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Reflective Practice Research in International Collaboration

Developing Teacher Education in Togetherness

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LIT

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Chapter 13: From Geopolitics to Rare Earths in Teacher Education

Erlend Bendik Myhre[1]

Abstract

Our modern world increasingly relies on most elements from the periodic table to sustain technological progress, enabled by global cooperation, complex supply chains, and free trade under the WTO. However, this system is fracturing as the Liberal International Order weakens, while climate experts stress the urgent need for global collaboration. As a teacher educator in geopolitics, I find that sustainability discussions often overlook geopolitical perspectives. Most of us think within disciplinary silos. Inviting an American Rare Earth Elements (REEs) expert into my Norwegian classroom was a concrete example of Internationalization in Higher Education, leading to more than I anticipated. His insights on REEs, supply chain vulnerabilities, and China's dominance over critical materials reshaped my understanding and that of my students, shifting our perspective toward systems thinking and material realities. The expert lectures on REEs exemplified how these elements connect geopolitics, the green shift, and the modern economy – all depend on rare earths.

Key words:

Rare Earth Elements (REE) – Systems thinking – Internationalization in Higher Education – Geopolitics – The green shift – Material realities

Prologue:

For the past six years, I have taught geopolitics in the teacher education social studies programme. During this time, I developed a geopolitics model and have since regularly refined and updated it, using it as an instructive example for students to learn how to employ modelling as a didactical tool in the classroom. The model can be used as a starting point for analysing any state's (or the EU's) geopolitical situation in the world and includes many concepts/terms to reveal a state's strengths or weaknesses.

One key aspect of the model that became increasingly evident was China's dominance in the whole supply chain of many important materials. In the media and among policymakers, it seemed the significance of Critical Raw Materials (CRMs) and China's dominance in this domain became more pronounced and frequently discussed. Notably, the European Union, the United States, and Japan were publishing detailed lists, every other year or so, of CRMs that underscored China's preeminent position in this crucial arena.

Among the various CRMs, one particular group that caught my attention was the seventeen Rare Earth Elements (REEs), which China held in a near-complete monopoly. While I acknowledged the importance of REEs and included them in my model, I recognised the need for a deeper understanding of why they were so crucial. Moreover, if REEs were so important, why would not the most advanced and richest countries on earth (USA, EU, and Japan) just develop their own complete supply chain? It did not make sense to me. Lindseth (2020, p. 83) might call this an experience of a discrepancy, or that the inner does not align with the outer.

This led me to look into the world of REEs to gain a better understanding of their significance and implications. My goal was simple: to comprehend the extent of the West's reliance on China for these critical elements and the challenges the EU and the US would encounter if they were to establish independent supply chains.

In researching REEs, I soon found that they are essential not only for military equipment, but also for many modern electronic gadgets such as smartphones and airpods, and for technologies that are part of the green shift, like electric vehicles and wind turbines. These elements thus seemed to be vital on many fronts, and I was surprised to find that the US had been a world leader in REE production in the past. How did China end up in this position?

From the mid-1960s to the mid-1980s, the US at the Mountain Pass REE Mine was the global leader in rare earth oxides (Nakano, 2021, p. 9; Scheyder, 2024, pp. 98–99). Then, slowly China started its journey to become dominant in rare earths. I encountered China's strategic intent, dating back to the 1990s when Deng Xiaoping likened China's role to that of OPEC for rare earths (Erickson & Collins, 2019; Nakano, 2021, p. 5; and Kalantzakos, 2018, who extensively documents China's mineral geostrategy). This strategic intent coincided with growing environmental concerns associated with REE mining and processing in the West, as well as the allure of outsourcing rare earth production. Notably, REE production at

Mountain Pass in the USA shut down in 2002 (Green, 2019). As globalization kept integrating the world, there were few worries that China would increasingly dominate the rare earth supply and other metals. Until a significant turning point in 2010, when China strategically used its REE monopoly during a dispute with Japan, resulting in the temporary withholding of exports. Prices spiked, creating a global scramble for processed rare earths. This incident prompted responses from the EU, Japan, and the US, complaining to the WTO and leading to the compilation of lists of critical raw materials (Nakano, 2021, p. 11; see also Scheyder, 2024, pp. 111–112). For Japan the incident drove a strategy to invest and help other resource-rich countries (Australia and eventually Malaysia) to develop rare earths, and in 2023, the country had reduced its dependence on China for REE from 90 per cent to about 60 per cent (Terazawa, 2023; see also Chomon, 2024, pp. 57–58). This has similarities to the 1973 oil crisis.

In the US, there were hopes of making the Mountain Pass Mine into a complete mine-to-magnet supply chain due to the high prices and national security concerns the crisis had raised. Molycorp, the then-owner of the mine, reopened it and invested heavily to reach this goal. However, in 2012, China flooded the market with REEs, prices dropped, and a few years later, Molycorp filed for bankruptcy protection (Scheyder, 2024, pp. 112–113). Today the EU and the US are still trying to break their Chinese REE dependence (Nakano, 2021, pp. 20–23), and although Mountain Pass Mine has been reopened by MP Materials, their REE concentrates must be sent to China for further refining, and the company is partly owned by a Chinese REE business, Shenghe Resources (Scheyder, 2024, pp. 118–119). Japan's position in the REE market is slightly better, as it makes its own magnets, which is the final step, and get some of its supply from outside China (Terazawa, 2023 and Chomon, 2024, pp. 57–58). The EU does not have its own supply of REE.

I still wondered why it seemed so difficult to develop a complete REE supply chain outside of China. Especially when rare earths seemed so crucial to so many things.

My curiosity deepened as I occasionally came across the possibility of one of Europe's largest REE deposits in Norway, situated just a few hours' drive from my classroom at the Fen Complex, Fensfeltet in Norwegian (Sintef, 2023; see the long history about the Fen Complex here: Simonsen, 2023). The possible importance of developing this mine grew on September 14th, 2022, when EU Commission President Ursula von der

Leyen emphasised the growing significance of REEs in her state of the union address. She stated that:

> Lithium and rare earths will soon be more important than oil and gas. Our demand for rare earths alone will increase fivefold by 2030. [. . .] We must avoid becoming dependent again, as we did with oil and gas. [. . .] We will identify strategic projects all along the supply chain, from extraction to refining, from processing to recycling. And we will build up strategic reserves where supply is at risk. This is why today I am announcing a European Critical Raw Materials Act. (von der Leyen, 2022).

Rare earths started to fascinate me, and I wanted to learn more. Moreover, I realized that these elements were integral to broader global systems, including the transition away from fossil fuels to combat global warming, the geopolitical vulnerabilities in a changing world order, and as examples of how the global just-in-time economy relies on almost every element of the periodic table. Additionally, the Fen Complex was connecting the local with the global. And currently there are no rare earth mines in Europe.

As a teacher educator, I saw REEs as a perfect interdisciplinary example for my students and an opportunity to, in a Klafki-inspired way, explore a specific subject deeply to reveal the complexities of broader systems. I began searching for someone to engage with me and the students.

