Understanding as Intellectual Virtue and the Nature of Scientific Progress

PhD Thesis Research Proposal

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Thesis Working Title

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Statement of Research Topic/Problem

How to identify the characteristics of scientific progress in real time has become more difficult because of the speed at which science is currently being done. Four accounts of scientific progress have been predominant in the philosophical literature, but each of them fails to adequately address what is constitutive of how science proceeds. The aim of this thesis is to identify how previous accounts have failed to recognise that the scientist and her disposition to act virtuously serve as a catalyst for scientific progress, while avoiding the pitfalls of poor scientific practice. Scientific progress should not be measured as a purely cognitive achievement but should incorporate a suite of intellectual virtues, and especially virtuous understanding, to achieve a more accurate view of what we should accept as scientific progress.

Significance of the Topic

Science grows ever more important as we face issues like the SARS-COV-2, i.e., *COVID-19*, pandemic, environmental disasters, climate change, fossil fuel and natural resource depletion, famines, and poverty. We hope that science will find solutions to these problems because governments and policy makers rely upon scientific research to make policy decisions and law that affect us directly. The general public also relies upon science to tell us what we need to know, and we expect that our doctors and the health sector have the most current and accurate research to make the most informed decisions about our health issues, especially when it comes to know about how to make healthful decisions for ourselves and for our family. Finally, we prescribe safe and effective procedures and medications. In these ways, we all depend upon SP.

When we assess scientific progress (SP) across all scientific disciplines, including biology, chemistry, physics, as well as medicine and engineering, we need to know that the experimental results of these disciplines are trustworthy, that the scientists and members of the scientific communities are conducting research in a reliable and informed manner. The progress that scientists and scientific communities make need to be assessed not only on individual achievements but also on their ability to exercise intellectual virtues. Since research methods may be susceptible to human error, biases, and vices, we need an explanation of SP that takes understanding as an intellectual achievement of good character into account.

Studying SP gives us insight into how scientific research should be conducted and promoted. Historic cases may be a good resource to show us what SP is, and they can suggest ways of how we should judge SP as it happens in real-time, rather than after something has been accepted for use and caused more problems than it solves. Studying SP will show us what we expect from scientists and scientific communities and how to make the process of determining SP more pertinent to current circumstances.

A better account of SP would help with the issue of which research to trust, and which research is worth pursuing. It would present us with a more informed picture about the research and the scientists and scientific communities who produce it. An account of SP that includes the intellectual virtues would include the ability to share and communicate in a manner that is understandable by a wide audience. Communication to the media would be circumspect, careful, and cautious, with acknowledgment of not only the benefits but the potential problems that the new advance could bring to light. Access to research would be easier to obtain, and would include more relevant information, like funding, sponsorship, and affiliations, and be prominently displayed. Replicated research would also be linked to the original research, whether that original experiment was successful or not. Scientists and the scientific community would be required to be more transparent when presenting new research.

A current topic of academic, as well as practical, concern is the *COVID-19* pandemic. Its study is an excellent opportunity to look at several aspects of SP over the past twenty-three months. The World Health Organisation (WHO) first identified *COVID-19*, on 31 December 2019, through a media statement placed on the Wuhan Municipal Health Commission's website. Subsequently, they started investigating the outbreak in Wuhan, seeking more information about the virus, its symptoms, and mortality rates (*Timeline*, n.d.). By March 2020 cases were being reported further away from the outbreak's origin point in Wuhan, China even though Wuhan had isolated itself from the rest of the world. On 11 March 2020, WHO declared *COVID-19* to be a global pandemic (*Timeline*, n.d.).

As cases of *COVID-19* and deaths from it continued to climb, some countries took immediate action to mitigate against its propagation by closing their international borders. They also put their populations into lockdown in the hope of curbing the spread of the virus. However other countries did little to prevent *COVID-19* from spreading and cases in these countries soared beyond control and resulted in millions of unnecessary deaths.

New Zealand confirmed its first case on 28 February 2020 (MOHNZ). On 20 March 2020 New Zealand closed its borders to non-residents and non-citizens, except for some categories, such as essential health staff. On 25 March 2020, the government raised the country's alert level to 4, where everybody had to remain at home unless shopping for groceries or other necessary items. This strategy worked to keep the *COVID-19* confined to border isolation facilities, and New Zealand was mostly free of community cases of *COVID-19* until the most recent outbreak of the delta variant which occurred on 16 August 2021.

The hope now is to distribute the *COVID-19* vaccine to as many people worldwide and hopefully wipe out the virus, as it will have nobody unimmunised to infect. At the time of writing, New Zealand's vaccination distribution has gone exceedingly well, reaching nearly 90% of its population being fully vaccinated by receiving two "jabs" of the Pfizer vaccine. WHO had originally estimated that it would be at least 18 months before a vaccine could be produced because of the research and experimentation required for a safe vaccine rollout. In March 2020 they issued "A coordinated global research roadmap: 2019 novel coronavirus" (*WHO: R&D Blueprint and COVID-19*), to outline a global research plan for making vaccines and possibly finding a cure. On 2 December 2020, the UK was the first country to approve the use of the new Pfizer-Biotech mRNA vaccine. On 3rd December, WHO released its first emergency use validation for the vaccine (WHO, 2020).

In less than one year, a novel virus spread widely across the globe and killed millions of people. It was quickly identified by modern science procedures; and, research in vaccines and cures for novel coronaviruses suddenly accelerated, becoming essential scientific research. Within eight months of the *COVID-19* outbreak being identified by WHO, a vaccine had been created and developed to mitigate against the virus. Thinking just of the progress that we have made with our knowledge, understanding, and appreciation of *COVID-19*, we have witnessed "SP" happen quickly in a microcosm of time. Under normal circumstances, we would not notice that SP had taken place until long after the triggering event had occurred, and sufficient time had passed for us to reflect upon important scientific discoveries. The example of the success of science to find a vaccine for the *COVID-19* virus quickly gives us an opportunity to observe SP in real-time.

How do we navigate SP in real-time? When we look at the philosophical accounts of SP, we notice that the usual examples employed by theoreticians are historical cases to classify what is considered SP and its contribution to change in scientific theories. To better appreciate how real-time SP may be contrasted with an historic view, we should review one account of SP that employs the historic view.

Thomas Kuhn uses "scientific revolutions" to explain SP through a "historic" lens (Kuhn, 1970). Looking at the history of science, he pinpoints certain times or events that clearly show SP, such as in physics: Einstein's theoretical improvements upon Newton's theories. Kuhn's structure of scientific revolutions shows how science evolves to solve problems or puzzles. That evolutionary account of SP is an informative part of viewing SP, but it does not necessarily help us when we want to see progress happening in real time. Looking at historical cases was a good start to looking at how we think about SP but such accounts of SP that rely upon historical cases need to expand and integrate with the most important aspect of SP which is, I think, enhanced understanding and the intellectual virtues that scientists and their communities possess.

We should broaden our investigation to include material that may not qualify as an example of SP but nevertheless may be an instance of progress generally. In *Bad Data* (2020), Peter Schryvers gives an example of progress that utilises statistical analysis and criminal psychology research data to create a crime predicting system. The program was designed by William Bratton and Jack Maple for use by the New York Police Department (NYPD) to reduce crime in city neighbourhoods. Jack Maple started by collecting statistics on crime in the New York Subway while working for the New York City Transit Police. He used the data collected to identify places and times on the subway where crime was most prevalent. That permitted officers to reduce the number of violent attacks, thefts, murders, drug sales, fare avoidance, and homeless people living in the subway.

This geographic based statistical work was supported by social psychology. George Kelling and James Q. Wilson, for example, introduced the "Broken Window" analogy where a broken window invites people to vandalise further. This analogy was based on an experiment performed by Philip Zimbardo who had left a broken-down car in a crime-free area of town. The car sat untouched for a week, despite its being abandoned. When he smashed one of the car's windows, it did not take long before the entire car was stripped of its parts. The people stripping the car were mostly middle-class white people. Zimbardo concluded that evidence of disorder led to more disorder and more serious crimes being committed.

