

# Diversity Is an Asset to Science Not a Threat

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## **ABSTRACT**

In this paper, Critical Realism is used as a theoretical framework to show that diversity is an asset to science not a threat. Critical Realism situates the reliability and reproducibility of science in the realm of the real and thus relocates the notion of “objectivity” from the person of the scientist to the process of science. This means that it no longer necessary to attempt to minimise the person of the scientist in pursuit of rigorous knowledge. The implication is that diversity both in terms of intellectual training (within limits) and in terms of being multicultural, gender, sexuality, multilingual, is revealed to be an asset. This is because the construction of knowledge draws on personal experience and having people with divergent experience interrogating the same problem is more likely to provide a reliable, reproducible solution. In the latter parts of the paper, the implications for teaching are described. In addition, it is demonstrated that this argument can be extended into different knowledge areas.

## **KEYWORDS**

critical realism, diversity, decoloniality, science, Bernstein

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## **Introduction**

The question of the nature of transformation in higher education institutions in South Africa has been high on the agenda since the #RhodesMustFall and #FeesMustFall protests of 2015/2016 (Fataar, 2019). Keet and Swartz (2015) developed a “proposed transformation barometer” which clusters areas of concern into three themes: governance; equity and redress; and transforming the academic project. The focus of this paper is to explore the nature of transforming the academic project within a STEM environment.

This paper arises from my own interest in the decolonisation conversation in South African higher education. I conduct research in both synthetic chemistry and in higher education. Like many natural scientists, when the protests began, I presumed that decolonisation was primarily a concern of the social sciences and humanities. But the furor that arose after the #ScienceMustFall video went viral piqued my interest (Adendorff & Blackie, 2020).

This particular video was a short clip from a larger conversation in which a student called for abandoning Newton's Laws amongst other things. The student's comments themselves should probably not be taken too literally. They were made in the heat of the debate by a social science student. Nonetheless, there was a very strong reaction from a small number of academic scientists. Most noteworthy was Professor Tim Crowe from the University of Cape Town whose primary position was that science is objective and thus there is no conversation to be had around the decolonisation of science (Cameron, 2016).

This claim that science is objective is strongly correlated with a claim that science is socially neutral. From this position, the call for decolonisation of science education is at best irrelevant and at worst a potential threat to good science (Adendorff & Blackie, 2022). Any attempt to argue that decolonisation is a social good and therefore must be taken seriously will not gain much traction—to argue for the development of a social good in a field which proclaims itself to be socially neutral is doomed to failure. However, if one can show that the knowledge project of science will be benefited by diversity and transformation, then the desired social good can be achieved as a happy by-product. Thus the desired end of transformation (Keet & Swartz 2015) can be achieved with the buy-in of the community which we desire to impact. It is the purpose of this paper to provide the intellectual foundation for the position that diversity is in fact advantageous for the knowledge project of science itself. This builds on previous work wherein we show that “knower blindness” is a major issue in STEM education (Adendorff & Blackie, 2022). This has, in fact, been a hallmark of both science and philosophy in the Western educational tradition (Grosfoguel, 2007). The key insight of this paper is the recognition that this “knower blindness” is a weakness in the intellectual tradition not a strength.

In this paper I will show that the way in which one thinks about knowledge matters. The notion that science is objective indicates a conflation of epistemology and ontology, and “knower blindness”—a blindness to the significance of the community of who hold and disseminate the knowledge. Knowledge is a social product. Through the use of Critical Realism, I will show that the logical conclusion of a realist approach to knowledge is that diversity is an asset to the advancement of knowledge. Drawing on Bernstein (2000, 2003), I then show that the shift to the recognition of the importance of diversity among practising scientists has an impact on how one approaches teaching and learning spaces. As a chemist, my own primary interest is to make this visible for STEM subjects and so illustrate the significance to STEM fields most explicitly. However I also show how this is potentially more widely applicable to all fields.

## Approach

The method used for this paper follows the first part of the process described by Bhaskar for the advancement of understanding existing social structures: RRREIC—Resolution; Redescription; Retrodiction; Elimination; Identification and Correction (Robert Isaksen, 2016). Resolution refers to the identification of some causes of the current situation. In this paper, this requires some consideration of the way in which science is understood. The insight provided by previous work (Adendorff & Blackie, 2020; Blackie & Adendorff, 2022) on the notion of “knower blindness” in science is taken to be a causal factor. Redescription

requires some explanation from Critical Realism in order to make explicit the ways in which the foundation of this theory properly locates the reproducibility of science in the real causal mechanism under interrogation (Blackie, 2022). Retrodiction is the process whereby the implications of this shift in perspective are drawn through to show the impact on the way in which we think about science. The consequence is a Correction—through this particular Redescription the human person comes into view and diversity can be seen as an asset. As this paper is focused on this one aspect, Elimination of incorrect Redescriptions and Identification of the most reliable Redescription is not relevant. Thus, rather than a full RRREIC cycle, what is given here can be understood as RRRC.

At this point it may be helpful to elaborate on the ways in which I am using some terms in this paper (this can be considered to contribute to “resolution”):

*Knower*: this is the person who holds the knowledge. Given that the argument I am presenting is situated primarily in tertiary chemistry education, the knower can be understood to be the academic chemist who both teaches chemistry and does chemistry research. This may be logically extended to students, but in this paper the focus is on the academic staff.