I called geologists working at the Fen Complex and emailed and talked to a Norwegian metallurgist with experience from China and several people associated with the various REE processing start-ups in Norway. But none of them had the time to come to our campus. From the conversations, I learned a lot, and I became more certain that to understand some of the complexity in the field of rare earth extraction and business, I needed to find actual practitioners. It also became evident that having individuals associated with the Green Party or environmental advisors with theoretical backgrounds wasn't enough. I needed someone with concrete hands-on experience who could give concrete insights from within the business. Lindseth (2020, p. 82) calls this practical knowledge *'svarevne'*, which might translate to the "ability to respond" or "respons-ability".

Then, luck hit me in one of my conversations with someone involved in launching an REE-processing facility in Norway. The man I talked to seemed very busy, and I had the feeling that he did not have the time to talk to me. To end the conversation, he said, "... maybe you can try and talk to my colleague, David; he might be willing to engage with you". I accepted and received an email with David's contact information. When I

saw his full name, David O'Brock, I got the feeling that I had heard the name before. It must have been in one of the books I had read.

I looked through my bookshelf and found him in Chapter 4 of a book called *The Elements of Power: Gadgets, Guns, and the Struggle for a Sustainable Future in the Rare Metal Age* by David S. Abraham (2015).

This was it! David O'Brock was the former CEO of Silmet (now called NEO), which was the only rare earth processing plant in Europe (Jüris, 2023, and Johnston et al., 2023). I reread the chapter where O'Brock is showing author Abraham around the rare earth separation plant located in a small Estonian town close to the Russian border. It dawned on me that this American, David O'Brock, is one of the few people outside of China with real practical expertise in the very specialized field of rare earth elements.[2] O'Brock possesses a rare perspective in the REE business, having hands-on experience in both REE processing and navigating the market, which is heavily dominated by Chinese companies under strong state influence (see, for instance, Allen, 2023; Bradford, 2023 or Erickson & Collins, 2019; and Kalantzakos, 2017).

I contacted Mr. O'Brock, and he generously agreed to come and share his knowledge with me and my students. The interactions with him and his lectures not only expanded my perspective but also profoundly influenced how I see the world and teach geopolitics. Moreover, it was an experience that seemed to engage the students because it touched upon several themes that they find important and relevant. This is also an example of internationalization at home. We stayed on campus, but we brought an expert perspective from abroad to our classroom.

The lectures by David O'Brock: From Mine to Magnets

The first lecture

David O'Brock, a seasoned veteran of the global mining industry, now stands before my eager students. I had invited him to share his insights on rare earth elements (REEs). His first lecture of the day, titled 'From Mine to Magnets', goes into the entire process, spanning roughly 34 intricate steps, that transforms raw ore into the pure REEs essential for creating super magnets.

With an engaging start, he poses questions to the students about their electronic gadgets – smartphones, electric vehicles, flat-screen TVs, digital

cameras, and green energy-producing wind turbines. Do they realize that all these technologies rely on REEs?

"Consider your smartphone", he explains. "REEs, make it vibrate on silent mode, reside in the speaker and microphone, give life to the display's colours, and some even give it that radiant glow. These elements are like hidden vitamins or spices in our everyday technology. We might not think of them as essential, but their absence would certainly be noticeable".

"The main thing to consider, when thinking about REEs, is the ones that are used in magnets", he says. "That's what the rare earths are normally needed for and what you want to produce if you are in the business".

He goes on to talk about how REEs also play significant roles in larger quantities – for example, an F-35 jet plane contains more than 400 kilos of REEs in its electronic systems, radars, and the electric motors in the rudders of a plane. Luckily, he shows a photo, so we understand what a rudder is. REEs are also used in military night-vision equipment and different communication systems and are helping nuclear submarines move forward. Electric vehicles house several kilos of REE magnets, and wind turbines more than half a tonne.

It's a captivating introduction. What might have seemed mundane initially now seems to have caught the interest of the students. Some are probably interested because of REEs' relevance in green technologies, others because of the military and thus geopolitical importance, but what really caught everyone's attention, I think, is how essential REEs are for electronic gadgets and smartphones.

Continuing from this engaging introduction, O'Brock embarks on a meticulous, step-by-step journey through the entire REE extraction process. He takes us through the intricate procedures, from identifying mineable ores to over 30 processing and refining stages required to separate REEs from other metals and from each other. To many students, I can interpret from their body language that this is painstakingly detailed – precisely what I had asked of them. From our preparation talks, I knew that this concretization part would underscore that getting these tiny elements pure enough for a finished magnet in a finished Tesla is not an easy process. And even though I am sure he simplified the processes, my own understanding of the intricacy and complexity widened.

We witness the entire journey, including milling, stone cracking, shaking, liquefying processes, pulverization, and more, until we have every REE in a pure, powdery form. These elements can then be alloyed with other

metals, he explains, to power the modern technologies we often take for granted.

However, he doesn't shy away from addressing the environmental implications. He points out that the whole process consumes extensive amounts of water and generates substantial waste, often contaminated with radioactive elements like thorium. The disposal of this waste poses challenges, and he displays a striking image of an artificial lake formed by radioactive waste from rare earth production facilities in Bayan Obo, Inner Mongolia, China. He emphasises that China's near monopoly on REE processing and refining is partly due to relaxed environmental regulations.

O'Brock then delivers this reality with a matter-of-fact tone, emphasizing China's geostrategic advantage in dominating the industry. "To China, rare earths aren't just about profits; they're about geopolitics ... Business is different when it is more important for the monopolist to keep the monopoly than to make money". He goes on to talk about how this aspect has led many REE startups in the West to bankruptcy because China has lowered its prices and basically sold at a loss to hinder the developing REE supply chains that are not dependent on China. I realize the peculiarity of this situation for Western companies that compete with Chinese companies under what is supposed to be the same WTO framework of rules that is supposed to secure fair and free competition.

The first lecture concludes, and we take a break. I overhear students engaged in discussions about REEs and their role in phones. Many who initially found the processing details boring are now fascinated by our international guest speaker – his deep knowledge and confident American demeanour. I shared many of the same feelings. After having read many articles and books on the topic, I could explain some of what O'Brock lectured on, but this was different, deeper, and more hands-on. It was probably as close to 'show', not 'tell', as my class and I were going to get concerning rare earths, and I felt some of his deep understanding was rubbing off on me.

From magnets to magnets – The recycling dilemma

In the second lecture, titled 'From Magnets to Magnets', the focus shifts to recycling. After witnessing the resource-intensive 'From Mine to Magnet' process and its environmental impact, the students naturally see recycling as a solution. Mr. O'Brock informs us that only 1% of REEs are currently recycled.

He explains why one can't simply remove a magnet from an old car and place it in a new one. Electric vehicles, it turns out, haven't been designed with recycling in mind, and the act of removing and reinstalling the magnet diminishes its effectiveness. He actually tried to do it himself, with no luck. O'Brock shows a picture of himself trying to remove magnets from his car without breaking them. He is a doer, he says; he cannot only read things in books; to understand them, he wants to go and try it. I am more of a reader myself, but I can feel the effect of his concrete approach. I knew about the low recycling rate before he talked about it, but the photo of him sitting there trying to remove a magnet from his own car makes it more real.

