VU UNIVERSITY AMSTERDAM

Handbook Metallurgy

About the soul of a staalmeester

Painting '*De Staalmeesters'* by Rembrandt van Rijn (1662)

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A thesis submitted in fulfilment for the

Master degree of Philosophy of Management and Organizations

In the Faculty of Philosophy, VU University of Amsterdam

Words: 23.983

July 26, 2018

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Preface

I always thought that everybody was thinking like me. Thinking in a straight forward logical way; the rational way of reasoning we learned at school and at the university. It did not come to my mind that people could think otherwise. Feelings and emotions are not rational so I gave these soft stuff very little thought. Neither was I sure about religion, so I pushed that away for a long time. It happened that I walked out of management courses where these ‘soft’ issues were on the agenda. It was until one management course in 1998 where philosopher Arnold Cornelis (1997) presented and discussed his book ‘logica van het gevoel’ that I started to give it somewhat more thought. When my father died in 1995 I could no longer keep a religious God out of my life.

But still the physical world was much easier to understand. I was lucky to make a profession out of it at Hoogovens, today Tata Steel, thé Dutch steel company (combining with Thyssenkrupp). The phenomena and processes at an integrated steel plant are very complex and therefore interesting, intriguing and challenging. You can spend a life time working to understand these processes. I believe that ‘understanding the processes’ is the most basic need of every business or company. Only when the processes are understood can the processes be optimized, improved, developed and innovated. No kpi (key performance indicator) can be met without understanding the processes.

At a certain moment it seemed time to write down everything I ‘understood of the processes’ in a handbook metallurgy. But upon writing my explanations for all the interesting cases something did not feel right. I wanted to write about the process of understanding rather than to explain past events. The process of understanding is a way of thinking and that is what I thought philosophy was about. For writing a philosophical handbook metallurgy I better had to start studying philosophy. So I did in 2015.

I also noticed that my reports on metallurgical events seemingly had less authority than they had at the beginning of my career in 1986. More and more my reports were

considered to be just an opinion amongst so many other opinions. I got the impression that I was the only one thinking this way and I started to doubt myself.

The study of philosophy at the VU of Amsterdam was a feast, a feast of recognition. Many philosophers think like me (or rather me like them). I have always been a black and white thinker but real life is not black and white and has more than fifty shades of grey as well. One can introduce more modes of existence to understand real life like Latour (2013) did (not 50 by the way), but it already helps when the intersubjective world is introduced besides the physical and mental world. The courses on philosophy gave me back self-trust that I'm not the only one thinking this way (that I'm not a solipsist).

I enjoyed the study very much from the first premaster course on ethics till the last extracurricular course on philosophy of science of theology and religion. The lectures of and discussions with the very enthusiastic and driven lecturers enlightened my days. I would like to thank them for that: Martin van Hees, Helen de Cruz, Annemie Halsema, Christian Krijnen, Jan-Willem Wieland, Ad Verbrugge, Hein van den Berg, Marijana Milosavijevic-Vujosevic, Johan Wempe, Govert Buijs, Lieven Decock, Olga Lizzini, Dirk-Martin Grube and Gijsbert van den Brink. I also enjoyed the interaction with my fellow students, thanks you all.

However they saddled me with so much interesting material that it became a real struggle to write my thesis. So much to write about, so many possible associations, so little time; this gave some stress. I think I wrote about 50 different draft versions each containing more than 40 pages. And although I did not send them all to my supervisor prof. dr. Govert Buijs it must have driven him mad. 'Arie, what exactly is the point you want to make ?'. In fact I wanted to write all my associations down because in one way or another they relate to my way of thinking, my thinking model. I would like to thank Govert that he did not give up on me; he really helped me in focussing my thoughts. I finally wrote 'about the soul of a staalmeester' (with a non-capital 's') and finished my anticipated Handbook Metallurgy.

I very much appreciate that prof. Henk de Regt accepted my supervisor's invitation to be my second reader. It feels like Descartes accepted, if he had been alive. When I read Descartes's 'a discourse on the method' I recognized a lot of my way of thinking. But de Regt's 'understanding scientific understanding' (2017) really helped unravelling

the puzzle of what is essential in the way of thinking of a scientist. In order to understand a phenomenon you have to understand the theory as well. For me this really cleared the confusion between the terms ‘understanding’ and ‘explaining’.

I also would like to thank Henk de Regt for adding an example of an intriguing phenomenon. In order to share my enthusiasm for understanding physical phenomena I sometimes raise, what I consider, an interesting question. Often this is somewhat later at parties (my family finds this very annoying because they heard it too often). ‘What would happen when you drive your car at 100 km/h and next to you the canary you took with you came out of his cage and flies freely above the passenger’s seat and all of a sudden you have to brake ? Will it be smashed on the front window or not ? Which item of knowledge will explain it ? The later the party the more complex the problem seems to be. De Regt adds a new one: to which side of an accelerating plane will a helium filled balloon go, to the front or to the rear ? I won’t give the answers but what it asks is ‘intelligibiligence’ (in order to pronounce this word it helps to break it up in two pieces: intelligi and biligence) which is what the thesis is all about.

I would like to thank my Tata Steel UK colleague Jon Jenkins and his son Matthew for reading and commenting on parts of the more than 2000 pages I wrote. They say I write like I talk. I guess it is the English way of saying that it is not good, but they add to say that they like the way I talk.

And last but certainly not least I would like to thank my wife Helene and kids Peter, Ruud, Leonie and Anouk for their patience and support. At moments of stress I’m not always fun to be with, but they always cheer me up. Thanks for that, I love you.

I would like to end with part of a Hebrew bedtime prayer: “Blessed is the Lord by day and by night, blessed is the Lord when we go to sleep and when we wake up, for in His hands are the souls, both of the living and the dead, in His eternal hand is the soul of all the living and the spirit of all humankind. O Lord *in Your hands I shall entrust my soul.* Amen.” For intelligibiligence is a gift of God but it is a blessing too when the soul, which contains intelligibiligence, comes to rest at night.

Happy readings

Arie Hamoen Zegveld, July 3, 2018

Chapter 1: introduction

1.1 main topic and structure

In the 80's and 90's of the 20th century the knowledge of a scientist was valued and respected. Scientific knowledge as such acquired this respected position because of its big advancements and achievements since the beginning of modern science in the 17th century. It was Descartes (1596-1650) who stood at the cradle of modern science. In the 20th century the notion that only science could describe the 'world as it is' was very much alive. Currents of thoughts like logical positivism at the beginning and scientism at the end of the 20th century illustrate this. An important aspect of the special status of science knowledge was its objectivity. Objective means that all knowledge including the knowledge of the knowing process itself is explicitly formulated and with methodical rigor. Subjective or personal input into the knowing process was thought to do nothing more than obscure the true meaning of things.

Critiques to the claim that scientific knowledge is objective came from philosophers like Michael Polanyi (1891-1976), Karl Popper (1902-1994) and Thomas Kuhn (1922-1996). These philosophers and others debunked the alleged objectivity of scientific knowledge. They claim that pure objective knowledge does not exist. Intended or not, they started a movement towards a more relativistic view on scientific knowledge. The knowledge of a scientist is not valued over the knowledge of a layman anymore.

Latour (2013) noticed this tendency towards relativism as well. In the introduction of his book 'an inquiry into modes of existence' Latour writes about a 'climate change' conference where different scientific disciplines were contributing. Latour writes that he was astonished when an industrialist asked a professor of climatology the question 'but why should we believe *you*[1], any more than the others?' (p. 2). In this thesis we will meet a staalmeester who had a similar experience. Exactly the same question was asked when the staalmeester reported on a metallurgical phenomenon.

[1] In Latour's case this '*you*' was a professor of climatology, in the thesis it is a *staalmeester* (which will be explained in section 1.2). In general for this thesis both are meant to represent the more common notion of a 'scientist'.

Although the question was the same in both cases the intention of the questioner or the perception of the receiver could differ. In Latour's case it could be that the questioner was confused by the fact that different disciplines gave different explanations and used different theories to the problem of climate change. The scientific knowledge involved seems 'context' dependent. To the staalmeester the question had a smell of relativism: his knowledge and experience seemed not to matter at all and equals that of a layman. Context dependency and the personal aspect of scientific knowledge meant that scientific knowledge lost its respected objective status.

But what exactly is scientific knowledge and did it really lost its objective status ? The main topic of this thesis is an inquiry into the distinctive feature of scientific knowledge and whether this feature can escape relativism.

Before digging into this inquiry another problem has to be dealt with first. Whatever distinctive feature there is (or not) and whatever objective standards it could meet (or not) the problem is 'how can *I* be sure that *I'm* not the only one thinking this' ? Because when I'm the only one thinking this I should start doubting myself and I will have a hard time convincing myself before others can believe me. This interesting and intriguing problem is called solipsism or 'the problem of other minds'. For a non-philosopher this problem might seem a non-issue but it turns out to be a philosophical challenge waiting to be understood and solved. In chapter 2 this problem will be addressed first.

Four approaches to this problem of other minds will be described. These approaches have in common that they try to close the gap between the subjective mental world and the objective physical world. One approach closes the gap with the help of God, the other by the denying the mental world. Probably the most appealing approach for the general population is called 'analogical inference'. Finally Nagel's (1986) 'view from nowhere' will be described. None of these four approaches seems to offer a generally accepted solution.

In order to solve the problem one has to go beyond the dualism of the mental and physical world. An obvious candidate for a 'third' world is the intersubjective or social world. Geertsema (2000) introduced the notion of the 'second person view' to bridge the subjective first person view and the objective third person view. In order to understand ourselves and our way of thinking the interaction with others is needed.

Acknowledging the existence of an intersubjective world would make solipsism, as a theory, incoherent. With this problem out of the way our inquiry into the distinctive feature of scientific knowledge could start.

Chapter 3 contains this inquiry into the distinctive feature of scientific knowledge. What exactly do we have in mind when we talk about scientific knowledge; is it ‘knowledge as a product’ or ‘knowledge as a knowing process’ ? Section 3.1 is about ‘knowledge as product’. In the second half of the last century a scientist possessed scientific knowledge simply because he or she studied at a university. What exactly it was the scientist possessed was not specified but the possession was considered to be distinctive in itself and it was objective. The scientific community guarded this objectivity by means of controlling the publications of this knowledge. Today there is an abundance of ‘knowledge as product’ that is easily and readily available with only a swipe on a smart phone. When ‘knowledge as product’ was considered to be the distinctive feature of scientific knowledge it lost this distinctiveness together with its so long cherished objectivity that can no longer be guaranteed. In section 1.2 it will be suggested that ‘knowledge as product’ is not what makes up the distinctiveness of scientific knowledge. A ‘handbook metallurgy’ should not contain the product but the knowing process that produced the product

In section 3.2 there will be a closer look at the knowing process. As suggested before this probably was the first place to look for the distinctive feature of scientific knowledge anyway. The knowing process is a mental process in order to ‘know’ things You know something when things are clear to you, when you understand things. From this formulation is follows that the aim of the knowing process is ‘understanding’. Modern science however went for ‘explanations’ as the aim of the knowing process. For reasons of objectivity this seems logical. An explanation is normally used to answer a ‘why’ question in order to justify the claim that was made. When one guards that only logic and facts are used in the construction of an explanation, the explanation will be objective. But the construction or reception of an objective explanation does not guarantee that the constructor or receiver really understands the phenomena dealt with in the explanation. In that case a scientific explanation misses the point. The unconfirmed story goes that Einstein once said that only when things are understood they can be explained, and when things cannot be explained they are not understood.

Therefore understanding seems to be the better candidate for the ‘distinctive feature of scientific knowledge’, but certain elements of explanations have important features as well. How to combine the features of understanding and explaining ?

De Regt (2017) provides a helpful insight here. De Regt distinguishes ‘understanding the phenomena’ (UP) from ‘understanding the theories’ (UT). Understanding the phenomena is the aim of the scientific knowing process and understanding the theory (or explanatory understanding) forms the means to achieve this aim. In order not to mix up the two types of understanding, de Regt called understanding the theory ‘intelligibility’. The knowing process is about connecting the phenomena at hand with the available items of knowledge and other background information and data. In order to use the available items of knowledge one has to understand these items, one needs intelligibility.

What seems crucial in the knowing process is making this connection. An often applied way of doing this is by means of constructing a model. The combination of understanding, intelligibility and constructing a model is what makes up the distinctive feature of the knowing process of the scientist. Derived from and very close to de Regt’s notion of intelligibility the notion of ‘intelligibiligence’[2] is introduced to represent this combination. Intelligibiligence is the ability to construct a model or a conception of the physical phenomena at hand in order to understand the phenomena. In order to construct such a model a scientist uses items of knowledge, other background information and data and therefore needs intelligibility. In section 3.3 the notion of intelligibiligence is worked out in more detail. A few examples of what it means to understand items of knowledge, like the deductive-nomological model and the causal approach, will be addressed. The example of the staalmeester will be used to elaborate somewhat more on the notion of intelligibiligence.

Intelligibiligence turns out to be a pragmatic way of understanding. Intelligibiligence is a skill, to be acquired by the scientist in the context the scientist lives and works in. It depends on the scientist’s personal preferences which items of knowledge and data to use and which not. The available items of knowledge vary with the times and discipline the scientists lives and works in. Both the terms ‘pragmatic’ and ‘context dependent’ cannot match up to the standard of objectivity defined by modern science.

[2] Intelligibiligence is a made-up word derived from and close to de Regt’s definition of intelligibility.

