Education & training

Education, education, education – powering the life sciences, empowering society

VII Education & training

Education is the engine of our knowledge society. It empowers us with the basic concepts, context and critical skills to be informed citizens and consumers. It equips us for our professional lives and it helps us deal with an ever-changing world, where continuous (re)training, more than any single job, provides security of work and income.

This is especially true for the life sciences. The life sciences play an important role in food production, in cure and care, in manufacturing products, in nature management and in ecological regeneration. These activities require highly educated professionals in a wide range of disciplines (biology, chemistry, physics, geology, engineering and medicine). These professionals fill many different functions: scientists, corporate researchers, developers, engineers, entrepreneurs, managers, teachers, farmers, consultants, civil servants, regulators and more. In 2008, more than half the graduates in biological sciences had a job outside of R&D after one year.[1] These professionals are everywhere. And they need to be, to help generate, translate and deliver life sciences knowledge in the form of new or improved products, processes or services.

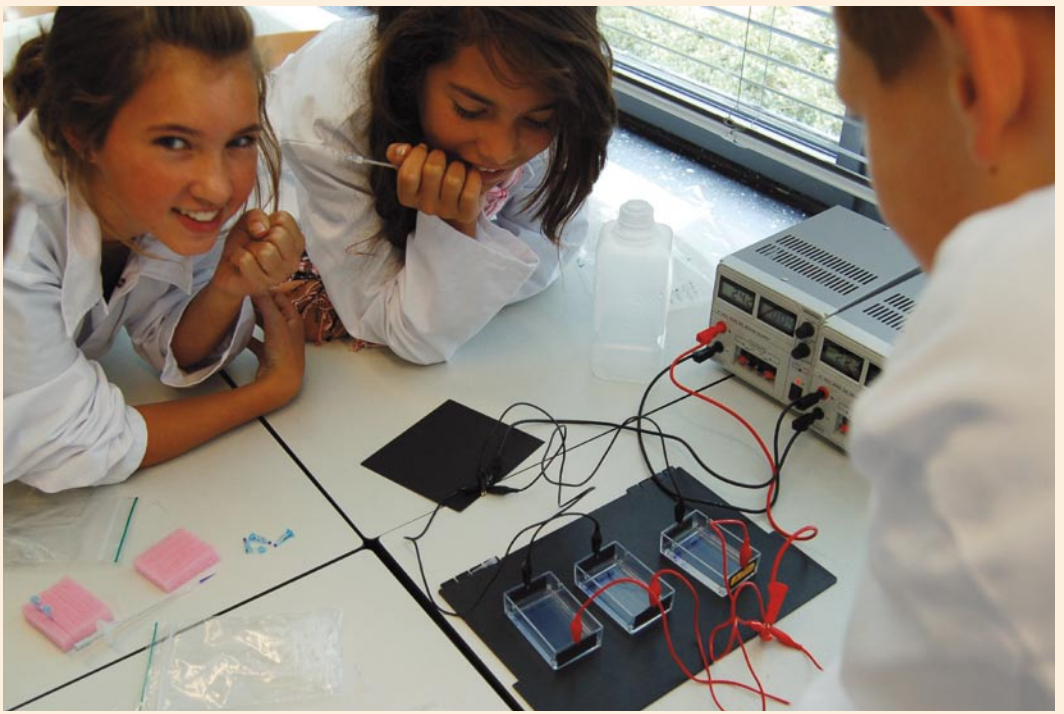
But that is not enough. As earlier chapters have argued, the success of an innovation ultimately depends on its adoption and use by individuals and companies. Before buying or investing in a new drug, green energy, improved crop and livestock, fermentation plant or nutraceutical, mature and responsible consumers will have to know that it is safe and useful. Scientists, business people, regulators, consumers – all need to understand basic life sciences concepts and technology to be able to generate, apply, regulate and use it responsibly, sustainably and to their benefit. Education is a *conditio sine qua non* for innovation.