Another issue he focuses on is that many REEs in various technologies are present in minute quantities, making their separation a costly and polluting process. Just like the mining of REEs has the problem that their concentration in the ore is very small, so that they normally need to be extracted as a by-product from other metals in bigger concentrations.

"For recycling to be viable", he stresses, "we need scale". At present, there simply aren't enough electric vehicles being recycled. And considering that the world still mainly drives fossil-fuelled cars, we would need a lot of mining before we actually have enough metals to be recycled to secure circularity. We would, due to the current geopolitical dynamics, expect a lot more mining and processing facilities in the West. This would take a lot of time and probably face a lot of opposition. Who wants a mine, or a processing facility close to where they live? Developing a complete supply chain, from mine to magnet, would mean handling a lot of waste as well. But this will need to be done a lot better than the radioactive lake in Inner Mongolia. Mining and processing have consequences that the West, for the most part, has outsourced to the rest of the world, and particularly China.

"So, how do we resolve this dilemma?" our speaker says, challenging the class. Various answers surface, but one older gentleman, who had asked to sit in on the lecture, suggests the simplest solution: "Stop using new technologies." O'Brock presents this suggestion to the students as a question, "He's right, isn't he? Can you just stop using modern technologies, like your smartphones?" The students vehemently oppose the idea.

As we break for lunch, I engage in conversations with students who now see the world through a different lens, shaped by our encounter with the international guest speaker who offered a real, concrete experience. At least as concrete as we can get regarding REE processing, since this is something that China is currently more or less a monopolist in doing. I have many of the same feelings as the students. Rare earths in particular, and material

use and mining in general, seemed less difficult and complex before the encounter with David O'Brock. I think about the Dunning-Kruger effect and how easy it is to overestimate one's own competence in this highly specialized and complex modern world we live in. Hijazi (2023, p. 77) captures my sentiment: "A result of the complexity and richness of reality is that our knowledge of the world is in a state of perpetual incompleteness".

As I walk David O'Brock to his train, I ask if the West will soon break free from China's geopolitical, rare-earth stranglehold, and he says that currently it is still a long way to go. The American attempt at reopening Mountain Pass – the mine that has been reopened once again – is still having to send its REE concentrates to China for the completion into magnets. A lot of practical expertise has been waning away in the West, so this might still take some time, and there is also a lot of specialized equipment that may take time to develop, he says.

At the train station, I thank him, and he gracefully agrees to come back sometime the following year and do something similar. In his hand is the mug I gave him with the university's initials on it. I am very grateful that he took one full day off work to come and spend a day with us. We learnt a lot from him, and he seems happy to have been compensated with a modest mug.

Critical reflection: What is at stake?

When I reflect on the richly narrated experience, I would like to emphasize a few topics that are at stake. These are a) material consequences, b) the recycling dilemma, c) global climate vs. geopolitical realities and Norway's place and d) internationalization at home.

a) Material consequences

Of course, it is obvious that smartphones, electric vehicles, and wind turbines need a lot of materials – if you think about it. However, since we in Norway are so insulated from the making of these products, we mostly do not realize or consider the complexity and consequences of making them. We swim in end products and are quite unaware of their life journey.

These lectures, in a sense, *rematerialized* the world for me. I am surrounded by processed materials, and I now look at them from a different perspective, a material perspective: Where do these things come from? How

are they made? Which input factors are needed? How is the journey of the material affecting nature and people?

The lectures brought me closer to material reality, and Mr. O'Brock's detailed explanation of the whole process from mine to magnet also contributed to a better understanding of what could await Norway and our local environment in the near future.

We are the best in the world at importing electric vehicles; now we need to take part in the making of them. Questions that have been abstract and disconnected in Norway due to global supply chains are becoming real and concrete due to both climate and geopolitical realities. We need to talk about mines, processing, waste disposal and locations for these facilities.

When the old man suggested the alternative – stop using modern things – both I and the students disagreed. Our insular period is ending; we are getting skin in the game (Taleb, 2018).

It is a lot easier to accept consequences that only affect other people or do the right thing (buy an EV) when there is no downside to it. The interactions with the REE expert made me pay closer attention to the material foundation of our modern society. For instance, while driving home from squash practice, most evenings my local tunnel is closed due to maintenance. I did not notice before or think about the material implications of this; now I wonder how much material goes into the maintenance of the tunnel?

b) The recycling dilemma

If we do not want to dig more into the ground than necessary, we need to recycle. Until the interactions with Mr. O'Brock, I did not realize that this was an issue in Norway. In my house, I have four different trash cans, and outside, there are even more alternatives for different waste. The dumps in Norway do not really look like dumps anymore. A Norwegian dump is now referred to as a recycling centre. My local centre may have more than forty different containers for separate materials. In my concrete reality, I have the impression that anything can be recycled. Circular materials use must be within reach if the rest of the world only copies Norway.

David O'Brock proposed that Rare Earth Elements (REE) are almost never recycled. When he showed the photo of himself trying to remove magnets from his own car and told us how difficult it was, I started to wonder what else might not be recycled when I hand it in. Once again, I got the feeling that something I had taken for granted in my material reality did not

match the actual reality. Moreover, I realized how easy it is to be fooled in our complex societies. Recycling seems easy when my only experience is to sort my waste at home and occasionally drive to a recycling centre and sort my waste. If not even larger magnets in an EV are recycled because of poor design, lack of scale, and thus high cost, what about elements within all these tiny gadgets we use? And since the imperative of the green shift is to replace all fossil transportation, we will need a lot more extraction before circularity is even possible.

c) Global climate vs. geopolitical realities and Norway's place:

The lecture emphasized the critical role of rare earth elements in the green transition, modern life, and geopolitics. From my background in geopolitics, I was aware of the significance of REEs and had witnessed the EU, Japan, and the USA declaring their intentions to reduce reliance on China. When it comes to climate and the green transition, Mr. O'Brock clearly illustrated how REEs are vital in green technology. And how they are not only essential for our modern lives, filled with smartphones and gadgets we consider indispensable, but also, from a geopolitical perspective, especially considering their use in military equipment. For the lecture, I think it was very important that he showed the very clear relevance for the students through emphasizing how the REEs make their phones work.

O'Brock explicitly stated that, for China, REEs hold geostrategic importance; their focus is on preserving the rest of the world's dependence on them, rather than making money. I could sense his frustration after having to deal with this for many years in the REE business. How must it be for a Western REE start-up that believes and relies on a market logic to face competition from Chinese companies that play by national security logics?

It served as a clear example of one great discrepancy I feel when I hear discussions on global warming; while the global battle against climate change necessitates cooperation and the most efficient use of resources, geopolitical realities drive the three wealthiest actors in global politics to seek independence from China's monopoly.

For the Norwegian state, this implies more concrete consequences concerning resource extraction for the green transition, with all the implications it carries for the local environment, discussions involving "not in my backyard" (NIMBY), and, significantly, the geopolitical needs of the EU. Both global climate action and international geopolitics are coming closer to our doorstep.

This experience solidified a perception of mine that the equations do not add up. Climate action requires global cooperation, but the world of geopolitics is increasingly tilting towards conflict, security, and self-sufficiency. While the climate issue is naturally global, the system of states operates at an international level, meaning between states with different interests. In geopolitics, we observe challenges, particularly from Russia and China, to the so-called liberal world order led by the USA. When international orders are destabilized, history indicates that there will be more conflict (Braumoeller, 2019).

