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Finding Joy in Science

W. Rickhaus and M. Rickhaus*

Abstract: This piece discusses the importance of sustainable education within the framework of the UN's 2030 Agenda for Sustainable Development. We emphasize the need to foster a lifelong love for learning by instilling curiosity, emotional bonds, and joy in students. We suggest simplifying teaching methods to maximize depth of understanding, integrating wonder and emotion into scientific education, promoting vertical exploration rather than just covering knowledge horizontally, and fostering resilience and independence through experiential learning. We also advocate for collaborative learning environments and incorporating real-world projects into education. Ultimately, the goal is to create spaces where students can explore, experience joy, and develop a lasting passion for learning.

Keywords: Education · Exploration · Joy · Next generation · Scientific mindset · Sustainable development goals

Werner Rickhaus wanted to take on a practical role after completing his Matura and worked with disabled and elderly people for ten years before becoming a secondary school teacher. In the classroom, he sought ways to incorporate the students' world of experience when teaching science and to create space for discovery and creativity. Later, as school principal, he was responsible for the introduction of project works in the final year, among other things. Today, together with his wife, he enjoys his family and forays into nature, always in search of the wonder of life.

Michel Rickhaus currently works as an SNF and FPFS assistant professor at the University of Geneva. His main research themes are synthesis of polyaromatic species and supramolecular assemblies. Besides the lab, he spends hours making figures, thinks about visual tools and how to pass knowledge on to the next generation, drinks lots of tea in the process and generally loves to bring talent together.

Sustainable Education

Changes on a large scale need visions. For the UN, this vision is the *2030 Agenda for Sustainable Development*, which consolidates national and international efforts to jointly solve major global challenges.[1] At the core of the agenda 2023 are the 17 *Sustainable Development Goals* (SDGs), which are intended to be achieved by all UN member states by 2030. Switzerland is part of the UN and thus required to implement these goals on a national level.[2] One of these goals speaks to education and its future development. It reads as:

Sustainable Development Goal 4: Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.

This goal reaffirms the importance of education to sustainably advance mankind and to improve the living conditions of individuals, communities, and entire societies. Drawing many useful lessons from the Millennium Development Goals (MDGs),[3] the **SDG-4** approaches education not as primary education but as a life-long learning process – a process that spans school, higher education, and vocational training. It is this aspect that we especially address in this article. In the context of chemical education, the key questions we need to ask ourselves are: How can we convince people to stay invested in science, even after they leave school? How do we, as educators, instill curiosity and engagement in a field that is typically associated with seriousness, rigidity, and the occasional explosion? How do we raise a generation that can speak truth to power? A generation of ambassadors that is understood? And how do we do so with a generation that is increasingly proficient in filtering information out?

We believe the answer goes well beyond better curricula, more immersive classrooms, and more entertaining lectures. **SDG-4** states the intention to ensure inclusive and equitable education for all, but there is a danger in taking the goal at face value: we will not reach better education by simply lowering the barriers to learning, *i.e.* by making it easier to absorb knowledge. **SDG-4**'s goal is not only for us to be fed, but to eat well. Spoon-feeding knowledge is anathema for reaching depths of understanding. Instead of seeking to maximize exposure to subjects, we should ask how we can incentivize learning. Only initiating a willingness to learn sets students on the path of life-long learning – the implicit target of **SDG-4**. We believe a key aspect of such an educational approach is to create emotional bonds between students and their subjects of learning. Simply put, they need to start caring – the rest will follow automatically.

Defending the World

Michael McCarthy is a British environmental writer and champions conservation efforts. In his seminal and sometimes painfully personal treatise, *The Moth Snowstorm*,[4] he asks: when conversational approaches seem to fail in light of missed goals and even though we destroy the only place we have for living, when the loud advocates seem to change the general trajectory very little and new approaches like 'sustainable development' and 'green growth' seem slow in their implementation, how can we change the pace of the destruction of the natural world? Others