*Diversity*: In this paper diversity has two important dimensions. First, there is diversity of academic formation within the broad scope of chemistry, i.e. all who teach chemistry can reasonably be assumed to be trained chemists but various training programmes have different strengths and so there will be some variation in skill set amongst those trained in different institutions and different nations. Secondly, there is diversity in terms of identity; this includes culture, language, gender, sexual orientation.

*Transformation*: transformation here is understood as the current societal imperative to undermine the social disparities of the past. In South Africa the current emphasis is on redress in racial terms.

*Decolonisation*: It is now widely understood that the Western canon of knowledge carries cultural significance associated with the power structure of coloniality. The task of decolonisation is the critique of that canon of knowledge and the attempt to create more curricula specifically and education systems more broadly, particularly for those regions that were subject to colonisation.

For clarity in the phrase “science is objective”, science is to be understood as “physical science”. Herein “physical science” will be used to denote any knowledge area for which the physical world is the realm of interrogation. This will be juxtaposed with “social science” which will be used to denote any knowledge area for which the social world of humanity is the realm of interrogation. It is important to recognise that there are number of subjects which make use of both of these. For example, ecology which usually sits in the science faculty requires interrogation of both the social world and the physical world (Price, 2019). Likewise, psychology usually sits among the social sciences, but elements such as neuropsychology include the brain scanning using MRI technology and thus require interrogation of the physical world (David et al., 1994).

The paper addresses the following important points. This is made explicit because it is conceptually quite dense and it will assist the reader in navigating the argument:

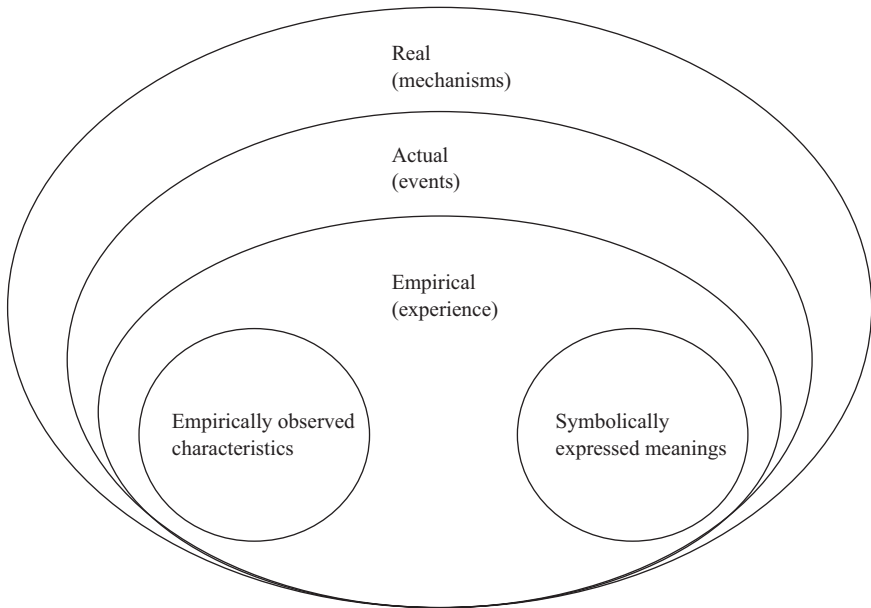
- 1) The way in which we conceive of knowledge matters.
- 2) There is a relationship between the knowledge and knower—concepts shape exploration. The concepts used shape the development of the knower through education. Importantly, concepts shape the way we interrogate the world.
- 3) Diversity is an asset to science not a threat.
- 4) Decolonisation or transformation will take time. It is iterative and will require the continual process of critique and improvement. Indeed it may be characterised by the adoption of a commitment to continual critique. It is not a state one can claim to have arrived at.
- 5) This process of continual critique necessarily requires the participation of the whole community (even if that participation for some is in the form of resistance).
- 6) The argument presented in this paper is an illustration of the way in which we think around impacting policies and procedures (the conception of diversity as an asset has the potential to shape hiring practices and therefore to accelerate transformation).

The paper also deliberately draws illustrations from the field of chemistry. Whilst these illustrations may be challenging to readers without a science background they are intended to show this argument can be sustained from within the discipline. These are vital to making a claim for diversity within the discipline. Nonetheless, the illustrations are not central to the development of the argument itself.

## **The Significance of Separating Ontology and Epistemology**

The main argument in this paper is to show that one of the ways in which we have considered “objectivity” in science is through the erasure of the particularities of the people who have created scientific knowledge (Grosfoguel, 2007). In order to dismantle this presumed connection, we need to consider the connection between what we are investigating and the knowledge that we have of that realm.