There is an ongoing war between Europe's two largest states, Russia and Ukraine, an increase in global military expenditures, growing resource consumption, and emissions increase. The US and China are the two largest emitters and are currently in what seems like an arms race. Moreover, domestic politics in the US is very polarized.

The logic of states revolves around ensuring their own survival. In Realist international relations theories, this is explicit, whereas in Liberalism, it is implied: Doyle (1983, p. 223) implicitly argues that Liberalism prioritizes state survival, as its institutions are designed to prepare for foreign threats and restrain internal aggression. If a state fails to defend itself, its liberal institutions and values become irrelevant.

The logic of the climate system and those working within it is centred on global cooperation to maintain a habitable planet for all. This is not just their mission – it is a reality. Stopping global warming requires replacing fossil fuels as an energy source, which demands extensive international collaboration. From within the climate system, nothing can logically be more important than this goal.

However, the logic of state security operates differently. For states, national survival is paramount, and when security is at stake, everything else – including climate action – becomes secondary. While both systems pursue what they see as the most important goal, states hold vastly more resources and political power than the climate system. When national security is threatened, the priorities of states quickly take priority over those of climate institutions and scientific communities. In moments of crisis, few concern themselves with climate change, no matter how real and urgent the problem remains.

On this issue, the lecture confirmed my own feeling of discrepancy between the worldview of the global climate leaders and the geopolitical realities that inform major states' security thinking. The geopolitical realities are far-reaching; the global climate cooperation needs to be deep and far-

reaching. REEs are an ingrained part of both realities. In this part, I sound clearer than I did; I forget how occupied I was with my one geopolitical system. The clear connections that I have now written out are a result of the lecture.

d) Internationalization at home

I had already acknowledged that my understanding of REEs was far from sufficient (see Lindseth, 2020, p. 99). That is why I ended up inviting O'Brock. Initially, my goal was simply to improve my geopolitical model, but through a deep dive into the practicalities of REEs, I now see how much more was at stake.

The collaboration with David O'Brock did not just provide theoretical insights; it also rematerialized both me and my students. We now understand better the importance of minerals and materials in geopolitics, climate policies, and supply chain security. Instead of remaining at an abstract level, O'Brock showed us very concretely how mining, processing, and recycling actually work, why recycling is so difficult, and how China uses its REE monopoly as a geopolitical tool. What we learned was not just knowledge; it was knowledge with "svarevne" (see Lindseth, 2020, p. 82), meaning practical knowledge from someone who had actual experience. And of course, in-depth knowledge has a tendency to increase complexity.

My students, most of whom are now teachers, are better prepared to engage with the increasing dilemmas of mining in Norway. From climate vs. nature trade-offs to the role of Indigenous rights in resource extraction to geopolitics, they can now teach about why minerals are essential for the green shift and give concrete examples from REEs.

I did not expect that I would now be part of a research group named Fensfeltet (the Fen Complex) that now includes historians, mathematicians, geologists, music educators, and faculty from early childhood teacher education. They came to the lectures, most of them with little prior knowledge about REEs.

The REE lectures opened the door for me to think in systems and materials and broadened my scholarly interests.

Our collaboration with David O'Brock has continued, and he has already been back for another lecture and a meeting with the research group.

Theoretical reflection

"I am what I see, I see what I am," writes Ahmad Hijazi (2023, p. 66), in a compelling reflective aphorism. His book is about how we humans navigate an increasingly complex world, and to make sense of all the things we do not really understand, we approximate. By that, he means that we simplify detailed information into something general or something we are already familiar with. This way of thinking helps us handle complex situations more easily, but it might also cause us to miss out on the full detail and variety of the world around us. The aphorism also relates to *bounded rationality*, introduced by Herbert Simon (Simon, H.A., 1990), which Meadows (2008, p. 87) describes as, "The logic that leads to decisions or actions that make sense within one part of a system but are not reasonable within a broader context or when seen as part of the wider system." Martin Wolf (2022) of the Financial Times argues that it might be "... convenient to think about the world in intellectual silos" and that this might work well in a stable world; however, to navigate "... today's storms ... we have to think systematically". Moreover, "It is not just theoretically true that everything depends on everything else. It is a truth we can no longer ignore in practice ... silos are perilous".

To address global challenges such as climate change, escalating conflicts, mineral shortages/material overuse, and growing community polarization, the imperative to understand perspectives beyond our bounded knowledge is clear. This requirement is central to the kaleidoscopic approach advocated by Helskog and Weiss (2023, pp. 22–27), which posits that to better comprehend the multilayered nature of complex issues, we must engage in an active, holistic exploration of different viewpoints. They write, "Within a kaleidoscopic epistemology, opposite perspectives can shed light on different elements of a phenomenon and be meaningful in their own right" (p. 23). This dynamic ability to shift perspectives reveals that "... instead of fixating on one pattern, several patterns can dynamically enlighten each other, bringing out a bigger and truer picture of complex issues" (p. 23).

The phenomenon of this essay is, of course, rare earth elements; they stay with us as we twist the kaleidoscope.

Material consequences: disconnected from material reality

As is with rare earths, most materials need to be dug out of the ground somewhere. As Dana Meadows writes (2008, p. 95), "Of course, cars don't come from a cloud, they come from the transformation of a stock of raw materials . . . .". And the green shift requires a lot of minerals; the International Energy Agency (IEA, 2024) writes that " . . . a concerted effort to reach the goals of the Paris Agreement (climate stabilization at 'well below 2°C global temperature rise', as in the SDS) would mean *a quadrupling of mineral* requirements for clean energy technologies by 2040. An even faster transition, to hit net-zero globally by 2050, would require six times more mineral inputs in 2040 than today." Considering REEs, they find: "Likewise rare earth elements may see three to seven times higher demand in 2040 than today, depending on the choice of wind turbines and the strength of policy support." When it comes to mining revenues, the same IEA summary says that revenues from coal mines today are ten times larger than revenues from energy transition minerals.

In a coauthored article at Euractiv.com, the executive director of IEA, Fatih Birol, and the chair of the Environmental Committee in the European Parliament, Pascal Canfin, write that the reliance on imported materials continues to be a cause of concern in many EU member states. They insist that critical minerals should not be considered a sideshow: " . . . instead they are part of the main event as Europe moves to a net zero energy future." Birol & Canfin (2023).

For rare earths, the fact is that Europe does not have a mine. There are prospects for one in Sweden, and there are prospects in Norway at the Fen Complex. The IEA (2024) has analysed the development lead time of mining projects to an average of 16.5 years.

For the last few years, Nordic Mining has been working to open Norway's first mine in nearly 40 years. It will produce a titanium oxide, which is on the EU list of Critical Minerals (Valmot, 2023). However, mining is not good for nature, and the company's plan to dispose of waste in the local fjord is currently in the legal system, as they have been taken there by a nature conservation organization. This is not unique for Norway. Reuters journalist Ernest Scheyder (2024) recently published a book about different American communities, including different indigenous groups and even botanists (defending the Thiem Buckwheat that thrives on lithium soil), that are fighting to keep mining away from their own backyard.