Life sciences education is as diverse as the life sciences itself. Biology is its main vehicle, especially in primary school. Biology is, literally, the science (logos) of life (bio). But the life sciences increasingly are part of secondary and higher education in chemistry, physics, geology, biotechnology, medicine and other courses. These disciplines are becoming more and more intertwined, not just in their practical application, but also in curricula and teaching. In the Netherlands, the modernization of life sciences education has begun in the last decade. A new curriculum framework was developed for 4-18 year olds. Initiatives were launched to improve vocational and university education and much emphasis was placed on targeting courses to needs in the marketplace.

In 2020 we envision the culmination of these and additional efforts in an integrative, uninterrupted process of life sciences education. Primary and secondary school teaching based on the concept-context approach will provide a large and steady inflow of students to higher education. Higher education in the life sciences is a top-quality, diversified curriculum with a strong focus on fundamental science and its applications. Graduation is but a transition in a process of lifelong learning that continues throughout a life sciences career, whether in academia or industry. Education is a partnership, built on cross-institute collaboration, efficient funding and strong, unified marketing. It delivers highly qualified and versatile professionals to all sectors and citizens that are informed and are able to make personal decisions about what they buy or the care they receive.

From a family tree to DNA and back again

Students working on genetic screening simulation using gel electrophoresis. From dispensing the DNA sample to "running" the gel and staining the DNA.



A. Life sciences education in 2020 – an integrative, uninterrupted process from primary school through university that delivers a large and steady stream of life sciences professionals

Education prepares. It can prepare you for further, more advanced education, it can prepare you for a professional career, but it can and should also prepare you for life – for functioning as an independent, critical citizen. Life sciences knowledge production is fast and includes many disciplines. Thus, education must be integrative and uninterrupted. It must combine knowledge and courses from different fields and link basic science to authentic contexts. Each stage in education must naturally flow from the previous and run into the next. In 2020 we foresee a life sciences education process that connects smoothly from primary education through universities to post-academic and industry training programs and that puts into effect lifelong learning ideals.

A linchpin in life sciences education in 2020 is the concept-context approach taken from primary and secondary biology education.[2] In this approach, practices from student's everyday life are brought into the classroom to illustrate the life sciences to improve how students view the relevance of the life sciences. The approach also links different stages of education. An example: in primary school the concept "animal" is taught by referring to pets like dogs, cats and fish. Education then progresses to the role of animals in producing milk, cheese and meat. In secondary and higher education, the focus shifts to evolution and socio-economic challenges such as animal rights and the effects of dietary changes on food supply. Thus, the meaning of the concept "animal" is elaborated by applying the concept to the everyday life of the student. Understanding of the concept "animal" increases through successive stages of life sciences education by using different practices.

In primary education, the concept-context approach will be centered on daily life, such as eating, cooking and animal care. This introduces the first life sciences concepts – plant, animal, behavior, ecosystem – in a way that children can relate to in their own lives. In secondary education, science and business come in. Life sciences concepts are progressively elaborated (gene, cell, molecule, organ, organism, DNA, proteins) and tied to real scientific and business practices in fundamental research and market sectors (food, health, agriculture, chemicals & energy). For example: the practice of mapping the human genome or that of rice and how that may translate into (economically viable, sustainable) solutions to health problems or food shortages.

RECOMMENDATION Accelerate introduction of the new concept-context curriculum to enhance students' perception of the relevance of the life sciences, and facilitate its implementation by building a strong life sciences education community of teachers, scientists and entrepreneurs

In 2020, this setup of life sciences education will deliver a large inflow of students into higher (university and vocational) education. Students will have experienced the wonder and relevance of the life sciences in primary and secondary school, and many will be excited by the field and the prospects of pursuing a career in it. We want to see annual enrollment rise in life sciences bachelors and bachelors with a strong life sciences component (university and HBO levels) from 5000 today to 7500 in 2020 (Figure 1).[3]

