disciplinary perspective as a student of techno-anthropology working with a socio-technical perspective on science and technology development. Furthermore, my views are likely to be influenced by experience from prior projects and the theoretical frameworks I tend to rely on when conducting studies.

Techno-Anthropological Field 5

Seeing as most culturally and socially contingent factors are established through practice, and are rarely detectable in e.g. written depictions of research, a case study with the possibility of examining a specific context seems necessary in order to capture all nuances relevant to this thesis' objective.

The present, thus, chapter introduces the form of qualitative case study used as a methodological framework and the related rationales. The specific methodological approach to the case study will be presented in the succeeding chapter 6. Following this will be an introduction to the chosen case along with explications of the disciplines present.

5.1 Framework: Qualitative Case Study

> "*Predictive theories and universals cannot be found in the study of human affairs. Concrete, context-dependent knowledge is, therefore, more valuable than the vain search for predictive theories and universals.*" (Flyvbjerg, 2006, p. 224).

With the framework provided by STS, knowledge production with its related social and cultural notions is rooted in practice and is frequently only visible in peoples practice or their own perceptions hereof. For that reason, I argue that the aims of this thesis cannot be examined as merely a literary study, but must involve the real world and contextualised knowledge. And one way to do that is through a qualitative case study. The close proximity to the real world in case studies, and thus real situations, enables the ability to gain a deeper understanding of phenomena and a more nuanced view of reality, as well as human behaviour and perception.

Considering this, I am also not attempting to develop or prove a predictive and context-independent theory, but to show what we can learn from a single case by identifying tendencies and relations which are relevant in interdisciplinary research concerning AI. Knowledge which can hopefully find its use in other cases of interdisciplinary research collaborations in the field of AI.

Being restricted in both time and resources, the primary empirical work of this study is based on a single case. This, however, should not be viewed negatively: As illustrated in the famous "Black Swan" example by Karl Popper[1], a single case can have immense importance for discovery and learning of a phenomena, even if one occurrence might not be representative for all phenomena in question.

[1] "*Popper himself used the now famous example "all swans are white" and proposed that just one observation of a single black swan would falsify this proposition and in this way have general significance and stimulate further investigations and theory building. The case study is well suited for identifying "black swans" because of its in-depth approach: What appears to be "white" often turns out on closer examination to be "black."*" (Flyvbjerg, 2006, p. 228).

Furthermore, even though it is possible to generalise from one single case, the value of formal generalisation is overestimated; especially when aiming to identify tendencies and relations which we can learn from, and not develop generalised theories, as is the case of this study. In addition, the in-depth nature of qualitative case studies often ensure that even single-case studies are multiple, because it can uncover many perspectives and links between phenomena.

One importance for the relevance of a single-case study, is dependant on choosing the right type of case in relation to the aim of the study. The approach in this study was strategic in terms of who I contacted in order to find a relevant research project to study, with the aim of maximising the utility of the single case. However, with time constraints, I was limited in the amount of time I could spend on finding a case, which meant I had less control of who I was being referred to and subsequently which research project I ended up studying. Although in some studies it might be more crucial to make a strict informed case selection, an advantage to a somewhat randomised or less controlled selection is the probability of avoiding bias concerning relevance and a relatively higher chance of uncovering something unprecedented or unexpected. And, even though the choice of a case is strategic, the results cannot (and should not) be determined in advance (Flyvbjerg, 2006).

5.2 Thesis Case: SCODYF1

The "AI for the People Center", located at Aalborg University (AAU), was established to advance AI research through conducive cross-sectoral collaborations between university, industry, and the public sector (AI for the People, 2021a). The importance of such collaborations are explained by the rapid development of new AI technologies along with its impact on a multitude of research areas and aspects of society (AI for the People, 2021b).

By virtue of its multidisciplinary nature, the center focuses not only on the technical aspects of AI but the societal as well, combining all five faculties of Aalborg University [2] in order to advance both future students' and researchers' competencies on the area (AI for the People, 2021a). As part of the internal collaboration at Aalborg University, the center both fosters and finances what they call "Bridging Projects": "*[...] where AI experts collaborate with none AI experts regarding a specific topic from the research field of the none AI experts' domain.*" (AI for the People, 2021b).

Due to all of these factors, I chose to contact AI for the People in the hopes of being allowed access to one of their Bridging Projects which could reasonably be expected to illuminate certain intricacies of interdisciplinary collaboration in AI.

The case used in this thesis is the active Bridging Project "*AI for optimizing indoor visual comfort from facial analysis*" (Part one of the Smart COntrol of DYnamic Façades, abbreviated

[2] Technical Faculty of IT and Design, Faculty of Humanities, Faculty of Engineering and Science, Faculty of Medicine, and Faculty of Social Sciences.

as SCODYF1) which was initiated by postdoc Civil Engineer Hicham Johra. As the title indicates, the project concerns local indoor visual comfort which are affected negatively by low illuminance and direct sunlight creating computer screen glares in offices. Artificial lighting and shading devices controlled by fixed illuminance sensors are limited in terms of providing satisfactory indoor visual comfort, seeing as many parameters influence the occupants local visual comfort: "*[...] the orientation of the occupants, the placement of the furniture, the setup of the lighting system, the position of the windows, the location of the sun in the sky or the cloud cover.*" (Johra *et al.*, 2021). Therefore, the objective of the project is to employ machine learning in a face analysis system in which the occupants' face is used as a sensor to evaluate their subjective local visual comfort. Based on video footage of facial and eye expressions the analysis algorithm will be capable of detecting subjective discomfort and provide feedback to regulate both lighting systems and shading devices to improve the local visual comfort (Johra *et al.*, 2021).

Spanning from January 1st 2021 to June 30th 2021, the pilot project is carried out as a collaboration between researchers primarily from the two AAU departments "Built Environment" and "Architecture, Design and Media Technology" with Hicham Johra as primary investigator along with five (official) project participants: Thomas B. Moeslund, Rikke Gade, Rasmus Lund Jensen, Ekaterina Aleksandrova Petrova, and Lasse Rohde (Johra *et al.*, 2021).

The Built Environment department is fairly new in name, as it was the result of a department and institute merging in the beginning of 2020, creating the largest department in Denmark concerned with construction, civil engineering, and the built environment (BE). With a foundation built on engineering with the addition of elements from social science and the humanities, they promote a holistic approach to research and education to solve complex issues and challenges to society. With more than 250 employees, the department's research is carried out in several state-of-the-art laboratories and a division of a multitude of research groups into three main areas. Although the SCODYF1 participants from BE are part of several different research groups, they all seem to be part of the research area "*Energy, Indoor Environment and Sustainability*", which has nine research groups working on different topics (Aalborg University, 2021c; Aalborg University, 2021d; Aalborg University, 2021e).

The department of Architecture, Design and Media Technology is one of a kind in a Danish context, working in the interplay between the fields of architecture, urban design, media, and technology their ambition is to conduct research with the user experience in the center while utilising both creativity and technology to solve problems. With approximately 150 employees, the departments consists of 16 different research groups, each with their own specialisation, with one of them being "*Visual Analysis and Perception*" working with Computer Vision (CV) and AI and the main vision of creating automatic analysis of human behaviour (Aalborg University, 2021a; Aalborg University, 2021b; Pedersen, 2020).

As the primary connection between the two departments, who account for most of the communication between the groups labelled *BUILD* and *MediaTech* for their respective departmental connections, Hicham Johra and Rikke Gade are the main informants in this case. Although their academic background will be further expounded later in the report (see section 8.1.1), it is relevant to convey that Rikke Gade with a PhD in Computer Vision is considered the AI expert in this collaboration, with Hicham Johra representing the Civil Engineering perspective with the specifications in BE.

With SCODYF1 being an ongoing project with no published results yet, I will not disclose any additional information regarding the technical focus, methods, and results of the project. With a focus on their collaborative process, I simply also deem it unnecessary with the technical details, unless it is imperative for understanding any social and cultural elements of their project.

5.2.1 Civil Engineering

Seeing as the case described in simple terms is a collaboration between Civil Engineering (CE) and AI experts and the previous chapter examined and presented multiple factors of AI as a research field, it seems prudent to examine the field of CE as well.

> "*[...] the word "engineer" is forged from the idea of novelty for producing something that does not exist in its natural state and that the human spirit invents thanks to its creative intelligence (ingenium).*" (Lemaître, 2018, p. xi).

Engineers can, thus, be and do many things whether it be inventing, designing, or producing either artifacts, machines, models, tools, methods etc.. As such, the core of engineering practice seems to be the notion of innovation; whatever that is taken to mean (Cardona Gil *et al.*, 2018; Liu, 2018). Being such a fundamental field which developed along with society and scientific discovery, it naturally led to many specialisations of engineering; one being CE (Lemaître, 2018; Grelon, 2018).

CE is perhaps the field that has contributed most to the survival of humans and ecologic systems as well as the development of modern society. These feats have been achieved and are still being performed through the design, construction, maintenance, operation, and rebuilding of environmental systems and infrastructure (Grigg *et al.*, 2001b). And in contrast to the field of AI, CE has a much older and far-reaching history:

> "*As a profession, civil engineering is about 200 years old and shares a common heritage with engineering, science, and management. Early civil engineers were scientists, managers, entrepreneurs, and general engineers; similar to other disciplines, civil engineering began to emerge as a distinct profession during the Industrial Age.*" (Grigg *et al.*, 2001b, p. 14).

Engineers have presumably existed since 1325 and in the 18th century specialisations began to appear, and among them was CE; a term coined by British engineer John Smeaton in 1768 to distinguish engineers serving the civilian population as opposed to the military. This was indicative of the emergence of engineering practice as independent from religious or political influence at the time (Grigg *et al.*, 2001b).

5.2.1.1 History of Civil Engineering

Despite CE being coined as a term over 250 years ago and existing as a profession for approximately the same amount of years, CE can actually be traced much further back in human history. It all began in early civilisation and since then the field has gone through four distinct periods of development, which will be briefly outlined in the following (Grigg *et al.*, 2001b).

Early civilisation to 1775: "*[...] humans have designed and built structures and systems for thousands of years.*" (Grigg *et al.*, 2001b, p. 15), and despite the humble beginnings of stone caves and tree logs as bridges, the ancestors to the field solved many problems of survival while also inventing basic systems and creating impressive structures. Since then, the size and complexity of structures built to serve society has only grown, with practitioners applying science and technology to solve practical problems throughout time. By the 14th century, much progress in engineering had already occurred, and the Enlightenment in the 15th and 16th century, with its focus on reason and rational thinking, brought new scientific methods and reliance on experiments and empiric observations to the practice of engineers (Grigg *et al.*, 2001b).

