How do we teach chemistry to students with disabilities?

Performing practical laboratory work is a central part of all chemistry educations, especially early in learning chemistry. Laboratory work is also an important part of sparking interest and retaining the students throughout their education in chemistry. Recently a physically disability student initiated a one-year master project within my research team. I have carried out a semi-structured interview with her regarding her background, what inspired her interest in natural sciences and how her disability has influenced her education. This interview sparked my interest in how we can help students with more severe disability through an education in chemistry to jobs in chemistry, that often do not have practical laboratory components (table 1).

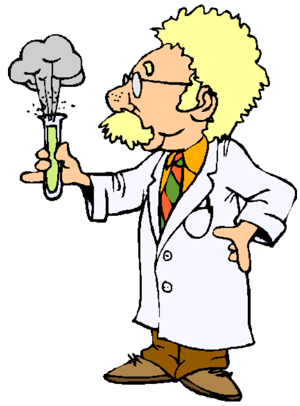

Figure 1: The classic picture of a chemist, performing practical laboratory work.

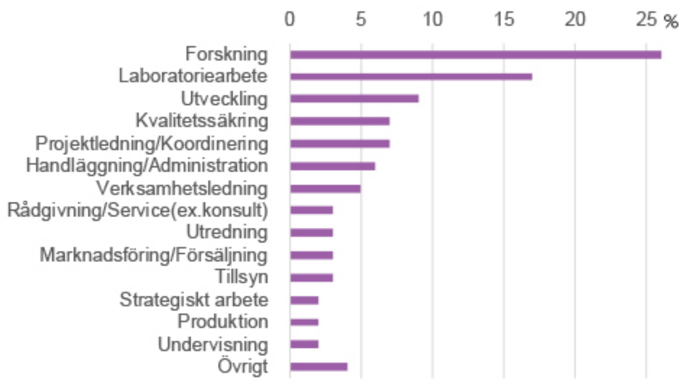

Table 1: Table showing the specific assignments that chemists in Sweden work with 2017 [1]. Approximately 50% of the job assignments do not include practical laboratory work. Likely even more, since the major category "Research" includes many theoretic disciplines and jobs as my own.

Two interesting results from the interview were:

1. She had noticed no difference in the support and tolerance for students with disabilities between her home country in southeastern Europe and Sweden. This challenged my

preconception of Sweden compared to countries in southeastern regarding attitudes towards disabilities.

2. She had a very clear memory on what sparked her interest in higher education within natural sciences. During high school a student from the university came to her school and presented. This was the key trigger for her to seek higher education in chemistry. Perhaps this was when she felt that she could become a “chemist”.

Wearing the white lab coat and performing practical laboratory work could be an important part in establishing an identity as a chemist and developing a sense of belonging to this trade (figure 1). Not realizing this expected stereotype could lead to disabled not feeling like true chemists [2, 3]. Inclusive teaching is important both to widen student participation and retention, this applies to all student groups and is not limited to students with disabilities [4]. Gravestock phrases it well ‘good practice for disabled students is good practice for all’ (cited in [5]).

When reviewing available literature regarding disabilities in teaching chemistry I found a very inspiring version of the periodic table, showing that many of the chemists that discovered the elements of the periodic table had various disabilities (figure 2) [6]. This illustration could help chemistry students that have various disabilities to identify themselves as chemists and feel that they belong to this trade. I will include this illustration in the introductory lectures in my future courses. This will hopefully inspire students with disabilities of any kind, and hopefully make them feel that they are in the right place and can contribute to the advancement of the field. It is interesting to note that the most common disability in this illustration is being blind. This also highlights the importance of safe laboratory practice and correct protective equipment. Key tools in chemistry have always been strong acids and strong bases that easily can cause blindness.

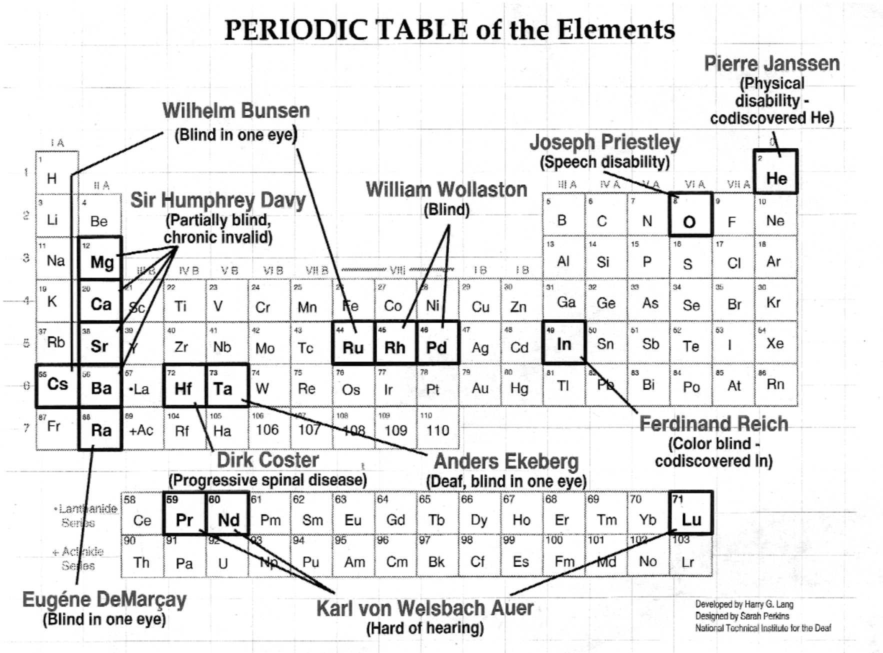

Figure 2: An inspiring version of the periodic table showing that many of the chemists that discovered the elements of the periodic table had various disabilities [6].