Our social priorities (health, food supply, energy security, sustainability) and our economic prosperity all hinge to a

Student influx in Dutch bachelor studies on life sciences or with important life sciences component

University Bachelor	2009 influx	Δ 08-09
GENERAL		
Biology	516	7%
Life Science & Technology	171	37%
Biotechnology	42	17%
Molecular Life Sciences	120	6%
FOOD		
Food and Health	81	8%
HEALTH		
Biomedical Sciences	410	-3%
Biomedical Technology	130	29%
Psychobiology	102	38%
Pharmaceutical Sciences	87	32%
Health and Life	31	-6%
CHEMICALS & ENERGY		
Molecular Science and Technology	102	15%
Chemical Technology	98	1%
AGRICULTURE		
Plant Sciences	22	47%
Animal Sciences	52	8%
TOTAL	**1,964**	**11%**

HBO Bachelor	2008 influx	CAGR 04-08
GENERAL		
Biotechnology	12	19%
Applied Biology	59	0%
Biology and Medical Lab. Res.	1,014	4%
Bio-informatics	61	-5%
Applied Science	108	-1%
FOOD		
Food Technology	110	-1%
HEALTH		
Medical Imaging and Radiotherapy Techniques	362	3%
Biometry	30	4%
Healthcare Technology	22	-18%
CHEMICALS & ENERGY		
Chemical Technology	229	8%
AGRICULTURE		
Biotechnology (Agriculture)	103	27%
Aquatic Ecotechnology	27	-6%
Horticulture and Arable Farming	130	-7%
Animal Husbandry	421	-3%
Animal Management	181	3%
Forest and Nature Management	166	-1%
SAFETY		
Forensic Research	67	18%
TOTAL	**3,102**	**3%**

Figure 1: Number of students and growth in bachelor studies at universities and HBO in the life sciences or with a strong life sciences component. The CAGR represents annual growth. Note that there are many more studies in which the life sciences are part of the curriculum, such as Medicine which had a 2009 influx of over 7000 students.

Sources: Informatie Beheer Groep, *Vooraanmeldingen voor het studiejaar 2009/2010, peildatum 04-07-2009* (2009); HBO Raad

large degree on the success of life sciences innovations. For that, we need a large number of life sciences graduates to work in both science and business.

The concept-context approach acquaints students in secondary education with science and applied science practices and the professionals in these practices. This will increase appreciation of the life sciences and its role in society, and by 2020 will result in a large influx of first-year students into higher education who are better prepared for it. Higher education is in this way an extension of the education they received thus far. There will be no discontinuity in the learning process, as there often is today. Students will know what to expect and what they can look forward to upon graduating. Better motivated students are also less likely to drop out before graduating. Higher intake and higher pass rates mean higher output – a large and steady stream of life sciences professionals.

B. Higher education in the life sciences in 2020 – a top-quality, diversified curriculum with a solid fundamental research training and strong market orientation that continues into lifelong learning

Top quality

In 2020, the output from higher education will have increased – but so will its quality. High-quality university and vocational education is a prerequisite for any knowledge society. In the Netherlands, life sciences education will be excellent. This can be traced back to the quality of teachers and facilities. Higher education institutes have a dedicated teaching staff, continuously trained in didactical skills. Top researchers are part of this dedicated staff, taking responsibility for education as well as performing excellent science. In 2020, professionals at academic institutes are valued for education in the same way as scientific output.

There will be many contact hours and a large amount of practical training and internship. The staff will be supported by guest lecturers such as entrepreneurs, consultants and other life science professionals. PhD students will also support the teaching staff. The teaching activities of PhD students will be valued as much as their research responsibilities. They will no longer see teaching as a low-value side job. They will really learn how to explain their research activities and pass it on to a new generation of life sciences professionals.

Significant investment in high quality teaching with emphasis on didactic skills and methods, research excellence and market orientation, between now and 2020, will result in top schools that deliver outstanding graduates.