*Correspondence: Dr. M. Rickhaus, E-mail: michel.rickhaus@unige.ch
Dept. Chemistry, University of Geneva, CH-1205 Geneva

have answered this before. A relatively modern answer is formulated in a compendium of essays entitled *Nature's Services: Societal Dependence on Natural Ecosystems* (**1997**).[5] It establishes economic worth to nature – this price tagging with real-world financial value has allowed arithmetic arguments to be made about the environment. Do you really replace a rainforest worth 200 million dollars in erosion protection, soil filtration, and air purification with a few cocoa plantations worth 2 million? This sort of argument can be very powerful when shackling yourself to trees no longer works – and people have prominently set on attributing economic worth on all principal natural systems supporting human life (Costanza, *Nature*, **1997**).[6] Powerful yes, but as McCarthy continues to argue, what about those aspects that are hard to put a price tag on? Nature Capital is selective and many times hard to measure. How do we assess birdsong, butterflies or scents of flowers? If we keep only what is worth money to us, would we still find delight in nature? Hardly. Nature needs to be defended more holistically, more thoroughly than simply pinning value to it. In a moment in time where we have been impotent to safeguard the world that surrounds us and new, more hard-headed and thus more realistic defenses seem fatally flawed regardless, McCarthy asks us: "*What are we to do?*" His answer is –we think - also the answer to growing sustainable education in our young.

Essentially, McCarthy suggests we should not only put forward the notion of being responsible for nature (sustainable development) nor the notion of its financial and utilitarian value (ecosystem services) but we should offer its joy as a formalized defense of the natural world. Joy that is, not just fun or delight. Joy as an intense happiness that looks not to one's gratification but outwards, to other people, purposes, or powers. Joy has a component of seriousness, and we could maybe best describe it as *passionate happiness*. Joy to McCarthy is our strongest defense against greed and short-sightedness, and it is free and open to all of us. Because it makes us care, finding joy, then, could similarly be key in establishing a lasting, sustainable relationship between students and science, sending them on a path of lifelong learning. An ideal approach, therefore, to reach the **SDG-4**.

We do sometimes talk about nurturing passion in our students, but while passion is a part of it, joy speaks to the heart. Nurturing joy is thus an entirely different business from nurturing passion, mostly because it is deeply personal. The crux thus becomes: how can we bring *joy in science* to our students? How do we do so while meeting school and state requirements, keeping budgets, and without hiring more personnel? After all, our resources for teaching are not limitless – even if we formulate ambitious goals. On top: Admirably as it is to give wholeheartedly everything to education, most of us have labs to run, grants to get, and evaluations to assess. Change in this setting can only happen if it is implementable in the current framework and without expecting self-sacrificial investment on the teachers' side. Small changes matter, – the beauty of teaching is that some students will eventually become teachers. Changes now will find amplification in the generation after. Here are a few things we consider to be doable today to enable children and students to find joy in science. And it all begins with us doing less.

Reduce to the Max

Spoon-feeding knowledge is not effective, yet the reality. Content is increasingly streamlined, interactive, immersive, and easy to digest. Should we as educators follow that trend? We would argue that yes indeed, we should simplify what we teach. But not to tell simpler stories, but to tell every story as simply as we can. Simplification to make a teacher's life easy is counterproductive. For instance, it may be much simpler to explain that addition is always *adding on* something. When we get to negative numbers later, that simplification becomes a hurdle. Equally, consider how we teach electron-nucleus relationships in atoms: how many times has the Bohr model (discrete radial distances) become a hindrance to understanding orbitals (diffuse probabilities) later? The challenge is to tell a story simply, not to find a simpler story. A kid will understand that you can ride up and down in an elevator above ground and that this does not change if you are below the ground floor. The addition of positive and negative integers becomes a ride in an elevator, simply by accessing the students' frame of experience. But because we have not replaced the story for a simpler one – like addition always increases a number, negative numbers do not exist, for instance – we reveal a ground truth without muddling the grayscales of the problem.

The act of simplification in that sense is firstly beneficial to ourselves. True simplification does not shy away from advanced problems like for example, how a motor works or what quantum theory encompasses. On the contrary, it mandates (if we follow Feynman's technique[7]) that we find ways to teach *everything* to a child. And where we do not find a way, it simply shows us the limit of our own understanding. Simplifying thus has tremendous potential for us as researchers, too. From there it is easy to adapt, from the audience of the uninitiated to our colleagues in other fields. Philip Ball stated for out-of-field scientists that step on the toes of established researchers:

Conflicts arise not so much because intruders claim to have all the answers (…). While it is possible for outsiders to ask important but overlooked questions, more often the truth is that they make the greatest scientific contributions when they are able to formulate their ideas in a way that is meaningful to the daily practice of those in the field.[8]

And from this state should come all our teaching. What one understands, down to its simplest terms, one can teach simply. Hybrid lecture halls, flipped classrooms and all the rest, it may have its place. But at the core is the simple call: become understandable – and therefore understood.