Students with various physical disabilities can still carry out many laboratory assignments. It is however important to adjust the laboratory, the tools and the time assigned to different aspects of the laboratory work [6]. The adjustments needed vary greatly with the person and the nature of the disability; flexibility is needed from the teachers and fellow students. In the case of the student I interviewed, she needs extra time to write. Not because of dyslexia, rather the actual writing with a pen or pencil. The electronic lab-notebook system we have implemented in my team helps her with this aspect. It also allows student and coworkers to use spelling tools when writing laboratory journals, this is also very useful for students that are not fluent in English or have dyslexia. This helps to overcome barriers for many students. From my perspective, it is very important that notes are taken during and after experiments, both to document the experiments and to help the students in their learning and understanding of the process. I have now supplied the students with tablets that they can use to take notes in the laboratory to avoid running back and forward between the office and the laboratory. This could also be deployed at first year students to improve record keeping and report writing.

Virtual chemistry and simulations

One possibility for students that have disabilities preventing them from carrying out practical laboratory work is to utilize virtual chemistry and/or simulations. I have discovered many online tools that can be used on tablets. The American Association of Chemistry Teachers has published a good collection of web based chemistry simulations [7]. There are also other useful tools discussed below [7-9].

Simulated laboratory work in physics

Finkelstein and coworkers have investigated computer simulations of laboratory work compared to classical, hands on, laboratory work in physics (DC current circuits) [10]. They show in similar results in knowledge and know how [10]. One strength of their study is the large group of students included (>200) leading to reliable data. Interestingly they found the students that had worked with the computer simulated laboratory work outperformed the students that had carried out classic hands on laboratory work, both in practical and theoretical tests. In this case I believe the main advantage of the simulated laboratory work is the time saved in avoiding assembling disassembling provided the students in the simulation more time to carry out the productive steps in the assignment, failing, changing, observing and eventually succeeding and understanding. This study shows that simulations can even outperform actual laboratory work [10]. However, simple DC circuits are very easy to simulate, with few parameters to consider.

Simulated laboratory work in chemistry

There are several experiments in chemistry that can be easily simulated, e.g. gas laws, density and chemical equilibrium [8]. Some experiments in chemistry are even preferred to simulate due to the high risks associated with students working at high temperatures and high pressures e.g. changing variables of the volume and temperature of a solid, a liquid and a gas sample and observing changes in density [7]. However, many experiments in chemistry, after year two, quickly become too complicated to simulate in a productive way.

I have however found several good computer simulations that can be useful for first year chemistry students. One good example from the University of Oregon is a web-based simulation of mixing various strong and weak acids and bases and then measuring the resulting pH with a pH electrode [9]. This simulation would be very useful for all chemistry students, especially since strong acids and based can be dangerous for inexperienced students. The simulation also includes buffered systems, a important concept for all working in chemistry [9].

Conclusions

For over 200 years chemists with various disabilities have been key players in chemistry (figure 2). It is important to be inclusive in our chemistry teaching and to make all students with an interest in chemistry feel at home in the discipline, irrespective of social background, ethnicity or disability. Failing to be inclusive will otherwise lead to society missing the contributions from future top researchers and key employees in industry.

To solve the medical and environmental challenges of the future we have to locate and retain the top students, irrespective of background and disabilities. We need to take measures to accommodate diverse backgrounds and various disabilities to facilitate studies and spark interest [6].

References:

1. Naturvetarna, *Här jobbar naturvetare inom Kemi.* https://naturvetarna.se/jobb-lon-och-villkor/jobb/har-jobbar-naturvetare/kemi/, 2017.

2. Browne, J., II, *Walking the Equity Talk: A Guide for Culturally Courageous Leadership in School Communities*. 2012, Corwin Press: Thousand Oaks, California.

3. Hargittai, B. and I. Hargittai, *Culture of Chemistry Elektronisk resurs : The Best Articles on the Human Side of 20th-Century Chemistry from the Archives of the Chemical Intelligencer*. 2015, New York: Springer.

4. Hunt, L. and D. Chalmers, *University Teaching in Focus: A Learning-Centred Approach*. 2013: Routledge.

5. Lucy Zinkiewicz, N.C., *Inclusive Practice within Psychology Higher Education.* PsycEXTRA, 2010.

6. Dorothy L. Miner, R.N., Anne B. Swanson, and Michael Woods, *Teaching chemistry to students with disabilities : a manual for high schools, colleges, and graduate programs*, 2001, American Chemical Society Committee on Chemists with Disabilities: [Washington, DC:] :.

7. AACT, *https://teachchemistry.org/periodical/simulations.* Chemistry Solutions, The American Association of Chemistry Teachers, 2017.

8. American_Chemical_Society, *Virtual Chemistry and Simulations.* https://acs.org/content/acs/en/education/students/highschool/chemistryclubs/activities/simulations.html, 2017.

9. University_of_Oregon, *Buffer solution pH Computer Simulation.* Greenbowe Chemistry Education Instructional Resources, http://pages.uoregon.edu/tgreenbo/pHbuffer20.html, 2010.

10. Finkelstein, N., et al. *Can Computer Simulations Replace Real Equipment in Undergraduate Laboratories?* in *Physics Education Research Conference 2004*. 2004. Sacramento, California.