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Systems education can train the next generation of scientists and clinicians

In recent years, there has been growing concern about waning interest in science, as despite advances in research and technology, fewer young people seem to be pursuing careers in these fields[1]. This decline can be attributed to various factors, including a lack of early engagement, inadequate integration of practical experience and insufficient alignment between educational stages. To address this issue, the National Academy of Scientist Education (NASE) and Academia Europaea (AE) propose the concept of 'multigenerational systems education', a comprehensive approach that draws inspiration from systems biology and systems medicine.

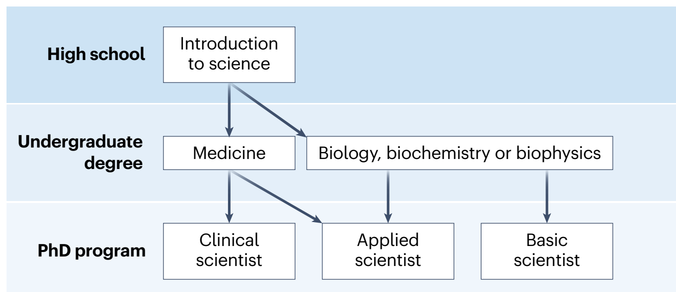

Fig. 1 | Multigenerational systems education. High school students are introduced to science and are then encouraged to apply for either a medical science degree or a biological science degree, which can then lead to one of three PhD programs, for clinical scientists, applied scientists or basic scientists.

The traditional methods of teaching science have failed to keep pace with the rapid advancements of the twenty-first century. Evidence of declining interest is reflected in the decreasing number of students enrolling in science courses at both the high school level and the university level[1]. According to recent studies, fewer students are choosing to specialize in life sciences, with many perceiving these fields as inaccessible or irrelevant to real-world applications[2,3].

One issue is the disjointed nature of science education across different educational stages. High school programs often lack the necessary hands-on experience, while undergraduate courses are often heavily theoretical, with limited opportunities for practical application. Moreover, PhD programs tend to be very dependent on the quality of supervision, which leads to inconsistencies in training and preparation for real-world challenges[4].

'Systems education' is a holistic educational model that emphasizes integrated, multigenerational learning pathways. This approach aims to create a seamless continuum of science education, from early high school exposure to advanced graduate program training. The core principles are early sensitization, knowledge transfer and real-world application tailored to different age groups (Fig. 1).

The first stage should focus on high school students. At this stage, the main goal is to spark interest and curiosity in science through experiential learning. High schools should integrate laboratory elements and hands-on training sessions into their curricula. Collaborations with local hospitals, research institutions and universities can provide students with opportunities to witness science and medicine in action. Interactive workshops, science fairs and mentorship programs with distinguished scientists can further enhance students' engagement and understanding.

The second stage targets undergraduate students, for whom the focus should shift to in-depth knowledge acquisition. Undergraduate programs should provide a balanced mixture of theoretical foundations and practical skills. Integrating laboratory practice into undergraduate education is crucial; these students should be allowed to engage in research 1–2 days per week, alongside their theoretical classes.

The final stage addresses postgraduate training. At this level, the emphasis should be on preparing students for real-world challenges and equipping them with transferable skills. Unlike traditional PhD programs that focus solely on the production of a thesis, systems education advocates for a more structured and skill-oriented approach[4]. The curriculum should include formal training in project management, data analysis, public engagement, and intrapersonal (self-management) and interpersonal (team-related) skills. Practical experience, such as industry placements and collaborative research projects, is also essential. Mentorship and continuous feedback are crucial to ensure that students are well prepared for diverse career paths, both within academia and outside academia.

The NASE, in close collaboration with AE, has established a multigenerational school system in the field of biomedical sciences that incorporates the aforementioned elements. Students regularly participated in hands-on laboratory training and practice in clinical simulation labs of local hospitals, where they performed procedures such as examinations and interventions on mannequins serving as surrogate patients. They also had the unique opportunity to be inspired by around 30 distinguished researchers, including 16 Nobel laureates, who continually supported the program's development. The students' selection criteria were curiosity, interest and quality. The program has been supported by the Hungarian government, municipalities, universities and companies, which provided the funds needed to ensure free education for the participants.

Over the past 12 years, achievements have been made. 24 laboratories have been established nationwide, involving over 200 high schools and introducing 3,000 high school students to biomedical sciences. According to a recent survey conducted among students leaving high school, only 35 of 138 students (25%) had a strong connection to science before entering this training, which increased to 56% by the end of the program. 77% of the students reported that the program enhanced their biomedical knowledge, and 85% stated that participation in the NASE program influenced their decision about further education. 97% of the students who were graduating from high school applied to university programs in life sciences, with 87% selecting a direct healthcare profession, among whom 65% opted for general medical practice.

The most talented students continued the program at the university level, at which point they were paired with pre-selected mentors. All four Hungarian universities responsible for medical education have joined the program, allowing all talented students in Hungary to pursue research in this new system. The curriculum for these students was designed to ensure a minimum of 40 hours of protected research time per month. This structure allows students to fulfill the educational criteria of the course and lead scientific projects. Although the program is still young, it remains to be seen how many of these students will become independent researchers in the future.

After their undergraduate studies, students can enter PhD programs, during which they choose from among three distinct career paths, to become basic, applied or clinical scientists (Fig. 1); the last is vital, as it prepares students for impactful roles within the healthcare system and will ensure healthcare professionals can effectively utilize the latest discoveries in real-life scenarios[3,5,6].

In conclusion, multigenerational systems education provides a promising framework for revitalizing interest in life sciences by creating a cohesive and continuous learning pathway. By sensitizing students early, offering comprehensive knowledge transfer and preparing the students for real-world applications, well-rounded and skilled professionals can be cultivated. Embracing this integrated method will not only enhance the quality of science education but also ensure that the life sciences remain a vibrant and dynamic field for future generations.

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References

1. Potvin, P. J. et al. *Sci. Educ. Technol.* **23**, 784–802 (2014).
2. Tyrrell, J. M. et al. *Front. Microbiol.* **15**, 1380045 (2024).
3. Hegyi, J. et al. *Eur. Rev.* **32**, 66–79 (2024).
4. *Nature* **627**, 244 (2024).
5. Hegyi, P. et al. *Nat. Med.* **27**, 1317–1319 (2021).
6. Hegyi, P. et al. *J. Clin. Med.* **19**, 1532 (2020).

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Competing interests

The authors declare no competing interests.