There are various ways of thinking about knowledge. Two of these methods which tend to be juxtaposed with one another are the positivist/empiricist approach and the interpretive constructivist approach (Wuisman, 2005). In the former, the goal is to faithfully represent that which can be empirically observed. In the latter, the goal is to create a meaningful description of a situation. Both of these approaches operate on the level of the experiential (see Figure 1). As a broad generalisation the positivist/empiricist approach is more commonly used in knowledge areas where the physical world is the realm of investigation, while the interpretivist constructivist approach is more commonly found where the social world is the realm of investigation. Each approach is valid on its own terms, but knowers who usually operate from one approach can tend to misunderstand, and therefore undervalue, the basis of the knowledge claim of the other. This gives rise to unnecessary confrontations such as the dismissal of the call for decolonisation of science (Adendorff & Blackie, 2020). Nonetheless, both approaches are situated in the empirical



**Figure 1: Engagement with the empirical is the only access we have to the real. Neither the positivist nor the interpretive requires a reality beyond the empirical.**

and neither approach necessarily makes any claims beyond the empirical. Some interpretive/constructivist approaches such as poststructuralism actively deny the possibility of saying anything meaningful beyond the empirical.

Bhaskar (1978) argues that there is an ontological reality that is the foundation of everything. That is to say that there are mechanisms (the real) which cause a particular event at a particular time (the actual) which may be observed (the empirical). That which is real encompasses the physical world and the social world. Thus through the empirical observation of an actual event using the scientific method one can come know something about the nature of the real. This is the defining feature of Critical Realism. Critical Realism is chosen at the foundation for this argument precisely because it can legitimately be used as a lens through which to view the interrogation of the physical world (chemistry) or the social world (chemistry education).

Let us consider a very simple chemical reaction. Vitamin C, ascorbic acid, is often pharmaceutically formulated into effervescent tablets. The effervescent tablet contains both ascorbic acid and sodium bicarbonate. When one drops the tablet into a glass of water it fizzes because of a chemical reaction between the ascorbic acid and sodium bicarbonate to form a “salt” of the acid which is more soluble in water. Carbon dioxide is produced as a by-product of the reaction which causes the fizzing (Haynes & Blackie, 2021). One does not need to know any chemistry at all to make use of this technology. Every day many people

around the world drop such tablets into water and happily drink the resulting solution without paying any attention to what is happening.

According to Bhaskar (1978) the chemical reaction is a real mechanism. The possibility of ascorbic acid reacting with sodium bicarbonate always exists. It is part of the nature of these two molecules. Furthermore, when they come into contact with one another in water at room temperature they will always react in the same way. When a person drops the tablet into the glass of water they initiate an actual event. In this case the event is empirically observable.

In a realist approach to knowledge then, the claim is that there is an ontological reality which we are trying to describe through investigation and interrogation. However, the way in which we describe that ontological reality will only ever be partially expressed, because that which is known (epistemology) is limited by at least two factors. These two factors are our capacity to observe and our current understanding.

## Recognising the Limitations of Epistemology

There are few scientists who would dispute either of the limiting factors to epistemology stated. When we consider the physical world, our observations are clearly limited by our instruments. The development of understanding of our world has been aided tremendously with the advances in technology that we have seen over the last hundred years. For example, our capacity to scan the human body has given a far better understanding of some diseases and injuries. X-rays were first used for medical diagnosis in 1896, and other imaging technologies emerged in the mid-twentieth century: positron emission tomography (PET) scans in 1951 (Rich, 1997), computed tomography (CT) scans in 1971 and magnetic resonance imaging (MRI) scans in 1977 (Filler, 2009). Medical knowledge gained using such instruments was simply inaccessible prior to the development of these technologies.

The second factor of the limitations of our current understanding is also a major issue. Through both undergraduate and postgraduate training we are conditioned to look at the world through the lens of the current understanding of the field. Returning to the example used previously—the chemist will observe the tablet fizzing in the glass of water and will describe what is happening through chemical concepts. In this case the creation of chemical species called “ions” are formed when the ascorbic acid reacts with the sodium bicarbonate. The concept of “ions” was highly contentious when first proposed in 1883 by Arrhenius in his doctoral dissertation. This was so contentious that he very nearly failed his PhD (Arrhenius et al., 2008). The existence of ions proposed by Arrhenius was based upon meticulous observation of particular systems. However, an ion is a charged atom—an atom which has either lost or gained an electron (Haynes & Blackie, 2021). The understanding of the atom at the time was that it was “indivisible” and could not change. The idea that an electron could be lost or gained was unthinkable. The concept of “ions” was an idea held in Arrhenius’ mind and then put onto paper in his dissertation. It was accepted by a few members of the chemical community, and then as more people began to experiment using this concept as the foundation of their empirical observations, it was found to be useful. Arrhenius was awarded the Nobel Prize in chemistry for this very work in 1903 (Arrhenius et al., 2008).

Now, when this kind of story is told, it is easy from the perspective of the physical sciences to presume that this shift in epistemology can be attributed simply to the power of the

theory. Epistemology here is raised to the level of ontology—ions exist, therefore once they were described, the acceptance of the concept was inevitable. Whilst it is certainly true that scientific knowledge does tend to grow in accuracy over time, this is precisely because a theory is refined by practising scientists who are testing the limits of a concept through experimentation. In other words, it is the social practice of science which leads to the improvement of understanding. This means that there is social power in play in the development of science (Blackie, 2022a). This is illustrated in a biographical essay on Arrhenius's life: "Upon its presentation, Arrhenius' dissertation had not met with broad approval, and had it not been for Ostwald's strong support, the idea that salts upon dissolution dissociate into ions would have had a much slower road to acceptance." (Arrhenius et al., 2008, p. 16). If Ostwald, an established influential chemist of the time, had not championed the idea, it would have taken far longer to be accepted. This was illustrated in the relatively slow uptake of the idea of the "cosmic egg" proposed by Georges le Maître which we now know as the Big Bang Theory. At the time, the common understanding was that the universe was static or in a "steady state". In fact, the phrase "Big Bang" came from derisory remarks from British astronomer Fred Hoyle who clung to the Steady State model (Holder, 2012).