The crime analysis system and social psychological findings led to the implementation of countermeasures by the NYPD. The techniques employed by Bratton and Maple reduced crime and homelessness on the NY subway dramatically between 1990 and 1995. In 1994, the newly elected Mayor of New York City, Rudy Giuliani, after having observed his success with NYC Transit Police, appointed Bratton NYPD Commissioner. Bratton and Maple continued to refine their system, which had the intended positive consequence of further reducing crime in New York City. Subsequently, many other police departments across the US adopted the system. Maple's system of analysing crime hot spots evolved into a sophisticated computer program called *CompStat*. *CompStat* began by measuring murder, forcible rape, burglary, aggravated assault, larceny, and motor vehicle theft rates. The program also collected the number of arrests an individual policeman had had in a lifetime and the outcomes of investigations of reported crime. As *CompStat* became more sophisticated, it began to collect information pertaining to misdemeanors, such as drug use, graffiti, and other forms of vandalism. What the program deciphered was in line with the "Broken Window" analogy Kelling and Wilson had propounded. *CompStat* was an impressive crime-fighting tool and spread to police forces across the USA and internationally (Schryvers, 2020, pp. 163 - 168).

This appears to be an example of good progress by advancing our ability to predict where crimes may occur and making sure that a police officer was present to reduce the probability that a crime would occur. Taking this on its own we see how effective the development of *CompStat* is for the reduction of crime. We should wholeheartedly endorse its being an example of progress.

With these two examples in mind, *COVID-19* and *CompStat*, we see how a study of SP may be motivated by current, practical problems. I will now turn to the four major accounts of SP that have emerged over the last century. I think all four accounts have useful aspects but none of them provide a full explanation of what SP is because they are focused too much on the historic view, like the one I outlined above by Kuhn. Given that we may explore current affairs, such as the *COVID-19* pandemic or the NYPD crime analysis, with an eye toward appreciating SP, we should do so. It is my contention that exploring SP *in real-time* will overcome some, if not all, of the challenges to each account of SP.

Literature Review

How to identify SP is a relatively new topic in philosophy, starting with Karl Popper's famous book, *The Logic of Scientific Discovery* (1960). In it, Popper proposed that SP was a function of getting closer to the truth even if the scientific claims of our best scientific theories were likely to be false. Popper's landmark book was followed up by Thomas Kuhn's, *The Structure of Scientific Revolutions* (1970), which proposed that SP occurred when new scientific theories were able to solve more problems and puzzles than preceding theories. Two more accounts have emerged; one, that SP occurs when there is an increase in accumulated knowledge (Bird, 2007), or two, SP occurs when there is an increase in understanding (Dellsén, 2016). As I will discuss later in this proposal there are advantages and disadvantages of all of these views. My primary aim in this thesis is to replace these deficient accounts with one that shows how critical intellectual virtues are for an account of SP. Now, I would like to give a brief outline of each account of SP. Also, to achieve my primary aim, I will have to give a brief outline of the virtue epistemological theory that is most relevant to my "understanding as intellectual virtue" account. It will provide a basis for looking at intellectual virtues and what character traits scientists and the scientific community should possess in order to ensure that SP is properly assessed and used.

1. The Semantic Approach of Scientific Progress

According to the *semantic approach,* science progresses when theories get closer to the truth. Sceptics have argued that our best scientific theory will likely turn out to be false. This has been shown throughout the history of science as a new theory replaces another theory, with the old theory either being modified or discarded as false. Given that this has been true of every previously held theory, this implies that our current theory will likely turn out to be false, too. New theories will be able to answer more questions than the previous ones, but a theory will never be true *simpliciter*. Philosophers have referred to this as the "pessimistic meta-induction" (Niiniluoto, 2014).

If the pessimistic meta-induction is correct, then the best we can hope for is scientific theories to get closer to the truth. Karl Popper proposed that science progresses as each new theory introduced is closer to the truth than the previous theory or theories. He proposed that each new theory was built on a prior theory, but that the new theory contained more true content than the old one and that the new theory gave us reason to set aside the false content of the old theory.

Popper first introduced his account of verisimilitude in his book, *The Logic of Scientific Discovery* (1960), and he expanded upon it in *Conjectures and Refutations* (1963/2002). The account takes verisimilitude to be the defining characteristic of SP. Each episode of SP can happen in great leaps, or in smaller increments, and can be classified as SP when a new scientific theory takes us closer to the truth than the theory it is meant to replace (Bird, 2007; Niiniluoto, 2019; Popper, 1960, 1965). Popper's definition of verisimilitude is:

> Assuming that the truth-content and the falsity-content of two theories t_1 and t_2 are comparable, we can say that t_2 is more closely similar to the truth, or corresponds better to the facts, than t_1, if and only if either

> a. the truth-content but not the falsity-content of t_2 exceeds that of t_1,
>
> b. the falsity-content of t_1, but not its truth-content, exceeds that of t_2. (Popper, 1965, p. 233)

Famously, Popper (1963/2002; 1972) proposed a definition of approximate truth that was intended to deliver on the intuition that subsequent scientific theories will include correct content of previous theories and exclude some of the incorrect content of antecedent theories:

> [a]n expression, A, is said to be closer to truth than B just in case A's truth content contains B's truth content, and B's falsity content contains A's falsity content, and one of these containments is proper. (Popper, 1965, p. 309)

In response, David Miller (1974) and Pavel Tichý (1974) showed that Popper's definition of approximate truth could not make any distinctions in truthlikeness among theories that included material that is strictly speaking false. A theory that is false can only be given a probability of being correct of "0." If two false theories with a probability of "0" are compared, then the probability of one of them being correct is "0." Therefore, false theories cannot be compared for their closeness to the truth. Wójcicki (1979; 1995a; 1995b), Psillos (1999), de Costa and French (2003), Millgram (2009), and Elgin (2017) continue to recommend other ways in which scientific truths might be better thought of as approximate or partial, such that half-truths or "the nearly true" may be captured by a range of alethic values.

Later, Graham Oddie (1981) tried to show that the semantic account is still an accurate accounting of SP, but he proposed to evaluate theories by breaking them down into their constituent parts and then comparing those parts of theories with one another. This would help identify those parts of scientific theories that have a higher degree of truth because they are more likely to be confirmed by scientific investigation, which would show a progression even if the theory as a whole was false.

Ilkka Niiniluoto (1987, 2014, 2019), likewise, developed Popper's original account to defend it against other theories of verisimilitude that began to emerge. Niiniluoto contends that SP is measured by how close to the truth a theory is compared with its predecessors. He does this by breaking down theories into their constituent parts which can then be compared with the previous theories constituent parts to work out which ones have a higher probability of being closer to the truth. This means that two potentially false theories can be compared, overcoming the problem that Popper had encountered with his definition of verisimilitude. So even if theories are false, they are still converging on the truth. Science, therefore, is always a work in progress so we will continually be updating our theories by pointing towards obtaining the truth.

Niiniluoto has defended his account of verisimilitude against Thomas Kuhn's account of "scientific revolutions" and, more recently, he has defended it against Alexander Bird's epistemic account of SP. Unsurprisingly, Niiniluoto believes that both Kuhn's functional account and Bird's epistemic account of SP fail (Niiniluoto, 2014). He argues that Kuhn's functional account has failed to adopt a means of measuring the distance a theory is from the truth. Kuhn's account is only concerned with the number of problems or puzzles that a new theory can solve. According to Niiniluoto, Kuhn's view cannot adequately determine the number of problems that each theory may be able to solve, thus making it nearly impossible to determine whether the solutions make headway in the scope of the problem or puzzle (Niiniluoto, 1987, 2014, 2019).

Niiniluoto criticises Bird's epistemic account by saying that the account cannot accommodate false theories. If we accept that progress is just a matter of accumulating knowledge and if most theories will probably turn out to be false, then it is difficult to see how accumulating knowledge of false theories is knowledge, if knowledge is justified true belief. An accumulation of false theories does not increase our knowledge so it cannot be a measure of SP, even if the new theories are thought to be justified. If we use the semantic account as a measure of SP, then we can say that what was true yesterday has now been shown to be false today and this new theory is setting us on course to converge upon the truth (Niiniluoto, 2014).

2. Functional Account of Scientific Progress

A second view of SP was introduced by Thomas Kuhn in his ground-breaking book *The Structure of Scientific Revolutions* (1970). Kuhn proposed that SP should be evaluated by a theory's ability to solve puzzles or problems. If a new theory solves more puzzles or problems than a previous theory, then the new theory shows there to be SP. He proposed that the scientific community itself would be the ones to judge whether a new paradigm solved more problems as they would be the ones using or discarding the new theory. If a new paradigm was accepted, then the old paradigm would be either subsumed by the new one or thrown away completely by the scientists using it, and this would be considered SP.