Interestingly both terms belong to the intersubjective world which will be introduced in section 2.3 in order to solve the problem of other minds. In section 3.4 the inevitable presence of the intersubjective world will be used to claim the 'detached'[3] character of intelligibiligence. Because of the detached character intelligibiligence escapes relativism and comes close to the pure objectivity of modern science. In sub section 3.4.1 the intersubjectivity of intelligibiligence will be approached with the help of Polanyi's (1966) notion of 'tacit' knowledge. In sub-section 3.4.2 the detached character of intelligibiligence will be justified.

Provided that both the professor on climatology and the staalmeester possess intelligibiligence this should convince the people to believe them, more than the others. When the others are also scientists who possess intelligibiligence one has to focus somewhat more on the specific aspects of the phenomena they studied and understand. Climate change is too broad a subject to understand as a whole. When the others are laymen one has to focus on what exactly they understand of the phenomena they try to explain and, most probably, seriously have to doubt whether to believe them or not.

Still one might long for the old 'modern' science with its big names like Newton and Einstein. This modern science was really objective and therefore different and better the newly defined notion of intelligibiligence. Descartes became known as the godfather of 'modern' science. In his work 'a discourse on the method'[4] (1637) both the base for dualism and the methodical rigor of objectivity are laid. With intelligibiligence scientific knowledge goes beyond dualism and is detached in character. But is intelligibiligence really so much different or worse than modern science ? This can be doubted. In chapter 4 Descartes way of thinking will be revisited by comparing the notion of intelligibiligence with Descartes's discourse. In the discourse Descartes describes the 'method of doubt' which comes very close to the notion of intelligibiligence, as will be explained in section 4.1. In the discourse Descartes also describes the working of the heart. This is a perfect example of what intelligibiligence is about, as will be addressed in section 4.2. In Cartesian dualism

[3] Detached from personal influences. In the thesis it will be referred to as detached in character to distinguish it from the 'pure objectivity' of modern science.
[4] For reasons of convenience 'a discourse on the method' will be shortened to 'discourse' in the rest of the thesis.

there seems no room for the intersubjective world which is a prerequisite for intelligibiligence. In section 4.3 some more words on the intersubjective world of Descartes will be written.

Scientists often share a kind of intellectual optimism that everything in the physical world could be understood, if not today then in the future. But up to now there still are limits to our understanding. In section 2.2.1 the God of gaps will be introduced when the limit of our understanding of a non-physical problem, the problem of other minds, is at stake. Section 4.4 elaborates somewhat more on the God of gaps at the limits of our understanding of physical problems. At a certain moment every scientist will reach the limits of what he or she could understand. At that moment the scientist has to 'believe' it.

"Why should we believe a scientist ?" For everything between chapter 2's 'problem of other minds' and the problems where the 'God of gaps' of section 4.4 is needed, the answer can be found in chapter 3: 'because of the scientist's intelligibiligence'. Although intelligibiligence has pragmatic and context dependent elements, it escapes relativism. The revisited Descartes of chapter 4 shows that these elements were present right from the beginning of modern science and did not hinder, but was a prerequisite for the impressive development and achievements of science and technology.

In this the last chapter three final comments will be made. Firstly: the title of the thesis suggests that intelligibiligence makes up the soul of our staalmeester. Does this entail that feelings, moral and a pious belief in God are not essential to the soul of our staalmeester ? Secondly: has intelligibiligence something to do with intelligence ? And finally how does a 'handbook metallurgy' fits in this thesis ?

1.2 explaining the cover page

Normally the cover page, including the title, subtitle and in this case a picture of a painting, should be self-explanatory once the thesis is read. Quite often the main title is kept somewhat vague or cryptic where the subtitle is supposed to represent the essence or the main topic of the thesis. This should be the case with this thesis as well, but still it seems useful to explain certain terms like 'metallurgy' and 'staalmeester'

upfront. Therefore a short introductory explanation of the titles and the painting seems to be appropriate.

In 1986 the author of this thesis graduated at the Delft University of Technology and acquired a master of science (MSc) degree. The former Dutch term for someone who graduated at an University of Technology was ‘engineer’ (ir.). There were times that technology was considered to be ‘applied science’ and therefore minor to science. Furthermore, partly because of the translation in English, an ‘engineer’ is often associated with a technical ‘hand’ worker rather than a scientist who is a ‘head’ worker. But in fact the only difference between a scientist and an engineer is that more of the scientists work at universities and engineers at companies. Both work on physical phenomena and problems. So in order not to confuse things the terms technology and engineer will be avoided as much as possible. Most of the time the term ‘science’ and its derivatives like ‘scientific’ or ‘scientist’ will be used.

At the Delft University of Technology the author studied at the faculty of Metal Science. His master thesis was on ‘continuous stir casting of AlSi alloys’. A master of science specialised in metals is also called a metallurgist. After graduation the metallurgist started to work for the Dutch steel company called Hoogovens, today Tata Steel. At Tata Steel the metallurgist specialised in iron making, primary and secondary steel making and continuous casting of steel billets and slabs. Metallurgical papers were written and presented at different steel making conferences all over the world. A few patents on technological inventions and innovations were acquired as well. So the master of metal science became a ‘master of steel’. The Dutch term for a ‘master of steel’ is a ‘staalmeester’. In the thesis the word ‘staalmeester’ will be used as a kind of spokesman or mediator for the author himself. The specific terms like ‘metallurgy’ or ‘staalmeester’ are used when the specific context of the author (time and place he lives in) is at stake.

The thesis is about the soul of staalmeester. It is an inquiry into the distinctive feature of scientific knowledge and whether this feature could escape relativism. In order to escape relativism the distinctive feature should not depend on the particular scientist. And it should not be distinctive to the staalmeester only. The distinctiveness has to be found in the knowing process. The knowing process is a process of the mind and another word for mind is soul. When the distinctive feature is accused of relativism it

touches upon what could be called the essence of the staalmeester[5], which is one reason to choose the word ‘soul’ instead of mind in the subtitle. But there is also a certain religious aspect to the word ‘soul’ which is absent in the word ‘mind’. The rational belief in the existence of God or at least a God of gaps[6] will be addressed in this thesis as well. The word soul in the subtitle is written without a capital ‘s’ because it is about a rational belief, not a religious belief. So the thesis is ‘about the soul of a staalmeester”.

But why is the main title a ‘handbook metallurgy’ ? Part of the answer can be found in appendix 1. Van Welij (2015) asked the staalmeester why he started to study philosophy. The answer was that after 30 years of studying steel making phenomena it was time to write down all the acquired metallurgical knowledge in a ‘handbook metallurgy’. Once started, the feeling came upon him that this would not make much sense. Most of the used items of knowledge could be easily found elsewhere and most of the to be described cases are standalone explanations that could not be easily applied outside the context it was written for. Instead of all the cases the handbook metallurgy should contain ‘a way of thinking’ (see appendix 1, answer 1). The handbook should not contain the product but the knowing process. The interview of van Welij was held shortly after the start of the study, so the answer was more based on intuition than on philosophical research. This thesis is about the way of thinking of a scientist and what might be the distinctive feature of this way of thinking. In chapter 3 the notion of ‘intelligibiligence’ will be introduced as the distinctive feature of scientific knowledge. Intelligibiligence has nothing to do with intelligence or something that can be found in books. It is a skill that will come and grow over the years. It takes time to become an experienced staalmeester. Unfortunately quite an important part of this skill is so called tacit knowledge, which cannot be made explicit and written down in a handbook. The best way to acquire the skill is interact and learn from other people preferably from those who possess intelligibiligence. Still this thesis can function like a ‘handbook metallurgy’ by pointing out what intelligibiligence is about.

The picture of the painting on the front page is called ‘de staalmeesters’ and is by the famous Dutch painter Rembrandt van Rijn (1606-1669). The link with ‘the

[5] In Dutch the expression ‘stepped on the soul’ means that you are hurt to the bone, it touches the very heart of your being: your soul.
[6] Sometimes referred to as ‘the God of philosophers’.

staalmeester' in the subtitle of this theses might seem clear but a closer look might call it little bit farfetched. The staalmeesters on the painting have nothing to do with steel making or science whatsoever. The men on the painting are textile quality inspectors. They inspect samples of their textile trade ware. The Dutch word for this kind of samples is a 'staal'. Staal is also the Dutch word for steel and this is where the faint connection comes from. But there is another connection between the painting and this thesis and that is the historical context the painting represents. The 17th century is considered to be the cradle of what is called 'modern' science. Especially Descartes (1596-1650) is considered to be the godfather of modern sciences and he was a contemporary of Rembrandt van Rijn[7]. The thesis hinges on the difference between modern science and its alleged objectivity and intelligibiligence and its detached character. In chapter 4 Descartes's discourse (1637) will be revisited and it turns out that Descartes shows many traits of intelligibiligence. This implies that Descartes, who is from the 17th century, is thinking like the staalmeester, who lives in the 21st century. Descartes fits from an historical point of view and qua physical appearance easily on the painting (see for an example his portrait on the cover of the Dutch translation of his discourse in appendix 2). Descartes and our staalmeester fit together because of their mental resemblance. They both have intelligibiligence as the distinctive feature of their knowing process, which means that their 'souls' are alike.

[7] Swaab (2014) wrote that Descartes's 'findings clearly left their mark on the Amsterdam of Rembrandt van Rijn' (p. 364)

Chapter 2: solipsism or the problem of other minds

This thesis is an inquiry into the distinctive feature of scientific knowledge and whether this feature can escape relativism. Why ? In order to convince people to 'believe the scientist, any more than the others'. But before digging into this inquiry in chapter 3, another problem has to be dealt with first. Whatever distinctive feature there is (or not) and whatever objective standards it could meet (or not) the problem is 'how can *I* be sure that *I'm* not the only one thinking this' ? Because when I'm the only one thinking this I should start doubting myself and I will have a hard time convincing myself let alone convincing others to believe me. This interesting and intriguing problem is called solipsism or 'the problem of other minds'. For a non-philosopher this problem might seem a non-issue but it turns out to be a philosophical challenge waiting to be understood and solved. In this chapter this problem will be addressed.

For the most of the general public solipsism would probably seem a non-issue, not worth mentioning at all. Although we don't know the exact details of one's inner life, it is not doubted that other people have inner lives and that they have similar thoughts. But how to justify this almost universal belief that others have minds very much like our own is a real philosophical problem. Because it is not so easily recognized, the problem is sketched in section 2.1.

In section 2.2 four approaches to the problem of other minds will be described. These approaches have in common that they try to close the gap between the subjective mental world and the objective physical world. In 2.2.1 the gap is closed with the help of God. Reductive physicalism denies the mental world, so there is no gap (2.2.2). Probably the most appealing approach for the most of general public is called 'analogical inference', which will be addressed in 2.2.3. Finally in 2.2.4 Nagel's (1986) 'view from nowhere' will be described. None of these four approaches seems to offer a generally accepted solution.

In order to solve the problem one has to go beyond the dualism of the mental and physical world. This is the subject of section 2.3. in 2.3.1 an obvious candidate for a 'third' world is introduced: the intersubjective or social world. In 2.3.2 the alternative notion of the 'second person view' introduced by Geertsema (2000) will be addressed. The 'second person view' bridges the subjective first person view and the objective

third person view. In order to understand ourselves and our way of thinking the interaction with others, so the intersubjective world, is needed.

2.1 what is solipsism and the problem of other minds

Solipsism or the problem of other mind is the idea that only the accessible mental contents of the solipsist himself can be known. The mental contents of other minds cannot be known. Thorton (n.d.) expressed solipsism as the view that 'my mental states are the only mental states'. This is not meant to mean that my thoughts are the only thoughts that exists but 'a solipsist can attach no meaning to the supposition that there could be other thoughts, experiences and emotions other than his own'. (p. 1). Quite often the example of pain is used to explain solipsism. A solipsist cannot conceive how 'pain' can be applied 'in another sense than an exclusively egocentric one'. (ibid). Even with this example in mind many people still won't consider it to be of interest. Maybe one will become a little bit more interested when one thinks a bit longer about the hurtfulness of pain. What to think of somebody who cut his finger on a piece of paper and starts to express very severe pain. How to compare this with the level of hurtfulness we ourselves experienced when we cut our finger on a piece of paper. We probably think the other one is exaggerating but we still don't know this for sure, we only have our own pain as a reference.

But the topic of the thesis is not about 'pain' it is about 'knowledge' or 'a way of thinking'. An example of a straightforward way or reasoning is: 'I think that two plus three equals five'. Perhaps the persons who started to get interested after the hurtfulness of pain will be lost again. It seems to be impossible that not everybody thinks this. But when the example would be 'I think that the ductility trough is causing cracks in advanced high strength steels' more people will consider it possible that not everybody thinks this. But to the metallurgist who thought this, it was as logical as '2 + 3 = 5'. So even when the 'common man' is not a solipsist still an argument is needed to convince the solipsists amongst our midst to believe the metallurgist more than the others.

The problem touches remark 3) in appendix 1. The staalmeester always thought that people think like him, that there is only one way of thinking, but this does not seem to

be the case. The staalmeester expected that one possible way of convincing people would be by taking the philosophical course on logic and with the help of syllogisms. The staalmeester did not realise that the problem resides on a deeper level and that 'the problem of other minds' has to be solved instead.

2.2 four approaches to the problem of other minds

Although it was not mentioned explicitly the problem of other minds resides in the more common notion of dualism. This dualism stands for the division between 'body and mind', or the 'physical and mental' world, or 'objectivity and subjectivity', or the 'third person and first person' perspective. The mental world of other bodies (including their brains) is unknown while the physical existence of other bodies is known. How is our body and brain connected to our thoughts, and how to be sure that when bodies or brains are similar that this connection is similar too ?.