In an attempt to accurately describe the physical world, it has been claimed that "[s]cience tries as much as possible to eliminate the role of the human subject" (Heylighen & Petrović, 2021, p. 232). However, the example of ions and Arrhenius show us that this can lead to "knower blindness" where the social activity of science is overlooked. This then leads to the claim that "science is objective". If we fail to recognise the role of the human person in the scientific endeavour, we will fail to recognise the ways in which the system may sustain a colonial culture, or indeed any culture! As Grosfoguel (2007) points out, this is the hallmark of parts of the Western intellectual tradition and is one of the major issues with respect to decoloniality.

## Decoloniality and Science Education

We must recognise that much of the scientific knowledge that we now hold is dependent upon technology and that much of the development of that technology was associated with Europe during the colonial era (McClellan III, 2010). The science of chemistry for example is inextricably linked with the development of precision balances (Read, 1995). Thus, we cannot get around the fact that much of what is taken as foundational in the physical sciences was developed in Europe, and a fair bit of that development was influenced by or funded by material gains of the colonial era.

Maldonado-Torres (2016) gives a model for consideration of decoloniality comprising knowledge, power and being. In a view of science which "tries to eliminate the role of the human subject" (Heylighen & Petrović, 2021) power and being are simply ignored (Blackie & Adendorff, 2022). But ignoring these elements does not mean that they do not exist. One of the ways in which we can view the practice of science is through the interrelationship of three dimensions: the realm of investigation, the conceptual world and the community of scientists in the field (Blackie, 2022a).

The realm of investigation and the conceptual world are directly related to one another. Investigating a chemical reaction will require chemical concepts. Whilst the chemical

reaction is dependent on a real physical mechanism, the chemical concept is a social construct developed to explain what is happening. That social construct of the chemical concept has been ratified through the chemical literature by the community of chemists (i.e. ions only became a chemical concept once it had been accepted by a small number of chemists—the concept only became legitimately “chemical” once it had been accepted by people other than Arrhenius). Because the chemical reaction is caused by a real physical mechanism which operates independently of humanity, the chemical reaction will not change on a time scale relevant for humanity. This is to say the mechanism which causes the reaction existed prior to life on Earth and will exist long past the demise of human life. Many of the concepts used in undergraduate science courses, particularly in introductory courses, may have been in existence for at least the last five decades and have changed little over time (Blackie, 2022b). They have thus shaped the field and the thinking in the field over this time. In this sense the established concepts themselves have causation and are thus “real” (Mingers, 2004). From this arises the perception in science that knowledge is socially neutral (Blackie & Adendorff, 2022). The “power” and “being” of the Maldonado-Torres triad (2016) are presumed to be insignificant, and the quest for decoloniality is dismissed as question for social sciences and humanities (Adendorff & Blackie, 2020).

However, the increasing call from within these fields for diversity and inclusion (Lalemi, 2019) suggest that it is high time that we take power and being into consideration. In 2020, a paper was published in one of the most prestigious chemistry journals, *Angewante Chemie*, in which a chemist made an argument suggesting that diversity is a threat to the development of the branch of chemistry known as synthetic chemistry. Unsurprisingly, this caused something of a furore in the wake of the #BlackLivesMatter protests; the paper was retracted and large number of the editorial board resigned (Kramer, 2020). Whilst this paper may be an extreme example, we must acknowledge that for as long as we hold the idea that “science is objective” and the consequential illusion that power is not operative in the practice of science, we are making several unconscious presumptions. First, whilst scientific knowledge may be an attempt at an objective description of reality, there is no evidence to suggest that scientists are necessarily “objective”. Secondly, when we think of the scientist as being “objective” and “rational”, these two qualities are frequently presumed to be quintessentially associated with cis-gendered, heterosexual, white men. Anyone who fails on any one or more of these descriptors must first prove their rationality before they are accepted as scientists (White et al., 2021; Diele-Viegas et al., 2021; Blackie & Adendorff, 2022).

Both of these presumptions locate the objectivity of scientific knowledge in the being of the scientist. Hence the omission of “being” in the Maldonado-Torres triad (2016) is simply not justified. I seek to show that not only is it erroneous to locate the objectivity of scientific knowledge in the being of the scientist, it is also to the detriment of the development of science.

According to Bhaskar (1978) the task of the scientist begins with the capacity to reliably and reproducibly observe a well-defined system. The more closely the system can be controlled, i.e. closed to obfuscating changes which may alter the outcome of the system, the better. For example, the temperature at which a chemical reaction is carried out can be a significant factor in the outcome of the reaction. At the institution where I work the temperature



in the laboratory can vary from around 35 degrees Celsius in Summer to around 10 degrees Celsius in winter. To report carrying out the experiment at “room temperature” is not particularly useful information, even though that is widely used in the literature and is taken to be approximately 25 degrees Celsius. Accuracy of observation and reporting requires taking note of the temperature of the laboratory every time the experiment is repeated and noting whether the temperature appeared to have an impact on the yield of the desired product. This is just one small example. A multitude of such variables need to be accurately and consistently recorded to ensure reproducibility of the work. The capacity to pay attention to this kind of detail may be aligned more to some personality types than others, but there is little evidence to show that it is correlated with gender, race or sexual orientation. Indeed, part of the process of scientific training is inducting the student into a way of observing that is useful and meaningful within the particular scientific endeavour.