He treated advances in science as cyclical. The cycle started with "wild" science where scientists are working on similar problems but without any agreement on method or paradigms. Eventually a paradigm would emerge that most scientists would follow, and a period of "normal" science would ensue, where scientists expanded on or tested the paradigm. Eventually a crisis would arise where there were too many problems for the established normal science to solve, so the science would undergo a period of "revolution." Sometimes a crisis may be delayed due to outside pressures, such as funding for research. However, after much experimentation and reconfigurations, a new paradigm would emerge and ultimately be accepted after it has established itself. A "scientific revolution" occurs when a theory or explanation changes science in a way that alters the paradigm used in the normal period of science. There could be resistance to the new paradigm, but more scientists would adopt the new paradigm as it solved more problems, and another period of "normal" science would begin.

Kuhn thought that scientists did "normal" science most of the time and that revolutions in science were exceedingly rare. It was in these rare revolutions where science made its most progress. However, they were the moments where SP could be said to have been made as the new paradigm solved more problems than the previous one.

An example of paradigm change that he considered revolutionary in science was the transition from Copernicus to Newton and then Einstein. Each scientist improved on past theory and explanation which led to being able to solve more problems and puzzles in physics. Newton's introduction of gravity made it possible to calculate and solve many problems, like the motion of the planets around the sun in much greater detail. Einstein then went beyond Newton's theories and created theories about the world on a quantum level.

However, Kuhn also thought that new paradigms of normal science could not be compared with old ones because there is no common measure with which to assess them; he labelled this phenomenon "incommensurability" (Bird, 2018; Preston, 2008). For example, Einstein's theory of relativity deals with the world on a quantum level whereas Newton's theories deal with the relationship between large objects. Both theories are used by engineers today depending on what they want to calculate. It is the same with geometry. If you are trying to calculate angles on a sphere you need to use different geometry (Reimannian) to what you would use for a flat plain (Euclidean).[1] The theories cannot be compared as they deal with different aspects of the world, one abstract and one empirical.

Kuhn also looked at SP historically, identifying what theories and practices changed science and counted as progress. It is easy to look back in time and identify times of Kuhn's normal science and what he considered revolutions. Today as science is changing so quickly and new specialisations appearing, as new theories are introduced and investigated, it is more difficult to distinguish normal science from revolutionary science, and hence pseudoscience as well.

3. Epistemic Account of Scientific Progress

On the epistemic account, Alexander Bird writes:

> Science (or some particular scientific field or theory) makes progress precisely when it shows the accumulation of scientific knowledge; an episode in science is progressive when at the end of the episode there is more knowledge than at the beginning. (Bird, 2007)

Bird thinks that if the aim of science is to increase our knowledge, then the accumulation of knowledge should be the criteria we use to assess whether something is considered SP (Bird, 2007). He appears to think the idea of increasing knowledge is intuitive, so it does not need to be explained. Bird follows the traditional definition of knowledge as justified true belief.

Bird's epistemic approach should be contrasted with the semantic and the functional-internalist account. He thinks that an increase in truth or an increase in problem-solving may be necessary but insufficient for SP. He criticises the semantic account by showing how accumulating knowledge by default will take us closer to the truth, much like the semantic approach, since knowledge is justified *true* belief. So, if we support any account of SP, it should be the epistemic approach. He criticises Kuhn's problem-solving model to assess whether the new theory is an improvement on the old theory and points out it is hard to establish how many problems or puzzles a new theory solves unless you define "problems" and "puzzles."

[1] It should be noted that within the history of philosophy a debate over the relevance of Kant's transcendental view in the *Critique of Pure Reason* (1787/1998) originated from his not distinguishing between pure and applied geometry, an important distinction to show that abstract mathematical structures may be used as a means of depicting the empirical world. Whilst some scholars have supported that Kant's dependence upon Euclidean space should not discount the importance of his theory (*cf.* Fernández 2004), others have suggested that we cannot learn much from Kant because of the discovery of Reimannian geometry (*cf.* Helmholtz 1977).

One point of frustration with Bird's account is his spending more time showing why the semantic and functional approaches are inadequate accounts of SP, instead of explaining exactly what kind of "knowledge" is being accumulated. On the traditional account knowledge is justified true belief; however, in light of Gettier counterexamples where you can have a justified true belief luckily, the epistemic approach will need to define knowledge more precisely (Niiniluoto, 2014).

Bird does concede that most theories will eventually be found to be incorrect and end up being declared false when a new theory is discovered to our knowledge. By choosing to use accumulated knowledge as a measure of SP it means that old theories now considered false remain in our knowledge base because we now know that that theory is false. We now have evidence that the old theory is false and therefore hold a justified true belief about the theory.

Seungbae Park agrees with the epistemic account but defends the Means-end Theory (ME) to contend with deficiencies that appear for the epistemic account (Park, 2017). This is where an event or incident contributes to or promotes an episode that is considered an advance in SP, they become the means by which progress is made. This then captures all the small incidences which aren't seen as major changes in our knowledge, but all contribute to increasing our knowledge about the natural world.

Park also offers a defence of knowledge accumulation against the concept of increased understanding (Park, 2017, 2020). He supports Bird's knowledge accumulation theory and defends the ME theory against Dellsén's challenges that SP only occurs when there is an increase of understanding a theory. Knowledge and understanding on this account are separable, and they should not be seen as connected. Dellsén prefers the increase in understanding, the noetic account, as he believes that accumulating knowledge without understanding would not be a legitimate case of SP (Dellsén, 2016).

4. Noetic Account of Scientific Progress

The relatively new fourth account has it that SP is a matter of an increase in understanding (Dellsén, 2016). Dellsén argues that an increase in understanding is different from an increase in knowledge. He explains that someone can have knowledge but not necessarily understand it. People can also use knowledge to build something without actually understanding how it works. Dellsén takes "understanding" as applied in the concept of SP to be used in a stipulated sense,

> an episode in science is progressive precisely when scientists grasp how to correctly explain or predict more aspects of the world at the end of the episode than at the beginning. I will refer to this as the *noetic account* of scientific progress. (Dellsén, 2018)

So, with this definition we can already possess knowledge about an aspect of the world, for example, trees have green leaves, but an advance in science would be when we could explain why trees have green leaves. Just having the knowledge that leaves are usually green does not tell us anything about how or why the plant has green leaves.

Understanding for Dellsén is more than just being able to explain something, it can also be an improvement in a theory's predictive power. This is not usually a feature of understanding used by others. Other opinions are that understanding is a species of knowledge itself (Bird, 2007; Dellsén, 2018).

He argues that the accumulation of knowledge for knowledge's sake does not mean SP has taken place. For example, you could count all the grains of sand on a beach which would give you knowledge, but it does not increase your understanding of the world in any way. Even if you were to count the grains of sand on every beach in the world to compare them it would be difficult to understand how this would be of benefit to anyone in light of SP. (It might help environmental planning committees with resource management but still would not be classified as SP.) Under Bird and Park's version of knowledge they would argue counting the grains of sand may be an increase in knowledge, in terms of collecting data about a phenomenon, but subsequently would not amount to any form of understanding (Bird, 2007). Dellsén is not against the need to collect data, as it is required, but the mere collection of data is not SP (Dellsén, 2018).

Dellsén also thinks that increasing understanding does not require justified true belief in the way that the accumulation of knowledge does. He considers that scientists do not need to hold a true belief about what they are working on because most theories end up being false, or incorrect in some way, and scientists are aware they are working with an approximation or the "best" current theory. Also, history shows that a lot of scientists were not justified in believing that their theory was true until it could be proved at a later date, for example, Einstein and Brownian motion, and Wegener's theory of continental drift (Park, 2017; Dellsén, 2018). Dellsén also feels that the Noetic account can explain minimalist idealisations, pragmatic virtues and epistemic value more easily than the epistemic account.

Although Dellsén captures some interesting aspects of SP as increased understanding I feel some of his arguments were a bit confused and missed important aspects of having a noetic model. He makes some good points about the inadequacies of the other accounts which a noetic account would help solve but the other accounts also have points which need to be incorporated in an improved account of increased understanding.