Four possible solutions to the problem will be discussed. Because the distinction between body and soul is often referred to as Cartesian dualism firstly Descartes's approach will be described. A second approach is taken by what is called 'reductive physicalism'; they simply deny the existence of a mental world. The analogical inference approach will probably be the most appealing approach to those who consider solipsism a non-issue. The fourth approach is given by Thomas Nagel (1986) and his 'view from nowhere'.

2.2.1 Descartes with the help of God

In his discourse Descartes (1637) describes a method on how to acquire true knowledge. This method became known as 'the method of doubt'. In short the method demands to discard (as knowledge) everything that is suspect to the slightest doubt. Only what becomes 'clear' and 'distinct'[8] to the mind counts as true knowledge. Descartes concluded that the one thing that could not be doubted was his own thinking. Therefore Descartes made 'thinking' the "very item of knowledge that is the most certain and obvious of all'. (1637a, p. 4). This 'very item of knowledge' was

[8] Both 'clear' and 'distinct' can be found on different pages in 'a discourse on the method'. Both terms will be explained in more detail in chapter 4.

formulated in a very specific way: “I think” (Latin: cogito). This first-person formulation of the ‘cogito’ (as it is standardly referred to) is essential to its certainty. This is emphasised by the certainty that comes with it namely ‘I am’ (Latin: sum). Your whole personality, who you are, your existence, is certain because you think. A claim about what a third-person thinks can never be as certain as what “I” think, because we never know for sure what other minds think. Here it becomes clear that the problem of other minds is already inherently present in Descartes’s discourse. Hyslop (2016) thinks so too: ‘the problem was clearly enough waiting to be noted as far back as Descartes (…), [h]owever, it does not seem that Descartes noticed it as a separate problem.” (p. 3). Indeed Descartes does not address the problem as such and he does not need to because of what followed directly after Descartes founded his first principle.

The first thing that becomes ‘clear and distinct’ to Descartes’s mind is that there is an all-perfect God who cannot deceive us. This argument is often criticised for its alleged circularity. Newman (2014) formulates this circularity as follows: “Descartes first argues from clearly and distinctly perceived premises to the conclusion that an all-perfect God exists; he then argues from the premise that an all-perfect God exists to the conclusion that whatever is clearly and distinctly perceived is true.” (p. 23). Newman also mentions that there are a large number of interpretations to avoid this circularity. A plausible interpretation is that Descartes saw both conclusions in the circular reasoning to be ‘self-evident’. Therefore “(…) because those conclusions have become self-evident (…) to try to doubt them is to think about them; but to think about them is to apprehend their truth.” (p. 28). So Descartes seems not to be bothered by this circularity and he established the foundations for the existence of both his own mind and of the existence of God.

Still the existence of the external world and the connection between body and mind have to be established. In the ‘meditations’ (1641) Descartes dedicates the sixth meditation to this issue. The title of the sixth meditation is ‘the existence of material things, and the real distinction between mind and body’. The existence of the external world and the connection between body and mind are not as self-evident or ‘clear and distinct’ as the existence of the ‘I’ and of God. “I find that [imagination] is nothing but an application of the faculty of knowing to a body that is intimately present to it—and that has to be a body that exists.” (1641a, p. 27). This means that, to Descartes

imagination differs from pure understanding (clear and distinct) and he wants to examine this difference. On the same page Descartes concludes: “Even after all my careful enquiry I still can’t see how, on the basis of the idea of corporeal nature that I find in my imagination, to prove for sure that some body exists.” (ibid). So Descartes admits that there is this strong idea that the physical world exists and that this comes from the imagination, but that cannot be proved for sure.

At this moment in the sixth meditation Descartes turns to what is given by ‘nature’. Descartes explains that ‘nature’ teaches him two things. Firstly

> “ (…) through these sensations of pain, hunger, thirst and so on, that I (a thinking thing) am not merely in my body as a sailor is in a ship. Rather, I am closely joined to it—intermingled with it, so to speak—so that it and I form a unit. If this were not so, I wouldn’t feel pain when the body was hurt but would perceive the damage in an intellectual way, like a sailor seeing that his ship needs repairs.”,

and secondly

> “(…) that various other bodies exist in the vicinity of my body, and that I should seek out some of these and avoid others.” (1641a, p. 30).

Hyslop (2016) concludes as follows: “Since God is no deceiver, and since He has created man with an innate disposition [nature] to assume the existence of an external, public world corresponding to the private world of the "ideas" that are the only immediate objects of consciousness, it follows that such a public world actually exists.” (p. 2). “Thus does God bridge the chasm between the solitary consciousness revealed by methodical doubt and the intersubjective world of public objects and other human beings.’ (ibid).

Descartes resolved the problem of other minds with the help of God, something which a lot of the general public won’t accept. In a certain way it seems very convenient of Descartes to establish the existence of an all-perfect God right at the beginning of his discourse. In order to explain things that are not ‘clearly and distinctively’ understood one can fall back on the existence of God. Quite impiously this is often called ‘a God of gaps’ but to Descartes it was much more. The existence of God was essential to his method. The existence of God cannot be doubted and is self-evident. Descartes goes that far that the knowledge of an atheist cannot be true knowledge at all. “ [When]

I was not aware of the existence of God (…) I can have no true and certain knowledge, but only shifting and changeable opinions." (1641a, p. 26). In the discourse Descartes writes: "[a]nd because there are men who make mistakes in reasoning, even about the simplest elements of geometry, and commit logical fallacies, I judged that I was as prone to error as anyone else, and I rejected as false all the reasoning I had hitherto accepted as valid proof." (1637a, p. 28). In the first meditation Descartes elaborates somewhat more: "[a]nyway, I sometimes think that others go wrong even when they think they have the most perfect knowledge; so how do I know that I myself don't go wrong every time I add two and three (…) ?" (1641a, p. 2). The last part of this quote was used in section 2.1: how can I be sure that I am not the only one thinking that 2 + 3 = 5 ? It is possible that I'm deceived by an ingenious demon, which could be the case when I "deny the existence of such a powerful God (…)." (ibid).

Thorton (n.d.) writes: "A modern philosopher cannot evade solipsism under the Cartesian picture of consciousness without accepting the function attributed to God by Descartes (something few modern philosophers are willing to do)." (p. 3) For those who are not willing to do this, other approaches to the problem of other minds will follow in the next three sub sections.

2.2.2 reductive physicalism

Another way to solve the problem of other minds is to deny the existence of a mental world and only consider the existence of a physical world. This would make the problem of other minds a non-existing problem. The advancements in biology, psychology and neurosciences are in favour of this thought. This so called physicalism tends more towards an organic unity than a separation between mind and body. Our thinking abilities seem to have a corresponding physical substrate in the bodily processes of our brain. So instead of us having brains, it says we are our brains (Swaab, 2014). The claim of this reductive physicalism is that we are pure physical creatures and all our mental, moral and religious experiences can be reduced to neurophysiological processes. The intuition that we have an immaterial mind that thinks and makes judgements is considered to be false. The non-reductive variant of physicalism still consider something 'psychophysical', but as a material substance, and thereby also denying an immaterial substance of the soul.

But physicalism still faces the same problem as Descartes in the previous section: one cannot be certain to what extent the external world exists. Descartes started with the existence of the mind and physicalism with the existence of one's physical brain. The 'brain in a jar' is often used to illustrate this. Imagine that our physical brain is separated from the rest of our body and put in a jar with life-sustaining fluid. A computer is connected to this brain which provides the brain with the same electrical impulses it normally receives. The computer would simulate reality and the brain would continue to encounter the same brain states without them being related to objects and events in the real world.[9] In fact an ingenious IT-demon could make the brain believe that 2+3=5 and that particular brain might be the only one that thinks so.

Geertsema (2000) says this about physicalism: "To avoid a rebirth of dualism the issue now became to explain mental operations completely in terms of the workings of the brain." (p. 49). Geertsema makes the remark that physicalism as an alternative to Cartesian dualism is in fact a result of Descartes own method of doubt that stands for the conviction that all intuitions should be dismissed as unreliable. This reduces the real world to the world of 'pure objective' science again, 'totally detached' from a specifically human perspective on the world. But Geertsema notices that just denying an immaterial mind leaves us serious questions. "If subjectivity is related to the mind and objectivity to the brain, it appeared that the explanation of one in terms of the other had to face serious difficulties." (p. 50). Nagel (1986) puts it this way: "that (…) physics is bound to leave undescribed the irreducibly subjective character of conscious mental processes, whatever may be their intimate relation to the physical operation of the brain." (p. 6).

So even when the claim is made that the mind does not exist one cannot escape the riddle of the nature of the very intimate relation between the psycho and physics. To Nagel (1986) it is clear that a theory that explains this intimate relation does not exist (yet). Nagel writes: "(…) that any correct theory of the relation between mind and body [no matter on which substrate it resides] would radically transform our overall conception of the world (…)." (p. 8). To Nagel physicalism is part of the broader tendency of contemporary life called scientism. "This view [of scientism] inherits the

[9] These kind of ideas have been explored and visualised in movies like 'The Matrix' (1999 and its later sequels) and Inception (2010).

crude appeal of logical positivism even though that particular version of idealism is out of date." (p. 9). Scientism represents the ideal that only one type of understanding, scientific understanding, is in charge of the universe. Everything there is must be understandable by the employment of scientific theories like todays physics and evolutionary biology. Nagel calls this '[w]asted time because methods already in existence will not always solve the problems they were not designed for. The methods needed to understand ourselves do not exist yet.' (p. 10). Such a theory could perhaps solve the problem, but physicalism does not, it only denies the problem of other minds.

2.2.3 analogical inference

For the most of the general public the solution of 'analogical inference' will sound very appealing. Because other human beings are very much like me and they behave very much as I do in similar circumstances, I'm entitled to infer that other human beings have an inner life that is very like mine.

There are basically two problems with this approach. The first objection is that it is logically impossible to check upon the conclusion, because the other mind cannot be observed. The second problem is that the inference is inherently based on one case, the case of the analogical arguer with his own experience.

A few words about this. One could say that there are cases where the arguer can check whether what he inferred from his observation of the other's behaviour that the arguer is indeed correct. There would probably be cases where this correlation is confirmed but there will also be cases where it won't. This for and against situations might very well neutralize each other. One could also argue that there are a multitude of correlations observed in one's own case. This argument also fails because it is not true that all instances of human behaviour observed from one's own case are accompanied by any mental state at all. The best we can say is that many instances of behaviour are associated with mental states but this is compatible with the conclusion that some human bodies behave like ourselves without having an associated mental state. Everything stands or falls with the principle that there is a causal link between mental events and physical behaviour. There are cases where this seems to be the case but there may be as many as cases where it is not so.

Therefore the problem stays. There seems to be no logical connection between the mental and the physical. It looks like there are mental states lying behind and explaining our behaviour but we don't know whether there is one relevant causal link that applies to all of us. To keep it close to the example already used a few times: when somebody writes on a whiteboard 2+3=6 what mental state could be linked with this behaviour ? At least we cannot infer it from our own mental state. The best one could say is that similar behaviours have similar causes but this makes the link between body and mind at least somewhat 'dubious'.

2.2.4 the view from nowhere

'The view from nowhere' is the title of a book by Thomas Nagel (1986). As Nagel writes "it is about a single problem: how to combine the perspective of a particular person inside the world with an objective view of that same world, the person and his viewpoint included." (p. 3). What Nagel tries to do is bring the subjective (first person) view and the objective (third person) view together in a higher view[10]. Nagel wants to 'objectify' the mind. "We ought, in other words, to be able to think of ourselves from outside – but in mental, not physical terms. Such a result, if it were possible, would qualify as an objective concept of mind'. (p. 17).

Even with an objective mind the problem of other minds remains. Instead of 'how can I conceive of minds other than my own', for a general objective mind the problem becomes 'how can we conceive of minds subjectively incommensurable with our own'. (p. 19). As an explanatory theory Nagel does not consider the 'analogical inference' theory very convincing. 'Clearly [without explaining, but see 2.2.3] this [analogical inference] is not true and we are in need of an alternative to this theory or we end up with solipsism: the inability to make sense of the idea of real minds other than one's own'. (p. 20).

Nagel also considers reductive physicalism (see 2.2.2) to be 'misguided' because it is just a 'monistic third person conception of one total objective world'. Nagel thinks that reductive physicalism has an impoverished idea of objectivity. The weakness of modernity is that another conception of objectivity has not been available in order to

[10] Sometimes this view is called a 'God's eye view'

construct an overall picture of the world including the mental. This is Nagel's project in his 'view from nowhere'.

Nagel still wants to start from the objective side. Like in physicalism the objective reality is given. Under this notion of realism a subjective reality (the objectified mind) cannot be understood. Another way of understanding has to be found. Nagel tries to do this by enriching the notion of objectivity. Nagel does not want to abandon the idea of objectivity entirely but rather suggests that the physical is not the only possible interpretation. He wants to consider the mind as a general feature of the world. We have to go beyond the 'small spatiotemporal neighbourhood' of our minds. But 'how far beyond this local point our understanding or the process of abstraction, generalization and experiment' our understanding can go is a question. But also Nagel admits that there is no reason to assume that everything about the physical world can be understood by the possible development of our physical conception of objectivity: 'physical science is after all just an operation of our minds and, we have no reason to assume that their capacities in these respects, remarkable as they are, correlate fully with reality'. (p. 19).

