



Teaching and Education highlighted

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Teaching and Education (T&E) was quietly introduced as a new category of article in *Journal of Applied Crystallography (JAC)* in an editorial by the then Editor Mike Glazer in 1994 (Glazer, 1994).¹ The brief for T&E articles in subsequent *Notes for Authors* was short and fairly broad: ‘Articles in this category cover all aspects of an educational nature related to the general field of crystallography’.

The first article in this category was a short note entitled *Three-dimensional periodicity and inversion axes in crystals*, published the following year (Sharma, 1995). One to three articles appeared in most subsequent years, until 16 were published in a special issue on *Crystallography education and training for the 21st century* in 2010 (Kantardjieff *et al.*, 2010). That issue perhaps temporarily exhausted likely authors, with the number of articles in subsequent years dropping back to one or two until three to seven became the norm from 2017 onwards. It looks like we are on an upswing; 2022 has seen five T&E articles in the first issue alone!

Initially, T&E articles could be submitted to any of the *JAC* Co-editors. It was soon realized though that T&E articles do require a special touch (see below), and a succession of editors were selected or appointed to focus on T&E submissions: Åke Oskarsson (Lund Universitet; 1997–2006), Katherine Kantardjieff (California State Polytechnic University Pomona; 2006–2015), and, since 2015, one of the authors of this editorial, Juan Manuel García-Ruiz (Universidad de Granada). To respond to the increase in submissions in recent years, and to help us realize our ambitions to extend the reach of the T&E section, we are pleased to announce the appointment to the *JAC* Editorial Board of a further editor, Louise Dawe (Wilfrid Laurier University, and also a co-author of this editorial), who will focus on T&E articles together with Juan Manuel García-Ruiz.

The editing of T&E articles needs an approach that is different from other submissions to *JAC*. It is usually not the novelty of the scientific content that is important but the novelty in the way in which established crystallographic ideas and concepts are presented, especially with reference to the expected level of the target audience. The T&E Editor(s) and, to some extent, reviewers should be experienced, active undergraduate lecturers. Crystallography is no longer taught to the same depth in undergraduate courses as in the past, partly due to the increasing emphasis on teaching translational medical, technological and societal skills, and partly due to the efficient push-button automation of modern diffractometers. To some extent, in the latter, crystallography is a victim of its own success. We should also not complain too much about the former, when applied crystallography is the focus of *JAC*.

What has been the impact, thus far, of T&E articles? Considering the audiences are primarily undergraduate and post-graduate students, and the aim is to educate rather than present results that may initiate further research, the common metric of numbers of

¹ The category was initially titled ‘Teaching and Education in Crystallography’, which was later shortened to ‘Teaching and Education’. The journal had a sole Main Editor until 2014, when two additional Editors were appointed following a transitional period (2011–2014) with a Deputy Editor.



citations is probably not a fair measure. A better indicator is the number of times a given article has been downloaded, noting that all T&E articles back to the first in 1995 are freely available on the IUCr web site. The 16 articles in the special issue of volume 43, issue 5, have each been cited on average 22 times and downloaded 6734 times. For comparison, the nine (other) open-access research papers or short communications in volumes 43 and 44 have each been cited on average 56 times and downloaded 4582 times. The populations in both groups are small and the citation metric is somewhat sensitive to singular articles, but it is clear that T&E articles are accessed more than regular research articles. Table 1 lists the top ten most-downloaded T&E articles in *JAC* to mid-February 2022.

Overall, 75 T&E articles have been published to date. There are occasionally articles in other categories, notably under Computer Programs, which are aimed at the same audience. Common topics are explanations of space groups and lattice concepts, tutorials and curricula, simulation software for teaching, laser-based tools to illustrate diffraction, and, increasingly, 2D and 3D models, often from 3D printing, as teaching aids.

The first issue of 2022 presented *CRISTAL-ITE: a single-crystal X-ray diffractometer scale model for scientific dissemination* (Giorgi & Berchadsky, 2022). With hands-on access to modern diffractometers, whether X-ray or neutron, generally impossible owing to radiation-protection concerns, such models allow students and the general public to get up close and personal with a tool that is essential in much of our research. We have come a long way since 1978 when one of us (GJMCI) fabricated a card model (Fig. 1) of a similar κ -geometry diffractometer to understand how it could reproduce the movements of the hand-operated Eulerian-geometry cradles that he had used for his thesis work. The sphere of confusion left a lot to be desired, but the simple card model did show how the bisecting setting preferred for X-ray data collections from extended-face crystals could be achieved. Using Hollerith punched cards was an unwitting nod to the dominant role that modern computing and/or electronic tools

Table 1

Top ten most-downloaded Teaching and Education articles.