5. Virtue Epistemology

Now that I have summarised the four accounts of SP currently on offer, I would like to give a brief summary of virtue epistemology, and one theory that will play a vital role in my view. Intellectual virtue was first introduced by Ernest Sosa in his landmark essay: "The Raft and the Pyramid" (Sosa, 1980). In it, he argued that the concept of intellectual virtue would resolve the debate between the foundationalists and coherentists in analytic epistemology. It was through his pioneering work that the literature on virtue epistemology began to take shape (Battaly, 2008).

Whereas analytic epistemology largely focused upon true beliefs and their justification, virtue epistemology has as its target the intellectual character of agents and communities in epistemic evaluations. Virtue epistemology differs from virtue ethics, which is focused on the moral virtues, by focusing on whether agents and communities have cultivated the intellectual virtues in such a way so as to promote knowledge. Whether the agent acted virtuously or not matters most for knowing, so the virtue epistemologist determines the outcomes of action in terms of the agent's properties.

There are two different positions within virtue epistemology: *virtue reliabilism*, which focuses on the agents' stable and reliable faculties, such as the senses, vision, hearing, intelligence, and memory, to understand intellectual virtues (Goldman, 2012; Greco, 2007; Sosa, 2007); and *virtue responsibilism*, which has it that intellectual virtues are features or properties of an agent that we have to work for and develop over time. A virtue responsibilist contends that the intellectual virtues are the result of cultivating the appropriate virtuous character traits, such as open-mindedness, intellectual courage, intellectual autonomy, conscientiousness, and intellectual humility (Battaly, 2008; Code, 1984; Hookway, 2003; Montmarquet, 1992; Zagzebski, 1996).

The characteristics and traits required to be intellectually virtuous appear to me to be the essential qualities that we should expect our scientists (individually) and scientific communities (collectively) to possess. Scientists are either disposed naturally to behave in ways consistent with these intellectual virtues or they need to be taught to develop them over time. I would argue that most of the character traits included under the intellectual virtues may be a characterological disposition of some scientists but that all scientists should undertake to develop these characteristics and traits fully. The scientific communities to which scientists belong should reinforce these virtues as the community also strives to attain the highest level of behaving consistently with the intellectual virtues.

With all the complications of conducting unbiased, independent research, and then publishing it, making sure it is understood, and used correctly is a huge expectation of scientists and their communities. However, if they were to develop intellectual virtues in association with their intellectual pursuit of understanding, they may be able to avoid most of the pitfalls currently attributed to research and its damaging effects in the public domain.

Statement of Research Questions

Introduction to Research Questions

From our discussion of different accounts of SP, we can appreciate that there is a difference between knowledge and understanding, so much of my contribution to the field will be to address how understanding is non-factive but that it contributes to a better conception of SP.

The primary question driving the research in my thesis is: *Should scientific progress as understanding be informed by scientists' cultivation of intellectual virtues?* If we begin with the assumption that I can have knowledge of something but not necessarily understand it and the main impetus for doing science is to enlighten us about the world around us, then we have to revise our picture of SP as a matter of understanding rather than the accumulation of knowledge. Let me use a toy example to clarify what I mean here. If I want to build a radio, I could buy a book that would give me the instructions for how to build one. I would need to understand how to read the book and how to follow instructions in addition to knowing what a book is and what instructions are, but I would not necessarily need to understand how the different parts of the radio work together or how the component parts of a radio convert waves into sound. So, if I were a radio scientist looking to create a radio with clearer sound than its competitors, I would need to understand what the composition of the best radios are and how those radios are able to convert radio waves into sound. To do that I would have to be an expert in radio engineering and radio wave science. For me to facilitate better understanding in these areas, I would have to be open-minded, conscientious, and humble enough to realise that I am not already an expert. In this sense, my character must be disposed in a certain way to be a better radio scientist. Once I understood how the radio worked then I could start changing certain elements of the radio to achieve my goal of a clearer sound being produced.

This is an example of understanding as a matter of intellectual virtue. It is largely built on knowledge, or what you have learnt over time. This would be an example of high-grade knowledge (Battaly, 2008). However, you can accumulate a lot of knowledge in a lifetime, but you may not understand all that knowledge. I think that high-grade knowledge and virtue-responsibilism should be included in the account of SP as understanding when understanding is best understood as an intellectual virtue. It is not enough to just accumulate knowledge if you do not have a full understanding of it, and one's understanding is founded in one's being intellectually virtuous. Scientists are only human, and they likely possess virtues and vices as everyone else does. Still, it is incumbent upon scientists to cultivate an epistemic repertoire that is intellectually virtuous for science to progress. Despite this, we must ask how do we determine what virtues a scientist or scientific community should possess so that we can then assess what progress they claim to be making is SP and good?

It is my intention to look at several questions that examine our concepts of knowledge and understanding in relation to SP. I will look at what is required for intellectual understanding as a virtue, and what characteristics it would entail. This will lead me to a deeper account of SP and its obligations.

1. What is the connection between understanding and knowledge?

Given the above story concerning radios, understanding appears to be a crucial part of progress, particularly specialised forms of progress like SP. Despite this, the question is **how dependent understanding is on knowledge?** One may be tempted to say that you cannot understand something of which you have no knowledge. So, some philosophers would say understanding is a species of knowledge (*cf.* Grimm, 2006). However, knowledge is also supposed to be factual, i.e. true or correct, but as the verisimilitude account of SP shows truth is a question of degree not kind, what is true today may be further from the truth tomorrow. To move to an account that includes intellectual understanding we would be able to factor in this phenomenon.

We usually start with some knowledge, i.e., justified true beliefs, about some phenomena, at least on a sensory level, but the more complex the target of knowledge is, the greater the likelihood is that we do not fully understand it. However, our ignorance of understanding the phenomena leads us to ask more questions about it, and we accumulate more knowledge (curiosity). Eventually we gain enough knowledge about the phenomena that we understand the phenomena. This may then give rise to new questions that we want answers to, so the process continues. But is it correct to call the information we have discovered or collected "knowledge"? Does it only become knowledge once we understand it? When does it become an accepted fact? There is an unceasing advance, with each increase in understanding adding to knowledge; however, an increase in knowledge alone does not always mean an increase in understanding.

We can collect enormous amounts of data but unless we understand what we are looking for or want to achieve the data is just accumulated knowledge, which does not necessarily contribute to SP. Accumulating knowledge must be accompanied by understanding for SP to occur. Think about the ancient discovery of lighting a fire by striking a flint stone with an iron pyrite stone. This was a kind of progress but purely a chance discovery and was thousands of years before science could explain why striking flint with iron caused a spark. So, we could say that the discoverers had "knowledge" of what the two rocks could do when struck together, but we would not ascribe to them any form of understanding. Similarly, the mere accumulation of knowledge in Alexander Bird's sense would be quite different from understanding.

2. Does the theory fit into the larger narrative?

In my view, SP includes an increase in understanding but in a way that is more developed than what Dellsén promotes. Understanding is not a species of knowledge but instead knowledge is a part of understanding for the purposes of assessing SP. The idea of measuring understanding as an intellectual virtue falls short because we would be attempting to measure something that cannot be quantified. Truth, knowledge, and understanding cannot be measured by a ruler or any numbering system. Using probability to try and work out whether something is probably better than something else fails as a measurement. Adding intellectual virtues and the desirable characteristics and traits of scientists and the scientific community may help with the measurement problem. Rather than thinking strictly in terms of quantifiable progress we may need to think in terms of qualitative change: what does this research change and has it improved the world, is it a beneficial change or not?

Understanding also needs to be expanded to include how new theories, discoveries, and methods fit into the narrative of science. Rather than just looking at one piece in a puzzle, any change needs to be viewed holistically, not just individually. This would include collaborating with other scientific disciplines to develop a holistic view of what the new research affects and impacts beyond its own sphere. Scientists not only need to know how something works but also whether it is appropriate to use. What might seem a good theory in one scientific context may be considered damaging in another discipline. That means scientists will have to be trained to act upon well-developed virtuous dispositions of what is expected in scientific practice and theorising, and in working together in various different scientific communities.