The problem with this concept of the world, that includes the objective mind, is that is has not been developed yet. But 'only a dogmatic verificationist would deny the possibility of forming objective concepts that reach beyond our current capacity to apply them'. (p. 24). Nagel believes in a kind of 'intellectual optimism' and that 'we possess an open-ended capacity for understanding of what we have not yet conceived'. The notion of 'intellectual optimism' will be used in the coming chapters and sections as well. Nagel calls this 'detaching from our present understanding and try to reach a higher order view which explains it' but 'we must also admit that the world probably reaches beyond our capacity to understand.' (ibid). Nagel mentions the example of extra-terrestrial lifeforms that most probably exist and which are probably not very close to us both in structure and behaviour. Most certainly we would be unable to read the manifestations of these creatures as behaviour, let alone link them with any mental concept of which we could have a first-person understanding. Earlier in the thesis movies where used as examples of getting a grasp of things we don't really know or understand. There are quite a lot of 'science' fiction movies[11] were extra-

[11] Like 'star wars' (1977 and later sequels) or 'battle star galactica' (1978 and later sequels)

terrestrial lifeforms are pictured. In fact the creatures have very different structures but even in these movies their behaviour and the suggested mental concepts behind the behaviour are very human like. It would be very difficult to understand the movie if it were performed otherwise.

This suggests that the problem of other minds or the general objective mind of Nagel is very difficult to understand and even when it is expected to be understood in a far future it won't be of much help now.

2.3 beyond dualism

The four approaches described in the previous section did not bring what might be called a received solution to the problem of other minds. Not everybody will accept the help of God, physicalists just deny a separate mental world, 'analogical inference' cannot be proven and the view from nowhere still has to be developed. What all these approaches have in common is that they have a limited world conception. There is only a physical world or a physical and a mental world. Like Nagel we have to go beyond monism or dualism but without relying on 'intellectual optimism'.

2.3.1 the intersubjective world

There is a 'third' world closer to hand than the one Nagel is waiting for: the intersubjective or social world. When one acknowledges the existence of the intersubjective world the problem can be made harmless.

Thornton (n.d.) writes "one might even say, solipsism is necessarily foundationless, for to make an appeal to logical rules or empirical evidence the solipsist would implicitly have to affirm the very thing that he purportedly refuses to believe: the reality of intersubjectively valid criteria and a public, extramental world." (p. 10). It seems too harsh to call solipsism a false philosophical theory but at least it shows the theory is incoherent because it needs the intersubjective world.

In the same line of reasoning 'language' can be an argument for the introduction of the intersubjective world. A solipsist requires a language to think or to affirm his solipsistic thoughts at all. Die hard dualists (who don't consider an intersubjective world) will come up with the so called 'private language argument' which has its origin

in the work of Wittgenstein. In his 'philosophical investigations' Wittgenstein writes about 'private language'. A language is "'necessarily comprehensible only to its single originator because the things which defines its vocabulary are necessarily inaccessible to others'. (Candish and Wrisley, 2014, p. 1). This does not seem to be of much help because this is exactly what solipsism is about. '[B]ut immediately after introducing the idea, Wittgenstein goes on to argue that there cannot be such a language'. (ibid). It seems interesting to use Wittgenstein's argument to attack the problem of other minds, but unfortunately '(…) every reading of the argument is controversial.' (p. 2).

Still language is primarily an irreducible public form of life that is encountered in specifically social contexts. In order to question, argue or doubt one has to utilize language. Such a context does not exist for a solipsist. 'A non-linguistic solipsism is unthinkable and a thinkable solipsism is necessarily linguistic.' (Thorton, n.d., p. 10). "That solipsistic thoughts are thinkable in the first instance implies the existence of the public, shared, intersubjective world that they purport to call into question." (ibid). The link between the inner and outer world is to be found in the intersubjective world.

2.3.2 a second person perspective

Geertsema (2000) introduced the second person view as the missing link between the first person (inner world) and third person (outer world) view. It is noteworthy that this is done right after Geertsema's discussion on Nagel's view from nowhere. Geertsema hooks on to Nagel's explanation of primary and secondary qualities. Nagel uses the differences between these two qualities to study the mental (as an object) and the physical in their own terms without explaining the one in terms of the other (as briefly described in section 2.2.4). Things in themselves have primary qualities and things like taste and colour are the so called secondary qualities. According to Nagel the primary qualities should give an explanation of the secondary. But if this would be the case this would mean that the properties of a thing in itself explain causally the way it appears to us. This would mean that physical properties relate to mental ones and that would be the causal link we were looking for in section 2.2.3. But this relation between primary and secondary qualities does not exist. Geertsema uses this example to introduce another approach: secondary qualities are there only as 'potential'. This potential becomes realized only when someone appreciates these

qualities and for example buys the thing. “Things do not exist in themselves but in relationships.” (p. 60).

For Geertsema it is clear that the basic diversity of our concrete experience both of the world and ourselves is far too complex to grasp in terms of dualism and certainly in terms of monism like physicalism. There are more sciences than just physics and psychology. Relationships are part of the real world as well. Geertsema puts this nicely:

> “Our sense of personal identity does not develop in the first place out of an inner subjectivity that I have in myself, even less out of objective knowledge about being a person as a result of critical reasoning, it begins as a response to somebody who relates to me as a person. The first person perspective of subjectivity and the third person perspective of objectivity are preceded by the second person perspective of responsiveness or answerability.” (p. 62).

The second person is a ‘homo respondens’. ‘The way we understand ourselves depends on our response to what is given to us both in the world and in ourselves as part of the world.’ (p. 63). This would imply that ‘objective’ validity and ‘subjective’ experience can no longer be separated. “As human beings we cannot avoid to give priority to the perspective of the second person. We respond to what comes to us as a given. At the same time, living our lives as finite and responsible people we are dependent on the structural possibilities that we can study by means of objective method.” (ibid).

Acknowledging the existence of an intersubjective world would make solipsism, as a theory, incoherent. With this problem out of the way our inquiry into the distinctive feature of scientific knowledge could start.

Chapter 3: scientific knowledge

This chapter contains the inquiry into the distinctive feature of scientific knowledge. What exactly do we have in mind when we talk about scientific knowledge; is it ‘knowledge as a product’ or ‘knowledge as a knowing process’ ? Section 3.1 is about ‘knowledge as product’. In the second half of the last century a scientist possessed scientific knowledge simply because he or she studied at a university. What exactly it was the scientist possessed was not specified but the possession was considered to be distinctive in itself and it was objective. The scientific community guarded this objectivity by means of controlling the publications of the knowledge. Today there is an abundance of ‘knowledge as product’ that is easily and readily available with only a swipe on a smart phone. When ‘knowledge as product’ was considered to be the distinctive feature of scientific knowledge it lost this distinctiveness together with its so long cherished objectivity which can no longer be guaranteed. But in section 1.2 it was already suggested that knowledge as product is not what makes up the distinctiveness of scientific knowledge. A handbook metallurgy should not contain the product but the knowing process that produced the product.

In section 3.2 there will be a closer look at the knowing process. The knowing process is a mental process in order to ‘know’ things You know something when things are clear to you, when you understand things. From this formulation is follows that the aim of the knowing process is ‘understanding’. Understanding is a personal thing and therefore problematic to the objectivity of modern science. Modern science focussed on scientific explanations as the aim of the knowing process. But still intuition tells that only when things are understood can they be explained. So understanding seems to be the best candidate for the ‘distinctive feature of scientific knowledge’, but certain elements of explanations have important features as well. This looks like a deadlock

. De Regt (2017) provides a helpful insight here. De Regt distinguishes ‘understanding the phenomena’ (UP) from ‘understanding the theories’ (UT). The knowing process is about connecting the phenomena at hand with the available items of knowledge and other background information and data. In order to use the available items of knowledge one has to understand these items. Crucial in this process is making the connection and that is often done by means of constructing a model or conception.

The combination of the two types of understanding and constructing models is what makes up the distinctive feature of the knowing process of the scientist. Derived from and very close to de Regt's notion of intelligibility the notion of 'intelligibiligence'[12] is introduced for this distinctive feature.

In section 3.3 the notion of intelligibiligence is worked out in more detail. A few examples of what it means to understand items of knowledge, like the deductive-nomological model and the causal approach, will be addressed. The example of the staalmeester will be used to elaborate somewhat more on intelligibiligence.

Intelligibiligence turns out to be a pragmatic way of understanding. Intelligibiligence is a skill, to be acquired by the scientist in the context the scientist lives and works in. Both the terms 'pragmatic' and 'context dependent' cannot match up to the standard of objectivity defined by modern science. In section 3.4 the presence of the intersubjective world will be used to claim a 'detached' character for intelligibiligence. With the detached character intelligibiligence escapes relativism and comes close to the objectivity of modern science. In sub section 3.4.1 the intersubjectivity of intelligibiligence will be approached with the help of Polanyi's (1966) notion of 'tacit' knowledge. In sub-section 3.4.2 the detached character of intelligibiligence will be justified.

3.1 knowledge as product

The common notion in the second half of the last century was that having studied at a university was enough to explain why the scientist should be believed. Without defining what this knowledge exactly was, it was conceived as a product that one could possess. It was the possession of items of knowledge like theories, principles and natural laws that was distinctive to scientific knowledge. These items of knowledge were stored in the 'head' and, more literally, on the bookshelves of the scientist. The scientist was supposed to know because he has this knowledge available. The feeling of our staalmeester was that this was not enough and that in fact he did not know.

In the mid-20th century this kind of knowledge was in fact quite distinctive or exclusive to a scientist. Not everybody could afford to go to college and the idea was that only

[12] Intelligibiligence is a made-up word derived from and close to de Regt's definition of intelligibility.

few people had the intelligence to acquire this kind of knowledge and store it in the 'head'. Today, in the second decade of the 21st century, 'knowledge as a product' is no longer distinctive or exclusive in this sense. Scholarships made universities reachable for everyone and the average educational level went up. Intelligence as the 'storage capacity of items of knowledge' became a common good as well. There is an abundance of this kind of knowledge readily available on the internet, with only a double click or a swipe on a computer, tablet or smart phone. In this sense the storage capacity of fifty years ago was very limited. The head and bookshelves cannot contain today's terabytes or even yottabytes. Also the items of knowledge of 40 years ago are regarded as 'outdated'. When the knowledge as a product was considered to be distinct in the above sense it certainly lost this status. At best this kind of knowledge can be used as reference work or background information.

What about its alleged objectivity ? In the modern and neo-positivist tradition, objective means that all knowledge has to be explicitly formulated and with methodical rigor. Subjective or personal input would only obscure the true meaning of things. At the Delft University of Technology it was taught that scientific theses and papers should not contain any personal pronouns. All traces of more personal nature should be avoided as much as possible. Only logic, mathematics and experimental evidence were to be considered in scientific work. It was the scientific community itself that guarded the objectivity of its products like the published theses, papers and books. These products became available in books, in libraries and were taught at schools and universities. All this knowledge, but also a lot of non-scientific knowledge, is available on the internet now. It is doubted whether everything that is available can stand the traditional scientific test of objectivity.

When 'knowledge as product' was considered to be the distinctive feature of scientific knowledge it lost this distinctiveness together with its so long cherished objectivity that can no longer be guaranteed. But in section 1.2 it was already suggested that knowledge as product is not what makes up the distinctiveness of scientific knowledge. A handbook metallurgy should not contain the product but the knowing process that produced the product.

3.2 the knowing process

The distinctive feature of scientific knowledge has to be sought in the knowing process. The knowing process is a mental process in order to 'know' things. You know something when things are clear to you, when you understand things. From this formulation it follows that the aim of the knowing process is 'understanding'. Understanding is a personal thing and therefore problematic to the objectivity of modern science.

Therefore modern science focussed on scientific explanations as the aim of the knowing process. An explanation is normally used to answer a 'why' question in order to justify the claim that was made. When one guards that only logic and facts are used in the construction of an explanation, the explanation will be objective. But the construction or reception of an objective explanation does not guarantee that the constructor or receiver really understands the phenomena dealt with in the explanation. In that case a scientific explanation misses the point.

An explanation also seems to be a kind of hindsight summary of what happened in the factual understanding process. In the process of understanding the scientist has to deal with a tremendous amount of data and accepted (and increasingly scientifically not-accepted) items of knowledge like theories and principles. Which data and items of knowledge to use and apply requires something that is part of the knowing process as well. Not at the end of the process, but in the process. So understanding 'items of knowledge and data' is part of the knowing process in order to understand the phenomena. So understanding seems to be an important candidate for the 'distinctive feature of scientific knowledge', but certain elements of explanations have important features as well.

Interesting in this context is a quote by Nagel (1986):

> "The understanding of the physical world has been expanded enormously with the aid of theories and explanations that use concepts not tied to the specifically human perceptual viewpoint. Our senses provide the evidence from which we start, but the detached character of this understanding is such that we could possess it even if we had none of our present senses, so long as we were rational and could

understand the mathematical and formal properties of the objective conception of the physical world." (p. 14).

Three parts of this quote seem to be of special interest. Firstly: the physical world is understood with the aid of explanations. This means that understanding the phenomena of the physical world is the aim and the explanations are the means. Secondly: although our senses provided the evidence this understanding has a detached character as long as we are rational and understand the mathematical and formal properties. So besides understanding the phenomena also understanding the mathematical and formal properties is involved. And because of this involvement our understanding can escape subjectivism and has a detached character. Finally Nagel mentions an objective 'conception' of the world. Is this conception 'given' or is it the product of the knowing process or is it a tool to the scientist in order to understand the physical word. To our staalmeester a conception is the same as a 'mind model'.