It is very easy to be pro-climate and the green transition if it has no cost but only benefits. In Norway, we enjoy many end products like the Teslas that the Norwegian state has subsidized. But now this is changing. And I sense that the new tensions increasingly divide people who used to agree, because the consequences of the green shift were felt elsewhere.

There are already wind farms put up in several places, and they are, of course, disturbing nature, and people are angry. The decision to develop the electric grid in Northern Norway, in connection with the electrification of an LNG gas plant at Melkøya island, is a perfect example of material consequences. In this area, there are different interests at stake in conflict over where a power cable should go: the industry that benefits vs. both fishermen and Sami people that lose, the Norwegian state against Sami interests, and nature concerns against climate needs. This, in turn, has led to political unrest within parties, regions, and local communities and between parties, regions, and local communities (Rustad, 2023).

We are slowly becoming rematerialized, and if we want a green transition, a lot more mining and a lot more wind farms, and a lot more grid development will come. Especially since the OECD can report that the countries that have been exporting most of the critical minerals to the OECD countries, like Russia and China, are increasingly restricting their exports. (Kowalski & Legendre, 2023, pp. 5–6). It is easy to approximate that setting up mineral supply chains can be done quickly if we need it, but mineral extraction has many obstacles.

Part of my rematerialization has been that I noticed material use everywhere; I mentioned the tunnel in my hometown that is closed most nights for maintenance. Apparently, built structure, also known as in-use stock, locks in a lot of future material use this way.

Krausmann et al. (2017) of the Universität für Bodenkultur (BOKU) school in Vienna, known for their research on material metabolism, found that roughly 50% of all materials extracted annually are used to augment or update existing material stocks (buildings, infrastructure etc.). Their analysis from 1900 to 2010 shows a 23-fold increase in global material stocks. And since globally we keep using more materials, only 12% of the inflow of materials comes from recycling. Developing countries are expected to drive further increases in material extraction through construction and infrastructure building. If developing countries' material stocks are to match that of industrialized states, stocks would need to be quadrupled. Which in turn will drive CO_2 emissions past climate targets.

This is a material reality, and I wonder how industrialized nations, which have locked in so much future material use through existing infrastructure, can tell developing countries that they should build less?

Ed Conway writes in his book *Material World* (2023, p. 197) that in developed economies every person has about 15 tonnes (15000 kg) of steel surrounding their life. This is the skeleton of hospitals, schools, houses, bridges, railways etc. Steel may be as good a measure of development as GDP. On average there are 4 tonnes of steel per person in the world. China, which has been building more than any other country in the last decades, is averaging about 7 tonnes per person. In Sub-Saharan Africa there is less than 1 tonne of steel surrounding each person (Conway, 2023, p. 203). So maybe 15 tonnes per person is a satiation level for steel?

Vélez-Henao and Pauliuk (2023), have developed a material requirement of a decent living standard, which details a minimum material requirement of about 6 tonnes per person per year for housing, school buildings, clothes, food etc. But I do not think that most people will stop at that level if they get there. Why would any people in the developing world stop increasing their material use before they reach the level of developed economies? It is a reinforcing cycle. More materials mean better access to school, for instance, which may improve chances of further material acquisitions.

The energy and material expert Vaclav Smil wrote a book called *Growth* (2019) that shows how humans and all human-made systems cannot seem to stop an endless journey of expansion. In an interview about the book, Smil says, "... I wanted to put it all together under one roof so people could see how these things are inevitably connected and how it all shares one crystal clarity: that growth must come to an end. Our economist friends don't seem to realise that." (Watts, 2019). As for the green shift, Smil is very sceptical and has no faith in the world reaching net zero by 2050.

Smil is a numbers man who does not like approximations. In his 2022 book titled *How the World Really Works*, the introduction (pp. 1–11) captures the theoretical framework for this reflection perfectly. On page 2, he writes that most people in modern societies have a very superficial understanding of how the world really works. The reason for this is that we are so *disconnected* from how food, energy, materials, machines, and devices are produced that we barely even approximate. More than 80% in affluent countries live in cities. "People are constantly interacting with black boxes, whose relatively simple outputs require little or no comprehension of what is taking place inside the box". And most of our experts are so specialized that "... experts in particle physics would find it very hard to understand

even the first page of a new research paper in viral immunology. Obviously, atomization of knowledge has not made any public decision-making any easier." (Smil, 2022, p. 2). He is also pointing out that most jobs that are highly rewarded "... are for work completely removed from the material realities of the earth" (p. 4). As for the green shift, he provides one dry comparison: "... in 2020 the average annual per capita energy supply of about 40 percent of the world's population (3.1 billion people) ... was no higher than the rate achieved in both Germany and France in 1860!" (p. 5). If these 3.1 billion should reach what Smil calls a dignified standard of living, they would need to double or maybe even triple their energy use, with all its consequences to the biosphere. Four pillars of materials that sustain modern civilization – steel, concrete, plastic, and ammonia – Smil says, are foundational material realities that are really hard to decarbonise or substitute. "In absolute terms, material demands have been rising in the world's most affluent societies, and they remain far below any conceivable saturation level in low-income countries ... " (Smil, 2022, pp. 6–7). As for our historic energy use, J.B. Fressoz (2024) recently wrote a book about how we have never transitioned from one energy source to the other. In fact, he shows that in absolute numbers we keep using more of all energy sources as new ones are added. So, we have never quit using any source of energy, which is related to Stanley Jevons' famous paradox. The green shift is about quitting fossil energy altogether. Considering Smil's remarks on how billions of people would require double or triple their energy use to reach a dignified standard of living and the prospect of world population increasing with nearly 2 billion more people in the next 30 years (United Nations n.d.), net zero by 2050 looks difficult.

I find Smil convincing, and I think a realistic material perspective is often overlooked. I wonder about all the other perspectives that I do not even realize exist.

The recycling dilemma: we need a circular economy

Only one per cent of rare earths are currently being recycled. One reason for this is that we do not hand in all our old electronic gadgets and phones. Instead, they are lurking in our junk drawers at home (Tabuchi, 2024, January 20). But even if we were handing them in, it would be both costly and technologically difficult to recycle the REEs because they are often in minute quantities and alloyed with other metals. Sprecher, Kleijn, R. et al. (2014) investigated the possibility of recycling one important rare earth el-

ement (remember there are 17 REEs in total), neodymium, from hard disk drives, and found many of the same obstacles: quantity, alloys, and cost. Globally, less than 20% of e-waste is properly managed (Rizos, & Bryhn, 2022, p. 2).

Reese & Hoffman (2021) claim that economically speaking, recycling makes little sense if you include all the factors from transport and water to rinse to machines or humans to take apart the different pieces and so on (pp. 49–50). It is easy to approximate that an iPhone with more than sixty different elements in it, including gold, should be valuable to recycle. I recently argued with my local electronics store because they said my used iPhone was worth next to nothing. I argued that all the elements inside, including the rare earths, are really difficult to process, but it was to no avail, and I returned home frustrated.