3. Should new puzzles arise from old ones?

Understanding more about our world solves many problems and puzzles but it also creates new problems and puzzles. It would seem the more we know, we realise that we have far more to learn than can ever be accomplished in one lifetime (intellectual humility). This has led science to become hyper-specialised. The pattern of scientific discovery that Kuhn discussed was how it appeared looking at scientific development retrospectively. During times when science was "normal", it was easier to tell if something was a great discovery or not. Now, new discoveries are made so quickly that new branches of science appear almost immediately. Some branches of science are "normal" science, taking the new paradigm and expanding on it, or the branch could be scientists building on it to find new paradigms. One is trying to understand how the new branch fits with the established paradigm and the other is trying to find out why the paradigm works if there isn't something even better.

Let's return to the earlier example of the NYPD *CompStat* program. While it was at first a very effective tool for aiding police in fighting crime, its use eventually expanded into areas that it was not intended for, with detrimental and dramatic effect. First, city officials used *CompStat* data to set "arrest" goals for police commanders and their officers. Patrol officers were expected to make a certain number of arrests per shift. To achieve these targets, they started arresting people, especially coloured or ethnic minorities, on "suspicion" of intending to commit a crime.

Second, police had reduced crime to the point where there could be no statistically significant difference in reducing it any further. The deployment of *CompStat* effectively undid a lot of the good work the police had been doing to reduce crime since the program also did not take into consideration events that could not be counted. For example, having a police officer present in a crime hotspot would often reduce the amount of crime because of a visible police presence. Since it is not possible to record an event that has not happened, there was no means of recording a crime that had been prevented by the police's presence. Relatedly, as crime went down, it became more difficult for police to hit their assigned targets. The *CompStat* program did not adjust targets based upon the reduction of crime that had already taken place. As the politicians were always promising "less" crime, more and more pressure was put on the police force to show how the Mayor had upheld his promise to "decrease crime".

Finally, police officers actively discouraged victims of serious crimes, such as theft, assault, and rape, not to file charges. Sometimes, officers would downgrade the severity of the reported incident. Since police started using *CompStat* goals to evaluate individual police officer's job performance and since it became more and more difficult for police officers to meet these targets, morale in the police began to decline.

Eventually Adrian Schoolcraft, an NYPD police officer, managed to expose the way the police were being instructed to work. Lawsuits were filed against the City of New York, by the Centre for Constitutional Rights, for breach of rights in relation to the "stop-and-frisks" order. The court ruled that the NYPD had violated the Constitution, and also

> It had perverted the goal of using stop-and frisk against "the right people, the right time, the right location" into a tool of discrimination against poor people of colour. (Schryvers, 2020)

An investigation into Schoolcraft's claims resulted in a report which stated,

> When viewed in their totality, a disturbing pattern is prevalent and gives credence to the allegation that crimes are being improperly reported in order to avoid index crime classification. This is indicative of a concerted effort to deliberately under-report crime in the 81st Precinct. (Schryvers, 2020)

So, is this an example of good SP? *CompStat* undoubtedly reduced crime in the community, but in doing so it had simultaneously created some unforeseen problems for the police and the public. If we merely focus upon solving problems and puzzles as a measure of progress, then the introduction of *CompStat* may be a good example of progress. Yet, if some advancement creates more problems than it solves, then surely the proposed advancement is an example of a regress and not progress.

While the ability of theories and methods to solve problems and puzzles can be used as an indicator of SP, it takes a fuller and more complete understanding of the whole picture to really judge the progress that could be made (open-mindedness). Scientists and scientific communities need to monitor what their research is being used for and if it is an appropriate use. The men who developed *CompStat* were not scientists, but they used statistical methods and a small piece of psychology research about communities without taking into account any of the other available research. Some subdisciplines of psychology research, like social psychology, have a history of finding that original, novel research was incorrect or not replicable. Scientists and the scientific community need to monitor more closely what their research is used for instead of publishing something and moving on to the next problem. I see this as an intellectual virtue of responsibility, taking care that one's research is not manipulated or exploited by people for their own advantage.

4. Should science be subject to resource constraints and restrictions?

Anything that seems like an improvement, that increases our understanding of some phenomena, or that allows us to build better technology appears to us as SP. **Sometimes however it is not a matter of the best paradigm winning but that which has the best financial backing and promotion, the paradigm with the best public relations!** Science seems to have become the new Wild West frontier with everything available to be used and researched by science, but the Sheriff has left town. If you have the scientific research to back your claims, or even just raise a reasonable doubt in someone else's research, there is nothing in place to prevent you from doing so. Even being peer reviewed has its limitations. If you have the means to promote your theory over others, either through financial backing, prestige bias, academic influence, manipulating societal thinking, then your theory may succeed where other better theories are ignored at best and ridiculed at worst.

A good case of a scientist who had a great deal of understanding, not only of how his new theories about electricity worked, but also a great understanding about their possible effect on people and the environment, was Nikola Tesla. Sadly, however, he was terrible at public relations, marketing and advertising his scientific advances and inventions. He is an example of a brilliant scientist whose many discoveries are behind much of the technology we use today, but he also kept some discoveries to himself so that they wouldn't be used to harm humanity. Although famous in his own era, at the end of his life he was considered to be insane, and for decades after he died, he almost disappeared from history (Carlson, 2013).

Unfortunately, even though he was a brilliant and clever individual, Tesla did not understand economics and the power of public relations. He was reliant on funding for his research. Thomas Edison was given the credit for the invention of electricity, although he had in fact used Tesla's work on direct current (DC). Edison was renowned for having great skills in public relations as well as a lot of money to pursue his goals. History shows how Edison used his wealth and campaigns to try and turn the public against Tesla and his invention, alternating current (AC) electricity, so that they would use Edison's DC electricity for the national grid. Edison was responsible for the invention of the electric chair in a bid to show that AC electricity was too dangerous to use.

Today Tesla is being recognised as a leader of innovation, and it is estimated he is personally responsible for more than 80% of the technology that we use today. Our national electricity grid, most electronics, remote controls, fluorescent and neon lights, wireless transmission, mobile phones, the AC motor, computers and the internet, to name a few, were all either invented or predicted by Tesla. Yet because of his altruistic nature toward his fellow man, and his desire to provide energy for free, he was unable to find financial backers and bring some of his inventions to life.

In terms of the progress of science, how does Tesla fit in? Would he have thought his inventions brought mankind closer to the "truth", solved puzzles and problems, or added to accumulated knowledge or understanding? He was concerned that his inventions might be used for war rather than peace and purposely did not release some of his more daring inventions, such as a device that could bring down buildings using vibration. However, for decades people have been looking at Tesla's patents and working out how he thought wireless energy could be supplied to mankind for free. Many of these people have made working models of wireless power transmission systems that could supply free energy, and quantum physics has caught up and verified this technology is possible. However, until recently the technology failed to receive financial backing or make it into the conventional world of electricity.

Free electricity generators produce no carbon emissions so any technology based on Tesla's ideas would help the Earth environmentally; we could reduce our carbon emissions overnight. We wouldn't need power stations; companies would have access to environmentally friendly energy that could replace the burning of fossil fuels. Although impugned by the fossil fuel industry, these theories are being proven again and again using sound scientific methods of experimentation. So, what is stopping these inventions from making it onto the market? Finance plays an enormous part; it is difficult to find someone to back you financially when your invention will not produce any revenue for the sponsor. So then why doesn't the government step in and seize this opportunity to not only provide free energy for their people but also clean up the planet at the same time? Once again, look at how much revenue is generated by the tax collected for the sale of energy, the government is not really motivated to move to an untaxed commodity.

So, was Tesla's inability to attract funding a fault of his or a barrier erected by a capitalist society based on fossil fuels? One could argue that Tesla had some intellectually virtuous characteristics and traits but failed in some areas that prevented him from realising his scientific ambitions. One could also argue that Tesla was let down by the scientific community as they failed to support his ideas and were not intellectually virtuous with regard to the characteristics of intellectual co-operation, intellectual open-mindedness or intellectual courage.

Funding continues to be a problem when it comes to SP as governments or corporations providing the funding often have their own agendas that they want certain research for. This can result in scientists finding the results they were funded to find and not independent, unbiased research. Once again it calls for scientists and scientific communities to put more emphasis on this problem, especially in terms of SP, and intellectual virtues would play a large part in solving this problem.