- 1 *How to read (and understand) Volume A of International Tables for Crystallography: an introduction for nonspecialists.* Dauter, Z. & Jaskolski, M. (2010). *J. Appl. Cryst.* **43**, 1150–1171. <https://doi.org/10.1107/S0021889810026956>.
- 2 *The experience of the 'Voyage dans le cristal' travelling museum exhibition.* Hodeau, J.-L. & Guinebrethiere, R. (2015). *J. Appl. Cryst.* **48**, 1276–1289. <https://doi.org/10.1107/S160057671501064X>.
- 3 *CRISTALES: a world to discover. An exhibition for schools and universities.* Garcia-Ruiz, J. M., Otorola, F., Garcia-Caballero, A., González-Ramírez, L. A. & Verdugo-Escamilla, C. (2015). *J. Appl. Cryst.* **48**, 1264–1275. <https://doi.org/10.1107/S1600576715007724>.
- 4 *Integrating biocrystallography into traditional biology and chemistry curricula.* Jaskólski, M. (2001). *J. Appl. Cryst.* **34**, 371–374. <https://doi.org/10.1107/S0021889801003624>.
- 5 *A tutorial for learning and teaching macromolecular crystallography.* Faust, A., Panjikar, S., Mueller, U., Parthasarathy, V., Schmidt, A., Lamzin, V. S. & Weiss, M. S. (2008). *J. Appl. Cryst.* **41**, 1161–1172. <https://doi.org/10.1107/S0021889808032494>.
- 6 *Jmol – a paradigm shift in crystallographic visualization.* Hanson, R. M. (2010). *J. Appl. Cryst.* **43**, 1250–1260. <https://doi.org/10.1107/S0021889810030256>.
- 7 *Applications of the Cambridge Structural Database in chemical education.* Battle, G. M., Ferrence, G. M. & Allen, F. H. (2010). *J. Appl. Cryst.* **43**, 1208–1223. <https://doi.org/10.1107/S0021889810024155>.
- 8 *Crystallographic shelves: space-group hierarchy explained.* Nespolo, M., Aroyo, M. I. & Souvignier, B. (2018). *J. Appl. Cryst.* **51**, 1481–1491. <https://doi.org/10.1107/S1600576718012724>.
- 9 *From the source: student-centred guest lecturing in a chemical crystallography class.* Zheng, S.-L., Chen, Y.-S., Wang, X., Hoffmann, C. & Volkov, A. (2018). *J. Appl. Cryst.* **51**, 909–914. <https://doi.org/10.1107/S1600576718004120>.
- 10 *HELIX: a helical diffraction simulation program.* Knupp, C. & Squire, J. M. (2004). *J. Appl. Cryst.* **37**, 832–835. <https://doi.org/10.1107/S0021889804016048>.

would play in many of the latest T&E articles, the Arduino platform being the tool in the example of *CRISTAL-ITE*.

Several other IUCr journals host T&E articles, generally on topics complementary to those of such articles in *JAC*. *Journal of Synchrotron Radiation* has published typically one per year since 2015, mostly on the physics of synchrotron sources. T&E articles in *Acta Crystallographica Section F: Structural Biology Communications* will focus mainly on