Why is the economic return from recycling smartphones surprisingly low? Reese & Hoffman (2021, pp. 107–111) write that the gold in an iPhone is valued at around 65 cents, and the phone's total scrap value, including metals like copper and nickel, remains modest. An iPhone 6 also contains about 31 grams of aluminium, valued at merely a nickel, considering aluminium's market price of $1,500 per tonne. This marginal financial incentive, compounded by the logistical barriers of recycling, greatly limits their recycling feasibility. Moreover, the minuscule quantities of other metals in the phone mean that it is more cost-effective to mine ore than to recycle phones. Collectively, the value from gold and other metals like copper and nickel is less than a dollar. Without groundbreaking advancements in recycling technology, smartphones are doomed to remain a largely untapped resource, piling up as future waste.

If we cannot recycle, it means more of consequences from digging in the ground. As the Krausmann et al. (2017) article above showed, when it comes to global material use, only 12% of new stock comes from recycled materials.

Recycling and the circular economy are not straightforward.

Global Climate vs. Geopolitical Realities

When I was trying to find an expert to come and talk to me and the students about rare earth elements, I remember talking to a professor of metallurgy at a Norwegian university. He had been working at a Chinese university for a while, and so I thought he could be a good candidate. During our conversation, I realized that he had never considered the geopolitical aspects

of the metals we were discussing. It was a big surprise at first, especially as he had been working in China as a Western metallurgy professor, but in the following months, I realized that this was quite normal. Moreover, even though I had developed my geopolitics model for years, I had not really bothered to go deeper into what critical raw materials really meant. They were in the model, but in my dematerialized unconsciousness, I did not pay much attention. These are, of course, examples of bounded rationality.

Today, I think both international officials and climate scientists working on global warming see the geopolitical side, and critical minerals have certainly become important in geopolitics and national security discourses. The two sides have different ultimate purposes: the climate side's purpose is to keep planet Earth liveable for human beings, while the geopolitical perspective, which is upheld by national security officials, is to keep their respective states safe. To combat climate change effectively, the world needs to cooperate and leave geopolitics and conflict aside, as UN Secretary-General Antonio Guterres and Executive Director of the IEA, Fatih Birol, have urged the world's leaders many times (United Nations, 2023, September 20; IEA, 2023, p. 4).

While the climate is global, geopolitics is mainly inter-national. International institutions rely on the support of member states. Sovereign states, especially the big powers, rely on themselves first and foremost and secondly on allied states. In times of insecurity for great powers, global warming is not the priority. These are our current times:

Climate:

On August 28th, 2023, four Guardian journalists asked 45 leading climate scientists from around the world, "How bad is it, and how can we limit the damage?" They also asked if "... extreme weather was hitting people faster and harder than expected" (Carrington et al., 2023) in response to extreme weather records in 2023.

The scientists affirmed that the observed global heating was in line with decades of scientific forecasts, highlighting that this had been predicted in their models for years. Even with the shock from unprecedented sea temperatures and Antarctic ice loss, they claimed that the world had still not crossed a tipping point towards uncontrollable climate change. However, each degree of further warming would bring us closer to irreversible consequences. They emphasized the urgent need for immediate action, meaning stopping fossil fuels. If not, the extreme weather of 2023 would become the new normal.

Geopolitics:

As Rodrik and Walt (2022) point out, the rules-based liberal order that has been dominated by the United States and its allies is deteriorating before our eyes. We are experiencing the highest number of violent conflicts since the Second World War (United Nations Security Council (2023). The director of the Stockholm International Peace Research Institute (SIPRI), the world's most important think tank on military armament, Dan Smith, said on June 12th, 2023, that "We are drifting into one of the most dangerous periods in human history" and that "It is imperative that the world's governments find ways to cooperate in order to calm geopolitical tensions, slow arms races and deal with the worsening consequences of environmental breakdown and rising world hunger" (SIPRI. 2023). And while we are experiencing the highest number of violent conflicts since the Second World War, tensions are brewing between the world's two greatest powers: the USA and China (see, for instance, Doyle 2023, Neumann 2024, or Leonard, 2021). These countries are also major trading partners, so instead of complete decoupling, the US is weaponising Chinese access to certain technologies, while China weaponises its mineral supremacy, the latest being REEs in December 2023. The weaponization of green metals like rare earths may also reduce the production of wind turbines and electric vehicles that are essential for the green shift. Moreover, the European Union may want to push Norway to get the Fen Complex up and running to have a secure supply chain.

How Chinese holistic thinking outsmarted the West

As mentioned already, in the prologue, the Chinese strategy of gaining a monopoly in rare earth elements, similar to that of OPEC for oil, dates back to Deng Xiaoping in the 1980s or 90s. With the fall of the Soviet Union and China's opening up to the world, the dominating thought of the US hegemon was epitomized by Francis Fukuyama's article, "The End of History?", which argued that Marx was wrong and that " . . . the end point of mankind's ideological evolution . . . " would be " . . . the universalization of Western liberal democracy as the final form of human government" (Fukuyama 1989, p. 1). Acknowledging its imperfections, this viewpoint nonetheless proposed Western liberal democracy as the 'least bad' system of governance, superior to all known alternatives. The core ideas in Liberalism in international relations theory, as I understand them, include a focus on the positive role of international institutions, mutual interdependence

through trade, and the democratic peace theory – which holds that democracies do not fight each other. Doyle (1983, p. 213) argues that liberal states form a "separate peace" among themselves but often behave aggressively toward non-liberal states.

The US, the undeniable hegemon for at least 20 years after the fall of the Soviet Union, acted on the aphorism "I am what I see, I see what I am," believing that China was starting to view the world through the same liberal lenses. *They were wrong*. As Doyle warns, liberal states often misread non-liberal regimes, assuming they will naturally adopt liberal norms over time.

Concerning rare earths, which the US had been dominating for twenty years until the mid-1980s, there was no issue with China taking on this matter. In linear liberal thinking, this was just creating more interdependence, and the US could outsource the dirty mining and processing of REE and buy back end product. China was more than willing to take on mining and processing of different metals, even though it destroyed a lot of nature (Harrell, S. 2023 has written a great book on this). Obviously, economic development was more important than protecting nature. To hinder more famines, environmental destruction was a small price to pay; by the year 1998, "... China was finally able to feed itself" (Harrell, 2023, p. 231).

In 2001, China entered the World Trade Organization, and an increasingly globalized world kept trading, and China became richer. Until the oil crisis of 2010, when China held back REE exports. The Japanese immediately realized that interdependence could be weaponised and tried to develop an REE chain outside of China (Australia for mining and Malaysia for processing). The US took a few years longer to realize, and the EU has now finally awakened. What they had to realize, I think, is that the Chinese Communist Party has never had any intention of turning China into a liberal democracy.

Juan Chomon (2024, pp. 43–76) applies the board games chess and Go as metaphors for understanding how the Chinese state's strategy is, and was, different from the US and EU. Western strategy often mirrors chess, where the focus is on direct confrontation and the elimination of opponents' pieces to achieve checkmate. The rules are the same, it is played on an open board, and the pieces move in linear, stable patterns. This reflects an analytical approach, breaking down complex challenges into manageable parts, focusing on individual components and their functions. The tactic of chess requires specific, calculated moves, symbolizing Western culture's preference for direct problem-solving and individualism.