Diversified

The life sciences are a cross-disciplinary field. This has multiple meanings. The life sciences are *multidisciplinary* in that they involve knowledge and expertise from more than one area of academic study or professional practice. They are *interdisciplinary* because of the new or extended knowledge that originates between and beyond existing academic disciplines or professions and from their interaction. Where boundaries between the life sciences blur and scientific and professional perspectives are integrated and connected to the practices of users, regulators and other stakeholders, the life sciences are *transdisciplinary* – a term without a firm and fixed definition, but intuitively applicable to the translational research in public-private partnerships.

The cross-disciplinary character of the life sciences implies two things: life sciences professionals must be versatile, able to collaborate on a wide range of subjects with a wide range of partners, and they must be highly-qualified, able to contribute their own specialist knowledge and perspective. The challenge is to develop a curriculum that combines disciplinary depth with cross-disciplinary breadth.[4]

RECOMMENDATION **Value top education the same way as top science to create a leading scientific landscape, with top researchers challenging students to surpass limits. Invent a rating system that encourages cross-disciplinary education**

One advantage that the life sciences have over other multi- or interdisciplinary fields, is that the life sciences are connected in both the science and technology base and end-market applications. Thus, higher education in the life sciences in 2020 will teach a strong life sciences knowledge base in the bachelor phase, including evolution, genetics, cellular biology, molecular chemistry, and systems biology and its application in food, health, agriculture and chemical

and energy production. This basic bachelor's program is cross-disciplinary, involving different institutes. Students will work on projects, in teams and with students of all specializations that the life sciences touch upon, such as biology, chemistry, physics, environmental sciences and food sciences. Students will also be introduced to business and entrepreneurial skills. All students, whatever life sciences field they specialize in, must have the same basic background in fundamental aspects of cell biology, biochemistry, biophysics, evolutionary biology, ecology and biomathematics.

In the course of the bachelor's program, students must choose specialist subjects through additional elective courses on top of the standard life sciences bachelor. In subsequent research or business master's programs, this specialism will be more deeply explored to become the student's primary area of expertise (e.g. medical biotechnology, plant sciences, genetics, food technology, climate studies or (bio)chemical process engineering). Minors provide the opportunity for further business and entrepreneurial qualifications, and throughout the curriculum qualities like collaboration, cross-disciplinary attitudes, communication, organization and working on a project basis are stimulated. In this way, in 2020, higher education in the life sciences will deliver versatile specialists with broad foundations across disciplines and a deep specialty in one.

Strong market orientation

It is clear that life sciences (higher) education in 2020, besides having a high-level scientific profile, has a strong market orientation. From primary school on, students are confronted with what the life sciences mean for real, everyday life. They are ingrained with the dual imperatives of unfettered (basic) research to generate new knowledge and perspectives and concrete, practical applications that are useful and have value to society and its citizen-consumers. The broad bachelor's and specialized master's setups, with their many minors and electives, allow students to tailor their studies to their interests and career ambitions. Students are exposed to different job environments early on, so that they can familiarize themselves and make informed decisions. Life sciences professionals from a wide range of academic and professional backgrounds serve as guest lecturers in their first terms. Large companies sponsor or host courses that are part of the curriculum, introducing themselves to and becoming acquainted with the new talent. Small and medium sized enterprises (SMEs) put research questions to schools for higher vocational education (HBO), giving SMEs access to resources beyond their budgets and students exposure to real-life problems in graduate work. Policy institutes, public and private research organizations and companies offer internships and positions to work on final theses.

