Young chemists voice in support of the SDGs

by Janine Richter and Emiel Dobbelaar

In 2015, the United Nations General Assembly agreed upon 17 Sustainable Development Goals (SDGs) that are to be achieved by the year 2030. These goals were adopted to ensure an economical, socially just and ecologically sustainable development on a global scale and to protect natural resources and the environment [1].

A leading role in the achievement of the SDGs falls to the chemical sector as developments in the chemical industry as a primary industry may shape the whole supply chain [2,3]. The implementation of sustainable chemistry not only affects chemical production, but also has an impact on industrial and consumer products, including (positive) effects on health and working conditions as well as economic growth [3-5].

A fundamental approach for the chemical sector to become active is couched in SDG 12 “Ensure sustainable consumption and production patterns” [6]. By implementing this SDG, the chemical sector moves to the center of various demanding challenges of our time, from plastic waste to solar energy conversion to air pollution, and can promote a development towards more sustainable solutions [7].

In this important discussion, the voice of the young generation (ages up to 35), representing over 56 % of humanity (4.4 billion individuals in 2020) [8], must not be ignored. As today's decisions will tremendously affect their future, a huge desire for meaningful contribution can be deduced from the increasing global environmental and climate activism. Young chemists especially possess the willingness as well as the chemical knowledge to improve processes in the whole chemical sector by the implementation of sustainable chemistry principles and are looking for ways to be part of the transformation. Their opinions and expectations are key for the sustainable development of industry and society alike.

In order to make young chemists' voices heard, we recently analyzed an overview over their opinions and expectations on the role and responsibility of the chemical sector for a sustainable societal and industrial transformation [9]. While the collected statements are summarized and presented in our previous publication, we now aim to put them into a broader context by comparing young chemists' views to other works and expert opinions on the topic in order to examine their expectations according to their feasibility with respect to the current circumstances.

Role and Responsibilities of the chemical sector

Regarding the role of the chemical sector, young chemists have clear demands for future development, calling for more responsible, indicatory and cooperative actions. First of all, the chemical industry is expected to pledge itself to the SDGs and sustainability in general. Thereby, young people see its role as a forerunner and demand the chemical sector to recognize this. The development towards a pollution-free, high-tech industry, serving as a role model for other (industrial) sectors, must be pursued. The chemical sector should avoid linear business models, be wary of product lifecycles, and recognize its responsibility towards building a circular economy. In order to reduce carbon emissions as well as the dependence on limited resources, the chemical sector must cooperate closely with other sectors and invest in renewable, green, and sustainable technologies. In these processes, transparency is significant to gain the trust of the civil society and especially the young generation, who represent the future work force [9].

The overall sentiment of the statements is in line with Cole-Hamilton's recent opinion piece in *Science Voices*, who sees chemistry and chemical engineering processes at the forefront of the transformation, encourages repair and reuse, demands better recyclability and highlights the importance of ethics in education as well as governmental incentives [2]. Moreover, complementing the idea of a moral and ethical science as well as the thought of cooperation for the benefit of society, Matlin *et al.* have introduced the concept of “one-world chemistry” [10]. Close partnerships of industry to academia and the public (media) are pointed out to enhance the flow of ideas and benefit all, supporting young chemists' propositions to increase multi-lateral cooperation. When considering the actual transformation of the sector, Anastas' vision of the chemical sector taking the step from conventional reductionist methods to systems thinking appears to be compatible with their views [11]. Although the simplification of complex chemical matters brought numerous benefits since the beginning of the industrial era, it also led to many unintended, negative consequences, affecting both people and ecosystems. Thus, chemists can only address today's sustainability challenges (and young chemists expectations) by considering the whole

complexity of our world, being attentive to full product life-cycles and investing in sustainable strategies rather than in old technologies that cannot meet today's requirements.

Products and Processes

Two main developments in industrial products and processes are considered crucial by young chemists: First, the product composition regarding the consumption of limited resources and the accrual of waste need to be optimized for a zero-waste approach. Second, a shift towards a circular economy and advanced recycling processes should occur. On the one hand, a modular product design with less composite or layered materials is proposed to facilitate the exchange and repair of individual components and separation processes for recycling. On the other hand, products of the future, according to young chemists, need to be produced from bio-based, and, therefore, renewable resources. In addition, special attention should be directed towards the application of safer, less toxic, and less pollutant chemicals and energy-efficient, carbon-neutral production. The chemical industry is also demanded to drive the development of power storage facilities, technologies for the use of sustainable energy sources and electronics with low energy consumption [9].