In contrast, Chinese strategy resembles Go, emphasizing broad territorial control and the strategic encirclement of the opponent. Unlike chess, where all pieces are on the board from the start and move according to fixed rules, Go begins with an empty board. Players take turns placing their stones (one player with black stones and the other with white) on the intersections of the grid on the board.

The placement of stones happens gradually over the course of the game, with each move building on the previous ones. Players do not move stones after they are placed; instead, they lay down new stones one by one on each turn. This holistic approach values the interdependence of moves within the entire system, focusing on overall patterns and relationships rather than discrete battles. Go's roots in East Asian culture align with holistic thinking, valuing context, interdependence, and relational understanding (see also De Oliveira, S., & Nisbett, R. E., 2017, for more on the geography of thought).

This fundamental difference in strategic thinking, Chomon (2024, pp. 43–75) exemplifies with China's approach to dominating the rare earth elements (REE) market (see also Shen, Y., Moomy, & Eggert (2020). Since the late 1980s, China has been systematically working to secure a dominant position in the global REE supply chain, a calculated effort aimed at long-term control rather than short-term gains. This strategy started to take shape notably with China's acquisition of American Magnequench in 1995, which gave it methods of magnet technology. This was another move to control the complex journey of REEs from the mine to the magnet. The acquisition marked the beginning of China's near monopoly in the REE industry, controlling critical stages from processing raw materials to producing advanced magnets essential for modern technology. But China's strategy didn't stop at technological dominance. Utilizing its WTO status and the global market dynamics, China has masterfully manipulated the REE market to discourage competition in refining and alloying, even paying a premium for REE concentrates to deter other countries from developing their supply chains downstream. Moreover, while China now has scale, competitors like NEO, the rare earth separation plant in Estonia, do not get access to modern Chinese gear and still must use their old equipment.

This Go-like strategy of encircling the market has allowed China to not just dominate the REE sector but also become a significant player in green technology. China controls most of the supply chains of green metals in general, from owning mines across the world through processing and development into final products in China. If a business moves production to China, it will get access to cheaper metals. If it does not, it will face com-

petition from companies that have a cost advantage. China now dominates a lot of green end products, like wind turbines, electric vehicles, and solar panels (Chomon, 2024, pp. 43–76).

In essence, while the West may often opt for direct, chess-like strategies focusing on immediate threats, China's approach in the metals sector is more reminiscent of Go, emphasizing strategic positioning and long-term territorial gain. This holistic strategy has enabled China to become a processing giant, particularly when it comes to green minerals.

In the last few years, we have seen the US changing strategy by introducing the CHIPS Act (White House, 2022, August 9) and the Inflation Reduction Act (IRA) (White House, 2023, August 16). The US may have started its process of de-risking from China. The CHIPS Act is intended to keep Western technology from Chinese hands (Western, because the US also put pressure on Japan for some input technology and the Netherlands to stop their company ASML from exporting advanced semiconductor lithography equipment to China), in particular, semiconductor technology. The IRA aims to support American supply chains for the green transition by providing subsidies, including to MP Materials, which owns the Mountain Pass mine, to create a complete supply chain from mining to magnet production. However, this could pose challenges because the company has a Chinese shareholder, Shenghe Resources, holding a 7.7% stake in MP Materials' stock (Zorpette, 2024). Shenghe might seek to prevent MP Materials from developing downstream processing capabilities in the US, as Mountain Pass currently supplies rare earth materials for refining in China, helping to preserve China's monopoly on rare earth processing and refining.

The change of industrial strategy in the US, which included restricting Chinese access to semiconductor technology, did not go unnoticed in China, which responded by stopping exports of critical semiconductor materials like germanium and gallium (Nguyen & Onstad, 2023). Furthermore, they are now tightening their exports of the key battery anode material graphite, which they also dominate. This is part of an escalating trade war between China and the US, which recently prohibited exports of even more microchip types from producer Nvidia (Economist, 2023). On December 21, 2023, China imposed export restrictions on REE equipment and prohibited Chinese REE experts from cooperating with foreigners (Nguyen & Onstad 2023).

Since the fall of the Soviet Union, the dominant liberal Western approach to international relations, rooted in interdependence and global institutions, has increasingly given way to geopolitics, autarchy, and zero-

sum thinking. International bodies like the WTO struggle to mediate, much like the UN Security Council, which is paralyzed by veto powers such as Russia and the USA. Mutual, complex interdependence is no longer seen as a strength; rather, it is a vulnerability that might be weaponised (Farrell & Newman, 2019). The most powerful actors in the world today are states, and their first concern is national security; this takes precedence over climate change.

Impact on Europe: Geopolitics and the Green Shift

Recently, the director of the National Security Authority (Hesla, 2023), a researcher in the Norwegian military, and one of Norway's foremost recognized experts on geopolitics (Hellestveit, 2022, pp. 168–169), have all stated that Norway is unprepared for the new geopolitical realities of the current international situation. "We do not have it in our backbone that things can go terribly wrong on a large scale," war researcher Tor Ivar Strømmen told the Norwegian broadcasting network (NRK). "He believes that politicians lack an understanding of the threats Norway is facing" (Brembo, 2023). Hellestveit argues that one key reason for this unpreparedness is that Norway has experienced a period of *deep peace*.

It seems our authorities have thought that war in Europe, or particularly in Norway, is unthinkable. With Putin's full-scale invasion of Ukraine, Western Europe and Norway are starting to wake up. Defence and security are becoming concrete things for Norwegians again because we recognize that war is a real possibility. Like the rest of the world, Norway is increasing its military spending.

The EU needs both green minerals and defence-critical materials. Norway possesses significant mineral resources beyond rare earth elements, many of which are of strategic interest to the EU. The Fen Complex may hold the largest REE resources in Europe, but other mining projects across the country are also being explored. In the material reflection, I have shown that material extraction, waste disposal, and the development of green end products – such as wind farms or an expanded electric grid – have already met significant opposition. Likewise, mining companies seeking to start operations in multiple locations across Norway are facing strong resistance.

Both the EU and the US are working to de-risk their supply chains from China, but this transition faces strong opposition from stakeholders such as indigenous groups, environmental organizations, and local communities. Norway has the potential to become a key supplier of green minerals for

the EU, just as the EU is becoming increasingly important for Norway amid rising geopolitical and geoeconomic tensions.

For decades, Norway has largely lived in an abstract world where security and material needs – whether for defence or the green transition – were taken care of elsewhere in the global supply chain. But as geopolitical tensions disrupt global trade and supply chains, Norway is being pulled back into the real world, where we can no longer just reap the benefits while others bear the costs. In much of the world, people have long understood that production comes with material consequences – now, Norway is beginning to experience this reality as well. If we are to face both geopolitical and climate realities, we must recognize that the extraction and processing of raw materials cannot always happen "somewhere else".

International collaborations in higher education

I should start by emphasizing that most of this article is a result of this experience with international collaboration. In itself, that is evidence of impact from getting hands-on, practical knowledge in-depth. And because I did not travel abroad but instead brought an international expert to the campus in Norway, I think the effect was broader.