5. What account best eliminates bias and interference?

Tesla's example with battling public relation campaigns and lack of funding is a story that echoes through history with changing characters. The enlightenment period saw scientists trying to break away from religion and establish itself as an independent domain based on empirical evidence. This was a big break away from the "scientific" truth as the church presented it to the general population, for what the world was really like. However, it would appear that science is not as independent as it would like to think, and this has made defining SP even more difficult. When funding from industry and government comes into play it would seem that science has merely changed the hand holding the leash.

If we look back at the last century, we uncover cases where science has been used to muddy the waters of the public perception of many crucial areas and problems being faced today. We can look at the ongoing debate about what the cause of climate change is, whether *COVID-19* was manufactured in a lab, about what the causes of cancer and other serious diseases are, about what is healthy to eat. The list could go on, but in any area that involves industry and large amounts of money, science is in danger of being used inaccurately to advise the public on the best course forward.

The nature of science is that the best theory or practice is only the best theory or practice until our knowledge and understanding expand and we have better theories and problem-solving capabilities. This is hard to maintain when there are other interests at work that try to manipulate science for their own agenda.

Prestige bias plays a big part in identifying SP. Scientists that are well known tend to gather more prestige than other lesser-known scientists. They tend to get published more often and will be cited more because of their name and not necessarily the research. Other collaborators who are not as well-known often get overlooked in a piece of research when they share the stage with a well-known person even though they may have done the majority of the work (Cranford, 2020).

Misuse of science: The tobacco industry used science to prevent laws prohibiting smoking being introduced in the USA. Even though research had been done that showed nicotine tar caused carcinogenic tumours, in the lung, on the face, etc, they found studies that also showed that when tested nicotine tar had not caused any tumours or cancer (O'Connor & Weatherall, 2019). This is definitely a case of scientific research being used incorrectly. There are many reasons why research results might not be replicable in different studies. This could be from the methods used, time periods, mistakes made in procedures, different animals used, etc. However, when selected research is compared many of these factors are not considered, and the research being compared is like trying to match oranges and apples. Most of the public do not look at the actual research because they do not understand the presentation of the facts and figures and the scientific language most research is written up in. Only another well-trained scientist in the same area could understand the research in its entirety, but anyone who conducts research has the ability to read through the method and conclusion to come to some understanding of what was done and what was achieved.

With prestige comes *the Matthews Effect*. The Matthews Effect is the situation where those who have notability in a certain area tend to reap more standing than those less well known in the same discipline (Merton, 1968). To put it in celebrity terms, it is like going to a movie because Tom Hanks stars in it, because Tom Hanks always acts in the best movies. The more successful movies he acts in results in his being offered the best scripts. The more he gets offered good characters to portray in successful films, the more his prestige keeps rising, to the point where we do not even ask what the movie is going to be about, we just go because we heard Tom Hanks was acting in it. Other less well-known actors may have been just as good in the part but the people producing the movie know that they will make more money if they can say Tom Hanks is in the movie. This also means Tom Hanks is free to choose whatever role he feels like doing. A character may come up in a movie that he really likes but the producers do not have a big budget so he can afford to take less money to do the movie. This helps the producers achieve more prestige, if he does a good job, as the film will get noticed, and possibly win awards, even though it was low budget. Being noticed and winning awards at the Oscars will increase all their potential earnings in the future.

Confirmation bias and negligence: If scientific research can be selectively chosen to present to the public, by big industry or government, if it is also selectively published or acknowledged by peers, within universities or other organisations according to the scientist's prestige, then how are we able to form an accurate picture of SP. If the nature of science is actually different to what we think it is, then how do we measure progress? If science can only ever be the "best theory" available at the time, there is no way of judging whether something may be an improvement or not. The history of science is littered with theories that have been shown to be incorrect, like phlogiston (Mauskop, 2002), but it also is full of theories that were discarded as pseudoscience and then turned out to be true, as in the discovery of doctors washing their hands between doing autopsies and delivering babies (Nuland, 2004). It would seem as science branches out there are more and more competing theories and the winners seem to be those who get the most media coverage.

6. What account of scientific progress engenders trust in the public?

Trust is a big part of a police officer's job if they are to be successful in preventing crime. The introduction of *CompStat*, while at first very good, had a dramatic detrimental effect on the police and the public. The police lost the trust of the people they were charged with protecting and serving. On top of the public becoming increasingly distrustful of the police force, the police were at risk from attack by an increasingly hostile and distrustful public. This is just one example of perhaps many advancements, thought of as progress at the moment of inception, but only later to have been discovered to have seriously detrimental consequences. This is due to many causes which would be highlighted in an increased awareness of what SP entails, a more fully expanded understanding combined with intellectual virtues.

Another example of trust arises from the question over vaccinations. Andrew Wakefield's research showing that MMR vaccinations cause autism in children has been well and truly debunked (Fiona et al., 2011). Despite this, people still fear having their children vaccinated. If people do not trust the science that shows the MMR vaccine is safe and will protect children from much worse, like measles and mumps, what is science doing wrong? Vaccines are a step forward in SP, yet people are still afraid of them. Is it because they have heard the autism theory or do they just not understand how the vaccines work? Some people may look at vaccines the way we now look at the old practice of bloodletting to cure illness. Or vaccinations amount to the equivalent of magic and witchcraft, a pseudoscience not to be believed. The fact that there are people who will not get vaccinated or vaccinate their children because they do not feel they can trust SP shows there is a problem to be addressed.

We need to change the way we look at SP so that we can have a clearer idea of what is happening in the scientific world, and what is changing. What was once considered pseudoscience now has solid research to show that ideas we once thought ridiculous or wacky are actually genuine experiences and have scientific theories to explain them. However, we still need some way to determine the difference. Scientific progress is accelerating and as the different disciplines begin to understand the underlying nature of the universe, we are going to have to change many of our current scientific beliefs.

Let's return to the example of the new *COVID-19* vaccinations, which is relevant to the issue concerning the communication of SP to the general public. The *COVID-19* vaccinations became available very quickly after the outbreak of the virus began in December 2019. Because of its wide availability so soon after the start of the outbreak, some people falsely believe that the vaccine is still in an "experimental stage" (See "Deputy PM: No Room for Threats of Violence Over Vaccinations" https://www.rnz.co.nz/audio/player?audio_id=2018819092). This shows how misinformation may proliferate given how science progresses in real time. It only appears to us non-scientists that the vaccine has rolled out quickly, or even *too* quickly. In fact, the story of the discovery and creation of the *COVID-19* vaccination started 50 years ago in a university laboratory, and the research was almost abandoned as it was not producing any practicable results. So what looks like real time advancements is built on a long history.

Even though the vaccine was developed over time, its release to the general public coincided with the toll that *COVID-19* was taking on the worldwide population. The vaccine has shown to be effective against *COVID-19*. Some people believe the vaccine to be ineffective because the Delta variant can still be caught by vaccinated people in what has been called "breakthrough" cases. However, that is again a case of misinformation. People who have received the vaccine (even just one dose) are less likely to suffer serious complications from the coronavirus.

CompStat and the *COVID-19* vaccination show progress in two different lights. *CompStat* advanced quickly through achieving results quickly, even though the results in the long term ended up being detrimental. *COVID-19* vaccinations were made through slow plodding progress with the results not reaching fruition until there was a real need for it. The money being made by pharmaceutical companies who are making billions from selling the vaccine, even at a reduced cost, has made a lot of people wary of the vaccine, even though the results so far are excellent at preventing deaths.

7. Is hyperspecialization good for the sciences?

CompStat is also an example of scientific hyperspecialization. Science evolves by solving problems, but as it does so new, more narrowly conceived problems arise. This leads to scientific disciplines splitting into smaller and smaller parts to concentrate on particular parts of the problem. The crime problem in New York City had many variables affecting the situation, the NYPD did not take all of these into their understanding of the problems. The creators of the *CompStat* program did not consider other psychological aspects, such as the effect of fear and distrust of the police by the public, the people they were there to protect, would have on the community as a whole. A true understanding of the problem and the different aspects needed to include many scientific disciplines to make real progress in the reduction of crime and making the community feel safe (Schryvers, 2020, p.163-198).