Nagel's quote contains important elements of the knowing process but does not clear things up. De Regt (2017) provides a helpful insight here. De Regt also distinguishes two types of understanding: 'understanding the phenomena' (UP) and 'understanding the theories' (UT). Understanding the phenomena is the aim of the scientific knowing process and understanding the theory forms the means to achieve this aim. In order not to mix up the two types of understanding, de Regt called understanding the theory 'intelligibility'. In section 3.1 it was mentioned that today many yottabytes of accepted and non-accepted knowledge are readily available. Which items of knowledge to use and apply requires at least understanding of these 'items of knowledge' so it requires at least intelligibility.

But the third element in Nagel's quote is important as well and that is the making of a connection between the phenomena at hand and the items of knowledge (preferably accepted ones) and other background data and information. And when these items and data are not available suitable idealisations and assumptions have to be made. De Regt mentions different tools for making the connection. One of them is constructing a model and this is a tool often used by scientists.

The combination of understanding, intelligibility and constructing a model is what makes up the distinctive feature of the knowing process of the scientist. Derived from and very close to de Regt's notion of intelligibility the notion of 'intelligibiligence' is

introduced to represent this combination. Intelligibiligence is the ability to construct a model or a conception of the physical phenomena at hand in order to understand the phenomena. In order to construct such a model a scientist uses items of knowledge and other background information and data and therefore needs intelligibility. In the next section the notion of intelligibiligence is worked out in more detail. A few examples of what it means to understand items of knowledge, like the deductive-nomological model and the causal approach, will be addressed. The example of the staalmeester will be used to elaborate somewhat more on intelligibiligence. In section 3.4 some more words will be written on the 'detached' character of intelligibiligence , as already mentioned by Nagel in the quote above.

3.3 intelligibiligence

In the previous chapter intelligibiligence was described as: the ability to construct a model or a conception of the physical phenomena at hand in order to understand the phenomena; in order to construct such a model a scientist uses items of knowledge and other background information and data and therefore needs intelligibility. In this section this will be made somewhat more concrete for the case of the staalmeester.

Intelligibiligence is more complex than just a matter of straight forward deduction. Today an abundance of items of knowledge and other 'big' data is readily available (see section 3.1). Scientists have to make judgements and choices on which items and data to use and which not. The choice often depends on how well the items and data suite the scientist best in facilitating the construction of the models. Besides understanding the items of knowledge the scientist attribute a value to certain aspects of a theory[13]. There are many different qualities and values of a theory. In the next paragraphs a few of these qualities will be addressed together with some examples for the staalmeester's case.

In section 3.2 it was mentioned that an explanation is normally used to answer a 'why' question in order to justify the claim that was made. In order to keep it objective the explanation should use logic and facts only. Hempel (1904-1997) developed the so

[13] De Regt added this 'value attribution' to qualities of theories in his definition of intelligibility (2017, p.40).

called ‘covering law model of explanation’ also known as the deductive-nomological model. Deductive stands for the structure of the argument and nomological for the use of laws (Greek ‘nomos’ is ‘law’). Natural laws normally describe a general pattern rather than an isolated event. The model is based on the principle of unification. With the use of these laws combined with specific initial conditions and other relevant background information the phenomena can deductively be explained or predicted.

An example: metals expand when the temperature increases (law), a hot tub is given as an initial condition (fact): this explains why a mercury (metal) thermometer will show a temperature increase when is it is dipped in the tub.

This model has some merits. It provides insight how things fit into a greater scheme, we can reason how a thermometer will react in cold or hot water, and there is logic in the argument. Logic is an often appreciated value for a scientist. Our staalmeester especially values the logical structure of an argument (appendix 1, point 3). But as mentioned in 3.2 this explanatory model sometimes misses the point. Sometimes the argumentation is sound but it does not provide understanding.

The most well-known example is the example of ‘the shadow of the flagpole. The covering laws are the ones from optics and geometry; the length of the shadow together with the position of the sun are the given conditions and so the length of flagpole can be explained. The argumentation is sound but it fails to uncover what is causing what. The position of the sun and length of the shadow is not causing the length of the flagpole, but the shadow length is caused by the position of the sun and the length of the flagpole.

As a response to this shortcoming of the nomological model the causal approach to explanation was developed. According to the causal principle the world works according to causal processes, interactions and laws. In essence the principle claims that there is always a cause for the phenomenon at hand. This approach is favoured by our staalmeester. He often uses the one-liner ‘not every event results in a defect, but every defect is the result of an event’. It means there is always a cause for the defect. The only thing to do is to find this cause. The problem is that there are often an endless number of possible events (process deviations) that could have led to the defect. It is in the process of finding the cause where intelligibiligence plays an important role. It is often a long and complex road to find the root cause and

understand the phenomena at hand. There will be dead ends, blocked roads, deviations, missed side roads and so on. But the principle stays: there is a root cause, it can be understood, there is no mystery involved.

In order to get an impression of this long and complex process, the example mentioned in section 2.1 will be used. One has to ‘look through’ the metallurgical jargon to get the idea, which is probably not too hard to do. Our staalmeester claimed that ‘the ductility trough is causing cracks in advanced high strength steels’. The road started with a customer complaint: a crack in a car wheel made of advanced high strength steels. One has to keep in mind that in the automotive industry the accepted defect rate is only a few parts per million. To narrow down the number of possible causes for the crack, our staalmeester had to estimate where in process route - from iron ore mining to the customers wheel pressing process - the defect most likely originates from.

The number of items of knowledge involved in this first estimation is already quite extensive. First of all the crack is made visible by means of a scanning electron microscope (SEM). Besides operating the microscope one needs knowledge of metallurgical thermodynamics and phase diagrams in order to understand what is seen with a SEM. What is needed next is at least some understanding of all the processes involved in the total process route: iron ore and coal mining, coke, pellet and sinter making processes, blast furnace processes, primary and secondary steelmaking processes, casting processes, hot rolling processes, cold rolling processes, galvanizing processes and the wheel forming processes at the customer. The first modelling is done here. This deformation model gives an idea and predicts how different defects like cracks evolve over all those processes. The SEM shows location and structure, the model gives an indication where in the process it most likely originates. Some processes modify defects, others just move them. Different heat treatments result in different crystal structures. Forming and rolling forces also influence structures and properties and so on. For the cracks in the car rim case the critical process turned out to be the solidification process at the caster of the steel plant. This is where the next judgements, choices and estimations have to be made.

The caster is an area where a scientist can spend a lifetime constructing models. At the caster the liquid steel is solidified. Different sub processes play a role during solidifying of liquid steel. Heat transfer through a water cooled copper mould, casting

powder between solidifying shell and copper mould, fluid flow of liquid steel in the mould, bending and unbending forces in the casting machine, primary and secondary cooling systems and patterns and a lot more. Constructing models is a must because one cannot look into the liquid steel flow in the mould. Physical models, mathematical fluid flow models and mental models are used to acquire understanding of what is happening in the mould.

Some of the items of knowledge are readily available, which is one of the big advantage of current times. Other sources are the contacts and knowledge exchange with Universities all over the world (form the USA to Japan,), on international steel making and casting conferences, visits to other steel works and, very important, with the operators working on the casting floor.

Most of the time there is a lot of (measured) data available as well. This could be of help to bring down the number of possible causes in the sub area of the caster. But as with the items of knowledge there is so much data available that our staalmeester has to judge which data to include or exclude from his search. Often the bigger problem is that despite the abundance of available data, the required data to construct the models is not available. How to construct the right database requires intelligibiligence as well. Once this dataset is set, the data analyse can start. Where in the 1980's it was already hard to analyse and plot 2 variables in a graph (by hand), today very advanced data-crunch software is available. This is another advantage of current times. With the help of, for example, principle component analyses multi variable data analyses can be performed. The big data analyses became a kind of profession on its own. But one often forgets that this data-crunching on its own does not provide understanding. One needs intelligibility to judge which data to use in the dataset and what to do with the outcome of the data analyses. The outcome of the crunch can be of help in constructing or modifying the model or as evidence for or against (parts of) the model. But it can also be of no use as well.

In the crack-case our staalmeester knew from previous cases that weather conditions could play a role and that it is useful to include them in the dataset. One of the striking outcomes of the data-analyses for the crack-case was that there was a significant influence of the wind direction. A pure data-cruncher will most probably stop here and denounce the northern wind to be the cause for the cracks. The cruncher would

probably suggest only to cast the steel grade when the wind blows from another direction. For somebody with intelligibiligence however this finding is only a clue or part of the model he is constructing. How does this finding fit in the model, or does it not ? Our staalmeester sat down at the caster at the moment the wind blew from the north. He observed that at one of the casters a door of the so called cooling chamber was missing and the draught caused by the wind locally cooled the slab deeper in temperature than intended. The door position (open, closed or missing) was not measured and therefore missing in the dataset. This could never have come out of a data-crunch. The effect of the draught on the surface temperature of the solidifying steel shell in the bending zone of the cooling chamber cannot be measured either. So without measurement our staalmeester modelled that the northern wind caused a locally colder steel slab (the solidified steel product of the caster).

For the next step in the understanding process a much deeper understanding of material properties at high temperatures (up to 1700 °C) is needed. The problem with the advanced high strength steels is that not all high temperature properties are measured and available yet. So again our staalmeester has to judge and make assumptions, inferences and idealisations in order to explain the phenomenon of the crack. An earlier constructed model for a similar steel grade showed that the slab temperature could be critical in situations where a so called ductility trough is present. A ductility trough is a temperature range in which the structure of the steel becomes less ductile or in other words more brittle. A brittle structure cracks more easily especially under the forces of the bending and unbending zone of the caster. For the advanced high strength steel the few degrees extra cooling brought the steel slab into this critical temperature range. Once this was understood measures could be taken to stay away from this critical temperature range even in the case of a door being open or missing. This was done by means of changing casting speed and cooling pattern. Which casting speed and cooling pattern to use was also simulated by means of different heat transfer and cooling models. These models were built and developed over the years to cover the area from the mould at the beginning to the cutter at the end of the caster.

The above described long road or process has elements of the ‘kairetic’ account of Strevens (2008), described by de Regt (2017, p. 66). The core of this account is the

so-called optimising process to identify the difference makers for events-to-be-explained. At some point one has to go as deep[14] as high temperature phase transformation and the other moment one can rely on more pragmatic assumptions. “Th[is] optimizing procedure leads to a stand-alone explanation, which is complete and sufficient for scientific understanding of the event. There can be many standalone explanations of one particular event, which can all be satisfactory and sufficient for understanding.’ (ibid). For sure the example of the staalmeester is a standalone explanation of the cracks and it is very possible that there are other standalone explanations to this particular event, whether from a different discipline or in future times.

The base principle of the causal approach was to find the cause. There are no mysterious things or coincidences like the wind from the north. For our staalmeester it is very difficult to understand that this principle can fail, but it does. In quantum mechanics for example the causal model is of no use. In order to understand the quantum theory one has to allow for indeterminism which is (at least for our staalmeester) difficult to understand or even grasp. It is very hard to understand the random decay of radioactive material. Compare it with an assignment to design a random generator, a device that generates random figures. Once designed the design is determined and therefore not random anymore.[15] In quantum mechanics matrix mathematics was introduced to provide this kind of understanding. But the problem with matrix mathematics is that it lacks another valued aspect of theories and that is visualisation.

Visualisation[16] is an important aid to scientists. This can be visualisations like in diagrams, graphs or figures. One of the benefits of current times is that it is quite easy to visualise even the more complex models in all kinds of animation or 3d representation. In the 1980’s data points had to be plotted on millimetre paper by hand. A linguistic form of visualisation is the use of metaphors. Some scientists use this linguistic form quite adequately and it surely shows their intelligibiligence. Visualisations can also help to grasp rather than to understand a phenomena. This is

[14] De Regt cites from Strevens (2008) work: ‘*Depth*: the causal and unification approaches to explanation unified-causally’.
[15] A real solution to this assignment would be using the decay of radioactive material
[16] De Regt calls the quality: ‘visualizability’. In this thesis the more general term ‘visualisation’ will be used.

of help when the limits of our understanding are at stake. Movies for example can do this. In this thesis already a few examples of movies were given. An example of something that is difficult to understand (at least to our staalmeester) is the notion of endlessness or infinity. It is very difficult to understand things that lay outside our spatiotemporal dimensions. Movies with the 'time as fourth dimension' as plot (and there are quite a lot of these movies) help to get a grasp what infinity is. With some intellectual optimism it is possible that what can only be grasped today could be fully understood in the future.

So intelligibiligence is an ability to exercise judgements, attribute values, skip or ignore data, make assumptions and idealisations, where to go deep and where to be pragmatic and so on. It is an ability that scientists develop as they learn and practice their craft[17]. Intelligibiligence is a pragmatic way of understanding and could not be acquired by learning explicit rules. One cannot learn to construct models by first learning explicit rules and subsequently applying them. Instead one needs to develop a skill by practicing, perhaps guided by someone who possesses this skill.

Why should we believe the staalmeester ? The questioner should follow the staalmeester along the road of his life. Not only part of the route but the whole route, including travelling to Japan in order to check the influence of casting powders in his model. The questioner also needs to know about all the side roads taken, the missed exits and dead ends, that finally brought the staalmeester to his final 'standalone' destination. And for certain there have been deviations taken which even cannot be made explicit by our staalmeester and which is called tacit knowledge.

