BRIDGING THE VISUAL GAP: TACTILE AND AUDITORY AIDS FOR CHEMISTRY EDUCATION

[1]Bhaskar,[2]Madhuri,[3]Chandu,[4]Varahalu
[1234]Students
Department of H&S

ABSTRACT

Chemistry, as a visually intensive subject, presents significant challenges for learners with vision impairment due to its reliance on diagrams, symbols, molecular models, and experimental observations. This paper explores innovative strategies to bridge the visual accessibility gap by introducing and evaluating tactile and auditory learning aids designed to enhance the comprehension of chemical concepts among visually impaired students. Through the development and implementation of raised-line diagrams, Braille-labeled models, audio-described experiments, and sonified data outputs, the study demonstrates that multisensory approaches can dramatically improve inclusion, engagement, and conceptual clarity. Feedback from educators and learners confirms that tactile and auditory resources not only make chemistry more accessible but also foster greater independence and confidence in science learning for students with visual disabilities.

I. INTRODUCTION

Access to science education is a fundamental right, yet students with vision impairments often face systemic barriers—especially in visually driven disciplines such as chemistry. From structural formulas and reaction mechanisms to lab-based observations and color changes, much of chemistry instruction depends on sight. These visual dependencies create exclusionary learning environments unless proactive adaptations are made.

In recent years, inclusive education practices have emphasized the importance of universal design for learning (UDL) and the integration of assistive technologies. However, chemistry remains one of the least accessible STEM subjects for students with visual disabilities. Traditional accommodations like verbal explanations and note-taking assistance are often insufficient when dealing with abstract molecular concepts or complex visual data.

This study addresses these gaps by focusing on tactile and auditory educational tools that allow visually impaired learners to engage with chemistry in a multisensory manner. The approach includes tactile graphics, 3D-printed molecular models, Braille-translated periodic tables, auditory experiment descriptions, and digital tools for interactive sonification of chemical data. The objective is not just to adapt existing content, but to reimagine chemistry education so it is equitable and empowering for all learners.

II. GENERAL STRATEGIES TO IMPROVE ACCESSIBILITY

With increasing international attention on accessibility, some strategies may already be familiar. Using Alt text on images and captions or descriptions on videos is a simple way to make your website or learning resource more accessible to people with VI. Colour and contrast are also important. Many people with VI have some useable vision and a careful choice of colours can make a big difference to accessibility. In graphs and figures, consider using text, symbols and patterns alongside colour, whilst also making gridlines and scales simple and bold6.

In school laboratories, accessibility can be improved in surprisingly simple ways. Tactile stickers of different sizes and shapes can be used for labelling. Braille label makers are also available, although these may have limited reach, as many pupils access learning using large print or screen readers. Plastic syringes can be modified with a notch in the barrel to measure specific volumes of liquid7. This is something that can be done quickly and cheaply by a school technician, showing that modifications are often thoughtful tweaks rather than expensive purchases. Audio technology is also available, for example talking thermometers, weighing scales or colour detectors. However, it’s also important to consider that adaptive technology can give rise to feelings of ‘otherness’ for a pupil with VI in a mainstream school and so may not be appropriate; it can also cause issues in a noisy classroom, where things may not be heard clearly.

III. TACTILE MODELS

Tactile models can be very effective in illustrating scientific concepts. One example is Tactile Collider, which was designed to make particle accelerator physics accessible to people with VI8. Pupils who took part in the project said that it inspired them to learn new things. More importantly, pupils who participated said the experience made them more confident to ask for modifications in school if they felt something was inaccessible. They also said it showed them that further study in the sciences was something they could aspire to.

Another simple example of a tactile demonstration is a building block model of a lithium battery9. The wooden pieces of the tower are decorated to represent the oxide and graphite electrodes and the lithium ions. The lithium ion pieces can then be transferred from one tower to gaps in a second tower to represent the charging and discharging processes. Plastic construction bricks have also been used to illustrate concepts such as periodic trends and even molecular orbital theory (Fig. 1)10. An important point to note about tactile models is that they should be carefully designed and tested with a VI audience in mind. It’s easy to make a tactile version of any scientific diagram but while something may seem obvious to a sighted designer it may not translate well into a tactile form. Complex structures and extensive details can become blurred, and the details lost when models or diagrams are too intricate. This can result in a model which is confusing for a pupil with VI. It is also important to note that models which are simple will still require some level of description in order to allow students to visualise the concepts being delivered.

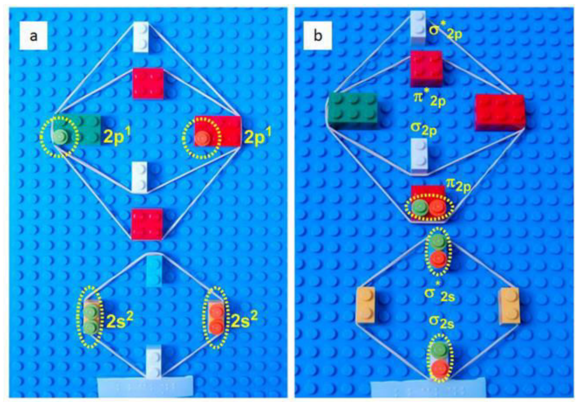

Fig. 1 Model of the molecular orbital diagram of a B2 species made with interlocking toy bricks. Small round bricks are used to represent the electrons in (a) the atomic orbitals and (b) the molecular orbitals. A model like this would be used alongside a verbal description. Image reproduced from ref. 10.