As science splits into smaller divisions, it creates more experts, experts who may have considerable knowledge in one small area. For example, biosecurity comes under the science of biology, but within biosecurity itself there are subdivisions which a scientist can specialise further, such as university, corporate or government laboratories, all have their own versions of biosecurity. Then there is biosecurity at the borders, hazardous goods transportation, local biosecurity, international biosecurity, just to name a few. Usually, a scientist will have some idea of what might be involved in other areas of biosecurity, but they will only be an "expert" in one particular biosecurity area.

We need an expert for just about every domain in our lives. In some cases, it is not hard to work out what sort of expert you need, such as when you build a house. Usually, you will approach a reputable builder whose expertise has been certified by the building industries association. The building association has experts who guarantee that the work being carried out by your certified builder will be up to a certain standard. This is the same for everyone who works on your house, plumbers, electricians, concrete layers, plasterers, painters, kitchen makers and installers, etc. All these people are experts in their own trade or are being supervised by an expert in that trade. However, they are only an expert in their own particular trade, you would not expect to go to your partially built house and find an electrician trying to install the plumbing.

Doctors and nurses must be registered by the appropriate experts in their own professions so they can practice medicine. But what happens when your doctor comes across something they cannot treat themselves? Usually, they send you on to another expert who has specialised in a smaller area of medicine. So, if your doctor thinks you have a heart problem, he will send you to a cardiologist. All of these specialists or experts are supposed to keep up to date with the latest research so that they can offer the best advice and treatments to patients.

We are led to believe that these specialists are experts in their field, but we also know that there are some doctors or surgeons who are better than others. We often seek advice from other people who have the same disease or issue we have as to who they would recommend to go and see. Some people do not ask, they just trust that the surgeon they are sent to will be able to do what is needed, some people like to ask friends and today you can search Google for information about your surgeon to get basic information to help you make your choice. However, at the end of the day you have to trust the surgeon you have chosen, or you will never have the operation you need. Comparing doctors however can be difficult because even though you might have the same condition as someone else you may be prescribed different medication. This may not be because one medication is better than another, but people react differently to different medications and what might be suitable for your friend may not be suitable for you.

8. What does understanding as intellectual virtue have to do with wisdom?

There is one other quality that SP as understanding as intellectual virtue should include and that is wisdom (Ryan, 1999). So, at least one question I will have to contend with in the thesis is: *with respect to scientific progress, what is wisdom?* For science, wisdom appears to be a combination of knowledge, understanding, and responsibility. Here is a simple but profound example. When the washing machine was invented, nobody looked beyond the convenience of such an amenity. Nobody thought of the detrimental impact that the washing machine might have on the environment. The machine uses toxic chemicals, consumes natural resources, and employs copious amounts of water with each use. The focus of manufacturers has been on health and cleanliness, which has now reached the stage that households are virtually 99.9% germ free. Today with *COVID-19* we do have to be more vigilant against bringing germs into the house. Still, we have to evaluate not only the benefits such a convenience will bring with it but the consequences that follow from them too. In this sense, SP as understanding is possible only when we have a more balanced view of the experimental results. It cannot always be about convenience or our pleasure.

Scientific progress needs to be re-evaluated in terms of understanding and the wisdom behind the progress. If all we have achieved is a greater ability to destroy ourselves and our planet then is it SP or a vain attempt to say we understand what we are doing?

9. What is gatekeeping and is it appropriate?

There may be a few people in the world who can sing exquisitely, pick up an instrument and play it at a professional level, write their own music, create, and conduct musical compositions, and achieve the label of musical genius. Most people are content with choosing one area of music to excel in, because to be the top of an area needs hours every day of practice and dedication. So, while they may be proficient in other areas of music, they usually have one aspect, like singing, piano, violin, that they specialised in to become an expert and well-known musician.

An Orchestra contains many different instruments, but each player understands the basic language they all speak, music. They can all take the music sheets and read their part amongst the many others. They can also rely on the Conductor of the orchestra to bring them in on time and keep everyone playing at the correct time, speed, intensity, and volume. They do not need to know how every instrument in the orchestra is played, they just need to be proficient in their own specialty and be able to read the music and follow the conductor. The conductor does not necessarily need to excel in any particular instrument, but he needs to be able to coordinate all the different musicians and instruments so that they produce a beautiful symphony that is coherent to the listener. A good conductor will be able to take the written composition, and use the orchestra, to attain the desired effect on the listener that the composer intended.

Science is like an orchestra, but at the moment it seems it is lacking the essential conductor. As science becomes even more hyperspecialized, the different subdisciplines within science either start ignoring other parts or cannot even comprehend what other subdisciplines are doing, even if they can speak a common language. Scientists cannot necessarily talk across subdisciplines because each subdiscipline uses specialised vocabulary. Sure, they may be familiar with the basic language of conducting scientific research but that may not be sufficient to talk across subdisciplines. This results in the orchestra getting woefully out of step, incoherent and unmelodious, and this is occurring in science.

For SP to be recognised properly the whole of the narrative needs to be viewed using understanding. However, I am not talking about understanding at the instrument level but at the level of the conductor. The conductor needs to know how each piece of the orchestra fits together and bring things together that apart would sound dreadful. In science a conductor would be gathering up all the strands of different disciplines and co-ordinating them, and working out what was appropriate for continuing study. Sometimes the introduction of different instruments into a particular orchestra does not work, such as a guitar in a brass band. Other times introducing something completely unthought of can have extraordinary results. It is the responsibility of the conductor to have this understanding so they can bring the whole compositional piece together. But at what level of the scientific community should the conductor be placed? Should there be one conductor or many. Do we require the same intellectual virtues of everyone, for example, the scientists individually, or do we just insist that the scientific community and its leaders possess the necessary characteristics and traits of intellectual virtue?

Scientific progress should take some of the responsibility for what it has produced. Progress implies something good; you have progressed from a low ability to a higher ability. But what if we thought of SP differently? We do not want to go back to the witch doctor days, but we need to be more aware of what SP is doing and what needs we actually have. The battle of euthanasia for those who are dying in excruciating pain is the result of SP. Those against euthanasia stated it would be the start of a slippery slope allowing these people to choose their own death, as it would eventually start to include to people who were dying having to be euthanised whether they wanted to or not. However, the protesters do not realise the slippery slope started a long time ago when doctors learnt how to prolong people's lives, even though they were taking longer to die and often painfully and in undignified circumstances. SP needs to be reunited with wisdom and ethics. We need to find a way of making advances in science that bring to the world a more holistic view of how the world works and stop trying to break it down into ever smaller pieces. How big would the orchestra be if every musician specialised in one note within one piece of music?

The music the orchestra is playing also needs to mean something to the audience. The audience needs to hear it in a context they understand to be able to judge whether they like the music or not. Sometimes the music is part of the story, with actors, pictures or words helping to convey the story, other times the composer is telling a story just using the music itself. We all have our favourite music genres and those we dislike but music has a big place in the world like science does. Just as we do not like some genres of music for different reasons, we can dislike certain aspects of SP. This is where different disciplines from science may be able to help. The arts and social sciences have their own knowledge and understanding and can tell us a great deal about ourselves and the world we live in. Taking these into consideration gives us the context we need to view progress, just as we need context to understand and enjoy different types of music.

So, while it might be nice, as philosophers, to work out how to judge SP and limit our perspective to cognitive improvement only there are many other variables that should be included. This will make it far more difficult to judge what is SP when we include, economics, politics, education, philosophy, sociology, psychology, and history. However, if we want to classify SP as an increase in understanding we cannot limit understanding to a mere cognitive perspective. To look at SP only from a cognitive perspective is to just skim across the problem without delving into the deep understanding this topic requires.

I think SP needs to be viewed through understanding, but an expanded form of understanding. It should include knowledge, understanding that knowledge, intellectual virtues and wisdom. It needs the ability to stand outside that progress and appreciate what its consequences could mean, by addressing it across all scientific disciplines, not just the specialised area it occurred in. It needs input from areas that are not usually considered "science", that is the arts and social sciences. Progress needs to be responsible and accountable.

Methodology & Forms of Analysis

Philosophical research takes a different form from most research in that it is not usually conducted as a laboratory experiment. My research will be based on literature research and thinking about the current accounts of SP and how they could be improved using research from the area of virtue epistemology. This will be mostly by conceptual analysis, using logic and thought experiments or analogies to define a new account of SP that includes intellectual virtues.