3.4 the 'detached' character of intelligibiligence

In the previous section it was shown that Intelligibiligence is the distinctive feature of scientific knowledge but it is a pragmatic and contextual way of understanding. Intelligibiligence is a skill, to be acquired by the scientist in the context the scientist lives and works in. It depends on the scientist's personal preferences which items of knowledge and data to use and which not. The available items of knowledge vary with

[17] See for example Sennet (2008) 'the craftsman' or Schön (1983) 'the reflective practitioner' for a much more extensive description of what practicing a craft means.

times and discipline the scientist lives and works in. Both the terms ‘pragmatic’ and ‘context dependent’ cannot match up to the standard of objectivity defined by modern science. Interestingly both terms belong to the intersubjective world which was introduced in section 2.3 to solve the problem of other minds.

In this section the inevitable presence of the intersubjective world will be used to claim a ‘detached’ character of intelligibiligence. Detached means detached from personal elements. By its detached character intelligibiligence escapes relativism and comes close to the objectivity of modern science. In 3.4.1 the intersubjectivity of intelligibiligence will be approached with the help of Polanyi’s (1966) notion of ‘tacit’ knowledge. In sub-section 3.4.2 the assignment of the ‘detached’ character of intelligibiligence will be justified.

3.4.1 tacit knowledge and the intersubjective world

It was Polanyi (1891-1976) who introduced the notion of ‘tacit’ knowledge. He reacted upon the debate whether the context of scientific discoveries has a different ‘status’ than the context of scientific justifications. This division in two contexts was introduced by Popper (2002, 1934/1959) in his book ‘the logic of scientific discovery’. Popper was clear about the scientific discoveries: ‘(…) my view of the matter, (…) is that there is no such thing as a logical reconstruction of this process.’ (p. 8). Popper immediately adds: ’it may be expressed by saying that every discovery contains ‘an irrational element (…).’ (ibid). For ‘eureka’ type of discoveries it seems still disputable whether it is rational or not. De Regt (2017) calls his kind of eureka discoveries the ‘phenomenology of understanding’ (PU) defined as ‘the feeling of understanding that may accompany an explanation, like an eureka moment.’ (p. 23). Our staalmeester had a few of these ‘eureka’ moments and although they seemed to come from nowhere they were always in some way related to his intelligibiligence, working day an night, and therefore perhaps not as irrational as suggested by Popper.

But back to Polanyi (1966)[18], he wrote:

[18] In the next paragraphs of this section the page numbers refer to this work of Polanyi or it will be stated otherwise

> *"*But it is futile to seek for strictly impersonal criteria of its validity, as positivistic philosophies of science have been trying to do for the past eighty years or so. (…) Hence the failure of the positivist movement in the philosophy of science. The difficulty is to find a stable alternative to its ideal of objectivity. This is indeed the task for which the theory of tacit knowing should prepare us*."* (p. 25).

"We can know more than we can tell' is an often used expression of what tacit knowledge is about. (p. 4). Well known examples are recognizing faces whereas it seems almost impossible to describe the particulars of the face. Or the impossibility to describe what it was when you grasped your ability to ride a bike. Suddenly it is there, you see it, can do it, but you cannot tell. This knowledge cannot be made explicit. Tacit is an antonym for explicit (Collins, 2010). 'The tacit power lies in our ability to integrate our awareness of particulars without being able to identify these particulars'. Polanyi goes that far that 'all knowledge is discovered by means of this tacit power and once discovered it is held to be true'. (p. 6). Polanyi defines two terms working in tacit knowledge: 'proximal' and 'distal'. There is a functional relation between those two terms: 'we know the first term only by relying on our awareness of it for attending to the second.' (p. 10). We cannot know the whole without these two terms. 'Whenever we use certain things for attending from them to other things they become like attending from our body. So we make a thing [a tool, a theory, a model] function as the proximal term of tacit knowing, we incorporate it in our body – or extend our body to include it, so that we come to *dwell in* it.' (p. 16). Indwelling is interiorising the proximal term to make a comprehensive whole of the distal. Or in other words knowing of the distal (outer world) cannot be without the proximal (inner world). To Polanyi there is tacit knowledge involved in all our knowledge.

Although this introduction on Polanyi's view on tacit knowledge might be a little bit short, the relevance to the current topic might be clear. With the notion of 'indwelling' Polanyi connects the body and mind. In that sense it could have been part of section 2.2 as well. But tacit knowledge including the process of indwelling comes very close to the notion of intelligibiligence as well.

To Polanyi it was clear that if we want to gain new perspectives and insights into the phenomena at hand, we have to utilize both explicit and tacit processes. To rely on a theory for understanding nature is to interiorise it. '[W]e are attending from the theory

to things seen in its light, and are aware of the theory, while thus using it, in terms of the spectacle that it serves to explain.' (p. 17). This is why driving a car or even a mathematical theory cannot be learned by reading a book alone. True knowledge lies in our ability to use it. This is intelligibiligence before the word was invented.

Like intelligibiligence, tacit knowledge has the character of a skill. Skills cannot be acquired from textbooks but only in practice because they cannot be exhaustively translated into explicit rules. To possess a skill is to have implicit tacit knowledge. Classic examples used by Polanyi are the skills to ride a bicycle or to play the piano. Collins (2010) specify the example of riding a bicycle as a case of 'somatic' tacit knowledge. "When we ride our bikes we do not self-consciously use any physical or mechanical model; somehow, with practice and training, the ability to balance on a bike becomes established in our neural pathways and muscles that we cannot speak about." (Collins 2010, p. 99). Somatic tacit knowledge, although often implicit, can in principle be made explicit because it is rooted in causal sequences that may ultimately[19] be explained and understood scientifically[20]. This does not hold for what Collins calls 'collective' tacit knowledge. This kind of tacit knowledge is located in society and can only be obtained when immersed in a society or community and which cannot be made fully explicit. The example Collins uses is the skill to apply the right rule in the correct way in the appropriate circumstances. This is something that cannot be explicated by means of a scientific description or explanation and subsequently could be used to build a machine that mimics human behaviour.[21] It is not difficult to see the resemblance with intelligibiligence. Intelligibiligence is an perfect example of 'collective' tacit knowledge. Tacit knowledge or intelligibiligence can only be acquired through immersion in the intersubjective world.

3.4.2 intersubjectivity and the 'detached' character

In the previous section it became clear that Intelligibiligence is inherently a combination of individual thought processes and social processes. For the individual

[19] Ultimately as with the ''open-end capacity' or 'intellectual optimism' of Nagel in section 2.2.4
[20] In fact this became reality see 'amazing: bike riding robot' on https://www.youtube.com/watch?v=zsxRZILJU5c (2018)
[21] Collins (2010) uses on p. 123 one episode of the movie 'star trek: the next generation' as a visualisation of what he means by this.

process of constructing models the interaction with other members of the community is essential. The two processes cannot be separated. Therefore intelligibiligence cannot be reduced to the relativism of the personal thought process. This was already clear to Kuhn (1922-1996) that whenever science is relative it is relative to scientific communities rather than to individuals. This irreducible combination of the first and second person aspects in intelligibiligence does not guarantee that it is value free though.

For a dualist, objectivity is formulated in terms of a value free ideal. For intelligibiligence this definition of objectivity seems problematic and unrealistic. But as Nagel already mentioned (see section 3.2) it 'has a detached character so long as we were rational and could understand the mathematical and formal properties of the objective conception of the physical world'. When values enter the intelligibiligence process one should not rely on the values but as much as possible on empirical evidence. One should not ignore evidence because it does not comply with one's values. Sometimes the evidence is ambiguous and a personal judgement has to be made. In that case the social process becomes important.

There are several ways in which the social processes can ensure that the understanding produced by intelligibiligence is detached and therefore objective. The interaction with other members of the community is a kind of 'sparring'. This sparring enhances a critical reflection within the community and also a critical self-reflection. Personal biases are balanced out by these social processes. This interaction is called 'in concordance' in cases where the community agrees with the individual judgement. In case when there is initially a disagreement concerning the individual judgement it becomes an interactive process and one has to come to consensus. In section 3.3 the community of our staalmeester was mentioned. The contacts with universities, conferences, other steel plants and the operators and colleagues at the own works constitute this community. Therefore intelligibiligence may be regarded as 'detached' in character and therefore trustworthy even if value judgements have played a part in the process of constructing the model that lead to the understanding of the phenomena at hand. Although the value-free ideal of modern science is unattainable, scientific progress is possible without it.

Intelligibiligence results in understanding the phenomena ‘at hand’. This ‘at hand’ means that intelligibiligence has contextual aspects. Intelligibiligence depends on the ‘time and place’ the scientist lives and works in. Intelligibiligence depends on contextual factors like the capacities, background knowledge and background beliefs of scientists in their context.

The ‘place’ the scientist works in is determined by the discipline the scientist has ‘mastered’ (metallurgy). The needed set of cognitive skills of intelligibiligence resides in this specific community the scientist belongs to (steel making). In section 3.3 it was pointed out that there is no universally standard set of items of knowledge accepted by all disciplines. The causal principle is favoured by our staalmeester but it is of no use to a quantum physicist.

But this is less relevant because, as we saw, the optimising process of our staalmeester led to a stand-alone explanation, which was complete and sufficient for scientific understanding of why the defect of cracks occur in advanced high strength steels. It does not exclude the possibility that there is a different standalone explanations acquired with another principle or a principle yet unknown. In section 1.1 it was mentioned that at the debate on ‘climate change’ different disciplines and different theories seemingly confused things. Most probably the different disciplines came up with standalone explanations of certain aspects of ‘climate change’. Climate change as a phenomenon contains so many aspects that it cannot be addressed as one big phenomenon. The same would be the case when at a conference on ‘material cracks’ our metallurgist presents his paper on the cracks in advanced high strength steels and a colleague from the petrochemical industry presents a paper on cracks in a certain type of plastic. Both presenters might possess intelligibiligence but an ignorant questioner could be confused on who has the correct understanding of material cracks. They both do.

The ‘time’ or the historical context also differs per scientist. For example the available items of knowledge will differ. Since the 17th century through the 1980’s , to the second decade of the 21st century the availability of items of knowledge and background information grew exponential. This does not make the knowledge of the 17th century or the 1980’s out-dated or false. It is very well possible that not only many past theories but also our current best theories are false. But even seemingly out-dated or false

theories may contain certain qualities that helps in constructing a model that leads to standalone explanations. And they all can be satisfactory and sufficient for understanding the phenomena at hand. So context dependency does not undermine the established detached character of intelligibiligence.

The inquiry into the specific feature of scientific knowledge of this chapter lead to ‘intelligibiligence’. Although intelligibiligence is pragmatic and context depend it is detached in character and thereby escapes relativism. For answering the question ‘why should we believe the scientist’ the only thing to do is check the scientist’s intelligibiligence. Sometimes it means that the questioner has to spent time to follow the scientist on his lengthy road and realise that some roads are tacit.

Still one might long for the old ‘modern’ science with its big names like Newton and Einstein. Modern science was really objective and therefore different and better than today’s science which despite its detached character is not totally free from the smell of relativism.

Descartes became known as the godfather of ‘modern’ science. In his discourse (1637)[22] both the base for dualism and the methodical rigor of objectivity are laid. With intelligibiligence scientific knowledge goes beyond dualism and does not reach the alleged objectivity level of modern science. But is intelligibiligence really so much different and worse than modern science ? This can be doubted. In this chapter Descartes way of thinking will be revisited by comparing the notion of intelligibiligence with parts of Descartes’s discourse. In the discourse Descartes describes the method of doubt which comes very close to the notion of intelligibiligence, as will be explained in section 4.1. In the discourse Descartes also describes the working of the heart. This is a perfect example of what intelligibiligence is about, as will be addressed in section 4.2. In Cartesian dualism there seems no room for the intersubjective world which is as explained in the previous chapter a prerequisite for intelligibiligence. In section 4.3 some more words on the intersubjective world of Descartes will be written.

Scientists often share a kind of intellectual optimism that everything in the physical world could be understood, if not today then in the future. But to date there still are limits to our understanding. In section 2.2.1 the God of gaps was introduced when the limits of our understanding of the problem of other minds, a non-physical problem, was at stake. In section 3.3 the notion of ‘grasping’ was introduced when the limits of understanding physical phenomena are reached. Section 4.4 elaborates somewhat more on the God of gaps. At a certain moment every scientist will reach the limits of what he or she could understand. At that moment the scientist has to believe it.

[22] All the page numbers in this chapter refer to ‘a discourse on the method’ (1637a), except where stated otherwise

4.1 ‘method of doubt’ or ‘intelligibiligence’ ?

In the discourse Descartes describes a method to found and acquire true knowledge. The method became known as the ‘method of doubt’. But Descartes uses ‘doubt’ only to arrive at the very base of true knowledge. The method of doubt tells us to discard everything of which one can have even the slightest doubt. Descartes had to discard everything he ever learned and hold for true. The only thing he could be sure of was ‘I think therefore I am’, also known (in Latin) as ‘cogito ergo sum’. Descartes made this ‘cogito’ the first principle of his philosophy. Descartes writes: “I am thinking therefore I exist, was so secure and certain that it could not be shaken by any of the most extravagant suppositions of the sceptics, I judged that I could accept it without scruple, as the first principle of the philosophy I was seeking.” (p. 28). Not much further Descartes writes that ‘it was a greater perfection to know than to doubt’. (p. 29). To Descartes it is of greater perfection ‘to know’, which is ‘to acquire true knowledge’. In order to do so Descartes developed “as a general rule that things we conceive of very clearly and distinctly are all true’. (ibid). In section 3.2 of this thesis the knowing process was also described as ‘to know’ and ‘to know’ is ‘when things are clear’ or ‘understood’. This means that Descartes’s ‘method of doubt’ is about ‘understanding’ as described in chapter 3 of this thesis.