Internationalization should not be only for the few who can travel abroad. As the Norwegian government has stated, high-quality education depends on international cooperation, and the government wants internationalization to increase (Kunnskapsdepartementet, 2020). However, internationalization must be more than just exposure to foreign people or languages – it must serve a clear educational purpose (Beelen & Jones, 2015). This is where Internationalization at Home (IaH) becomes important. Beelen & Jones (2015, p. 69) define Internationalization at Home as:
"... the purposeful integration of international and intercultural dimensions into the formal and informal curriculum for all students within domestic learning environments."

This collaboration exemplifies why internationalization should not be limited to mobility programmes. Bringing an international expert into the classroom provided deeper, practical engagement with global challenges through a deep dive into some tiny elements from the periodic table. Instead of students passively receiving theoretical knowledge, they interacted with someone who could answer concretely with hands-on experience about most aspects of a very specific topic (see Lindseth, 2020, p. 82). We experienced the opposite of approximation.

Moreover, the impact extended beyond the classroom. Lindseth (2020, p. 83) describes how discrepancies between expectations and reality lead to reflection and new directions. Concerning this topic, we had many, for instance, the difficulty of recycling REEs. For me, it led to looking into other recycling problems that I had not thought about. Plastic is an example of something that is barely recycled.

The collaboration with O'Brock unexpectedly led to interdisciplinary research engagement (Fensfeltet), illustrating how international cooperation can reshape academic structures.

This experience shows that IaH is not just an alternative to exchange programmes; it can be a catalyst for long-term academic collaboration, research initiatives, and systemic thinking.

Meta Hodos

I will end this essay with a reflection on my journey instead – what Lindseth (2020, pp. 95–99) calls *meta-hodos*, how knowledge evolves through movement and reflection. This path started with me trying to figure out what was so peculiar about rare earth elements. I wanted to understand them better to improve my geopolitics model. I would never have imagined that this tiny question would lead me into so many fascinating and complex issues.

What stands out from the concrete reflection is how lucky I was to come across someone with deep practical expertise from the real world of rare earth elements. That encouraged me to go further and deeper into areas of knowledge I would not have considered before. As Lindseth (2020, p. 82) points out, knowledge gains responsiveness (svarevne) when it is tested in real-world contexts, allowing it to connect with complexity rather than remain abstract and approximate. O'Brock's expertise was not just theoretical; it responded to real dilemmas and deepened my understanding in a way that purely academic sources could not. Moreover, that deeper understanding of REEs allowed me to see connections in many different directions across disciplines.

What I call rematerialization, which of course came to me as I realized how disconnected, or dematerialized, I was, changed the way I see my surroundings. This shift is in line with Lindseth's (2020, p. 83) idea that discrepancies between what we assume and what we encounter in reality can lead to deeper reflection.

Especially since I drive to play squash several nights a week, material maintenance had been right before my eyes for years without me paying attention. Suddenly, I started to notice how often the roads were maintained and how often my local tunnel was closed at night for the same reason.

The theoretical reflection on geopolitics and climate change became a lot longer than I had imagined. When I realized that one reason China could gradually capture the REE monopoly was due to its holistic, Go-like strategic thinking, compared to the more linear, chess-like approach of the Americans, my understanding expanded. I see now that many systems interact and that REEs and their supply chains provide a good entry point for understanding many of them. My way into systems thinking has been through this extensive deep dive into REEs.

This has affected my teaching and my research, and to my surprise, also many of my colleagues from many different disciplinary backgrounds, who are now part of our research group on minerals and REEs. A PhD student has even joined the group, with a project on mining and the rights of indigenous people.

Finally, I will refer to an article that connects to many of the writings in this paper. One of the authors is Johan Rockström, whom I mainly knew as a climate scientist famous for developing the planetary boundaries concept (Rockström et al., 2009). In early 2024, he published an article with Lawrence et al. (2024) titled "Global Polycrisis: The Causal Mechanisms of Crisis Entanglement". The abstract is as follows:

The term "polycrisis" appears with growing frequency to capture the interconnections between global crises, but the word lacks substantive content. In this article, we convert it from an empty buzzword into a conceptual framework and research program that enables us to better understand the causal linkages between contemporary crises. We draw upon the intersection of climate change, the COVID-19 pandemic, and Russia's war in Ukraine to illustrate these causal interconnections and explore key features of the world's present polycrisis. (Lawrence et al., 2024)

Postscript

In April 2025, President Trump escalated the tariff war with China. The Chinese response revealed the power of controlling the rare earth supply chain.

In addition to tariffs on American goods, China imposed export licensing requirements on seven medium and heavy rare earth elements – samarium, gadolinium, terbium, dysprosium, lutetium, scandium, and yttrium –

along with their compounds, oxides, alloys, mixtures, and products (Jin et al., 2025)

This was no coincidence. The only U.S. rare earth mine, Mountain Pass, mainly produces light rare earths, while these seven are the hardest to replace. For a neodymium magnet to stay magnetic above 80–150 °C (Curie temperature), it must be doped with the heavy rare earth dysprosium (Constantinides, 2017)

Samarium, meanwhile, is vital in military equipment that requires magnets to maintain magnetism at even higher temperatures (Bradsher, 2025).

The measures triggered a crisis and "full panic" among car manufacturers outside China that rely on such magnets for braking and steering systems as well as electric motors (Amann, Carey et al., 2025).

The military, even more dependent on rare earths (drones, missiles, submarines, jets, robotics), was next (Emont, Somerville & MacDonald, 2025). In July, the Pentagon invested $400 million in MP Materials, owner of the only U.S. rare earth mine. Yet even if MP manages to refine ore all the way into magnets, it will still need dysprosium (Sanderson, 2025).

Greenland may offer a long-term answer. As of October 2025, the Tanbreeze project in southern Greenland has heavy rare earths and is majority-owned by U.S. company Critical Metals Corp, and the U.S. government is considering taking a stake (Mining.com, 2025).

After months of escalating tension and mounting export controls, the situation reached a new turning point this morning, 9. October 2025, just as this essay goes to print: China announced sweeping new export controls on rare earths.

The new directive will require licenses not only for raw materials but also for any foreign-made magnets and semiconductor components containing even 0.1% Chinese-origin heavy rare earths.

China's commerce ministry said the new measures were intended to "protect its national security and interests" and prevent the "misuse of rare-earth materials in military and other sensitive sectors." The ministry added that it had found some overseas companies had significantly harmed China's security by transferring Chinese-origin rare-earth materials and technology to others for military use.

China's commerce ministry said the rules would be phased in from December 2025, with most export licenses for military users to be denied and exports to semiconductor manufacturers reviewed case-by-case.

"The timing of this new policy is strategic," said Gracelin Baskaran, a critical minerals expert at the Center for Strategic and International Studies.

And added that the move is a clear effort to hinder the development of industrial base capabilities in the United States and its allies, while also seeking to prevent the "leakage of technical capabilities" from Chinese firms to foreign counterparts (McMorrow. 2025).

The months since April 2025 have confirmed Deng Xiaoping's quip: *"The Middle East has its oil; China has rare earths."* Rare earths have never been more critical (Allison, 2025).

Notes

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[2] Scheyder (2024, p. 106) quotes the Molycorp CEO Mark Smith in 2010 complaining to the US Congress that his company had seventeen scientists competing against six thousand Chinese rare earth-focused scientists.

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