IV. Experiments using other senses

Much of chemistry education involves experiments and it can be very challenging to make these accessible for pupils with VI. However, some ingenious solutions have been found that rely on senses other than sight to monitor chemical processes and reactions. A fascinating example is the use of onions to detect the endpoint of a titration11. Sodium hydroxide inhibits the formation and release of pungent sulfur compounds from onions and neutralisation of the solution with hydrochloric acid releases a strong onion odour. This experiment can be easily adapted for pupils with

VI12 and provides an interesting (albeit smelly) alternative to coloured indicators for sighted pupils. A simple phone app has also been developed to detect the endpoint of titrations using a wide range of coloured indicators13. The software is freely available, which maximises accessibility, and the endpoint of a given reaction is signalled by sound or vibration. Olfactory changes have also been used to illustrate the concept of adsorption of organic molecules onto activated carbon14 and to probe the kinetics of ester formation15.

V. CHALLENGES AND OUTLOOK

There have been some exciting advances in making chemistry accessible for pupils with VI and this is by no means a comprehensive review. However, there are numerous experiments and areas of chemistry where accessibility has not been considered. Given the attainment gap in secondary school and the fact that so many pupils with VI feel discouraged when accessing science, it is important that the chemistry community works to make school chemistry accessible. A diverse workforce is one which values different skills, and by opening up the chance to study science to more young people we will be able to solve problems in more inclusive and exciting ways.

VI. CONCLUSION

The integration of tactile and auditory aids into chemistry education represents a meaningful step toward creating inclusive and accessible learning environments for students with vision impairments. The findings from this study confirm that when abstract chemical concepts are made tangible and audible, students are better equipped to understand and internalize complex ideas.

Beyond simply offering accommodations, this approach redefines how chemistry can be taught in diverse classrooms—where multisensory learning tools benefit not only those with disabilities but can also enhance engagement for all students. Educators play a pivotal role in embracing accessible teaching methods, and institutions must support this with training, resources, and policy frameworks.

In conclusion, bridging the visual gap in chemistry education is not only a technical or pedagogical challenge but a moral imperative. By committing to inclusive strategies, we can ensure that vision-impaired learners are not sidelined in science, but instead are fully capable of contributing to and thriving in the chemical sciences.

REFERENCES

1. Slade, J. Educational Attainment: Summary of Official Data on Children and Young People with a Vision Impairment in England (RNIB, 2022). https://www.rnib.org.uk/professionals/health-social-care-education-professionals/knowledge-and-research-hub/reports-and-insight/educational-attainment/.
2. Hewett, R. & Douglas, G. Inclusive design: its impact on young people with vision impairment. J. Technol. Pers. Disabil. 3, 277–290 (2015).
3. Chandler, M. Young People not in Education, Employment or Training (NEET): November 2015 (Office for National Statistics, 2015).
4. Palan, R. "I seriously wanted to opt for science, but they said no": visual impairment and higher education in India. Disabil. Soc. 36, 202–225 (2021).
5. Rizzo, K. L. & Taylor, J. C. Effects of inquiry-based instruction on science achievement for students with disabilities: an analysis of the literature. J. Sci. Educ. Stud. Disabil. 19, 1–16 (2016).
6. Katsnelson, A. Colour me better: fixing figures for colour blindness. Nature 598, 224–225 (2021).
7. Chataway-Green, R. K. & Schnepp, Z. Making chemistry accessible for students

with vision impairment. Sci. Sch. 64, 1–5 (2023).

8. Appleby, R., Edmonds, C. & Watson, R. Tactile Collider: a new approach to the communication of fundamental science to visually impaired people. Res. All 4, 16–32 (2020).
9. Driscoll, E. H., Hayward, E. C., Patchett, R., Anderson, P. A. & Slater, P. R. The building blocks of battery technology: using modified tower block game sets to explain and aid the understanding of rechargeable Li-ion batteries. J. Chem. Educ. 97, 2231–2237 (2020).
10. Melaku, S., Schreck, J. O., Griffin, K. & Dabke, R. B. Interlocking toy building blocks as hands-on learning modules for blind and visually impaired chemistry students. J. Chem. Educ. 93, 1049–1055 (2016).
11. Flair, M. N. & Setzer, W. N. An olfactory indicator for acid-base titrations. J. Chem. Ed. 67, 795–796 (1990).
12. Chataway-Green, R. K. & Schnepp, Z. An accessible olfactory titration experiment for the visually impaired. SSR Pract. 104, 32–33 (2022).
13. Bandyopadhyay, S. & Rathod, B. B. The sound and feel of titrations: a smartphone aid for color-blind and visually impaired students. J. Chem. Educ. 94, 946–949 (2017).
14. Patchett, R., Watson, R., Davies, J. & Schnepp, Z. Carbon for water treatment: a chemistry experiment that is accessible for vision impaired people. J. Chem. Educ. 99, 494–499 (2022).
15. Bromfield-Lee, D. C. & Oliver-Hoyo, M. T. An esterification kinetics experiment that relies on the sense of smell. J. Chem. Educ. 86, 82–84 (2009).