## The Value of Diversity

It is important to recognise that each individual scientist will have different gifts and proclivities. Synthetic chemistry requires mixing specific quantities of chemicals in specialist glass apparatus, sometimes using pure nitrogen or argon rather than air. If we imagine two hypothetical students doing postgraduate studies in synthetic chemistry, one has a hobby of baking and the other of mending broken bicycles. By way of caricature, the student who bakes may be more meticulous in weighing, measuring and noting things like temperature and colour. The student who mends bicycles may pay more attention to the physical set up of the glassware and gas lines. Nonetheless, both need to grasp either through trial and error or active teaching that the whole set up is important. Regardless, they are still likely to make slightly different choices when trouble shooting or designing a new experiment. This difference is not a problem. It is an essential part of the wonderful creativity that can emerge when different people work alongside one another.

Likewise different educational backgrounds will impact how a scientist approaches a problem. Someone trained in chemistry and mathematics will ask slightly different questions to someone trained in chemistry and microbiology. This is again an asset to the advance of the scientific endeavour. If the goal of science is to narrow down to the most accurate conceptual description of a situation, then provided there is some methodological overlap and all are working from the same conceptual starting point, ten scientists with slightly different trainings and slightly different ways of paying attention will achieve more than ten hypothetical scientists with exactly the same training and exactly the same focus. The point here is that the desire to “eliminate the role of the human subject” (Heylighen & Petrović, 2021) in science is not only impossible, it is entirely foolish to attempt to do so. Lonergan (1992) asserts this positively “Genuine objectivity is the fruit of authentic subjectivity”.

Unequivocally, then, the argument I am putting forward here is that the particularity of the individual is a profound asset in the scientific endeavour. The combination of education and life experience brought to bear on a specific scientific problem will yield a unique approach. However, this argument is put forth in the context of understanding science to be a communal effort, not an individual one. That is to say the individual insight is tested in community and only really bears significant fruit when shared. Science proceeds

through conversation and collaboration which allow critique and refinement of moments of individual insight. Insight is always individual, but scientific progress is always communal. The idea of the existence of ions was Arrhenius's insight—the Archimedean cry of “Eureka!” is always the delight of the individual. The scientific community serves two purposes. The first is to test the insight. When presented, do others see what has been intuited through observation. Is this insight potentially valuable? The second is to refine the insight—to discover the limits within which the insight holds true. It is important to note here that I am assuming that the person investigating is trained within the scientific field—it is reasonable to require a person employed as an academic chemist has the requisite qualifications in chemistry.

Grosfoguel (2007) discusses the power dynamics in the attempted erasure of the ego that occurs in knowledge production in the sciences and philosophy. The argument made here is in agreement with Grosfoguel but is nuanced by the recognition that in the case of physical science there is a real mechanism which is beyond the human culture under interrogation.

## Implications for Transformation

I have shown that, provided a scientist has the necessary foundational training, diversity is an asset to the progress of science. There is one further conceptual step to make to show that diversity of personal experience is also an asset. Lonergan makes it clear that insight is rooted in personal experience (Lonergan, 1992). In an intellectual setting “experience” comprises one's previous exposure to the subject, the mental models constructed to make sense of what has already been learned and whatever life experience is drawn into that sense making (Blackie, 2019). Thus, one's experience of the world in general feeds into one's mental grappling with any intellectual endeavour. Nonetheless, mental models which draw on analogy from the world are ultimately deficient. The persistence of the misleading Bohr model of the atom which was based on an analogy to the solar system is an example of the limitations and power of mental models (Haynes & Blackie, 2021). However, when people are working towards a common intellectual insight, being able to draw from a multitude of life experiences is more likely to provide better models. Bernstein (2000) refers to these as “repertoires”. Life experiences divergent in cultural contexts, physical environments and potentially different ways of navigating society required by sexual orientation will provide a greater diversity of mental models. The substantial advantage of the divergent mental models and imagery provided by different mother tongues perhaps deserves special mention here given the multiplicity of language present in South Africa.

An illustration of this is the discovery of the concept of “zero”. Whilst the Greeks had mastered geometry and other facets of mathematics they had no concept of zero. This was developed by Hindu mathematicians. Logan writes:

I believe that the explanation for this phenomenon does not lie in an examination of Greek mathematics but rather, in an examination of Greek philosophy and logic and its contrast with Hindu philosophy and religious thought. Paradoxically, the position I reach is that the rational and logical thought patterns of the Greeks hindered their development of algebra and the invention of zero. (Logan, 1979, p. 17)

The point here is that one's cosmology or worldview can limit what one perceives to be intellectually possible. Logan argues that Greek cosmology prevented the mathematicians of the Greek culture from conceiving of notion of "zero". The different cosmology afforded by Hinduism did not have the same intellectual constraint.