Many concepts named by young chemists have long been known, though their relevance has only increased. In a model circular, zero-waste economy, when the end of life of a product is reached, it should be recycled [12,13]. However, not all products can be

recycled. For open-environmental applications such as cosmetics or pesticides, materials have to be developed that undergo degradation fast and completely [12]. In this case, careful attention should be directed towards the environmental impact and toxicity of the degradation products when released into the biosphere [14]. According to Kümmerer *et al.*, products that cannot be degraded safely or recycled should be stored in an appropriate way to allow for future recycling through advanced processes. Thus, there seems to be a need to assess the properties of an end-of-life product during product design already, especially when it comes to reducing the complexity of material compositions for better recycling properties, as well as a need for the advancement of recycling processes, in line with the propositions of young chemists (*vide infra*) [12,15,16]. This need is exemplified by Matlin *et al.* and their analysis of the whole life cycle of aluminium, plastics, and textiles, representing three very different industrial fields [3]. In each field, improvements by chemists could have a significant impact on material circularity. To achieve betterment, Mohan and Katakojwala name ten specific drivers for circular chemistry, such as systems thinking (*vide supra*), renewable raw materials and the *Five R* (reduce, reuse, repurpose, recycle, and recover), that should be implemented by industry [17]. Another issue observed in the case study of Matlin *et al.* is the prevalent use of energy from fossil fuels which is also perceived by young chemists [3]. Beyond a transition towards the use of more renewable energy sources for chemical production (including concepts such as Power to X) [18,19],

Expectations towards the chemical sector. A summary of key aspects in the answers of young chemists when asked about expectations towards the role and responsibility of the chemical sector. [reproduced from ref. 9]

Products and processes. A summary of key aspects in the answers of young chemists when asked about the kind of products and processes that are needed to shape a sustainable future. [reproduced from ref. 9]

to achieve a sustainable and carbon neutral future, Cole-Hamilton points out that currently privileged parts of the global population have to reduce their consumption while the development of currently deprived parts of the population has to proceed without a huge consumption of fossil fuels. This also applies to general consumption behavior. Besides a rethinking at the consumers' side on repair versus replacement, more and better take-back schemes, reparability and recyclability should be crucial considerations in product design and should be supported by a governmental framework and a good infrastructure [2].

While young chemists demand a lot of the chemical sector itself, they also specifically demand the ban of single-use plastic packaging and the development of sustainable alternatives. This action can be (and is being) taken and incentivized by governments and policy-makers [20]. New bio-degradable materials from natural sources are named to replace conventional plastics. However, linear product use even of more sustainable alternatives can again represent a massive waste problem if not executed responsibly, as is evident e.g. by the ill-informed use of fertilizers and statements made by Kümmerer *et al.* regarding open-environmental applications (*vide supra*) [2,12]. Additionally, potentially more costly sustainable solutions may harm poorer populations disproportionately. Thus, careful considerations of consumer behavior are necessary when such supposedly more sustainable alternatives are proposed [21].

Science and Education

To face the challenges of developing sustainable products and processes, fundamental and applied research as well as a well-educated workforce with innovative ideas is required. Young chemists, currently, feel a lack of education in the field of sustainability and express a strong desire for the implementation of environmental and sustainable chemistry in chemical education. More practical classes and interdisciplinary teaching should thoroughly prepare them for future tasks. Young chemists also ask the chemical industry to participate in science education, e.g. by sponsored scholarships, training programs or the provision of well-equipped laboratories in developing countries. Moreover, young chemists highlight the need for chemistry education in schools to start much earlier. Modern teaching techniques, the use of modeling software or artificial reality, and everyday examples where chemistry improves our lives could increase children's interest in chemistry and its impact on individuals as well as on other disciplines [9].