1775 to 1900: Despite the previous period bringing advancements, the launch of the Industrial Age and the emergence of modern society involved many radical political and technological changes throughout the world which shaped CE as a field and profession. Increasing populations and new settlements required both resources and technological systems, leading to the inventions like "*[...] the steam engine, water power, canals, railroads, and other advances setting the stage for modern society.*" (Grigg *et al.*, 2001b, p. 14). Despite only few identifying themselves as CE's in the beginning of the 19th century (with 512 in the United states in 1850), it was still gaining attention in various ways, e.g. George Washington who was a CE in his early career. Furthermore, the industrial revolution, beginning around 1820, increased the use of steam engines and brought more technological developments, unfortunately alongside the deteriorating public health became an issue. Due to the latter seeming more pressing, the recognition of CE's and their role in society was low as opposed to other professions, such as doctors and nurses. This, however, is not much different from today's society. But as needs grew, so did the innovations and numbers of CE's (20,000 in the United States by 1900), and soon "*Civil engineering was becoming a discipline, with its own body of knowledge and professional standards of practice.*" (Grigg *et al.*, 2001b, p. 20).

1900 to 1975: Marked by several consequential wars, this short period saw many technological developments "*[...] including the telephone, radio, television, computer, automobile, aircraft, submarine, and satellite.*" (Grigg *et al.*, 2001b, p. 14). As a part of the war-efforts, all types of engineers were increasingly needed and requested, and much responsibility was placed on their shoulders, e.g. as was seen with the Manhattan Project[3]. Along with the stress of war and periods like the Great Depression, the increasing availability of the new technologies and

[3] The U.S. led research and development project during World War II which produced the first nuclear weapons in form of the atomic bomb.

increasing living standards post war prompted more development in terms of infrastructure that far out-reached previous expectations (Grigg *et al.*, 2001b).

1975 to 2000: The conclusion of the 20th century brings us to the Information Age with globalisation prompting the further development of technologies to enable instant access to knowledge and communication as well as new ways to organise different layers of society. However, the globalisation also brought more challenges to the surface and drove attention in CE toward solving problems with e.g. poverty and access to resources as well as climate changes. (Grigg *et al.*, 2001b).

5.2.1.2 Areas of Civil Engineering Practice

"*As technology and civilization unfolded, areas of civil engineering developed, gradually forming the diverse specialties that exist today under the umbrella of the profession.*" (Grigg *et al.*, 2001b, p. 23).

Similar to the field of AI, CE is a diversified field. And yet, instead of converging from several fields into one hybrid field, CE has emerged and expanded, through several decades and centuries, from what was once a simple field, to a complex amalgamation of specialities that extend into many different corners of society. Among these lie the following key specialities:

- Construction Technology: Due to structures becoming larger and more complex, CE's have turned their focus towards the many techniques that can be merged in the field of Construction Technology: "*[...] machines, materials, energy, and management techniques.*" (Grigg *et al.*, 2001b, p. 23).
- Buildings and Structures: The combination of new or rediscovered materials with the evolving construction technologies has led to the improvement of buildings by enabling the planning and construction of new types of buildings: "*The birth of the steel industry in the nineteenth century enabled engineers and architects to plan new types of buildings and frames. Steel frames, along with the elevator and a growing density of cities, led to development of the skyscraper.*" (Grigg *et al.*, 2001b, pp. 23–24).
- Transportation: With the ever-growing need of going from A to B, transportation infrastructure has always been of high importance, but the more dramatic developments only took place after cars became a more common good, leading to the invention of modern asphalt and pavements. Now, transportation requires mega projects, and not just for constructing roads, but also railroads, tunnels, bridges, and even infrastructure for the aviation industry.
- Water, Wastewater, and Environmental Engineering: Solving problems of economic, health, and convenience through the management of water and wastewater has been in the limelight for a long time, and today CE's further this practice by involving e.g. problems of ecology as *environmental engineers*.

- Water Resources Engineering: Due to waters multiple purposes in and risks to society, CE's further develop techniques in a field separate from the aforementioned environmental engineering.
- Disaster and Emergency Management: Born from both the experience of failures in the field and disasters in the history of society, an interest in risk and disaster managing, along with safety engineering, and forensic engineering, evolved as part of CE (Grigg *et al.*, 2001b).

From the listing, the many roles of CE's is apparent. But the rapid growth of modern society and advancements of technology has and still do lead to many challenges and demands to the field of CE, and it is continually changing engineering practice with impressive speed. One thing remains though, and that is the two overall roles CE's play: "*[...] building and managing infrastructure and sustaining environmental resources.*" (Grigg *et al.*, 2001a, p. 2). With the continued involvement of CE's in societies most pressing problems, this role is present in six primary infrastructure systems related to the previously mentioned specialities, namely: *Water*, *Energy*, *Wastes*, *Transportation*, *Communication*, and *Built Environment*. The latter being the context for SCODYF1 and, thus, the case of this thesis. Through these, CE's continues to have a relevance providing structures and systems everywhere on the planet, contributing in imaginative ways to both technological and societal development (Grigg *et al.*, 2001a; Grigg *et al.*, 2001b).

In relation to this thesis project, one of the most interesting future trends is the accelerated development of technology and knowledge diffusion, which prompt the CE's to adapt to the use of new technologies and work modes in their practices. Granted, changes in CE are driven by both social, technological, and economic developments, but the most drastic arena is that of information and communication technology, which generates a need for computer literacy among researchers and practitioners: "*The technology that drives solutions is unlikely to start with civil engineers; however, a large part of our job is to adapt to technologies.*" (Grigg *et al.*, 2001a, p. 4). With the traditional lines of CE not advancing with the same speed as newer fields, like computing, it creates the need for a new kind of Civil Engineer; building atop the technical skills and the image of the *pure technician*, new skills in communication, among others, are a prerequisite to succeeding in this ever-changing environment. It speaks of a need for assimilation to the more interdisciplinary milieu of knowledge production in modern society and being open toward other frame of references in order to preserve the relevance of CE. In summation: "*Civil engineers have a great future, but they are not in it alone.*" (Grigg *et al.*, 2001b, p. 43)(Grigg *et al.*, 2001a; Grelon, 2018).

The latter sentiment in the quote is especially evident when examining published literature on the topic of CE or at least with relations to it. From figure 5.1 CE seems to have a considerable number of interfaces with other disciplines (both conforming and contrasting with CE) and deals with several subject areas; quite similar to the field of AI. Thus, it simultaneously illustrates the complexity of CE and that it is far from an isolated discipline. This characterisation will be further acknowledged and explained in the analysis of this report (see chapter 8).

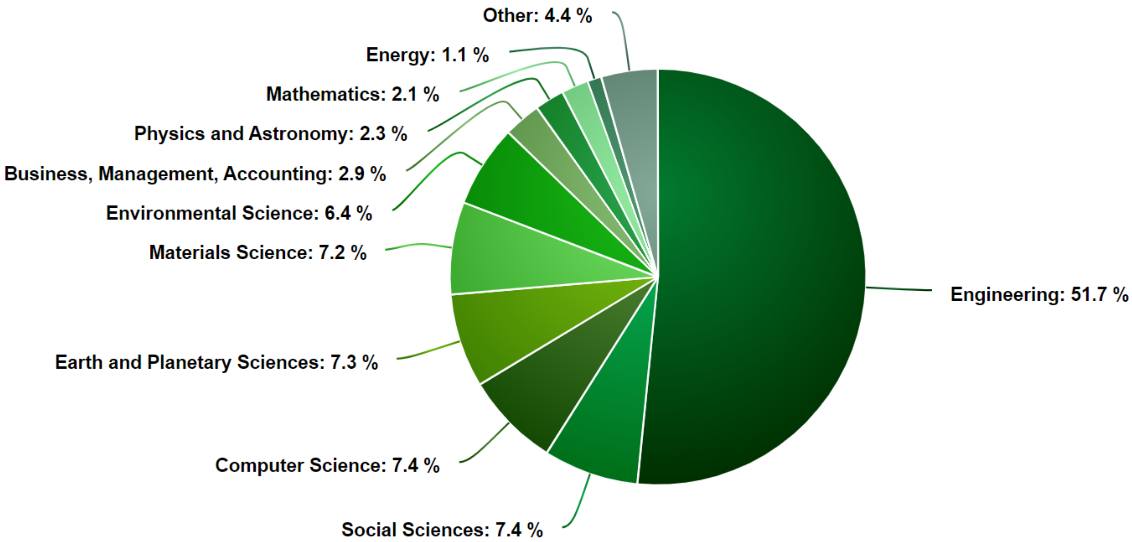

Figure 5.1: Pie chart based on SCOPUS' document analysis feature showing a division of documents by subject area from the 73,171 results of the search string ("Civil Engineering") with occurrences in titles, abstracts, or keywords (App.B). The category 'Other' consist of 17 different subject areas, with some contributions being undefined.

6 Methods

The following chapter outlines the methodological approach to the empirical data gathering related to this thesis, along with reflections on certain limitations. Additionally, a synthesis of the fieldwork and resultant data will conclude this chapter.

6.1 Fieldwork in a Changed World

As we have all experienced through the course of 2020 and now 2021, the global pandemic COVID-19 has affected a lot of different areas in our lives. So naturally, the conditions under which we are able to socialise has also limited the fieldwork related to this thesis in certain ways, creating the need for alternatives.

Gaining an understanding of the cultural elements that affect cross-disciplinary work collaborations is something that cannot be done without a focus on the work practices, as mentioned in section 5.1. However, with the current conditions due to COVID-19 Aalborg University has been mostly locked down, rendering it impossible to conduct fieldwork as observation or participant observation while being physically present at the site. Instead, I gained access to their meetings conducted through Microsoft Teams, although these were a seldom occurrence, resulting in only one meeting observed post interviews in the middle of April, concerning the results of their prototype tests (see App.G).