## Homophily Can Undermine Good Intentions

The consequence of the value of diversity, both in an intellectual and in a multicultural sense, is then clear. However, to say that diversity is good for the science is necessary, but not sufficient in itself to facilitate the establishment of a more diverse representation in a faculty or a department. In hiring practices it is essential to actively attempt to overcome the tendency to homophily.

Sociologists use the term "homophily" to describe the tendency of individuals to form associations, friendships and relationships with those who share common characteristics (age, race, religion, class background, leisure interests, etc.). In other words, social networks tend to be composed of people who are similar to each other on one or more dimension. (Twine, 2018)

In the case of hiring academics, homophily can show up in multiple dimensions. There can be a bias towards those who "fit the culture" (McGee, 2021). There can also be bias towards those who come from within the system. The significance of diversity in developing thought means that all institutions and all departments should actively seek to increase diversity for the sake of the enhancement of the science. In addition, diversity of educational experience should also add to the overall improvement of teaching, provided the department actively reflects upon teaching practice in a collaborative manner. However, if the appointments committee is unaware of the pull of homophily, when a choice arises between two equally qualified candidates, it is more likely that the "comfortable" candidate will be chosen. That is the candidate who appears to align with the department rather than the one who increases the diversity. There may be other good reasons for making such a choice, but the argument presented herein is that the unconscious bias seated in homophily is likely to be relatively detrimental in the long run for both the development of science and the improvement of teaching.

It is important to be clear here that diversity here refers to both diversity of academic training within chemistry and diversity in terms of personal identity. However, this is not to suggest that there should be any imperative to diversity beyond what is understood as chemistry. Bernstein (2003) makes it very clear that the value of specialist knowledge and that which defines a field as a field is characterised by a distinct method of training and distinct method of interrogation. The purpose of this paper is indeed to make visible to significance of the social element of science without undermining the value of the knowledge project.

## Implications for Science Education

In previous work on the decolonisation of science, we have shown that major changes to the content that is taught in science education is not desirable (Adendorff & Blackie, 2020; Blackie & Adendorff, 2022). The physical sciences tend to have strongly hierarchical knowledge

structures (Bernstein, 2000). This is to say that knowledge is built layer upon layer. For example, in chemistry, understanding how a chemical reaction happens requires an understanding of the structure of the molecule and where there are particular zones of electron density, each of these requires an understanding of chemical bonding and knowledge of the Periodic Table. Therefore the content of an introductory chemistry course in Brazil or the United Kingdom or Kenya will be essentially the same, because the same fundamental ideas need to be in place. Local variation on more advanced courses may occur, but the variation will be in focus not in content. That is to say that the one institution may choose electrochemistry over polymer science, but the content of one electrochemistry course is still likely to be largely similar to courses offered by other institutions on electrochemistry.

Chemistry is a particularly tough nut in this respect because as humans we have no chemical intuition (Blackie, 2014). Technologies have been built around chemical transformations for eons. The development of both bronze and iron are chemical technologies. However the development of these technologies was achieved through trial and error until a desirable outcome was attained. Then the “recipe” was repeated. This “recipe”-based approach underpinned the craft of alchemy (Read, 1995) and the same is true of many traditional practices. Modern chemistry relies on a molecular understanding of systems and the focus of chemistry is on the explanatory power of the science, rather than the dissemination of methods. The consequence of this is that the inclusion of content from traditional knowledge systems is not particularly viable for chemistry. This is precisely because the traditional knowledge systems make use of the technology of chemistry without the sophisticated explanatory power that comes with a molecular understanding. As stated earlier, the development of a molecular understanding is inextricably linked to the development of precision balances, which itself was linked to the technological advances fuelled by the explorations which wrought colonisation (Haynes & Blackie, 2021). The situation may well be different in other knowledge areas such as botany or ecology. Where possible the inclusion of knowledge relevant to the locality should be done, but care is needed to ensure that this is properly included in a manner that is coherent, well-structured and consistent with the parent science (Adendorff & Blackie, 2020, Blackie & Adendorff, 2022).

Returning to the Maldonado-Torres triad of power, being and knowledge (2016), the emphasis on the variation of knowledge to reflect diversity and achieve decoloniality will thus vary substantially depending on the specific subject. It is not simply a matter of bringing in the voices of the previously colonised in the physical sciences. Nonetheless, the shift in the understanding of the development of scientific knowledge that I have outlined herein will have an impact on the teaching of the subject in the dimensions of power and being.

Bernstein (2003) had an interest in the way in which education can unconsciously sustain social inequalities. He made the “distinction between what is relayed (the message) and the underlying pedagogic device that structures and organises the content and distribution of what is relayed” (Bertram, 2012). This is to say that “the structure of knowledge and pedagogic practice is just as important as the content of knowledge in shaping subjectivities, and in reproducing or transforming power relations” (Whelehan, 2005).

In a subject whose object of interest is the physical world such as chemistry, knowledge is often presumed to be socially neutral. Whilst that position is certainly open to debate, it is

hard to argue against the notion that chemistry is more likely to be socially neutral than history in terms of content. Nonetheless, it is clear that Bernstein's (2000) distinction between the content of the knowledge and the manner of delivery in all its complexity mean that we must attend to the manner of delivery as well.