Already 10 years ago, Wiek *et al.* presented an extensive review about the necessary key competencies individuals should have for promoting a sustainable development. Systems thinking, strategic, normative, anticipatory and interpersonal competences were identified as crucial, however, not sufficiently imparted in adult education [22]. When reflecting on young chemists' statements, this has not changed to date and adult education still seems to be devoid of teaching these proposed sustainability competencies. This is also

Changes in chemical science and education. A summary of key aspects in the answers of young chemists when asked what needs to change in chemical science and education. [reproduced from ref. 9]

Support by industry and politics. A summary of key aspects in the answers of young chemists when asked how politics and industry can support the realization of the expectations of the younger generation. [reproduced from ref. 9]

evident by a recent piece by Garcia-Martinez, where it is stated that chemistry education (still) needs to be rethought and updated to the needs of the 21st century. This is, according to him, the most effective way to also adapt chemistry research and industry to these needs [23]. Thus, the urges of young chemists echo a call for change that has been proposed for a long time but not properly addressed. To foster change, Zuin and Kümmerer propose that sustainability practices should be taught e.g. by case examples in existing lectures and lab courses rather than adding more subjects to the already crowded university curricula [24]. Here, young chemists also seem to be very much in line with their proposition that green and sustainable chemistry should “become the norm rather than the novelty” [9].

Beyond this, Zuin *et al.* point out the importance of green and sustainable chemistry education not only for schools and universities, but also as a life-long education and learning process for professionals [4]. This includes regular exchange and a cooperative discourse among stakeholders from all disciplines. Thereby, considering only the field of chemistry will not be sufficient, but the concept of sustainability (and sustainable chemical practices) has to be implemented into other curricula, such as economics and social science, as well. Regarding interdisciplinarity, Cole-Hamilton considers especially the topic ethics underrepresented in scientific education. He regards a course like “Good chemistry—methodological, ethical, and social dimensions” [25], designed by the European Chemical Society (EuChemS), as an essential precondition for any scientist [2].

Support by Politics

To ensure a sustainable and wealthy future, politics must give science a higher priority, according to young chemists. This involves more financial funding for research and education, especially in sustainable science, as well as more scientific advisors on a worldwide scale. Politics also should not miss the chance to make people part of the solution. Furthermore, it has a heavy responsibility to guide the industry's development towards more sustainability and its rising demands of (sustainable) energy. This requires a regulatory framework with strict sanctions for non-sustainable actions by companies. Likewise, companies conducting a sustainable transformation could benefit from incentives such as tax reductions or rewards that give sustainable products competitive advantages. Thus, policy guidelines and regulations could give a framework for close cooperation between the industry and environmental authorities as well as the civil society. This should

go along with strict self-supervision by the chemical industry as well as independent observers to avoid ‘green-washing’ [9].

Beyond our work on expectations of young chemists towards the chemical sector, representatives of the European Young Chemists' Network (EYCN) have also highlighted the importance of early-career chemists contributing to policy making in a recent article [26]. The authors strongly suggest the further development of the “science for policy” approach, where scientific evidence is the main foundation for political decisions. This agrees with the results of our overview and complements the named article's call for (early-career) scientists to make their opinions and knowledge heard, namely among policy-makers.

An analysis of 37 national-level strategy documents published by Weiser *et al.* in 2020 revealed that there is indeed a lot of room for this, as concrete measures to foster sustainability are regularly missing. Therefore, they phrase recommendations for future resource strategies. However, it is emphasized that such strategy papers by themselves can merely have small effects if not closely linked with regional, national and international action [24]. For future development, Weiser *et al.* already demanded more flexibility and anticipatory action from politics and industry alike in 2017 [15]. Since rarely all risks and hazards of new processes can be foreknown, it is even more important to constantly evaluate products and processes and be prepared to adapt them as necessary and chemists play a significant role in this.

Conclusion

The comparison of young chemists' expectations towards the chemical sector with recent literature and experts' opinions on the topic shows that young chemists have a differentiated and realistic image of what should and could be done. Their demands are in good agreement with measures considered necessary by experts to promote a transformation towards sustainability. The similar claims of both relevant groups mutually complement each other and demand proper attention and action. Chemical industry and politics alike appear to be reacting too slowly to recent developments and impede themselves in necessary transformations. To meet current and future challenges, the different stakeholders (chemical industry, politics, academia, organizations, civil society) should work together; transparency and trust are needed. The challenging transformation of the chemical sector should be met with strict self-supervision, external stimuli and quality contemporary education.

Multi-lateral dialogues that include more scientists and a young generation that will be most impacted by today's decisions can be a chance for a strategic, sustainable development of the chemical sector for the benefit of society.

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