As compensation for the sparse amount of meetings in my period of investigation (none were actually planned when the fieldwork commenced), I was allowed access to their written communication: Email correspondence and work notes. Although these forms of data are not equivalent to observations of work practices at the respective campuses at Aalborg University, they had the possibility of providing some insight into their cross-departmental communication and serving as somewhat *indirect observations* (Bernard, 2006b) of their work practices in the SCODYF 1 project, as some of these were explicated in the communication. Despite possibly limiting the depth of understanding of their work practices, it had the advantage of being a nonreactive way of gaining unfiltered knowledge about their thoughts and work, seeing as I was only sparsely visible as an observer when being CC'ed[1] in emails.

6.2 Interviews

With the aspiration of gaining insights into my informants opinions and experiences related to the topic of investigation in an efficient manner, I have chosen to conduct semi-structured interviews; a decision partly due to the circumstances surrounding my fieldwork (time and resource constraints).

[1] Receiving a so-called *carbon copy* of their email correspondence while being visible to all recipients, but unobtrusive as I did not interfere with the communication.

A strength to the semi-structured interview method lies in its dual nature, which of course relies on the construction of an appropriate interview guide. It grants the ability to produce reliable and comparable qualitative data, while still allowing the freedom of unstructured interviewing. This works especially well when wanting to remain in control of the topics touched upon in the interview but without constraining the informants' answers or my own ability to work inductively and going off on a new interesting tangent (Bernard, 2006c; Kvale and Brinkmann, 2015).

Wanting to compare the data from both interviews I started out by building an overall interview guide, providing the same structure and general themes and research questions for both interviews. However, due to the informants occupying different roles in their project and having different perspectives, the interview guide were adapted to include specific interview questions for each or different phrasings of certain questions.

Even though it might be unavoidable to lead an informant during an interview, I mainly attempted to ask open-ended questions, prompting the informant to lead the interview, in order to leave room for new perspectives not considered while constructing the interview guide. However, certain questions were designed as *directive probes* based on what an informant had mentioned prior to the interview or simply longer questions in order to gain a deeper insight into their perspectives. During the interview, further probes were naturally used in the attempt to extend answers or explanations, which I do not deem necessary to expound here (Bernard, 2006c).

The intentions of these interviews is, thus, primarily to gather knowledge on their express opinions and experiences with cross-disciplinary collaborations and underlying and/or culturally contingent aspects or tensions.

6.2.1 Limitations

Despite all the advantages of the semi-structured interview method, interviews will always have to deal with an amount of uncertainty in terms of accuracy in the answers when not combined with observations. This is a result of *thought* and *practices* not necessarily being equivalent and "*Even when people tell you what they think is the absolute truth, there is still the question of whether the information they give you is accurate.*" (Bernard, 2006c, p. 245). Equally important, in most cases our work practices are constituted by many (both small and large) tacit or latent practices and thought processes, which - as is the nature with tacit and latent knowledge - are difficult or perhaps even impossible to articulate, also in an interview (Polanyi and Sen, 2009).

Thus, my claims in the analysis of the interview data is based on the informants own views and experiences which may not necessarily be an accurate depiction of practices. However, I argue that it still provides a relevant perspective to understanding some of the underlying cultural or epistemological aspects affecting cross-disciplinary research in AI. Additionally, through access to their written communication and shared work documents I will attempt to gain an insight into the more or less tacit parts of their work practices, though I acknowledge that the insights I can gain will be somewhat limited.

6.2.2 Notes on Transcription and Field Notes

Due to the analysis revolving around social and cultural themes which are often more abstract, I have chosen to fully transcribe the interviews in order to not overlook any important remarks (Bernard, 2006c). However, the transcription style is another point. Transcription standards are related to the type of analysis for which the transcriptions are intended. Seeing as I am not conducting e.g. a semantic analysis, but my analytical focus is instead on the content of what my informants are expressing, the transcriptions where conducted rather roughly: Pause lengths, sound or single word probes, overlapping words and prolonged syllables are not indicated. The following rules have been applied to the transcription process:

...	An ellipsis indicates words trailing of or sudden change in the sentence.
( )	Single parenthesis contains comments to explain context of the transcribed statement prior to the parenthesis.
[ ]	Brackets indicate uncertainty about the words contained within.

Despite its simplicity, I argue that this transcription style adequate for the level of analysis pursued in this thesis. Furthermore, the rougher style of transcription has the purpose of providing a smoother reading experience.

Apart from the two interviews, I participated in two meetings: One introductory meeting between Hicham, Rikke, and myself; the other being a meeting where the students associated with the MediaTech team presented the results of their prototype.

During the introductory meeting, I wrote descriptive *jottings* along with relevant snippets of dialogue. In the second meeting it was possible to keep more detailed jottings and notes concurrently seeing as I was not an active participant and was able to focus almost exclusively on listening, observing, and documenting. The field notes from both meetings were elaborated immediately afterwards in order to ensure a high amount of details and accuracy, using the jottings as memory triggers. The notes from both the introductory meeting and the presentation of their results take on a descriptive form, with the latter being supplemented with notes of a more analytical and reflective character. More details can be found at the outset of each appendix (see App.F-G) (Bernard, 2006a).

6.3 Fieldwork Synthesis

The following table 6.1 contains an overview of the fieldwork conducted in relation to this project and the data produced. All data except the emails and work notes (due to confidentiality) can be found in the appendices attached to the thesis (App.C-G).

Date	Type of Fieldwork	Data
March 5th 2021	Introduction meeting with Hicham Johra and Rikke Gade	2 pages of notes
March 26th 2021	Interview with Rikke Gade	Duration: 38 min. 9 pages of transcription
March 29th 2021	Interview with Hicham Johra	Duration: 75 min. 19 pages of transcription
July 9th 2020 to April 7th 2021	Emails and work notes	Approximately 64 emails from 16 correspondences, 33 pages work notebook, a 14 slides presentation
April 16th 2021	Observation of meeting	6 pages of field notes

Table 6.1: A table portraying the fieldwork conducted and its related type and amount of data.

Analytical Approach

7

In this chapter, the approach applied to analyse the empirical data will be characterised along with the grounds for the structure of the following chapters.

7.1 Thematic Analysis

In order to gain an in-depth understanding of the data and produce a comprehensive portrayal of the results, I found it necessary to perform a considerably structured analysis, with inspiration from Braun and Clarke's six phases of *thematic analysis* (Braun and Clarke, 2006).

Phase	Description of the process
1. Familiarizing yourself with your data:	Transcribing data (if necessary), reading and re-reading the data, noting down initial ideas.
2. Generating initial codes:	Coding interesting features of the data in a systematic fashion across the entire data set, collating data relevant to each code.
3. Searching for themes:	Collating codes into potential themes, gathering all data relevant to each potential theme.
4. Reviewing themes:	Checking if the themes work in relation to the coded extracts (Level 1) and the entire data set (Level 2), generating a thematic 'map' of the analysis.
5. Defining and naming themes:	Ongoing analysis to refine the specifics of each theme, and the overall story the analysis tells, generating clear definitions and names for each theme.
6. Producing the report:	The final opportunity for analysis. Selection of vivid, compelling extract examples, final analysis of selected extracts, relating back of the analysis to the research question and literature, producing a scholarly report of the analysis.

Figure 7.1: The six phases of a thematic analysis as presented by Braun and Clarke in "Using thematic analysis in psychology" (Braun and Clarke, 2006, p. 87).

Being restricted regarding time and resources, the method of analysis was adapted to be more agile in relation to overlapping some of the phases (see figure 7.1), thus explaining why the approach is not as stringently structured as the original. See appendix H for the full log of the process. However, with the amount and kind of data available for analysis, I argue this approach to be adequate for the level of analysis I seek to achieve.

7.1.1 Procedure

The process of gathering or constructing data, by e.g. reading CC'ed emails and transcribing interviews, lead to a natural familiarisation of the data. Afterwards, the qualitative coding process begun, utilising NVivo 12[1] to read data while simultaneously constructing and applying codes. This initial coding of all data resulted in 82 separate codes being created, which were then reviewed in terms of accuracy, divided into sub-codes, or sorted/collated into categories. Furthermore, notes taking during the first coding process were reviewed in relation to creating new or altering existing codes, before coding any further. The second iteration of coding were conducted with particular attention to codes constructed late in the first coding process or

[1] A software program for qualitative analysis.

in between the two iterations. Despite the mostly inductive nature of the analysis, it must be noted that the theoretical focus established prior to the coding process naturally led the attention towards certain elements in the data and, thus, influenced the codes created and later on how these where categorised in themes.

Finally, all categories were reviewed in relation to the content of the coded extracts and the coding process was concluded by producing quantitative visualisations to help identify the most prevalent themes and relations based on coding density (App.H). Although, due to coding references varying in length, from half sentences to entire paragraphs, the accuracy of this quantitative representation of qualitative data needs to be considered with this in mind.

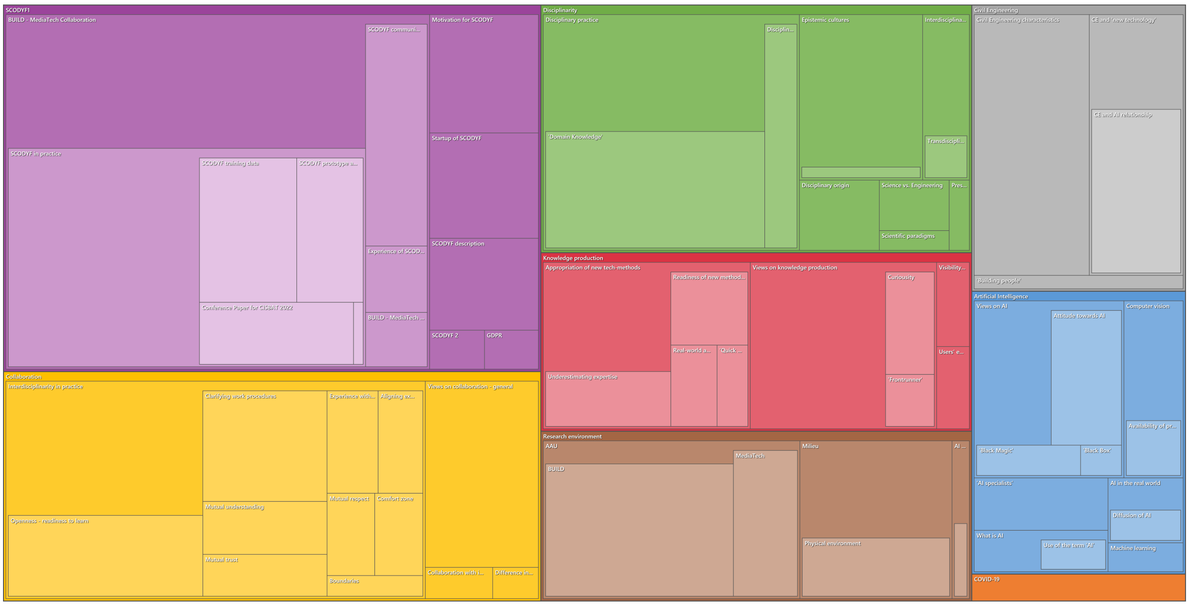

Figure 7.2: Structured as a tree map this hierarchical landscape chart was created in NVivo, portraying the codes created during the thematic analysis. It is sized in relation to the number of coding references and the colour density portrays the representativity in the dataset, i.e. number of items coded with the respective code. Certain categories have not been included in the visualisation, such as all codes used to identify which person the data is related to as these are not thematically relevant to the analysis. Visual expansions of the most prominent categories can be found in appendix H.