According to Bernstein (2000), education can be thought of as a specialised form of communication. So what happens when one shifts one's understanding of the objectivity of the scientific endeavour? Let us consider the two ways of viewing science itself that have already been juxtaposed in this paper. As has been argued above if we unconsciously locate the objectivity of scientific knowledge in the being of the scientist, then there will be a desire to ignore or compartmentalise any individual's particularities. Because the short white English man and the tall black Xhosa woman should both get the same results when performing the same experiment, the tendency will be to presume that individual variations are best ignored. However, if, as I have argued above, the individual particularity is a necessary and useful addition to the practice of science, then there is merit in valuing and thus paying attention to the particular offerings of each individual student. All students must ultimately be trained to observe accurately and communicate clearly those observations, but we can draw much more explicitly on the variation of experience precisely because it is in the small variations that the creative spark of inspiration is likely to be found. This has the potential to change how we view the students sitting in front of us.

When objectivity is located in the being of the scientist, the task of training a scientist is primarily achieved through transmission of knowledge. In the transmission from lecturer to student the desire is to attain the most faithful reproduction of the knowledge. The primary purpose of education is knowledge gain. My goal as lecturer is to assist the student in that knowledge gain. I have no expectation that I will gain much, if anything, in the process. However, when I am aware of the *gift* of the particularity of each individual person grappling with this knowledge, personal transformation comes into focus. The goal of education shifts to a possibility of new emerging understandings when this person interacts with this knowledge. In this scenario a student interacting with the idea of the atom and making sense of what that is and how that can be understood will draw on mental models and find ways to make sense of this for themselves. As an academic my own understanding both of the atom and of how people can think about the atom has the potential to be enlarged or deepened by engagement with every single student. Thus not only will the student be transformed in the process of learning, but provided I am paying attention to the communication that is coming back at me, I too may be changed. Education is thus no longer primarily transmission, it is necessarily more dialogic. This dialogic position is aligned with Grosfoguel's (2007) critique of the Western intellectual tradition.

If I, as an academic, am open to the possibility of learning each time I enter the lecture theatre, there is immediately a shift in the power dynamic in the experience for everyone. I still hold power that the students do not have, but my willingness to learn requires an open stance and receptivity. In this scenario the lecturer's level of uncertainty and anxiety induced by not knowing is likely to be far lower than the average position of everyone in the room, but they do share that experience just a little bit. The lecturer is no longer the one who holds all the control. This kind of change can happen in every lecture theatre

tomorrow, it simply requires a shift in understanding that will impact the pedagogical practice of the lecturer.

At a necessarily slower rate, the recognition that diversity is in fact good for science will slowly transform hiring practices. In the first instance this may have an impact on how postgraduate students are selected in research groups where there is competition for places. Selecting for diversity on both intellectual and personal attributes will shift the “face” of the next generation of scientists. Alas in most places the turnover of academic staff is slow, so even when thinking has changed such that diversity is seen as essential for the enhancement of science, it may still take a good number of years for the demographic profile of a department to reflect that commitment. Once that has happened the myth of the bastion of rationality being the white, cis-gendered, heterosexual male will be shattered forever. As most societies are increasingly multicultural, there will be no room for anyone to think that any knowledge pursuit is not for them simply because they lack role models (Lalemi, 2019). Importantly, in such a world no one cultural experience can be presumed to be normative. I sincerely hope that the experience of Nigerian-American engineer Shola Oyedele will become an artefact of history: “There’s so much resistance to women and minorities in tech. For me to get the same recognition as my peers . . . [b]eing good isn’t enough; you have to be exceptional.” (Quoted in Twine, 2018.)

Ultimately, I hold that, as an academic, every experience that I have regardless of context has the potential to influence how I show up in the lecture theatre (or any other site of interaction with students in the real or virtual world). I am the product of my experience. The manner in which I think about the process of doing science shapes how I teach. The manner in which I think about myself as a scientist shapes how I teach. The manner in which I view the students shapes how I teach. And every teaching experience informs the next one. My responsibility is to reflect on experience such that I can at least partly open myself to the potential of becoming aware of any of these aspects having a negative impact on the experience for my students. This is not to suggest that I have control over the impact that I do have. The impact that I have will surely vary from situation to situation. Nonetheless, I have some control over my own intentionality.

## **Extending the Reach into Other Knowledge Areas**

The argument for the value of diversity in intellectual interrogation must hold for any field. The benefit of deriving this argument from the work of Bhaskar is precisely that one can apply similar thinking to other knowledge fields. No substantial shift needs to be made if one is applying a realist approach to a field where the object of interest is in the social world rather than in the physical world (Mingers, 2014). On one level it can be argued that there is no essential difference between observing a chemical reaction and observing human behaviour. Thus the need for diversity in all fields holds. In a similar manner a lecturer of chemistry and a lecturer of sociology may both be equally poor at paying attention to the students sitting in front of them.

However, as pointed out in my introduction to Critical Realism, it is important to note that not all approaches to knowledge building require a realist foundation. I am not going to spill much ink here arguing for the importance of a realist approach. I am simply going to

acknowledge that there are other valid approaches to knowledge building. One's cosmology necessarily influences where one plants one's philosophical stake in the ground with respect to knowledge building. My own stance is somewhat pragmatic. The cosmology described by Bhaskar which is now known as Critical Realism is currently providing me with a profoundly useful framework within which to deeply critique normative aspects of science education. To the extent to which I have thought about the implications of the existence of the real, the actual and the empirical, I can live with the consequences.