Since my study will not involve research on human participants and since it will not involve the exploration of sensitive subject matters, I will not require ethical approval as I will not be conducting any experiments that would require participation from human beings or animals.

Thesis Outline

The thesis will be divided into two sections: (A) Groundwork for an Account of Scientific Progress and (B) Scientific Progress as Virtuous Understanding. Part A will be composed of Chapters 1 through 6, and Part B will be composed of Chapters 7 through 10.

Chapter 1 Introduction

In this chapter, I will introduce the problem of scientific progress(SP). To do that I will have to motivate my project by calling on some examples of the way we currently appreciate SP. The discussion will involve summarising some famous examples from the literature, as well as outlining some specific cases that are not normally included in discussion of SP. One deficiency of the literature on SP is its overly narrow conception of what counts as science. To my mind, the literature has been too focused upon large works of science, rather than on common everyday problems of engineering that contribute to our appreciation of SP. I will then ask some questions about these examples and the problems created when all the factors involved are not considered adequately. Finally, the chapter will end with a summary of what I will do in the remainder of the thesis.

Chapter 2 Semantic/Verisimilitude Account of Scientific Progress

In this chapter I will conduct a literature review of the semantic account of SP. This will start with Karl Popper's original account and look at accounts that attempt to support Popper's account. Popper's account of SP is referred to as the semantic or verisimilitude account, which looks at science as getting ever closer to the truth. Scientific progress in this account means that a new theory, that replaces or adds to an older theory, brings us closer to the truth. David Miller and Pavel Tichý argued that Popper's account of approximate truth failed to consider the situation that most theories are eventually proven to be false. If both theories are false, you cannot make a comparison between those theories to work out which one is closer to the truth as neither contains any truth. Graham Oddie and Ilkka Niiniluoto both argued that Popper's account could still be used if altered slightly to break down theories into components and then work out how many components in the theory were factual. Then the theories could be compared to see which had more components of truth within it.

Chapter 3 Functional Account of Scientific Progress

Chapter 3 will be a literature review of the functional account of SP. This will begin with an overview of Thomas Kuhn's, *The Structure of Scientific Revolutions* (1970), and look at accounts that attempt to support his account. Kuhn's functional account pivots around the ability of science to solve puzzles and problems. If a new theory solves more problems and puzzles than a previous one then this should be considered SP. He introduced the concept of "incommensurability" (Bird, 2018; Preston, 2008), which showed that different theories could be difficult to compare because they were so completely different. Kuhn was also the first to use the phrase "paradigm", although in his later work he maintained that the way the word was now being used was not what he intended. Alexander Bird argues that Kuhn's account of "being able to solve more problems and puzzles" is itself problematical because often new theories create more problems and puzzles to answer, and are we looking at the big problems or the little problems when we try to count them.

Chapter 4 Epistemic Account of Scientific Progress

In this chapter I will conduct a literature review of the epistemic account of SP. This will involve several different philosophers, starting with Alexander Bird and Seungbae Park. Bird and Park's epistemic account supports the concept that SP is measured when we can say we have accumulated more knowledge. Park added to and tried to strengthen Bird's original account by including what he called "means-to-an-end" advances, where little advances are made that contribute to a much larger increase in knowledge. There is some debate over this account as they have not provided a definition of knowledge. Ilkka Niiniluoto provides the definition that knowledge is justified true belief, and if this is the case then the epistemic account would suffer from the same problems as the semantic account. I will also be looking at Darrell Rowbottom who argues against the epistemic account if knowledge is taken to be justified true belief. Finnur Dellsén also argues against the epistemic account as he thinks accumulating knowledge does not measure SP if we do not fully understand the knowledge we have gained.

Chapter 5 Noetic Account of Scientific Progress

In this chapter I will conduct a literature review of the noetic account of SP. This will mostly be on the work by Finnur Dellsén as this is a fairly new account to the literature. He argues that an increase in understanding of the knowledge we have is what constitutes SP. He makes a case for understanding as it does not require justified true belief in the way knowledge does. However, I feel he does not make his account of understanding strong enough and I think it needs expanding, which is what I will be looking at in this chapter as well.

Chapter 6 Virtue Epistemology

In this chapter I will conduct a literature review of virtue epistemology, focusing on how the intellectual virtues are deployed in virtue responsibilism. There are a lot of different aspects to virtue epistemology but I will be concentrating on intellectual virtue through the lens of virtue responsibilism which will involve perspectives from Ernest Sosa, Heather Battaly, and Linda Zagzebski. I will also look at some of the work that has been done on individual characteristics and traits that are aligned with intellectual virtue, such as open-mindedness, intellectual honesty, intellectual autonomy, and intellectual curiosity. This review will form the foundation of my account of SP as virtuous understanding.

Chapter 7 Causes Behind and Failures of Scientific Progress

In this chapter, I will be looking at different factors that can influence SP in negative and positive ways. I think that assessing SP from a purely cognitive perspective does not give us the ability to discern between good and bad SP. I will be considering other aspects that impact on scientific research, such as, biases, economics, social pressure, education, culture and public relations. I will also be considering how hyperspecialization and consilience in science can positively and negatively affect SP. Part of this chapter will contend with science as a community and social effort, since very few scientists work alone on any given problem. I will be looking at different bias effects, such as the Matthews effect, confirmation bias and neglect, prestige bias, and the misuse of science. Also economics, which includes how scientists get funding for their research and the financial returns research can give big companies. Highlighting all of these influences on SP should show that the current accounts of SP are inadequate and need expanding.

Chapter 8 Scientific Progress as Understanding

We have a lot of accumulated knowledge, things that we know work, but often we do not understand why it works. I think this can be a dangerous situation if we do not completely understand the consequences of what we are doing. We may have to accept that we will never acquire a complete knowledge of our world through science, but science may allow us to have a better understanding, if used correctly. Understanding supersedes knowledge when assessing SP, but the two are inextricably bound together in a cycle of gaining knowledge, understanding that knowledge, which leads to more knowledge. However, without understanding knowledge itself is not sufficient as a measurement of SP. Understanding needs to be expanded upon from the Noetic account to a comprehensive explanation of what it really means to understand something in science, and how that is one part of measuring SP.

Chapter 9 Understanding as Virtue

Understanding, as it has been conceived by Dellsén for example, is not enough if it is not supported by intellectual virtues. Taking virtue responsibilism which looks at the intellectual virtues, virtue understanding could be included. Virtue responsibilism looks at characteristics such as open-mindedness, intellectual honesty, intellectual curiosity, intellectual autonomy, and intellectual humility, all of which could contribute to a theory of virtuous intellectual understanding, which I think would add a dimension that is currently missing from any account of SP.

Chapter 10 Scientific Progress as Virtuous Understanding

In this last chapter I will complete a summary of all the arguments and present a possible account for SP that includes virtuous understanding as a characteristic or trait that scientists and scientific communities need to possess for scientific discoveries to lead to genuine progress. Reassessing how we judge SP with the addition of virtuous understanding will hopefully mean that research is conducted responsibly, results communicated in a manner understandable to all, and responsibly used if applicable. This would increase people's trust in science and acknowledge what it has the ability to achieve and what it cannot achieve. It would also acknowledge that most SP is a temporary step, that could be wrong, until the next results of new research arrive.

In a perfect world scientists and scientific communities would reach the virtuous standard of wisdom, and acknowledge that even when science shows us we can do something it does not mean we should do it.

Resource Requirements

Research in Philosophy does not require many resources as it is mostly a cognitive activity. I will require access to the University of Waikato Library and databases, an office with computer and internet access.

I will attend conferences locally and internationally. Where possible, I will seek external funding to cover the costs associated with attending conferences. Due to the current situation with *COVID-19* it is probable that no travel may be possible and conferences will be attended by Zoom meetings.

Timetable for the project

- Part A: The Groundwork for an Account of Scientific Progress
    - Complete Chapter 2-5 drafts, June 2022
    - Complete Chapter 6 draft, December 2022
- Part B: Scientific Progress as Virtuous Understanding
    - Complete Chapter 7 draft, December 2022
    - Complete Chapter 8 draft, March 2023
    - Complete Chapter 9 draft, June 2023
    - Complete Chapter 10 draft, October 2023
- Complete Introduction and Conclusion, December 2023
- Review, edit and finalise thesis, February 2024
- Complete final revisions, April 2024
- Submit thesis, May 2024

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