The first visualisation (see figure 7.2), a hierarchical map, was utilised as an aid in the identification of prevalent themes in the data set from a quantitative approach. Not surprisingly, being the case for the thesis and thus the background for the data, the *SCODYF1* category is quantitatively the most represented in the data set. What I find most interesting is the lack of any codes concerning with conflicts, tensions, or barriers, seeing as this was partially expected due to the often found difficulties with interdisciplinary work and synthesis of people from different disciplinary backgrounds and epistemic cultures (see chapter 4).

Therefore, to gain insight into how the data relates across the categories, the data was mapped through the network analysis and visualisation software Gephi. Here, the mapped and visualised relations are based on a coding matrix presented by NVivo, showing which codes cross each other in the coded extracts. From figure 7.3, we see a tightly interwoven hairball network, indicating close relationships between all codes and categories, where codes are most adjacent to those they share a majority of their relations with.

The mapping provided an aggregation of the codes into six clusters, which can be identified from the colouring of the nodes and are annotated in the visualisation. The following listing presents a characterisation of the six clusters along with specifications of the most prevalent codes in each.

1. SCODYF1 research environment: Containing both elements of the SCODYF1 characteristics in relation to practice and the surrounding research environment and milieu.
    - The research environment present a division between BUILD and MediaTech, although this is mainly in relation to the physical environment and their relatively separated work practices in SCODYF1.
2. SCODYF1 collaboration characteristics: Containing elements important to characterise the SCODYF1 collaboration.
    - Concerning the practice surrounding SCODYF1, the comparisons between BUILD and MediaTech and their communication seem most prevalent.
3. Aspects of collaboration: Presenting aspects important to collaboration from the informants' perspectives, based on both past experience and the practice of the SCODYF1 project.
    - The alignment of expectations and an open attitude appear as meaningful in relation to interdisciplinary collaboration.
4. Knowledge production: Identical to the coding category of the same name.
    - Presenting the notions of curiosity and real-world applicability as relatively important in relation to the informants' views on knowledge production
5. Disciplinarity and culture: Containing most elements related to disciplinary practice and its socially contingent character.
    - This cluster shows an focus on epistemic culture and what distinguishes these, however no codes indicating any conflicts in this relation.
6. Civil Engineering and Artificial Intelligence: Contains codes concerning both Civil Engineering and Artificial Intelligence, mostly seen in relation to disciplinarity and what affects the relationship between the two.
    - Civil Engineering and its relationship with and attitudes towards AI have a large visual presence in this cluster.

All these themes identified from the categorisation, quantitative representation, and clustering analysis, have upon closer inspection proven to be both in alignment with expectations provided by the theoretical perspective of this thesis, as well as highlighted unexpected relations important to the context and aim of the thesis. This will, thus, be presented in the analysis starting with the characterisation of the important elements (SCODYF1 in practice, Civil Engineering, Artificial Intelligence etc.), before presenting what constitutes the relations between these and how this can present interesting aspects of interdisciplinary knowledge production in the context of the case.

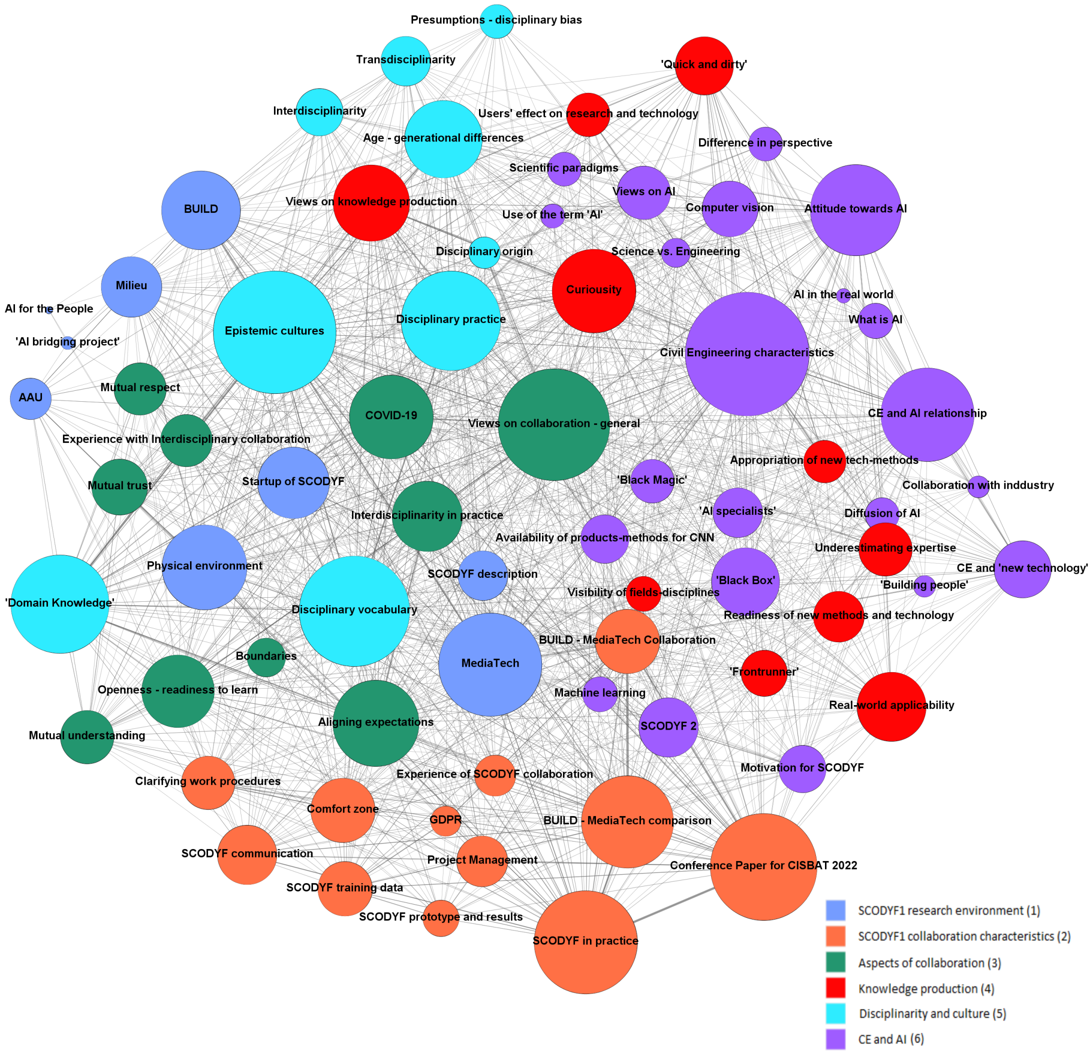

Figure 7.3: A mapping of the coding categories relationships based on the coding statistics from Nvivo. Created within Gephi, the nodes represent the individual codes and the edges represent the relationships between them. To provide a representational visualisation, the layout has been structured by applying the layout algorithms *Force Atlas 2* and *Expansion*. The nodes are sized according to degree (number of code references) and coloured in relation to a calculated modularity, which illustrates a clustering of communities within the network (Venturini *et al.*, 2015). The protocol for the procedure of the visualisation can be found in appendix H.

Part III

Results

Analysis

8

As might be apparent from the theoretical framework, I went into this thesis and the SCODYF1 case with some expectations of conflicts between epistemic cultures and approaches to knowledge production in interdisciplinary collaboration: Expectations founded in my own experiences from previous semester projects. As is often the case with inductive qualitative work, this was not an angle which could be followed through till the end. While this focus is still relevant, conflicts were not at the center of attention in the SCODYF1 project, resulting in a slightly altered and expanded perspective to include more nuances.

Despite the relatively small size of the case, there is an abundance of factors at play, which will be presented in this chapter. This analysis takes its starting point in a description of the SCODYF1 project in practice followed by characterisations of the academic backgrounds of the key informants and their perceptions of their own research fields and disciplinary backgrounds. Tendencies which can be identified from these factors and their internal relations will be explicated subsequently. In this, it will be apparent that my focus is not on identifying clashes of epistemic cultures and other social or cultural factors creating boundaries in interdisciplinary research. Instead, I turn to identifying relations between the many cultural and social factors present in the interdisciplinary knowledge production at the intersection between AI and CE, trying to gain an understanding of what both motivates and challenges the collaboration. Finally, through this I will attempt to present what can be learned from the bridging of differences in the SCODYF1 project.

8.1 SCODYF1 in Practice

While on paper the SCODYF1 project spans from January 1st 2021 to June 30th 2021, it actually started in early 2020, when Hicham Johra sat in his office being annoyed by the glare of the evening sun and an ineffectively controlled shading device, prompting him to think: "*[...] hmm, would be nice if we had a system that just tracks my eyes and figure out [...] if the shading is working well or not.*" (App.F, p.12, ll.421-423). After remembering a presentation of AI for assessing indoor comfort at a conference, Hicham started to research and confer with colleagues to ascertain the novelty and value of his idea. Finding no research on this specific approach to provide easier indoor climate comfort, the process of negotiating and attaining funding, support, and participants for the process began; a process which was characteristically slow-going with the bureaucratic milieu of academic research. This ultimately ended with the project SCODYF1 being formed as a AI Bridging Project by Thomas B. Moeslund as part of the AI for the People research center by the end of 2020, with Hicham as the principal investigator. By December 2020 Rikke Gade had joined the team and assumed what can be viewed as an unofficial leadership role for the MediaTech team, due to already having two student assistants with experience relevant to the project employed (App.D-F; P.C.).