Hard and Soft

When we teach science, we teach truths. The earth is round, apples fall from trees, the planet heats up. And yet we often fail to teach that the same event can be seen from many angles. McCarthy formulates it like this:

For if I say to you, I saw an insect, which is strictly true, what will that tell you? Nothing […] But if I say to you, I saw a spirit, which is what it felt like, then at once we are in a different territory, we are in the territory of the imagination, and we begin to approach the wonder of the event, and the joy of it: that on a Sunday morning in March […], I saw the spirit of the spring.[4]

How can we, as educating scientists, describe both the insect and the wonder? If we give room to the sensation of the event while we teach the way it works and how we might predict it, we begin to weave rationality and emotion together. When we look back to our own experience in school or university, were not these teachers essential for our careers who have done exactly that: show us the wonder of a thing? They have captivated us with the spirit, then showed us the moth, too. Maybe we should begin to formulate this more overtly as a daily teaching goal, *especially* in science.

Digging Deeper

Our educational system rewards diligence and accuracy over curiosity and experimentation. As a consequence, we nurture the learning type 'well-behaved and hard-working'. With the gain in efficiency, current curricula typically cover as much knowledge as possible and continue striving to do so. We increase this efficiency-based approach by spoon-feeding knowledge, simplifying for the sake of easier, more time-efficient teaching, that inherently leads to a loss of the ability to navigate complexity. If we optimize for efficiency, we cover much ground, yes, but in terms of experienced understanding, a hike is often better suited than a flight with a jet.

Instead of having students cover knowledge laterally, we should strive to make them move *vertically*, allowing them to dig deeper into subjects. Is it really true that complex subjects can only be approached when enough fundamental knowledge has been gained beforehand? Do we need to cover basis knowledge as fast as possible to get to the good stuff earlier? The acquisition of prior knowledge poses the inherent danger of uniformity of thinking. Learning vertically means experimenting with your thoughts and approaches. It does run against trends of instant gratification, participation trophies, and superficiality. A simple example – we generally set solvable exercises. We fear if we deprive students of the (easy) reward of a correct, simple solution, they will no longer be willing to invest time. Ask any parent: is joy not also found while doing rather than purely in the moment of success? Establishing personal relationships with science is strongly correlated with the opportunities for students to autonomously explore and experiment. Some children live in environments that give them plenty of stimulation and space to do so, others do not. Inclusive and *equitable quality* education asks to provide these opportunities for all.

Explore and experiment means being frustrated, being in neck deep, and learning to be comfortable with it. A hike in the woods without a map (or a GPS) is inherently more dangerous yes – but with the right mindset infinitely more rewarding.

Learning is a constant equilibrium between under- and overstrain. In the current system, it is educators who decide where the students (on average) stand in this dynamic process. But every person is different – instead of modulating the dose of the challenge, it seems to us much more straightforward to teach our young to become comfortable in challenging situations and teach them coping strategies (like sequestering large problems into smaller sections, using sources of additional knowledge, *etc.*).

It is vital that students are not left alone in these processes (see next section). Setting students up to experience failure often, but never alone, empowers supplementary learning on demand. What stronger incentive to learn is there than to overcome challenges that surpass your current state of knowledge? Key is that you *want* to solve the problem in the first place and that you are comfortable in finding the tools that will help you to do so. Learning through that approach is perhaps less streamlined and less efficient – again it is much more chaotic and frustrating and thus has higher demands on mentorship – but ultimately, the knowledge we need is the knowledge we retain. Pupils and later students must learn to access their own space of experience to solve (or at least advance) problems and that is inherently incompatible with a one-fits-all approach. If you give children an empty room without any toys it will not be met with great enthusiasm. But return a while after and the room will be filled with activity – and likely joyful ones at that. Children are extremely proficient at occupying themselves – if we give them the time to do so. Again, that does not mean they will learn completely on their own – we do need to educate them, and we do need to cover ground. But we do not need to make it easy for them all the time.