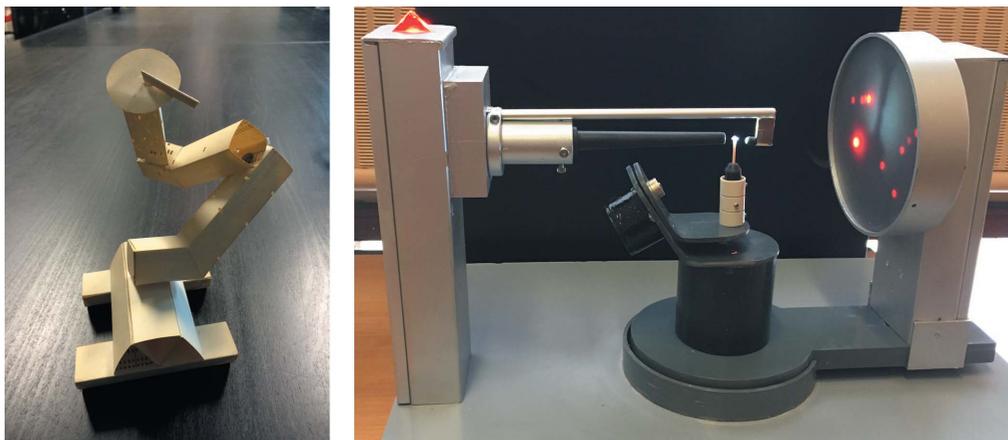


Figure 1

Ancient and modern aids to understanding and teaching the geometry of four-circle single-crystal diffractometers. On the left, a simple card and paper-fastener model from 1978 (photograph: G. J. McIntyre), and on the right, a modern automated model, considerably more sophisticated, yet still constructed from everyday materials [reproduced from Giorgi & Berchadsky (2022)].

biological crystallography. While *Acta Crystallographica E: Crystallographic Communications* does not have a dedicated T&E category, there is a call currently open for submission of articles to a special issue on *Modern approaches and tools for teaching crystallography*.

It is an exciting time for the T&E section of *JAC*. Louise Dawe and Juan Manuel García-Ruiz outline their vision of the future of the section here:

We share a vision of crystallography education as a means for building community. While *JAC* is home to many rigorous studies, we view it also as a base upon which to share ideas and build a passionate foundation for the next generation of scientists who will engage in future studies. We welcome authors to share their thoughts, experiences and stories of learner engagement. We recognize that those we seek to engage in learning crystallography are not restricted to graduate-level students but include elementary students entering crystal-growing contests, high-school students working on science-fair projects and undergraduates learning about molecular geometry. This community also includes primary-school children learning about phases of materials for the first time, families visiting geology displays in museums, politicians making decisions about resources, and retirees visiting libraries and public lectures. How do we strike passion in these various populations of life-long learners? We hope that you, the readers of *JAC*, will share your ideas as articles to answer this question. We also share a vision of the T&E section of *JAC* serving those who are already enthusiastic about crystallography. We hope to move forward with two new initiatives:

(i) The pandemic served as a catalyst for ‘instructional innovation out of necessity’: for example, asynchronous recordings, virtual tutorials and new apps as placeholders for skills development until hands-on opportunities were possible. We welcome contributions that share your remote-instructional crystallography successes and challenges. What new practices will become part of your regular practice? And what lessons have been learned through unpredicted problems? We invite you to send your own experiences as an article to the T&E Editors of *JAC*, and we will facilitate the review and editing process.

(ii) During our research, we have sometimes made pictures or videos that show a new discovery or beautifully illustrate existing ideas, processes or mechanisms. Too often, they are only published as supplementary materials or go only onto one of our slides for a meeting talk, or at worst exist only in the deep holes of our computer files. Why not share them with our colleagues?

We envisage that *JAC* will offer you a new type of article to convert your outstanding ‘by-products’ into invaluable pieces of outreach. You will also be able to share your cartoons, apps, protocols, comics, video clips *etc.* Your work will be available for reuse by the community under a Creative Commons licence with attributions. This vision, for shared crystallographic materials, will help all members of our community to improve communication in their own research and education presentations. It will help to promote not only a better teaching of crystallography but also a science-based citizen culture.

We understand that there are many publication forums where you can share your T&E initiatives. We hope that you will choose to share these in *JAC*.

Many of the challenges described by Kantardjieff *et al.* (2010) to introduce the special issue on *Crystallography education and teaching in the 21st century* are still ahead of us. The cloud of the current pandemic has produced at least one silver lining: going virtual in many educational and conference forums has accelerated our expertise in several of the web-based tools for education proposed by Kantardjieff (2010) to close out that special issue.

We finish this editorial by thanking the past T&E Editors, Åke Oskarsson and Katherine Kantardjieff, other *JAC* Co-editors who have edited T&E articles, past Main Editors, the staff of the IUCr Editorial Office, and the numerous authors and reviewers who have made the T&E category the success that it is today.

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