Specifying the outcome of the project seemed quite straight-forward and merely required smaller discussions once the project was commenced in January 2021, and then the more practical circumstances of the project needed to be decided; i.e. the project was to consist of a laboratory setup for collecting data to be used in a correlation analysis to develop and test an AI algorithm for assessing visual indoor comfort to evaluate the effectiveness of the concept for a single case in a laboratory, before estimating feasibility in scaling up the project (App.E; P.C.).

The initial planning of the project was carried out "on the fly" (App.F, p.9, l.300) due to Hichams limited experience with designing and managing projects. Being new at this, however, did not deter Hicham who views it as normal practice in academia to carry out things you are untrained for and therefore having to learn through trial and error or others experiences. The project structure, thus, intentionally left room for improvement and changes reflecting the flexibility which Hicham argues is expected of researchers (App.F).

With inspiration from Gantt charts, the project was structured around four work packages, each with several tasks, and five related deliverables divided into three of the work packages:

- Work package 1: Acquisition of data to train the algorithm.
  - Deliverable 1: Training data.
- Work package 2: Algorithm development.
  - Deliverable 2: Algorithm.
- Work package 3: Test and demonstration of the algorithm.
- Work package 4: Documentation and dissemination.
  - Deliverable 3: Documentation of the process in a technical report and videos.
  - Deliverable 4: Conference paper.
  - Deliverable 5: Application for the continuation of the project: SCODYF2.

BUILD is responsible for the first and third work package, while MediaTech carries out the second and they both are responsible for the fourth. This division of labour between the two teams might make it seem like a project of a more multidisciplinary character. However, when taking into account that the work packages were carried out simultaneously and required deliverables to go from one team to the other, and that the fourth work package required even closer collaboration reality appears different. The project then synthesises two practices of knowledge production and takes the form of an interdisciplinary project of the more simple *integrative-synthesis mode* on the surface, although one could argue that it moves toward an *agonistic-antagonistic mode* of interdisciplinarity (see section 4.3 and 8.3).

Hopefully, the results of the pilot project can be used as an example to support their application for a continuation of the project or new projects on the area, especially seeing as it can be difficult to start from scratch. But when trying to obtain funding and support for these types of projects, "*[...] having a prototype that works, and showing that you have already collaboration and an appropriate team who has done something that works is [...] a token of [...] insurance that you can actually deliver what you promise.*" (App.F, p.16, ll.566-568).

With the project coming to an end in June 2021 and with the deadline for the submission for the CISBAT 2021 conference on April 30th 2021, I have been able to gain insight into a large part of the process, though much of it has been in retrospect or from old written correspondence. From this I have gathered that the collaboration and communication between BUILD and MediaTech has transpired mainly in the form of email correspondence back and forth concerning various aspects: Clarifications of expected outcome, work procedures, data format and needs among others. Along with this has been attachments containing e.g. the training data produced by BUILD for MediaTech to utilise when training the algorithm prior to testing it. The rest of the details have been settled or presented in two meetings, the latter of which I was able to observe (see section 6.3). As a result of my own experience with collaborations, I personally have a preference for face-to-face meetings or at least verbal communication when details need to be discussed and decided. Therefore, I was naturally curious about the limited number of meetings and whether this was a consequence of the COVID-19 pandemic or other underlying rationales. Both Hicham and Rikke expressed how COVID-19 only had little to do with the sparse verbal communication, seeing as it was possible to discuss most details in written form. Furthermore, digital meetings were no hindrance for them, as they had no need for a physical table between them or any non-digital visual aids, e.g. a blackboard. Though they both agree that they might have met in person and inspected the laboratory together under different circumstances, it certainly was not a necessity to do so. Especially considering they both have experience with the concept of and practice related to working in a laboratory with the purpose of obtaining or producing various kinds of data, and for that reason to see the laboratory in person to understand what was being discussed about it; shared pictures and detailed descriptions seemed to be enough. Hence, their research and collaboration did not appear to be limited by the circumstances caused by the pandemic, besides some difficulties early on concerning access to the laboratory, but nothing that became seriously impeding to the process (App.D-F; P.C.). However, if the project should continue and they end up struggling with specific problems, e.g. achieving something from the data, then the circumstances would be different. According to Hicham, in this situation they would need to "*[...] think more about how to rearrange the protocol for acquiring the data, then it's much better if we are all, or if at least, for example, me and Rikke, we are in the lab in front of the stuff and try things, live in person, this will be the type of situation where, yes, being in person would be much more beneficial than online.*" (App.F, p.13, ll.463-466).

A majority of the written communication between the two teams, post project startup, concerned the first two deliverables (training data and the algorithm), but primarily the former. The format of the data was clarified through detailed dialogue resulting in a *quite fixed* data format, but in some cases explanations from BUILD were still needed for MediaTech to make sure the data was correctly processed. During these clarifications, the physical environment of the laboratory setup was further discussed: Size, flexibility, and naturalness of the setup, lighting conditions, background of the footage, and how this affects the data and subsequently training of the algorithm. These discussions were carried out through the sharing of images, asking questions, and deciding the best approach and was, thus, mainly focused on achieving the most reliable results to evaluate the theoretical concept of the project in practice (App.E-F; P.C.)

The work carried out by MediaTech with the algorithm led to an online meeting concerning their prototype for detection of glare from facial analysis and the results in relation to whether they could actually read comfort and discomfort from the face accurately. In this meetings, the student assistants from MediaTech presented which methods and pretrained machine learning models they have employed to extract faces from images provided as part of the training data. Followed by the levels of accuracy for the different methods, they then proposed ideas for future work to improve the results and overcome challenges related hereto, e.g. in the form of false positives. It was, thus, decided that more training data would be preferable, although for now it would only be possible with more of the same type. The hope is that further work can include training data acquired from a less controlled environment, closer to real-world conditions, to advance their insights into how the algorithm can be improved. The meeting also provided a setting for dialogue concerning the conference paper submission due in the end of April; what it should contain in terms of description, approach, and results, along with decisions about who is responsible for writing specific parts of the paper. Due to being new in the field of visual comfort in buildings Hicham has included a specialist on visual comfort in buildings from DTU[1] to ensure a high level of detail in the explication of the project background. While Hicham and BUILD seem to be responsible for the majority of the paper, MediaTech are tasked with the presentation of the results of the prototype and the related technicalities, with drafts being sent back and forth between the two teams (App.F-G).

8.1.1 SCODYF1 Participants

The official participants in the SCODYF1 project are, as mentioned in section 5.2, divided into two teams in relation to their respective departments in the following manner:

- MediaTech: Rikke Gade and Thomas B. Moeslund.
- BUILD: Hicham Johra, Rasmus Lund Jensen, Ekaterina Aleksandrova Petrova, and Lasse Rohde.

Besides the aforementioned, the project has involved several others in the form of e.g. colleagues who were consulted regarding specific elements or working in the periphery and student assistants carrying out specific tasks and playing a more central role (App.P.C.)

As previously mentioned (see section 5.2), Hicham and Rikke were the ones corresponding most across the two teams. This was further evident at the meeting observed in April concerning the results of the prototype algorithm. Here it became apparent that the two student assistants responsible for much of the work with the algorithm had not met with the BUILD participants present at the meeting, Hicham and Rasmus (App.G).

[1] The Technical University of Denmark.

Being the most prominent figures in the SCODYF1 collaboration, Hicham and Rikke are naturally also the two informants most present in the data (App.H). Consequently, most of the expressed opinions will be rooted in their perspective and perceptions. While this might not provide an accurate or generalised representation of their entire department, discipline, or field, it is evident from the fieldwork and resulting data, that the experience gained from working in their respective fields for several years and interaction with both immediate and peripheral colleagues has enabled them to perceive some tendencies and form opinions about these in relation to their own outlook. This has brought forth, among others, some interesting factors of interdisciplinary collaboration (which they also have experience with prior to SCODYF1) as well as the relation between AI and CE. However, to understand these fully, it is first and foremost necessary to know what forms their perspective in terms of academic background.

As specified earlier, Rikke Gade has a PhD in Computer Vision (see section 5.2), but her education started with a bachelor degree in electrical engineering and a master degree in "Vision, Graphics and Interactive Systems" (Aalborg University, 2021f). The PhD provided further specialisation in CV; a subfield of AI which "*[...] focuses on replicating parts of the complexity of the human vision system and enabling computers to identify and process objects in images and videos in the same way that humans do.*" (Mihajlovic, 2020). In other words, "*[...] computer vision is basically writing software that can process images and videos. So instead of having humans looking at videos and trying to understand what happens, we want the computer to understand what happens in the videos.*" (App.E, p.1, ll.11-13). To do this, they need to utilise some basic image processing to identify certain elements in images, like edges and colours, and then they use machine learning to understand what it means, i.e. what the image contains. According to Rikke "*[...] it often comes down to deep learning based methods*" (App.E, p.4, l.134), where CV involves what is called Convolutional Neural Networks (CNN): A particular type of algorithm which has played an important role in the advancements of both CV and Deep Learning. This is partly due to the fact that CNN requires much less pre-processing in order to classify aspects or objects in an image compared to other algorithms which involve more manual work (Saha, 2018).

Rikke perceives her own field as both science and engineering. The former in relation to developments of new methods or applying existing methods in new fields to figure out what provide the best results. The latter is found more when they use existing methods and apply them to solve a problem. With the combination of software and image processing, CV might be considered an interdisciplinary field, but Rikke views it as one discipline which can be applied in many interdisciplinary collaborations. In this sense, it is often through collaboration with other people and fields, that their work and knowledge finds application. And this is also the case with SCODYF1, where CV is applied to understand and identify which facial expressions show discomfort in relation to the indoor visual environment, and this information is to be used by BUILD to adjust the lighting or shading devices accordingly (App.E).

On the other hand, Hicham's career as a CE started in France whose university system is relatively unique. With an intensive two year preparation course, focused on maths and physics, Hicham could then spend the next three years specialising in CE with a focus on construction and geotechnics. An Erasmus taken at Aalborg University focused on energy in buildings, indoor environment, and sustainability, followed by work as a research assistant in the old Department of Civil Engineering at AAU, led to a PhD concerning new heat pumps and building initiative stability. As a postdoc Hicham has since 2011 been working on a lot of different research topics: "*[...] material science, heat pump systems, ventilation systems, indoor comfort, energy flexibility, building data, control, smart system and so on.*" (App.F, p.1, ll.28-29). In these topics, the focus lies on applying science, through the engineering of different technical solutions and find real-world application for them. Despite his diversified history of experience, the focus on visual comfort is relatively new for Hicham, and quite far from his original training. But it is Hicham's experience that it is quite normal to move away from ones original training within the field of CE (App.F). In fact, it can be seen as indicative of the recent developments within the field.