Descartes also seems to notice a difference between understanding and explaining. Descartes writes:

> “In earlier years I had made some study of logic in the philosophy course, and of geometrical analysis and algebra in mathematics, three arts or branches of knowledge that seemed destined to contribute to my plan. But, on examining them, I noted, in the case of logic, that its syllogisms and most of its other techniques are employed more to *explain*[23] things to other people that one *knows*[23] already or even, as in the art of Lull, to speak injudiciously about those of which one is ignorant, than to learn anything new.” (p. 16).

So logic is often used to explain to others that what one already understands. This resembles what is said in the first paragraph of 3.2: only when things are understood

[23] Italics by author

they can be explained. This was what our staalmeester had in mind with his statement 3 in appendix 1. The staalmeester hoped that logic could convince other people but only as in a hindsight way, just in order to justify his claim. The staalmeester also recognizes that some people use logic to convince others of things they are completely ignorant of. According to the staalmeester some politicians and managers are good at this: they 'Lull'[24] or talk about things they don't understand.

In the 'ibid' quote above (belonging to p. 29) Descartes mentions 'clearly and distinctly'. There seems to be no general understanding of what Descartes really means with 'distinctly'. Descartes himself adds "(…) there is some difficulty in being able to identify those [things] which we conceive of distinctly". (p. 29). Bennet (1990) writes that according to Descartes 'distinct' is 'a perception that contains in itself only that what is clear. Bennet says: "I reluctantly follow the custom of using 'clear' and 'distinct' to translate Descartes's words, though they are certainly incorrect. 'Vivid' and 'clear'—in that order—would be nearer the mark." (Bennet, 1990, p. 7). Although it is not clear what Descartes exactly means by distinct it does not seem very farfetched to consider 'the causal principle' as something that is distinct. At least to our staalmeester this principle contains in itself only what is clear. Descartes, as we will see in the next section, favoured the causal principle as well.

It is of greater perfection to know than to doubt. To know is to conceive things clearly and distinctly. Like in section 3.2 Descartes uses two different terms for understanding in the process of acquiring true knowledge. These are the essential elements of intelligibiligence. One important component of intelligibiligence is still missing: constructing a model. This will be addressed in the next section.

4.2 Descartes's intelligibiligence

In section 3.3 intelligibiligence was described as the ability to construct models or conceptions of physical phenomena at hand in order to understand the phenomena; a scientist uses items of knowledge and therefore needs intelligibility which means that value judgements and choices have to be made which items and data to use.

[24] Only those who understand the Dutch language will recognize this as a 'verb, to others it refers to the art of Lull mentioned by Descartes.

Theories and principles are items of knowledge. In section 3.3 it was described that our staalmeester favoured basically one principle: the causal one. Descartes was also after principles, but not necessarily just one:

> "First, I have tried to find in general the principles or first causes of everything that exists or can exist [in] the world (…) [a]fter that, I came to examine what are the first and most common effects which one can deduce from these causes (…) [c]onsequently, I did not think there was any other way to make them useful to us, than by progressing from effects to causes and by engaging in many individual observations (…) I venture to declare that I have not noticed anything which I could not explain quite easily by the principles I had found." (p. 53).

In this quote one might notice the optimising process described in 3.3: 'progressing from the effects (cracks) to causes (ductility trough) and engaged in many observations'. Not only engaged in many observations but also the many possible ways to travel as Descartes mentions on the same page:

> "But I must also acknowledge that the power of nature is so ample and vast, and these principles so simple and general, that I am able to observe hardly any particular effect without knowing from the beginning that it can be deduced from the principles in many different ways, and that my greatest difficulty is normally to find in which of these ways the effect depends on them." (ibid).

Although Descartes perseveres in talking about principles (plural)[25] it becomes clear that the causal approach, or more specifically the causal-mechanical approach, is favoured by Descartes. This becomes very clear in chapter 5 of the discourse. In chapter 5 Descartes explains how he understands the working of the heart in the body. This forms an excellent example of Descartes's intelligibiligence.

To Descartes the human body is in essence the same as that of animals or even like all other physical items. The physical world can be approached in a causal-mechanical way. Descartes works out a causal-mechanical model with the help of which he explains the working of the heart. After doing this Descartes remarks:

> "Finally, so that those who do not know the force of mathematical proof and are not used to distinguish true reasoning from plausible reasoning, should not venture to

[25] Most likely Descartes included his first principles of the cogito and the existence of God.

deny all this [working of the heart] without examining it, I would like to point out to them that the movement I have just *explained*[26] follows necessarily from the mere disposition of organs that one can see with the naked eye in the heart, from the heat which one can feel there with one's fingers, and from the nature of blood which one can know from observation, in the same way as the movement of a clock follows from the force, position, and shape of its counterweights and wheels." (p. 42).

This quote shows that Descartes values the metaphor, which is a linguistic visualisation tool. Because of the mechanics involved Descartes uses the metaphor of a clock. It is very well possible that Descartes also made a sketch or a drawing of his model of the heart. In the model the heart is a kind of heat pump that pumps blood around. In the 17th century apparently one was aware of our nerve system which seems to have a more direct link to the brains than could be explained by the movement of blood. Neurons and the nerve system did not become known before the 20th century. Descartes showed his intelligibiligence by explaining the working of the nerve system with the use of his model by considering the neurons as 'spirits that are the most agitated and penetrating parts of the blood'. (p. 45). In this way he could explain why nerves react so fast and still uses his model of the transport system of the heart and blood.

A basic assumption in Descartes's model is that the heart is the hottest part of the body and therefore it works like a heat pump. To Descartes this assumption could be verified by means of feeling it with 'one's fingers'.

With this example the context dependency of intelligibiligence becomes clear. Besides the fact that neurons where unknown also oxygen had to be 'discovered' (around 1772). Descartes could not know that oxygen rather than heat or spirits is transported and that oxygen contains energy and heat. All kind of chemical and biological theories where unknown to Descartes. That is why Descartes addressed the physical world mostly in a purely (causal)-mechanical way. Still with the help of Descartes's model and Descartes's understanding of the workings of the heart, real advancements in the preservation of health were made.

[26] Italics by author

Descartes constructed a theoretical model to understand the working of the heart. In order to do this he valued the deductive qualities of logic, mathematics and used the causal-mechanical principle. Descartes also used metaphors and thereby valued visualisation as an useful tool. These are all clear examples of Descartes's intelligibiligence. Perhaps the discourse is not so much describing the method of doubt but can be seen as a 17th century version of intelligibiligence ? This section showed the context dependency of intelligibiligence but what about the 'intersubjective world' in Descartes's discourse ? This will be the subject of the next section.

4.3 Descartes's intersubjectivity

In section 3.2 is was explained that intelligibiligence is a combination of individual thought processes and social processes. Because the two processes cannot be separated intelligibiligence cannot be reduced to relativism. But it looks like that the discourse is about Descartes individual thought processes only. Descartes does not make it a secret that the discourse represents his way of thinking and his alone. It is also completely written from a first person's perspective. This would make it very doubtful whether Descartes could reach the pure objective status of modern science and perhaps even lacks the detached character of intelligibiligence. Where are the social processes in the discourse ?

It is to be expected that the intersubjective world is hard to find in Descartes' work, since Descartes 'invented' 'Cartesian' dualism.

A first remark is that although individual and social processes are inherently present in intelligibiligence it does not mean that they have to be equally present. Descartes himself wrote that the discourse was established in a solitary environment 'shut up in a small room in which I could converse with my own thought'. (p. 12). Descartes favoured the time spent on the individual thought processes. This is recognised by our staalmeester as well. The individual thinking process is something that goes on day and night and even (or especially) during the social process of interacting with others. This is probably the reason why intelligibiligence has traits of 'autism'. Concentrating on the phenomena at hand leaves less room for something else. And because this is at the top of the mind almost 24 hours a day it is not surprising that 'eureka' moments

will occur. When a scientist is intrigued by and interested in the phenomena at hand, it will occupy most of his individual thinking process.

At the beginning of the discourse Descartes mentioned that he travelled the world and interacted with people of other cultures and disciplines. Descartes writes that during this traveling he was “at all times giving due reflection to things as they presented themselves to me so as to derive some benefit from them”. (p. 10). But Descartes derived not much benefit from this and he came to the conclusion to better do this on his own. Descartes started with his own thinking process which resulted in the writing of the discourse. For intelligibiligence travelling makes sense mostly to reflect on the phenomena you want to understand and to tune the models you make. All the travelling of our staalmeester was not done to hear how others present their understanding of cracks in advanced high strength steel. Most probably the others don’t have the same cracks at all or don’t produce the kind of advanced high strength steels like our staalmeester. Almost certain ‘the other’ would not have given this specific phenomenon any thought at all. So the travelling was done to reflect on the own model and to find evidence in favour or against the model.

So most probably the intersubjectivity of Descartes is not in the discourse, but, when addressed at all, in later work. As for Descartes’s model of the heart perhaps no later work might be available. But Swaab (2014) writes that ‘Descartes bought carcasses for his research at the cattle market’ and that on the painting ‘anatomy lesson of dr. Deijman by Rembrandt van Rijn’, dr. Deijmand is searching for ‘the seat of the soul’, which is ‘according to Descartes the gland’. (2014, p. 363/364). Most likely Descartes did not do the research on carcasses all by himself but interacted with others perhaps even with doctor Deijman.

Descartes also ‘sparred’ with contemporaries like for example Constantijn Huygens (1596-1687). In the introduction to the Dutch translation of the discourse (1637b, p. 10) it is said that Descartes could imagine that his soul was exchangeable with Huygens’s soul. De Regt (2017) also mentions the ‘sparring’ between Descartes and Huygens. De Regt writes that ‘Huygens was highly critical of Descartes’s philosophy and physics but agreed upon the view that mechanical explanations is the only true route to scientific understanding’. (2017, p. 166).

Finally the community of colleague philosophers and other readers of the discourse are part of Descartes's intersubjective world as well. In chapter 6 of the discourse all the readers are invited to send in objections to which Descartes 'shall try to deliver his reply'. "I shall be very glad for them to be critically examined, and so that one might feel all the more free to do so, I beg all those who may have any objections to take the trouble of sending them to my publisher, through whom, on being informed about them, I shall try to deliver my reply at the same time.' (p. 61). Descartes kept this promise, for example in his 'meditations on first philosophy' (1641).

So both the individual and intersubjective processes are in place for Descartes' discourse. Descartes's intelligibiligence contains all the elements defined in chapter 3. So for those who think that the old 'modern' science of Descartes is different or better than 'intelligibiligence' as described in this thesis, probably focussed on other aspects of Descartes' work. Or when one sticks to the idea that Descartes is the godfather of modern science and that intelligibiligence is not modern than the revisited Descartes suggests that perhaps 'we were never modern'[27] ?

4.4 God of gaps

There can be at least two views on the limits of scientific understanding. On the one hand there can be a certain intellectual optimism that suggests that everything can and will be understood in the long run. It looks like Descartes shares this kind of optimism when he writes that he discovered 'a number of truths in the sciences' by overcoming 'five or six principle difficulties'. He only needed to overcome two or three others to 'fulfil his aim completely'. (p. 55). In a footnote to the Dutch translation of the discourse it is suggested that Descartes's aim was to understand the origin of life. (1637b, p. 129). On the other hand one has to admit that, at least today, there still are limits to scientific understanding. This is where a 'God of gaps' is needed.

In section 2.2.1 Descartes admitted that he could not perceive the existence of the physical world 'clearly and distinctly'. The problem of other minds is hard to understand, but it can be understood with the help of an existing God. Descartes acknowledges that not everybody would accept the existence of a powerful God:

[27] This is also the title of a book by Latour (1993) which addresses this same issue.

> “Some people would deny the existence of such a powerful God rather than believe that everything else is uncertain. Let us grant them—for purposes of argument—that there is no God, and theology is fiction. On their view, then, I am a product of fate or chance or a long chain of causes and effects. But the less powerful they make my original cause, the more likely it is that I am so imperfect as to be deceived all the time—because deception and error seem to be imperfections. Having no answer to these arguments, I am driven back to the position that doubts can properly be raised about any of my former beliefs. I don’t reach this conclusion in a flippant or casual manner, but on the basis of powerful and well thought-out reasons. So in future, if I want to discover any certainty, I must withhold my assent from these former beliefs just as carefully as I withhold it from obvious falsehoods.” (1641b, p. 2).

In the light of intelligibiligence and its limits, this is an interesting quote. In the previous sections and chapter it became clear that both our staalmeester and Descartes favoured the causal principle. This principle even became the first principle of both their intelligibiligence. In 3.3 it was mentioned that for our staalmeester it is very difficult to understand that this principle can fail. Our staalmeester has troubles with really understanding indeterminate processes and a notion like tome as a fourth dimension. Descartes seems to face the same kind of limits. To Descartes gravity as a an ‘invisible force from a distance’ was hard to understand (De Regt, 2017, i.e. p. 147). These limits can be stretched a little by means of the ‘grasping’ aspect in intelligibiligence. In this sense the science fiction movies were mentioned. But grasping is not the same as real understanding.