Go Together

Finding joy is highly individual, as we have outlined. But to go on a journey that sets you up to fail often is risky – and you should not have to do it alone. Ideally, each student would have their teacher (or better: mentor) who walks with them on their journey. Ideal, but naturally not very practical. In reality, while project-type work is done even at high school, children are ill-equipped to tackle this shift in workspace. They are supposed to write an independent work or thesis and they have generally little clue how to begin. A simple open challenge is for instance to give chemistry pupils (or likely even students) a mixture of rocks, sand, and salt and ask them to separate the components. It is surprising how uncomfortable children can be when there is no clear recipe for how to tackle such a 'simple' problem. A blank page is the ultimate intellectual challenge after all and as we outlined, the current system does not enable navigating overstrain well. With unsurprising consequences: teachers dread these sorts of workshops or group works – the potential for chaos, the lack of being able to meet teaching goals, and the challenge associated with grading. Not to be underestimated is the emotional level as well: wherever possible, teachers tend to avoid situations that confuse, overwhelm, frustrate, or bore pupils. The dynamic in the classroom could tip over and the ensuing chaos could become uncontrollable.

Such learning settings clearly require more than one educator in the room, and beyond doubt increased teacher/student ratios. This also applies if we begin preparing young pupils for independent project-orientated work with small, more narrowly defined tasks. Coaches are key, especially when just starting out. If your project is to count biodiversity in a river and you find little, it's frustrating. A coach can turn the 'we have seen nothing' into 'what have you not seen?', frustration into new lead questions, confusion into Eureka. Joy is eventually found – the importance is to keep walking the path and that is easier together. With these experiences, pupils become more independent, creative, resilient, and responsible – key competencies, especially for the natural sciences. A complete overhaul of how we organize teaching is not target-oriented, but we should regularly open up room for 'chaos' with an increased supervision rate. Finding coaches to help do so might even be simpler than expected, especially for primary school. Teacher education consists partly of teaching internships. What if we turn these teachers-in-making into mentors who accompany a group of children over a longer period of time? Every Tuesday afternoon a dive together into chaos, mentoring an independent group work for an entire school year or more. What kind of teachers these would become!

Step Outside

Most didactic content can be turned into a project. Consider a cooking class for instance. Instead of only teaching recipes, what would happen if the brief was not making a lasagna but a *contest* for the best lasagna? What if we split the class into groups and let them try things? We can still define clear learning outcomes (everyone knows how to make a lasagna), but we can gamify the approach, and enable experimentation. If it is (somewhat) supervised would it not be much more likely that the children will remember what is essential to a good lasagna because they have *tried* (and maybe, god forbid, failed). Would they not have learned the importance of documentation to be able to share this distilled recipe with others? Would they not have found joy in eating the winning lasagna together? And would it then really matter that it had taken three afternoons instead of one?

We stated it before – independent work (the essence of later scientific research) is generally an overload for most pupils and students in the current system. If we want them to be able to become comfortable with developing their ideas and approaches, we need to start early. Who is to say that (as it is currently) the first independent work begins in your teens? If we have our first independent project at the beginning of our basic education, we gain time to develop it as we progress through the ranks, and by the time we write our first real thesis, there is a trove of experience to draw from. Ideally, we progress from trial and error to independent creation. Besides, why would we not bring our leisure to work and *vice versa*? The beauty of compulsory education is that we create guaranteed, protected spaces for engagement – independent of the individual life situation. Many non-governmental organizations (NGOs, non-profit entities) have fantastic projects but struggle more and more to find people willing to engage. It is curious why do we not integrate these better into our schools – why do our children not observe a piece of nature for several years, breed new tomato varieties, or build an urban garden? Mostly because we see

school and leisure as separate pieces and still leave too little room for projects at school. But stepping outside the classroom now and then is a win – no wonder are the fondest memories of school usually exactly these occasions – pursuing one's interests out of the regular context. From caring comes incentive, from incentive gain in knowledge.

Clear to us is: The more we create spaces of exploration, the stronger the links we form with the discoveries we make. Maybe finding joy is to walk a path, having time to stop and to tell others about it. We are certain this is true for school, which would once again become what it originally meant: *Schola. Leisure*. And it is joy, the strongest force we can muster, that makes us return, over and over, to the things we care about.

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Author Contributions

W. Rickhaus and M. Rickhaus have collected data, discussed and wrote the perspective.

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