8.2 Developments in Civil Engineering

As modern society develops, so does the field of engineering and especially the field of CE due to its close connection with societal challenges (see section 5.2.1). One interesting part of the development is specified by Hicham as the increased focus on humans as part of the equation of BE. While earlier there has been much focus on societal challenges, the physics of buildings, and the more structural parts, we now see a deeper focus on humans as individuals experiencing and affecting buildings either directly or indirectly; which seems relevant when considering that humans spend approximately 90% of their time indoors (Velux, 2021). This has greatly affected the way CE is perceived and how knowledge production is approached in the field. As Hicham explains it, they have a lot of core theories and understandings in CE, which are quite stabilised, but when more human factors enter the buildings, and humans are no longer perceived as this separate entity that simply appears in the buildings, then more knowledge about humans and their behavior needs to be applied (App.F):

> "*[...] as soon as you integrate humans into the mix, everything becomes much, much more complex. And we need the help of people who know more about humans; the Psychologist, the anthropologists to sociologists for the behavior part and acceptability; economist and political science and so on for the economic and legislation framework; and of course, medicine, doctors [...] and biologists for all the health issues and so on.*" (App.F, p.3, ll.71-76).

As such, CE has broadened its perspective as a field. But it also means that a lot of outside or separate disciplines have to become sort of a peripheral part of the discipline. Add to that, the fact that advancements in technology, i.e. computation and machine learning, has increased the focus on using technology to improve the human experience in buildings through e.g. automation, then it is not surprising that CE is an increasingly complex field (see section 5.2.1.2). Hicham views it as this big paradigm change, which is a result of the disruption that these new technologies create in the buildings. So what was previously an optimisation of buildings in a more isolated manner, is now about optimisation in with new elements thrown into the context which should be accounted for: Level of acceptability, user behaviour and demands, technological integration and constraints, integration within a city. In other words, CE and BE is now a "*[...] multi-multi objective optimization, and we have to integrate it more and more.*" (App.F, p.5, l.155). But this is often easier said than done. While there are many potentials for implementing new technologies in buildings, there has existed a sort of apprehension amongst CE's working within BE, sporting the attitude "*[...] well, it's too complicated, we just can't integrate all that [...]*" (App.F, p.5, ll.157-158). But if they wish to keep up with other fields and the societal demands, then they are no longer able to avoid all these factors. This has created a sometimes strained relationship between CE and the prospects of having to deal with new technologies, AI included, and move out of their comfort zone (App.D+F). But why does this apprehension or even trepidation exist?

8.2.1 Civil Engineering and Artificial Intelligence

During his interview, Hicham mentions several times that CE can sometimes be a bit behind regarding the integration and application of new technology. But it is certainly not for lack of interest or theoretical potential. It simply has to do with the level of maturity of the technologies and whether they can find value in the constructions of BEs.

The AI field itself is even criticised for a consistent gap between scientific claims proposed by researchers and engineering achievements in relation to the application of AI (Ekbia, 2003). In relation to Rikke's field, CV, she mentions that it is often difficult to achieve a high accuracy in real-world settings as opposed to a laboratory that always provides the right conditions. And even though they might achieve a high accuracy by some standards, it will not be enough for e.g. quality control in a production line because the factory needs it to be 100% accurate. So it requires a lot of work to reach a level of maturity which is good enough for real-world application in certain contexts (App.E). And the digitalisation of buildings is a very recent development and, thus, not very mature yet: "*Some of it is because, even though the algorithms existed for years, the methods for data gathering, testing and so on, concerning buildings were just not developed enough.*" (App.D, p.2). With the BE, the issue lies in it often being the last field to be introduced to new and ground-breaking technologies from other fields, it results in a gap between the advancements of new technologies and the applications of them in CE (App.F).

That is not to say that this gap exists in all areas of CE, but it appears to be at least partly true when looking at recent advancements with computing in CE. When briefly reviewing the selected papers for some of the newer conference extracts regarding computing in civil engineering and building engineering, it is evident that there certainly is a great interest in the use of computing in the field, and within that lies AI and machine learning among others. However, fields or methods such as AI, CV, machine learning, and deep learning etc.

do not seem to be the primary focus based on how frequently they are mentioned, which is not overwhelming. Rather Building Information Modelling (BIM) and Construction/Civil Information Modelling (CIM) seem more visible. Furthermore, there are noticeable priorities among areas of theoretical interests or application: Computer-aided engineering and decision making, assessment of structural conditions, detection of defects, modelling, building analytics, improving energy efficiency, as well as the monitoring, tracking, and evaluation of construction performance, to name a few. It is thus, more about trying to improve tools and models for carrying out CE or construction work by applying algorithms and machine learning. With these area of interests in the spotlight, there appear to be little focus on actually incorporating AI or machine learning into the design of BEs (Lin *et al.*, 2017b; Lin *et al.*, 2017a; Cho *et al.*, 2019; Santos and Scheer, 2021).

Consequently, due to this gap or discrepancy between theory and practice regarding advancements in AI, there has developed this tendency with more *conservative* CE's who would rather rely on their traditional approach to knowledge production and *old stuff* in their own field and are reluctant or even afraid to work with new technologies. CE's are starting to see more opportunities in applying things like Big Data and algorithms to their fields, but for the building sector Hicham still experiences this propensity towards perceiving AI as *Black Magic* or a *Black Box*. Many more words can be used to describe AI in this context and they are mostly negative: Too scary, too complicated, too challenging, dangerous etc. (App.D+F; P.C.). Thus, many people within the context of CE or BE seem to be skeptic about AI, and some are simply categorically against it. Hicham even has first-hand experience with the latter, when getting a conference paper reviewed by other CE's working in the same field: "*[...] one reviewer had nothing to say about the structure and such of the paper, but were simply against the whole concept of teaching automation in building engineering.*" (App.D, p.2).

And still, there has been a persistent interest in and fascination with AI for many years now. Of course, one of the reasons for this is the great potential for applicability, once the different methods and technologies reach an adequate level of maturity. Besides this, AI is simply something that permeates many areas of our society. It has become a buzzword for both academic and public discourse as well as popular culture, and it seems like almost everyone wants to take part in this interesting phenomenon. Despite this, AI still remains as a black box or black magic, at least partly. It is something that the general public and researchers from other areas know everything and nothing about at the same time.

> "*Because that's the thing yeah, we all hear about it we all read some publication about it and some other universities or some very nicely produced advertisement from companies talking about the future, the future, the future but that they make people believe it's actually right now but we know from experience that there's a huge difference between the nice ad from a big corporate and the reality of what they actually can make right now for commercial use, and there's an easy 10 years gap. Or you are very disappointed, you think it's super advanced but if you dig into it, it's like*

"okay it's nothing special just nicely branded". And so that's also maybe why people are just skeptical about AI being a thing right now, the fact that they're just so used to have you know over hyped technologies." (App.F, p.8, ll.257-264).

As the quote indicates, Hicham sees this discrepancy between the AI discourse and applicability in the real world. Stated previously, this is something that has been criticised in relation to the discourse surrounding AI: "*[...] there is a tendency in AI to exploit the Eliza effect*[2] *by smoothly conflating the real-world events being modeled with the tiny stripped-down versions that are in the models.*" (Ekbia, 2003, p. 25). What this means is that AI is often described in terms, which has a misleading effect, because they implicitly suggest that AI systems are more intelligent than they are, and applicable in real-world contexts, when the opposite is often true. And this effect is furthered by an "*attribution fallacy*" (Ekbia, 2003, p. 352), where people accept what is presented as true because it takes advantage of humans' tendency toward identification from association (Ekbia, 2003).

With AI perceived as this *umbrella term* (App.E, p.4, l.124), i.e. a very big field which is a combination of many different things, the AI experts can even experience difficulties in using the term AI or simply prefer not to because it is too general. As Rikke explains it, only a few people, if even any, can be considered to just work with AI, and that might only be people who are working on a philosophical theoretical level. For the rest, who are developing methods, artifacts, or others, it is defined and described in more specific terms, i.e. CV, robot control, speech recognition, and deep learning among others. But the use of AI nomenclature is also dependant on the context and recipient: "*[...] if I had to write something, to a newspaper, or something like that, I would probably use the term AI, because to the very broad public, they would have a sense of what is AI. But if I talk to other engineers, or specialists in my own field, I would define exactly which methods we use.*" (App.E, p.4, ll. 130-133). This indicates that navigating such a complicated field, even as one of the experts can be difficult. And the vastness and complexities of the field is further visible in the fact that some methods are even black-boxed to the AI experts themselves. This was explicated during the meeting about the SCODYF1 prototype. As mentioned, MediaTech has worked with applying CNN algorithms, but they were not able to provide e.g. a description or visualisation of how the convolutional layers in the network works. And this was not them lacking any knowledge or training, it is simply not possible. Other experts in CNN has tried to visualise it, but it is often too difficult to show and describe the complexities, and this is accepted as one of the premises for working with CNN's (App.D+E+G).

But the reason that AI is still a buzzword can be viewed as a self-fulfilling prophecy. AI experts keep using the term AI in more public discourses, because most of the readers either do not know anything about the specific subfields and methods, or they cannot understand

[2] In the AI community, the ELIZA effect describes "*The tendency of humans to attach associations to terms from prior experience. [...] The ELIZA effect is a Good Thing when writing a programming langugae, but it can blind you to serious shortcomings when analyzing an Artificial Intelligence system.*" (Raymond, 1996, p. 172).

it. But at the same time, if the nomenclature presented to the public stays abstract, it is a never-ending cycle of simplifying a field. And this can actually end up over-complicating it or creating misunderstandings of its use, as is seen with the *ELIZA effect* and *attribution fallacy*. And the tendency to exaggerations of what is possible with AI, can result in an overestimation of the level of complexity, for those who do not have prior knowledge about it, making them believe it is far beyond their reach. Additionally, the opaqueness and abstract presentation of AI's inner processes is actually something that can cause mistrust in engineers (Luckey *et al.*, 2021). In that regard, AI is a difficult field to navigate for those not native to it. As Hicham expresses it:

> "*[...] we all have a boundary, and it's a comfort zone. And then outside of those comfort zone, there are certain buzzwords, and we might have some, you know, prejudge ideas about that, positive or negative. And some people will be under and over enthusiastic about stuff they don't really understand. And some people will be a bit skeptical or afraid about things that they actually don't really know. And I think this is typically the case in my field for those AI technologies. [...] everyone knows about it, we've all heard of it everywhere in the society, but the amount of people who actually truly understand how it works, to actually assess if it's complicated or not, if it's dangerous or not. And if it has a potential or not, then this [ed. the amount of people] is actually quite quite small.*" (App.F, pp.5-6, ll.174-181).