Students are strongly encouraged to experience at least two different job environments firsthand, like research in academia and industry, or policy and consulting. Even if a student knows early on in which environment he wants to work, experiencing several job situations is important as the boundaries between environments are fading and public and private stakeholders work more and more together. Working together requires professionals to speak each others' languages. A student may, for example, do an internship on R&D policy for a government department and write her final thesis in an industrial biotech lab. In addition, there are research and teaching assistant positions in academia as well as an online job fair where employers in

the life sciences field offer “side jobs” to students (e.g. during summer vacations). In this way, most students will already have worked in the field, for more than one organization, before graduating. They learn and earn a bit extra, familiarize themselves with career opportunities and start building a network. Employers in turn get a good, close-up impression of the next generation of life sciences talent and will follow their careers. Thus, even if a first or second job takes a graduate elsewhere, the company he interned with may hire him five years down the line. In this way, higher life sciences education delivers outstanding, versatile specialists who are both well-equipped and well-prepared for the (job) market (Figure 2).

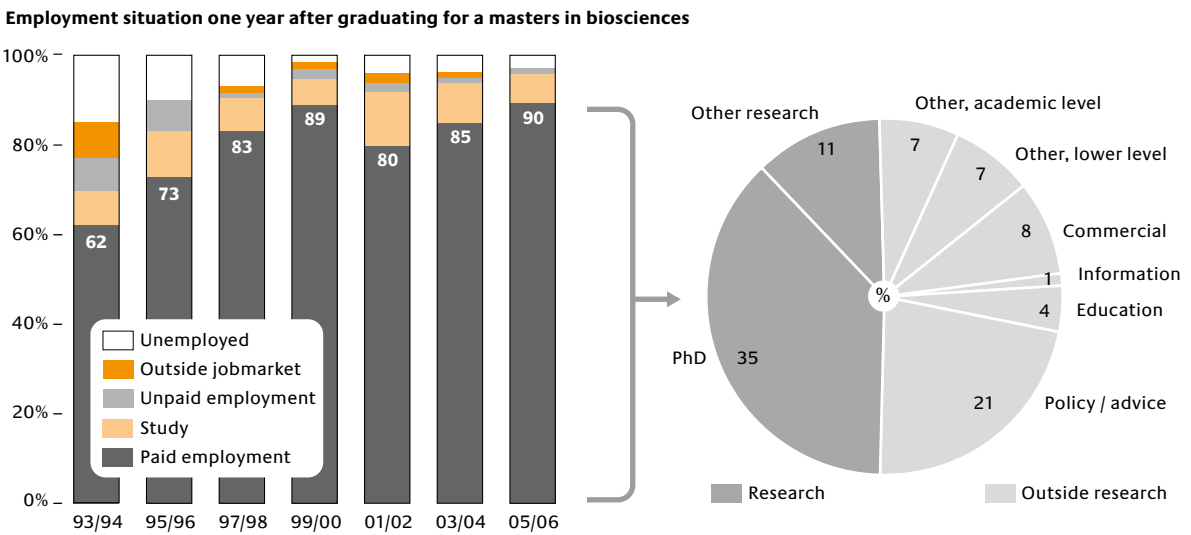


Figure 2: The employment situation of former biosciences students one year after graduating with their master’s degrees
Source: Netherlands Institute of Biology (NIBI), *Annual employment situation inquiry* (2008)

RECOMMENDATION Involve the professional field in life sciences education in a sustainable way, making them part of the value chain by offering guest lecturers, internships, graduation projects and side jobs, and giving them excellent professionals in return

Continuing into lifelong learning

Education in the life sciences does not end with accepting a job. PhD students, post-docs, researchers in companies, PPPs or academia, policymakers, business people and others embark on a future of lifelong learning. This is not a single institute or an common curriculum, but a motley collection of company and industry training programs, postgraduate education, refresher courses, master classes, centers for entrepreneurship, etc. Parties involve and benefit from each other. Companies retain institutes for higher education to provide parts of their in-house training, universities employ sector professionals in topical refresher courses.

Lifelong learning in the life sciences is a reflection of the open innovation paradigm. It is about variety and integration, not consolidation. If a program or a course exists and it is good, other institutes do not try to replicate or subsume it, but connect, collaborate and enroll their own people in it. Every interested can “mix and match” depending on its needs and priorities and add new initiatives. For example, the Life Sciences and Health innovation program first put together a sector-wide training program for PPP researchers almost exclusively from existing initiatives in 2009. In the same year it set up, with and at Nyenrode Business University, a business education program open to all life sciences.