In the quote above Descartes says that without the existence of God our own existing or ‘I’ would be the product of fate or change or a long chain of causes and effects. This sounds very much like Darwin’s evolution theory, although Darwin’s well-known work ‘on the origin of species’ was published more than 200 years later in 1859. One might object that with his intellectual optimism Descartes thought he could understand the origin of life as well. But with the own existence or the ‘I’ Descartes meant the soul and not the physical body. Descartes thought he could understand the physical existence of things like our body. To Descartes our body is the same like that of animals but our existence, our ‘I’ or our soul is given only to humans by God. “I had described the

rational soul, and shown that, unlike the other things of which I had spoken, it could not possibly be derived from the potentiality of matter, but that it must have been created expressly.' (p. 48). Despite all intellectual optimism, even that of Descartes, the origin of physical life is still not understood, otherwise it could be given to some body. How exactly the human 'animal' evolved into a human 'human' (with a soul or mind) is also far from being understood.

Part of a scientist's Intelligibiligence is to 'grasp' things that go beyond a real understanding. When grasping is what is at stake it means a scientist reached the limits of his understanding. The origin of life and the missing link in the evolution comprises such a limit. In this case a useful item of knowledge is the theory of probability. Intelligibiligence would tell the scientist that the evolution theory is against all odds even with millions of even billions of evolution years available. The odds are as low as when a hurricane moves over a scrap yard and produces the most modern aircraft. A scientist can only be impressed by the very complex and intelligent structure of single cell, let alone that this single cell comprises also information and capacities to transform this one cell into the most complex organisms. A scientist would show more intelligibiligence in acknowledging an Almighty Creator or Intelligent Designer than ascribing it to a long chain of causes and effects.

Against this argument one could ask for the theoretical principles behind the existence of an Intelligent Designer that can be used to construct a model. It was already suggested that the existence of God was one of Descartes fundamental principles so it was an essential part of his model. But for those who don't accept the existence of God as a principle: they haven't come up with another principle that explains the phenomena that are at the limits of their understanding either. At the limits of their understanding they could rely on intellectual optimism that maybe somewhere in the future it can be completely understood. But for now, when they don't accept a God of gaps the only thing they could say is that although they cannot explain it that they 'believe' it.

In chapter 2 we saw that the connection and interaction between the body and the mind is very difficult to understand. When the question 'why should we believe you' focusses deeply on solipsism it will be hard to explain it and convince other people. The best we could do is make the theory incoherent with the help of the intersubjective

world. In the case of solipsism the general public won't have problems with just 'believing' it rather than to really understand it. The only thing the general public won't admit that to 'believe it' is to 'believe in the existence of God, Who designed things like they are'. Descartes admitted this from the very start.

One way of arriving at the limits of someone's understanding is repeatedly asking the 'why should we believe you' question. One will always arrive at a point where the question cannot be answered. If you really understand the origin of life, physically or mentally, why can't you give it to somebody or someone ? With intellectual optimism there is hope this can be understood in the future, for now we have to 'believe it', because there we live and we think. When you ask our staalmeester why a radioactive element decades randomly he will answer: because 'I believe God designed it this way'.

For everything between solipsism and the origin of life why should we believe a scientist ? Because the scientist possesses intelligibiligence which is detached in character. Although intelligibiligence has pragmatic and context depend elements, it escapes relativism. The revisited Descartes shows that all these elements were present right from the beginning of modern science and did not hinder, or perhaps are a prerequisite for the impressive development and achievements of science and technology.

Chapter 5: final comments

"Why should we believe a scientist ?" For everything between chapter 2's 'problem of other minds' and the problems where the 'God of gaps' of section 4.4 is needed the answer can be found in chapter 3: because of the scientist's intelligibiligence. Although intelligibiligence has pragmatic and context depend elements, it escapes relativism. The revisited Descartes of chapter 4 shows that these elements were present right from the beginning of modern science and did not hinder, but perhaps on the contrary were a prerequisite for the impressive development and achievements of science and technology.

In this last chapter three final comments will be made. Firstly: the title of the thesis suggests that intelligibiligence makes up the soul of our staalmeester. Does this entail that feelings, moral and a pious belief in God are not essential to the soul of our staalmeester ? Secondly: has intelligibiligence something to do with intelligence ? And finally how does a 'handbook metallurgy' fits in this thesis ?

The notion of intelligibiligence was introduced as the distinctive feature of the scientific knowing process. In chapter 3.3 the intelligibiligence of our staalmeester living in the second decade of the 21st century was described and in chapter 4 the intelligibiligence of Descartes who lived at the beginning of the 17th century. With over three centuries between them in fact intelligibiligence was de-contextualised and it was determined that intelligibiligence is detached in character. But intelligibiligence is about understanding phenomena and theories and about constructing models. It says nothing about feelings, morals or a religious belief in God.

Toulmin (1990) tried to re-contextualise Descartes for example by elaborating on Descartes's position towards feelings. In section 2.2.1 Descartes's struggle to explain the existence of the external world was drawn. Descartes found out that 'imagination' (important part of 'grasping') was different from 'real understanding'. Descartes had the same struggles with how to appoint a position to 'feelings'. Because they are not part of the mental world of intelligibiligence Descartes parked it as 'something what our bodies do to us'. Toulmin uses this ambiguous position when he writes: "Descartes position implies that a philosopher can disclaim all responsibility for his erections, unless he has a good reason for deciding to have one." (p. 40). Of course both

Descartes and our staalmeester have to deal with feelings but feelings are not addressed like the physical phenomena they want to understand.

Intelligibiligence is about values, but values attributed to items of knowledge and not about moral or ethical values. But of course morals and ethics are part of everyone's live and therefore also of the lives of scientists. Descartes mentions specifically in the discourse: "to carry on living from then on as happily as I could, I formed a provisional moral code for myself consisting in only three or four maxims (…)." (1637a, p. 21). For sure our staalmeester lives by a moral code as well, not consisting of three or four maxims but of ten commandments, which one can find in the Holy Scripture[28]. Although intelligibiligence is not so much about these kind of values it will be a good thing for society when everybody would adhere to a certain moral code. Why ? Because intelligibility is inevitable part of the intersubjective world and a moral code is indispensable for living as happily as we could as homo respondens in this world.

When belief in the existence of God is part of intelligibiligence it is rather a rational than a religious belief. In the discourse it is unclear whether Descartes had a rational or religious belief. Perhaps the fact that his moral code does not literally contain one of the ten commandments one can suggest it is rather rational than religious. Descartes acknowledges that believing in God requires a different order of understanding: "the path to heaven is open to the most ignorant and the revealed truths that lead there are beyond our understanding". (1637a, p. 9). Descartes also admits that God's existence can be better known from the Holy Scriptures than from scientific understanding: "it may be inferred from the Holy Scriptures, that knowledge about Him is much clearer than that which we have of many created things, and, as a matter of fact, is so easy to acquire, that those who have it not are culpable in their ignorance." (1641b, p. 1).

The main title of the thesis is 'about the soul of a staalmeester'. The thesis is about 'intelligibiligence'. Intelligibiligence is not about feelings, morals or a religious belief, so does this means that these things do not belong to the soul of the staalmeester ? Far from that. It only means that when the issues at stake are on feelings (other than professional intuition or imagination which are part of intelligibiligence) or on ethical dilemmas or on the personal faith the question 'why should we believe you rather than

[28] For example Exodus 20.

others' cannot be answered with the rigor when physical phenomena are at stake. On matters of feelings, ethics and personal belief the staalmeester's opinion is just an opinion amongst others. But on physical matters where the question implies that the intelligibility of our staalmeester is doubted one touches upon the soul, the distinctive feature of a scientist's 'way of thinking'.

Intelligibiligence is not a matter of intelligence, it is just a matter of common sense. Descartes formulates this nicely:

> "(…) good sense or reason[)] is naturally equal in all men, and that consequently the diversity of our opinions arises not from the fact that some of us are more reasonable than others, but solely that we have different ways of directing our thoughts, and do not take into account the same things. For it is not enough to possess a good mind; the most important thing is to apply it correctly." (1937a, p. 5).

Descartes wrote his discourse in French because it could be understood by a broader public than the intellectuals who wrote in Latin. The principles used are simple and general so when the issue is brought back to the basics of straightforward cause and effect they could be understood by everybody. What is needed is a kind of curiosity and interest for wanting to understand things. Both Descartes and our staalmeester mentioned the long roads and ways to travel in order to arrive at the basics. That might cause troubles to the receiver of an explanation. A final quote by Descartes:

> "Still, just as in Geometry there are many demonstrations that have been left to us by Archimedes, by Apollonius, by Pappus, and others, which are accepted by everyone as perfectly certain and evident (because they clearly contain nothing which, considered by itself, is not very easy to understand, and as all through that which follows has an exact connection with, and dependence on that which precedes), nevertheless, because they are somewhat lengthy, and demand a mind wholly devoted to their consideration, they are only taken in and understood by a very limited number of persons." (1641b, p. 2)

So the receiver has to show some interest as well at least they have to be interested enough to take the somewhat lengthy road. Intelligence is nice to have but does not make the difference. Intelligence tests are often focussed on how fast one can process

information and data. Computers and artificial intelligence (AI) can do this much faster than the human brain can. The cpu, chip storage and the clock speed in GHz of our brain cannot compete with AI. But intelligence does not imply intelligibiligence. AI probably won't sit down at the caster to look what happens when the wind blows from the north. And even when an intelligent robots would sit at a caster or fly to Japan in order to construct and verify a casting powder model would this robot in the end produce more standalone explanations or produce more patents than a dedicated scientist ? And if they don't produce more why use robots instead of real people ?

So not intelligence, but a certain interest and curiosity is needed for intelligibiligence. Because there is also tacit knowledge involved it is often difficult to explain what an intelligibiligent scientist understands, especially when the road is as lengthy as 30 years. The receiver has to acknowledge this as well. Perhaps tacit knowledge is part of the distinctive feature of most of the professions and not only that of a scientist. It is the skill, the experience that makes the professional or expert. Here may lay a big risk for current society[29]. Thanks to all the available technology there is a tremendous amount of data available: big data, internet of things and AI are just a few examples. The same is true for the availability of items of knowledge. Almost every standalone explanation in the world, confirmed or unconfirmed, scientific or unscientific can be approached with a simple swipe on a smart phone. It has become very hard to make the right judgement and choices on which data and items of knowledge to use. Data mining and crunching became a profession on its own. Understanding the software requires its own intelligibiligence. Quite often the data crunchers know how to use the software but do not understand it. In general it seems that society becomes more and more superficial. Superficial in understanding the phenomena but also in the contacts with the intersubjective world. Both are important elements of intelligibiligence so the risk in current society is that this more in depth knowledge won't be acquired any more. Still it seems essential to future developments.

A handbook metallurgy therefore should not contain standalone explanations. This would only add to the number of items of knowledge and that is not what is needed to really understand things. A handbook metallurgy should be about intelligibiligence, about the soul of a staalmeester, as described in this thesis.

[29] Ulrich Beck writes about this issue in *risk society* (1986) and *reflexive modernity* (1994)

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Attachment 1: I study Philosophy / Filosofie magazine / December 2015, p. 81. © author: Carolien van Welij, photography: Merlijn Doomernik.

IK STUDEER FILOSOFIE

'Procesbeheersing in de staalfabriek is een filosofische kwestie'

Wat verwachtte je van de studie?
'Hoe kan ik verstand en gevoel bij elkaar brengen? Analytisch denkvermogen heb ik wel tijdens mijn studie in Delft ontwikkeld. Maar ik liep tegen kwesties aan waarbij gevoel, mensenkennis en empathie een rol spelen. Bijvoorbeeld: waarom loopt een vergadering niet? Of waarom erger ik me aan iemand? Filosofie is de verbindende factor tussen logica en gevoel.'

Wat was de aanleiding om filosofie te gaan studeren?
'Voor de staalfabriek wilde ik een leerboek schrijven over procesbeheersing. Wij maken hier zo'n honderd verschillende staalkwaliteiten. Om die processen te verbeteren moet je eerst de complexiteit terugbrengen tot de basis. Ik waarschrijf dat mijn boek ingaat op 'de juiste manier van denken'. En een boek met een filosofische insteek wil ik niet als amateurfilosoof schrijven.'

Wat denk je aan je studie te hebben?
'Op het vlak van mensen overtuigen kan ik nog veel leren. Ik ging er altijd van uit dat iedereen zo denkt als ik, maar dat is niet zo. In mijn laatste rapport aan het management gebruik ik nu eigenlijk opbouw als in het boek dat we voor ethiek gebruiken. Ik begin met twee premissen waar je niet onderuit kunt, en verbind daar aan de conclusie.'

ARIE HAMOEN (53) is manager kwaliteit, technologie en communicatie bij Tata Steel in IJmuiden. Hij

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"Process control in a steel plant is a philosophical matter"

What was the reason to start the study philosophy ?

1) I started to write a handbook metallurgy. There are more than 100 different steel grades. In order to control and improve the apparent complexity has to be bought back to basics. The handbook should be about this process of bringing it back to basics, about 'the way of thinking'. This is a philosophical approach so I had to study philosophy before writing the handbook.

What do you expect to learn ?

2) How to bring ratio and feeling together. At the University of Delft I developed an analytic way of thinking but in daily practice I run into all kind of other situations as well. Human interaction, empathy all kind of non-rational things as well. Philosophy tries to deal with this as well, so I hope to find some answers there.

What do you think to take out of the study ?

3) How to convince people. I always thought that people think like me, that there is only one way of thinking, but this does not seem to be the case. In my last report to the management I used the style of premises leading to the conclusion. When the premises are accepted the conclusion could not be denied. That should convince them.

Attachment 2: Cover of Dutch translation of Descartes's *Discours de La méthode; La dioptrique'Les Météores; La géométrie* (1637)