In relation thereto, Hicham mentions several reasons for why CE and BE are not front-runners in applying AI. One of them being the aforementioned amount of focus on this field in relation to new technologies. Another reason is that there is simply not enough *building people* in the field of AI and those related to it. And computer scientists, in Hichams opinion, tend to "*[...] give up all that they are [...]*" (App.F, p.7, l.222) in relation to pursuing their own fields, that they have no idea what *building* is in terms of engineering.

8.3 Motivation behind SCODYF1

The outlined relationship between AI (Computer Vision) and CE (Built Environment) speaks of a need for them both to become more familiarised with each other. This might lead to the actualisation of the potential spotted in the collaboration between these two fields.

And this familiarisation was and still is part of Hicham's motivation for the SCODYF1 project. While both Rikke and Hicham are driven by an academic curiosity in relation to whether the concept of an algorithm for detecting visual discomfort from a face is even possible, this is mostly an intermediate step in proving that it can be used in building engineering as a way to improve indoor visual comfort. From Hicham's perspective the potential for demystifying AI to the field of BE is also an important incentive for the SCODYF1 project:

> "*I mean I took this small project as an occasion, an opportunity to kickstart, let's say, the activity to, for me to understand better and have a concrete example of something that works, learn better about it and yes diffuse it through my colleagues and the rest of my department because it will come anyway and we should not be [...] behind. [...] We should not wait five or 10 more years.*" (App.F, p.8, ll.266-270).

This objective and rationale moves the interdisciplinarity of the SCODYF1 collaboration towards the agonistic-antagonistic mode, although not entirely. While it calls attention towards the limits of the participating disciplines and the benefits of closer association between them, it does not constitute an attempt to establish a new interdiscipline (see section 4.3). But how can this diffusion be achieved in practice? From the SCODYF1 project, I see three focus areas which can jointly play a part in this:

1. The technology
2. The people
3. The collaboration

8.3.1 The Not so Scary Technology

We have already established that AI has many negative connotations due to a number of reasons, which makes non AI experts apprehensive, also in the CE field. This indicates a need to change the perceptions of AI, away from this mystical and opaque black magic which is too complicated to understand. Right now, there seem to be a lot of high expectations to AI due to theories and methods presented through both research articles and popular culture or buzzwords, and this makes it seem to be more complex than the real world practice of AI (see section 8.2.1). One solution has been proposed in a related field: AI and machine learning techniques for smart city applications. Here it is argued by Luckey *et al.* (2021) that "*To enhance confidence in AI, the "black-box" nature of AI algorithms for smart monitoring needs to be explained to engineers.*" (Luckey *et al.*, 2021, p. 3). The solution should lie in promoting XAI (explainable artificial intelligence) through proper categorisation of the various AI algorithms and their connected use in the current context (Luckey *et al.*, 2021).

This might, certainly, be helpful for those who need an overview and wish to know more before diving into AI. And trying to figure out if there is a "*[...] subset of all the AI technologies and methodologies that will be more appropriate to the building [environment]*" (App.F, p.7, ll.245-246). However, experience and concrete examples of application are missing from this equation when considering the aforementioned issues and the fact that the overview might still prove to be too abstract. Furthermore, being able to provide a concrete and clear example or prototype of a concept that works, can be "*[...] the best way to convince people [...]*" (App.F, p.8, l.276), and a way to incite confidence in starting new projects involving AI related technologies or methods (App.F).

Additionally, despite being such an old field, central to societal developments for many years, CE in relation to the BE is often one of the last fields to be introduced to new technology developed in other fields. By collaborating with AI experts, instead of waiting for the technologies to mature enough for themselves to apply, CE's might have an easier time staying on top of the current technological developments and become innovative front runners. Furthermore, the BE is also often overlooked in academia as an exciting research field for other disciplines to study and develop. This is something Hicham wishes to rectify, starting at AAU. Providing a working prototype as a result of a collaboration between CE's and CV specialists, might work as a way of putting CE and BE more firmly on the map of AI research areas, and proving that such collaborations can be valuable (App.F).

Another way to prove the value of collaborations with AI experts or including AI methods, is by being transparent about the availability of the products. The fact that the CNNs used for SCODYF were from-the-shelf products; pretrained, efficient, versatile, cheap or free, fairly simple, and very powerful with cloud computing. It was something that both seemed to surprise and impress Hicham and Rasmus at the prototype meeting, and facts they saw important to include in the conference paper about SCODYF1. It will simply make it even easier to explain how it can be used in their own field, and because CE's are not necessarily used to new technologies being so readily available for their context, it is an immediate advantage to be able to provide them with a concrete example; and through this show them that working with AI methods and tools does not always require a lot of work to appropriate to their field. The fact that it is more simple than first expected shows, according to Hicham, that "*[...] it is the right time in terms of the maturity of the technology.*" (App.D, p.5).

8.3.2 The People: Us and Them

When collaborating with people who have a different disciplinary background, work in different milieus and are part of specific epistemic cultures, the boundaries can end up being barriers (see chapter 4). Of course, technical work is not homogeneous, and neither is AI or CE practice. But they might not be as different as initially expected. And when trying to explore each part in relation to collaboration across the disciplines, it would be highly relevant to show that, despite the AI field having a complex reputation, the AI experts are in fact not that different from CE's. And this rationale can be supported in many ways.

Firstly, both fields appear to put the human in the center of attention (see section 8.1.1): CV in a more literal sense in that they are trying to replicate or automate human tasks related to vision; CE and BE is more about changing the surroundings of the humans. Nevertheless, they both have an immediate focus on humans, but still in a somewhat technical manner, seen from my own perspective.

Secondly, when listening to Hicham and Rikke's experiences with working together, and the process of clarifying BUILD and MediaTech's work procedures, it makes it pretty clear that they both have this technical way of approaching problems and a somewhat straightforward way of approaching knowledge production. Their view on knowledge seem at least partly positivistic, with appreciating a dichotomy between true/false, working/not working etc.. Knowledge is not taken as an abstract construct, and in the end they seem to agree that having something concrete makes it easier to prove the value of a product (App.E-G; P.C.).

Thirdly, despite using different methods, theories, and working mostly separately on tasks, their approaches towards problem solving appear quite comparable. With both BUILD and MediaTech vieweing their own and each others work as an engineering practice, they concur the purpose of their research being to apply their knowledge in new and innovative ways, preferable in the real world. With no discernible needs to translate their knowledge and cross language barriers, they do not seems to be impeded by the differences they have in relation to differing "*domain knowledge*". The difference in domain knowledge is both apparent in their communication, though in a small scale, but it is also something they comment on themselves. This indicates that they are aware of these differences, but there is a mutual trust and respect in relation to each others status as an expert in their relative fields, and this is not questioned with anything else than curiosity (App.E-G; P.C.).

Furthermore, tacit knowledge or intuitive understandings do not appear as a barrier to the communication or collaboration. Of course, there were smaller needs in relation to clarifying the work practices and some questions about technical details presented by the other team, but no direct or indirect misunderstandings and misinterpretations of what was being said or written were discernible from the data (App.E-G; P.C.). As Rikke expresses it:

> "*I think we're quite close to each other here. Even though we are doing completely different things. But I think [...] our kind of training as engineers or something, it's the fields here are quite... at least with with Hicham, who I'm talking to here, I don't know about the other people in his department, but this is the interface we have. I think we have quite a common sense of defining things and being specific and yeah, what is data like and I think he also has some understanding of what we can do with CV, for example. So we have not spent a lot of time discussing anything here, I think. Yeah, there was some understanding from before the project.*" (App.E, p.3, ll.72-78).

Of course they are not identical, they do after all have disparate educational, social and cultural backgrounds in relation to their research and department affiliation. However, they are also very similar fields in terms of interdisciplinarity and both Rikke and Hicham have much experience with interdisciplinary collaborations (which does seem to be normal in their immediate research milieu). Subsequently the differences they do have, seem to be perceived as strengths instead of boundaries or cultural gaps. In that regard, it is not as surprising that they do not seem to be impeded by differences in perspective or epistemic culture. The fact that they are used to working across disciplinary boundaries and being open to other perspectives, might be why their epistemic cultures do not seem to have very rigid boundaries (App.E-G; P.C.).

8.3.3 There is Help Around the Corner

Despite the increasing focus on innovation having its downsides[3], it has also had some positive effects on the knowledge production culture in engineering. These are evident in the way engineers are trained in the 21st century with a focus on interdisciplinarity and transverse projects, along with international mobility, which prompts them to associate with other disciplines and subsequently step outside their daily framework and be confronted with different ways of doing things. This promotes and encourages agile thinking along with an openness towards the unknown, which can lead to an adaptability towards different professional cultures (Cardona Gil *et al.*, 2018).

This is a development which is reflected in Hicham's own experiences with and approach towards interdisciplinary collaboration, where it is viewed as a norm, at least among the younger generations of researchers, and it feels natural to take part in collaborations with people from other disciplines: "*It's like, we've always done it, I think.*" (App.F, p.2, l.60). And despite not always understanding the rationale of people from other disciplines and epistemic cultures, they still trust their judgement and accept it in respect of their differing knowledge. The interdisciplinary research milieu is especially promoted and favoured at AAU, according to Hicham, who expressed that they have "*[...] enough freedom to explore a lot of different topic of research and we have time to learn about it.*" (App.F, p.2, ll.32-33).

The field of CV can be viewed in the same sense. And interdisciplinarity is especially revered by Rikke and her colleagues seeing as they can develop many methods or tools, but the applicability of them is most often found in other fields or in collaboration with them (App.E). Thus, from this perspective, interdisciplinary collaboration also seems to be necessary for the continued relevance of AI as an applied science dealing with real-world challenges, and not only a theoretical construct that keeps developing without any or only a few engineering achievements (Ekbia, 2003).