C. The life sciences education system in 2020 – a partnership built on cross-institute collaboration, efficient funding and strong, unified marketing

This vision for 2020 is built on partnership. It could only come about through collaboration by and between all institutes for education and training, large and small, basic and advanced. The same principle applies to both higher education and lifelong learning in the life sciences: collaborate at home, compete abroad. To deliver the numbers of outstanding, versatile and specialist professionals we need, the Netherlands must come together as one bioregion and pool resources. If every university and school for higher vocational education, every disciplinary department within them, and every sector, company and PPP were to build its own independent, proprietary life sciences education and training infrastructure – resources would be wasted and the results would leave us inadequate, weak and uncompetitive on the world stage.

Cross-institute collaboration

The broad life sciences bachelor's program in 2020 is the first cross-institute program of its kind. Students circulate, gain instruction from many different institutes and groups, and receive a joint degree from their "home" university and the collective. They then decide where to specialize in their master's. Although typically centered around a single university, these master's programs also involve other institutes and make the most of their respective research and education specialties. There are partnerships with other leading (European) universities to further broaden and deepen the curriculum. Every institute for higher education has its own focus areas and distinguishing master's programs, but the fact that all are part of the larger Dutch life sciences education infrastructure gives them a distinct edge over competing programs internationally and makes them much sought-after partners.

Efficient funding

The partnership character of life sciences education in 2020 is also reflected in its funding. There is a greater involvement, also financially, of industry – not just in postgraduate or industry programs, but in graduate and undergraduate education as well. (Higher) education institutes allocate dedicated budgets to life sciences teaching that do not compete with research funding. Government supports this practice, for example by providing matching funding that is earmarked and cannot be redirected elsewhere. (Public) funding is tied to student numbers, teaching intensity and the use of expensive facilities like clean rooms, equipment and (bioinformatics) ICT. There is a premium for education that is evaluated as excellent, based on predefined quality criteria that are monitored regularly. Multimedia and online teaching methods relieve the burden on teaching staff and free up resources for contact hours and practical work. A small part of budgets is reserved for education experiments, that, if successful, are incorporated into established, regular programs.

RECOMMENDATION Provide structural funding for life sciences curricula at higher educational institutes, student-number based and which allow intensive practical education using actual life science materials and methods. This funding would not be able to be redirected to other courses or to research

Strong, unified marketing

In 2020, Dutch life sciences education actively positions itself as a diverse but unified system. It is marketed at

home and abroad, individually and collectively by (higher) education institutes, companies, sector associations and government organizations. They speak with a single voice. The Netherlands, as a single bioregion, makes a unified, world-class environment available for education and work in the life sciences.

Talent follows opportunity. The strong science base of the life sciences, the excellent (and lifelong) education, the wealth of job opportunities in business, PPPs and academia and the vibrant, dynamic innovation landscape give the Netherlands a strong proposition to attract and retain the best talent. In 2020, the numbers of domestic and foreign life sciences students in Dutch higher education have increased by 50%. The Netherlands also attracts (researcher-)teachers from around the world, both as visiting or tenured professors. Its universities and vocational schools are preferred partners for leading international institutes for higher education in the life sciences.