Nonetheless, there is one important distinction between the physical sciences and the social sciences that needs to be acknowledged. When one is dealing with the exploration of human behaviour, one may stumble into the complexity of the double hermeneutic (Price, 2019). In all studies regardless of the object of study, the interpretation of the researcher will be shaped by existing concepts and social and cultural influences. When one is studying atoms, the hermeneutic of interpretation of data only operate in one direction. The researchers' conceptual frame of reference does not alter the behaviour of the atoms. However, if one is conducting education research, then both researcher and the subjects of the research will have conceptual frames of reference. The manner in which a student answers a survey, for example, will vary depending on their understanding of its purpose. There is thus the hermeneutic of the researcher and the hermeneutic of the student. These two come into relationship with one another through the research. If the researcher and the student are in multidimensional relationship, i.e. if the researcher is also a lecturer on a course the student takes, for example, there may also be complex power dynamics in play.

This double hermeneutic does not mean that a realist approach is a fruitless endeavour. It simply means that any attempt to articulate that which is perceived to be real through the investigation must be recognised as having likely influences which may obfuscate the understanding. This is why it is necessary in such research to make clear the standpoint of the researcher and the location of the research. It is not easy to reliably account for the hermeneutic of the participants of such a study, but providing some details of the particularity of the situation will allow others to draw more general conclusions in a meaningful way.

Nonetheless, the general principle of the need for diversity of positionality of knowledge builders remains. In the teaching of subjects where a realist approach is taken to knowledge fields where the human person or the social is the object of study, the subject matter tends to be much more fluid and dynamic than in those fields where the physical world is the object of study. This is again because of the double hermeneutic. As the saying goes "history is always taught by the victors". The knowledge presented in such subjects will be profoundly influenced by the self-understanding of those who control what is taught.

It is no accident that the vast majority of papers written on the project of decolonisation have been authored by those working within the social sciences. The task of education of in the social sciences can be thought of as the development a particular social "gaze" which will then influence how one engages with society. However, then making visible the inconsistencies of the emancipatory claims of education and the recognition that education is always political. Who produces knowledge, what knowledge is produced and what knowledge is "left out" are central questions of inquiry within the politics of knowledge. (Jansen, 2019, p. 13)



As the multitude of labels of baby boomer, generation X, millennial and so on, imply, each generation grows up with different perceived threats and different life experiences, so the dominant narrative necessarily will shift. Thus in these knowledge areas in particular, diversity of age may also be an important consideration.

## Conclusion

Because I am a trained chemist teaching chemistry at a tertiary institution in South Africa my research interests include synthetic chemistry, i.e. making molecules with a desired specific purpose, and chemistry education. I have titled this paper “Diversity is an asset not a threat”. This claim plays out in three different ways in the three different realms afforded by Critical Realism.

- 1) In the physical realm: The outer limits are an atomic/molecular level understanding to an atomic/molecular problem and/or bringing an atomic/molecular level technology to bear on a real-world problem, i.e. we are restricting the legitimate field of study to chemistry.
- 2) In the conceptual realm: One must have succeeded in formal training at a recognised institution in chemistry. There is a canon that currently constitutes “chemistry”. This canon is neither exhaustive nor indisputable. Nonetheless, it is reasonable to demand proof of understanding of that canon as a legitimate entry to discussion.
- 3) In the social realm: the community of chemists is currently an invisible, anonymous force. We need to think deeply about what it means to critique the work of another. Do we inadvertently look for social cues such as personal reputation, institution and gender or do we really let the science speak for itself?

In this paper I am not making any argument that is detrimental to either the physical or the conceptual realm. What I hope I have made visible is that denying influence of the social realm is to the detriment of chemistry. In chemistry, the role of the social (herein, the community of chemists) is substantially underplayed to the extent of blindness. Let us dare to tear the veil, because it costs little, but has much to offer. Significantly this approach speaks directly to action towards transformation as required by the barometer of Keet and Swartz (2015). I have not dealt with the demographic makeup of the student body in the context of this paper. Nonetheless, it provides a starting point from which one can consider the implications for students.

From the foundation of Critical Realism I have shown that, in placing focus on the social realm, diversity is revealed to be a significant asset in the practice of science. When we take a realist approach the objectivity of science lies in the underlying real mechanism rather than in the body of the scientist. Thus, we can allow for the deep value of individual experience in the practice of science. Drawing from Bernstein it then follows that this shift in understanding of the location of objectivity potentially impacts the way in which science is taught. The significance of this paper is to suggest that, in the exploration of the question of the possibility of the decolonisation of STEM education, we have now arrived at a position which shows that diversity is in fact advantageous to the practice of science itself. Thus, in interrogating the question of decolonisation of the curriculum, we have developed an



argument for the necessity of transformation of the demographic composition of the academic staff. Significantly, this argument is not driven by a desire for social justice, but rather is inextricably linked to the knowledge project of science itself. In the end the socially just outcome should be attained, but the means through which we achieve that end in no way jeopardises the integrity of the knowledge project. In fact, the argument herein is that diversity is ultimately in service of the knowledge project, and to fail to diversify is to its detriment.

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