

A new approach to making scientific research more efficient – rethinking sustainability

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The role of sustainability in scientific laboratories is gaining attention. However, it often remains unclear how to effectively implement sustainable practices.

After noticing the amounts of waste generation and energy consumption by research in life sciences, we, the authors of this article, set out to make our own protocols more sustainable. We did so by searching for optimization opportunities in our practices. Drawing from our experience in the laboratory, we then took the step to share our insights at dedicated events within research organizations and by hosting the international “Green-LaboratoryWork” conferences. Lastly, we founded [ReAdvance](#), an initiative to foster the education and implementation of sustainability within science. The combination of our research experiences and our knowledge of environmentally friendly practices allowed for the development of a new understanding of sustainability. In our experience, for sustainable approaches to become applicable, they have to be conceptualized in a manner that is not fundamentally altering research plans.

A new concept of sustainability

Sustainability is often misunderstood as a mere trade-off in favor of reducing climate change. In contrast, we propose that proper sustainable practice is focused on improving scientific procedures. In its essence,

sustainable practice is the act of making protocols and experiments more efficient and impactful after analyzing the purpose and the execution of each step. The optimized performance then minimizes the environmental footprint left behind (Fig. 1). This understanding also resolves resistance generated by the fear of disturbing processes. Furthermore, it provides new incentives for change due to the accompanying economical, scientific, and mental benefits. While it often remains elusive how to initiate such change, the 6R concept offers an instructive framework.

The 6R concept

We developed feasible strategies and protocols on how to implement sustainable practice. The 6Rs, denoting Reduce, Reuse, Recycle, Rethink, Reject, and Repair, are the underlying concept for these solutions. It should be noted that the order has evolved historically. Functionally, they might be reordered as shown in Fig. 2. The concept thereby facilitates the translation of sustainability into actionable and pragmatic steps.

Reduction—the fundamental principle

Reduction refers to decreasing the amount of material, energy, and hazardous substances used. However, it

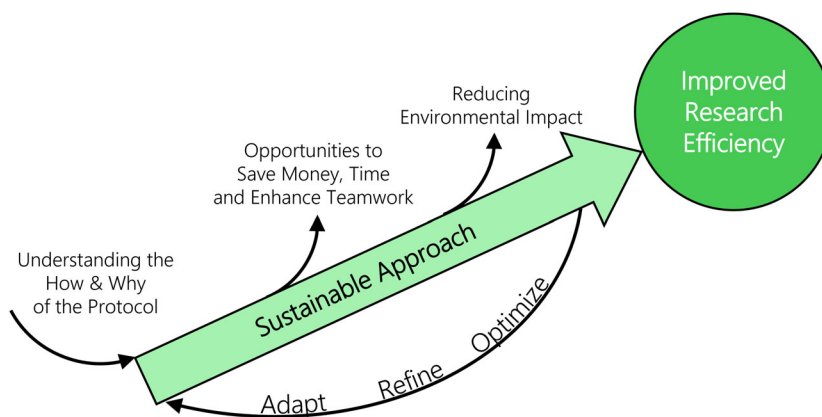


Fig. 1. Sustainability is an approach to improve scientific conduct. Sustainable practice serves as a mode of conduct. A thorough understanding of each step in a protocol is necessary to unravel new opportunities to improve procedures. Therefore, a sustainable approach has to be refined and tailored to each protocol individually. However, sustainable conduct is advantageous, for example, by reducing costs, speed up processes, or enhance teamwork. As a result, the unavoidable environmental impact of research is mitigated.

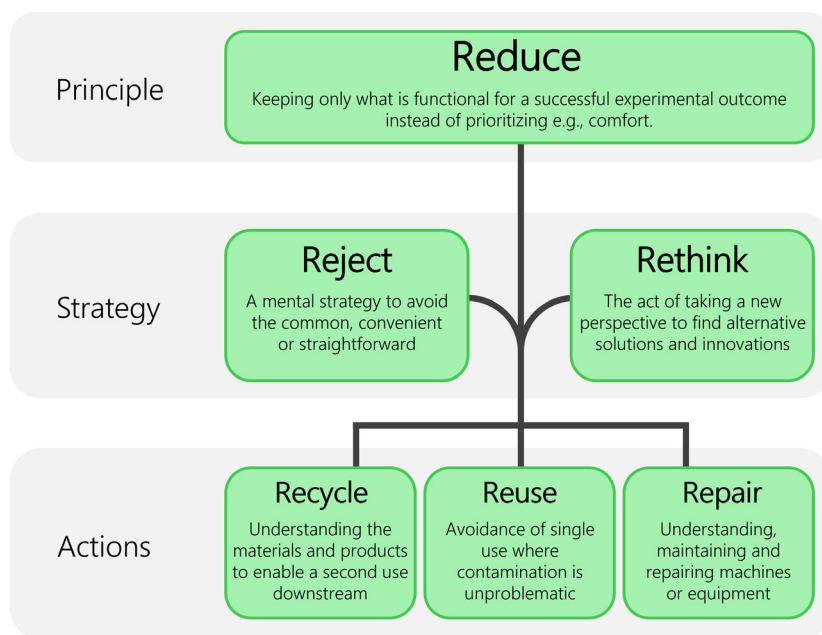


Fig. 2. The 6R concept as a concrete framework toward sustainability. The 6R concept is a way to conceptualize sustainability, in order to derive actionable steps. The guiding principle is to reduce, whether it is lessening costs, time-efforts, mistake frequency, or toxicity of handled chemicals. Thereby, the environmental impact of science will also be reduced. The strategy to identify opportunities for such change is rejecting and subsequently rethinking the common. Recycle, Reuse, and Repair are exemplary actions that grew historically as a part of the 6R concept. They are helpful reminders because they come less intuitively to the attention of most researchers.

also entails the reduction in financial expenditures, time utilization, the occurrence of errors, and therefore mental exhaustion.