With collaboration between CE and AI appearing very beneficial and with a lot of potential, then it brings us to the importance of promoting collaboration. Hicham's objective of trying to instill confidence towards AI in his fellow CE's can be supported further by emphasising that, at least at AAU, there are top specialists right around the corner (at MediaTech) whose set of skills is a valuable resource and they are open towards collaborating on topics relevant for CE and BE (App.D+F). In this sense, the CE's do not need the hassle of trying to become AI experts themselves or conduct half-hearted appropriations of methods, often ending up with results that are only usable on the surface. They can simply, as Rikke expressed it, "*leave it to the expert*" (App.E, p.6, ll. 200-201), who knows how and when to use the appropriate methods to achieve the desired results (App.E+F). Additionally, there is no need for complete

[3] "*The recent increase in interest given to the notion of innovation is an indicator of the disappearance of the sociotechnical ambition for progress.*" (Cardona Gil *et al.*, 2018, p. 8), with the focus of engineering turning from developing society in relation to human needs towards creating markets and profits through the invention or creation of products, which reflects a priority of more individual self-interests. Furthermore, it can limit engineering activity to concerning the immediate future, as opposed to long-term solutions and benefits (Lemaître, 2018).

understanding of each others' fields before commencing collaboration. It is a partnership, where each has a role to play, simply because they cannot carry out each others' tasks:

> "*Once again, we don't necessarily have to understand the core operation of all that, we have to guide the specialist how to apply [ed. it] to [...] a building. I mean, it's just like now we all use computers. I'm sure no one knows how micro processes working, but we can still see the use of it for a lot of different tasks.*" (App.F, p.6, ll.203-206).

Hence, diffusing AI to CE is not about the CE's understanding enough in relation to AI in order to use it themselves, but about understanding that interdisciplinary projects can be mutually beneficial for CE and AI. Furthermore, there is a lot of untapped potential for application of AI in CE, we just need to draw attention towards it, and how to best approach it. And small pilot project, like SCODYF1, can open CE up to including AI and AI experts more in their field, by showing why it is not scary in practice.

Discussion 9

Artificial Intelligence is a vast and heterogeneous interdisciplinary field, which has gained a lot of traction since its commencement. As a result it can be perceived and experienced as a complicated field to navigate, especially with the existence of multitudinous perspectives, epistemic cultures, and knowledge production practices. Straddling the boundary between science and engineering (assuming a dichotomy between the two), this complexity is only expanding with the amount of interfaces AI has with other fields. Having people from different fields and disciplines, however, often poses the risk of creating tensions due to differences which can be difficult or impossible to translate. These rationales lead to the construction of the following problem statement, which set the frame for this thesis:

> *How are differences in epistemic cultures and milieu experienced by researchers participating in the practice of knowledge production within an interdisciplinary project involving AI?*

I, therefore, commenced a study of this in the context of an interdisciplinary research project, SCODYF1: A project combining the fields of CE/BE and AI/CV in the interest of optimising indoor visual comfort from facial analysis through AI.

However, the process of attaining empirical data, and subsequently analysing it, provided results which were quite disparate from the initial expectations: Differences in epistemic cultures, approaches to knowledge production, and disciplinary practice etc. between the two teams did not engender any boundaries which were difficult or impossible to cross or work around. In fact, no substantial conflicts or tensions were visible either above or below the surface of their interdisciplinary practice.

Regardless, studying the SCODYF1 project did reveal a multitude of aspects influencing the success of their collaboration, indicating the existence of interesting tendencies affecting the relationship between CE and AI.

And many of these factors have to do with attitudes towards other disciplines as well as interdisciplinary collaboration. Attitudes, especially among CE's, which can be enhanced and utilised to achieve the second motivation behind the project: The diffusion of AI. There is a definite appreciation and reliance on practical examples, both on the side of BUILD and MediaTech. The fact that they prefer concrete examples of applications, as opposed to abstract notions and concepts, is relational to their views on knowledge, which at least partly reflect the AI experts' assumptions of knowledge and knowledge production (see section 4.2.1).

And this is something we might learn from when regarding the future of interdisciplinary collaborations between CE and AI. Demystifying and diffusing the use of AI in certain fields through projects like SCODYF1, can provide other researchers with a frame of reference when considering the value of collaborations with the field of AI. While second hand experience can rarely be equated to first hand experiences, it can still provide some insight into the people working in the field of AI, and reveal that they might not be so fundamentally different in their epistemic culture and approach to knowledge production. In that sense, it might be a catalyst to changing negative perceptions and bias towards AI and AI experts into an openness towards engaging in interdisciplinary collaboration and forming new opinions based on their own experiences.

Furthermore, in relation to the engineering field, which has gone through a lot of changes through its existence, the constant push for innovation might be seen as a way of "*[...] breaking with the disciplinary separation and the Cartesian approach to problem solving (i.e. breaking down a difficult question into many simple questions, solvable separately)*." (Lemaître, 2018, p. xiv). Consequently, CE's are used to both bringing in knowledge from other disciplines and collaborating with people who have different world-views or approaches to knowledge production. While one might view AI as used to inserting themselves in different fields with potential for applicability, CE appears opposite. Because buildings are such a central thing, they are used to including many disciplines in their own work

CE's openness and broad focus in terms of areas of application should actually provide a prime disciplinary milieu for collaboration with the field of AI, with epistemic cultures that are not a hindrance but actually an asset to the collaboration. CE has existed as an interdisciplinary applied science for longer than the AI field, and is in that sense maybe more mature. So if the AI field should evolve and perhaps transgress the limits of collaborations with other disciplines (which are perhaps a result of epistemic boundaries), then perhaps we need to take a page out of the CE practice book, so to say.

Epistemic cultures and differences in milieu can play a big role in the hindrance of interdisciplinary research between two very complex and vast fields, but instead of letting it take that role, we could try to learn and acknowledge what these differences mean and where they matter, as well as how we can actually use them as an advantage when trying to cross or diminish the boundaries. Although approaches concerning this has been presented before, i.e. hybridisation of fields or imagination, creolisation of culture, and cosmopolitan approaches to knowledge production (Baus, 2009; Jamison *et al.*, 2011; Jouvenet, 2013), these are mostly conceptual, whereas the lessons from the SCODYF1 project provide some concrete practical ways to circumvent any challenges.

Projects and collaborations like SCODYF1, thus, appear to have the potential to soothe prejudices and worries about the incorporation of AI in other research areas. Especially, when considering how CE's promote epistemic curiosity as an integral part of good research practice, among others. And if we further cultivate their approach and outlook on differences (as variances in expression) it might make it seem less daunting to commit to an interdisciplinary project with new and intimidating technologies or disciplinary practices. And if there are differences in something as fundamental as views on knowledge, should we perhaps simply approach collaboration with mutual trust in each other's expertise, despite not understanding it fully, because we accept that there are things which we ground in tacit knowledge and practice and cannot simply explain to others or understand from others through mere dialogue? It is something that is learned through years of practice, and as Hicham expressed it: "*[...] is it worth investing so much energy into a new field, when you have specialists right next to you who want to collaborate?*" (App.D, p.2).

10 Conclusion

In summation, this thesis started from a curiosity towards the complexities of Artificial Intelligence and perceived differences of its difference from other fields, along with how this is perceived in practice. This, therefore, led to the following problem statement:

> *How are differences in epistemic cultures and milieu experienced by researchers participating in the practice of knowledge production within an interdisciplinary project involving AI?*

A somewhat simplified answer to the questions is: The SCODYF1 participants do not experience any particular differences in epistemic cultures or milieu in the context of their interdisciplinary collaboration, combining the fields of Computer Vision (AI) and Built Environment (CE). Instead, the issues and challenges of the relationship between the two fields on a more general level can be identified from their retrospective explication of previous experiences.

Firstly, the gap between theories and real-world applicability in the field of AI cause the Civil Engineers to either have too high expectations or be apprehensive towards collaboration with AI experts. Furthermore, the confusion surrounding AI as a conceptual, methodological, and theoretical toolbox, often perceiving it as *black magic*. It is, thus, the informants ambition to counteract these, starting with their project. From this secondary objective of the SCODYF1, the case presents some valuable lessons for a better future understanding of AI and interdisciplinary collaborations with other fields, grounded in the context of civil engineering and the built environment. Among these are the importance of diffusing and demystifying AI in the field of CE through both concrete examples of applicability, and importance of an open approach towards interdisciplinarity and relevance of portraying AI experts and their approaches to knowledge production in terms that do not alienate them to those apprehensive towards new things and changes in their existing practice.

In the case of no prior experience with a situation it is often a question of learning by doing, but this requires a certain openness to just dive right into unmarked territory. And, should the results live up to Rikke and Hicham's expectations, then their project can serve as an inspiration to their colleagues among others, with the use of concrete examples and proof that a collaboration of that nature is possible and even beneficial. Thus, it might help foster an openness and curiosity towards engaging in new interdisciplinary collaborations across the boundary between Civil Engineering and Artificial Intelligence. This has the potential to result in more cases of collaborations which can be used to incite further action and improve both the interdisciplinary milieu and the amount of possible contexts for application of AI. And within this, lies the importance of trusting in the knowledge of other experts, and actually taking advantage of differences in epistemic cultures and approaches toward innovation. Through this, there is a potential to improve the relationship between two fields which could both benefit from a bigger interface with each other: Computer Vision and Built Environment. With time, this might be relatively translatable to their respective comprehensive fields, namely Artificial Intelligence and Civil Engineering.

The literature reviews conducted in relation to this thesis and the further reading of literature on related topics, suggest a relatively non-existing focus on the aforementioned. Although there exist a relatively high amount of literature on the cultural and social factors in interdisciplinary knowledge production, these are often more generalised theories or rooted in cases quite different from the present thesis. Forsythe's anthropological studies of artificial intelligence (Forsythe and Hess, 2001) might be viewed as an exception to the former claim, but with the radical developments within the field of Artifical Intelligence in the last couple of decades, her work can in some instances be viewed as relatively outdated. Furthermore, even if the scope of this thesis moves in the same theoretical sphere as previous work, the context and specific objectives differ.

Particularly, this study provides insights into the epistemic mechanisms at play in the contextual reality of interdisciplinary collaboration between the BUILD and MediaTech departments at Aalborg University. The novelty of the SCODYF1 project's focus, along with the lack of previous collaboration between CE and AI experts, supports the uniqueness of the present thesis and the hitherto unprecedented factors relevant in this relatively new cross-section of fields.

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