Quote from Kerst Boersma

“**Research on the quality of biology education**

Without hesitation, I support the emphasis on biology education in this book. Furthermore, I hope that the concept-context approach inspires policy makers in the life sciences, as it did the authors of this book, and that they recognize its potential. Continuing the line of argumentation, I would argue that research on the quality of biology education, and in particular on the quality of its learning and teaching processes, should be considered the engine of high-quality biology education. The urgency of this research, however, is at odds with its present appreciation in the Netherlands. Until recently, the Faculty of Science at Utrecht University housed one of the leading research groups in biology education in Europe. Shortly after my superannuation, however, it was decided to not fill the vacancy of full professor and to terminate our research for financial reasons. From a national perspective, this reduction of research in biology education is not acceptable. The Netherlands requires at least one research group of sufficient extend that focuses on the quality of biology education. Such a research group cannot and should not compete with biological research and should be safeguarded. ”

Kerst Boersma, retired Professor Didactics of Biology at Utrecht University

D. The results in 2020 – highly qualified and versatile life sciences professionals for all sectors, and informed citizens who are receptive to innovation

It is our ambition to deliver, through education and training, a large and steady stream of life sciences professionals to all sectors in 2020. These professionals are the life blood of the life sciences. As blood delivers nutrients and oxygen to organs, so life sciences professionals circulating through academia and industry disseminate knowledge and inspiration. They are the primary vector for knowledge transfer, especially tacit knowledge that is not easily transferred. To the life sciences professionals of 2020, cross-disciplinary, public-private collaboration comes naturally. It is how they were educated. In their studies they learned to operate in different environments (academia, business, government) and to work with people of all life sciences stripes. They are also highly mobile, moving from one position to the next – from researcher to entrepreneur, to business developer, to civil servant, to professor, to investor, and back, and round again.

This also makes the life sciences professionals of 2020 a driving force behind cross-fertilization between disciplines and sectors. They break the language barriers and bring partners from different fields together in innovation. They are pivotal figures in a network of professionals – researchers and practitioners – that they started to build during their formal education: studying at several institutes; working in teams with students of other disciplines and with different (educational) backgrounds; in summer jobs, internships and thesis positions in academia, government and industry. Throughout their career, their collaboration in PPPs, bilateral and other ventures and lifelong learning programs, they continue to meet and work with each other, maintaining and expanding the network.

Finally, the life sciences professionals of 2020 are entrepreneurs, encouraged from the outset to take risks in research and business, to seize opportunities and to be comfortable with uncertainty. They carry that entrepreneurial spirit with them and transmit it to others.

In addition, and by no means less importantly, life sciences education in 2020 delivers informed citizens who are receptive to innovation. Life sciences education educates consumers so that they can make decisions guided by fact rather than fear. This will make them more receptive to innovation, but also protect them by giving them the context and critical skills to evaluate the merits and dangers of new products, processes or services themselves. Primary and secondary education are especially important, but higher education, lifelong learning and public education all play a role.

A lot of marketing power is expended in the food, health and wellness industries. A lot of lobbying and populism pervades discussions on climate, energy and pollution. Citizens need to be able to make their own personal (lifestyle and political) decisions, and life sciences education prepares them for it. As essential as life sciences professionals are, this may be education's biggest contribution to life sciences innovation.

RECOMMENDATION **Have sector organizations set up a network for the life sciences (students and professionals) to organize: marketing, meetings, mobility, social communication and matching of market needs and education**

E. Recommendations

This chapter makes five main recommendations, summarized below. They contain actions that can only be successful when taken up by the field and government together, in a joint approach.

- Accelerate introduction of the new concept-context curriculum to enhance students' perception of the relevance of the life sciences, and facilitate its implementation by building a strong life sciences education community of teachers, scientists and entrepreneurs

- Value top education the same way as top science to create a leading scientific landscape, with top researchers challenging students to surpass limits. Invent a rating system that encourages cross-disciplinary education

- Involve the professional field in life sciences education in a sustainable way, making them part of the value chain by offering guest lecturers, internships, graduation projects and side jobs, and giving them excellent professionals in return

- Provide structural funding for life sciences curricula at higher educational institutes, student-number based and which allow intensive practical education using actual life science materials and methods. This funding would not be able to be redirected to other courses or to research

- Have sector organizations set up a network for the life sciences (students and professionals) to organize: marketing, meetings, mobility, social communication and matching of market needs and education

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