As a guiding principle, reduction requires the exclusion of steps that are nonfunctional or nonessential. By comprehending the underlying objectives and mechanisms of each step in a given protocol,

preservation of quality and outcomes is assured, while opportunities for optimization are identified. In turn, this facilitates the reduction in consumables and chemicals used. Practically, this entails scrutinizing the rationale and also the execution of each step.

Although the benefits of reduction are manifold, they were particularly evident during the COVID-19

pandemic. Escalating costs of essential supplies, such as pipette tips, posed challenges for research groups. Similarly, the scarcity of gloves during lockdown periods significantly disrupted laboratory operations.

Even in the absence of extraordinary circumstances, prioritizing convenience over efficiency results in the unnecessary operation of equipment such as microscopes, sterilizers, ultralow freezers, water baths, and fume hoods [1,2]. This contributes to excessive energy consumption, filter clogging, and wear-off. In essence, reducing should replace other often hidden guiding principles such as habit or convenience that influence our actions.

Enhancing experimental design is another aim of sustainable practice. Reducing experimental expenses is indeed achievable through statistically informed planning. The aim is to conduct fewer experiments while maximizing statistical power [3–5], thereby enhancing validity and animal welfare [6]. For instance, during microscopic analysis, one single slide could be used for multiple controls, thereby reducing the number of slides as well as controlling for staining artifacts across different slides.

Reject & rethink—adopting a new strategy

This principle can be understood as the act of taking a new angle. Rejecting denotes the act of deliberately distancing from common or convenient practices. By questioning established norms, the process of rethinking is initiated, encouraging the exploration of alternative solutions and novel perspectives.

In simple terms, rejecting and rethinking describe the perception of a laboratory with open eyes. It is about finding means to establish high standards. Convenience or missing enthusiasm are common causes for hampering innovation in a laboratory. Scrutinizing each step of a protocol, even seemingly ordinary ones, holds the potential to yield significant enhancements. Streamlining the way of preparing sodium dodecyl sulfate gels might help to run an entire experimental set in single day while reducing costs related to wasting consumables. Omitting a washing step might not only save time but also preserve sample quality. Such steps can be rethought and rejected when, for example, tissues during preparation for flow cytometry are smaller or amounts of proteins during purification are less than the protocol was originally set up for.

Embracing sustainability by rethinking which chemicals should be part of an experiment is a way to protect the health of researchers. Choosing alternatives to ethidium bromide, fixatives, or mounting media does not just help to reduce environmental footprints, but

also benefits well-being and safety [7–9]. Rethinking the practice of how waste or equipment is handled can open up new possibilities for recycling and collaboration. With reference to financial perks, the collaborative utilization of equipment facilitates the acquisition of high-end instruments and splits maintenance expenses among the users. Scientifically, sharing equipment often sparks innovative ideas for novel approaches, techniques, and software features.

Reuse, recycle, repair—three tangible actions

These three words provide a practical understanding of potential actions, which often do not come naturally to the mind of the researcher.

Reusing items frequently requires careful consideration, particularly where contamination is possible. When implemented successfully, reduced waste generation can save significant amounts of money often paid by institutes through deduction of funding from individual groups. Likewise, reusing consumables such as filters, buffers for electrophoresis, or staining solutions can save remarkable amounts of money paid by groups directly. With reference to best practice, it also highlights steps requiring special attention and precision that might otherwise go unnoticed. Falcon tubes can be repeatedly used for preparing solution such as sodium dodecyl sulfate-gels or buffers, thereby preventing overcrowded fridges and benches. Similarly, tip boxes can find new life as staining chambers. Striving to decrease the usage of consumables also motivates the refinement of pipetting strategies. Altering the order of pipetted chemicals can in turn improve sample quality by reducing processing time.

Recycling is a broad term for different forms of down and upcycling [10,11]. Establishing recycling programs may be time-consuming but foster a collective effort that enhances engagement among team members. This not only improves knowledge exchange but also boosts motivation in the workplace. A stronger feeling of belonging and an emotionally meaningful objective might potentially alleviate the high burden of burnout and depression in the scientific community [12,13]. Moreover, considering the composition of consumables can help to improve experimental design, for example, in experiments such as Fluorescence-Activated Cell Sorting, where materials are chosen according to the tendency of cells to stick to certain polymers [14].

Repair denotes restoring rather than purchasing anew. As a result, space use can be optimized, and expertise is retained instead of investing effort into accommodating to a new machine. Additionally, this

aspect might be apprehended as the prevention of reparation. This entails every researcher assessing whether they have a comprehensive understanding of the equipment, including the often complex software they operate. This ensures minimized downtime due to errors and, perhaps more importantly, enables scientists to reap the full potential of the available settings.

In summary, we obtained the best results by appreciating sustainability as an approach to science. Instead of directly trying to reduce a footprint, the aim is to make scientific practice efficient, and thereby lessen our environmental impact. By adopting this perspective, opportunities for change come to light more easily and often even appear trivial. Sustainable practice is a routine that runs along doing science, as shown by multiple researchers worldwide [15,16].

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