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EDITORIAL

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Influencing the practice of chemistry education

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Chemistry Education Research and Practice (CERP) is a journal for teachers, researchers, and other practitioners in chemistry education and its existence is grounded in the desire to influence the practice of chemistry education. This influence may be direct, with articles advocating particular teaching approaches or strategies; or indirect, with articles sharing some further insight into an aspect of learning chemistry that may subsequently inform the practice of teaching chemistry.

The breadth of audience of readers poses a significant challenge for authors contributing to discipline-based education journals such as CERP, which has been described in the previous Editorial (Seery *et al.*, 2019). In this Editorial, the focus is on those who read CERP with a view to improving their own practice or the practice of others. How can CERP authors influence the practice of teaching chemistry?

Diffusion of innovation

A report on discipline-based education research published by the US National Research Council (2012), commonly called the DBER report, uses the work of Rogers (2003) to frame how innovative ideas are embedded in practice:

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- *Stage 1: Knowledge*: the individual learns about the innovation and seeks information about it.
- *Stage 2: Persuasion*: the individual evaluates the innovation and begins to develop a positive or negative attitude.
- *Stage 3: Decision*: the individual decides to adopt or reject the innovation.
- *Stage 4: Implementation*: the individual puts the innovation into practice, possibly with some modifications, yet some uncertainty remains.
- *Stage 5: Confirmation*: the individual looks for support for his or her decision. At this stage, the individual may decide to discontinue the innovation, either by replacement (adopting a better innovation) or by disenchantment, because the innovation does not meet the individual's needs.

Situating readers in the field

One of the commonly reported difficulties of those who seek *knowledge* about some aspect of teaching chemistry is the volume of information available, which can be overwhelming. This is a reflection on the successful growth of, and interest in, chemistry education. With two dedicated journals for chemistry education alone, there is an ever growing catalogue of information about chemistry education and chemistry education research. Our keen practitioner may happen on any particular article within their interest which will act as the first point of contact with that topic. With interest sufficiently piqued, this is likely to act as the gateway to an individual's growth in knowledge of the topic, through what is presented in that article, along with how that article is situated in the context of the field generally. How can articles assist with helping our reader gain greater knowledge of a particular topic?

The growth of the field of chemistry education research means that articles will likely report some increment in our understanding about teaching and learning chemistry, or analysis of application in a particular context. Articles are not books or surveys, and authors will rightly focus on the additional knowledge gained from their work in their reports. It is impossible to survey all that is known about teaching organic chemistry, for example, in an article describing students' understanding of some particular mechanism, and it is not the intention of this Editorial to advocate that. However, authors will have an extensive understanding of the field in which their work is situated, and introductory sections of articles are a useful place to summarise briefly the key aspects of knowledge relating to, in our example, important aspects of what is known about students' understanding of organic chemistry. This will provide a non-expert with a useful survey to advance their own understanding and awareness of that

Table 1 Reviews and perspectives (marked with *) covering various topics relevant to teaching and learning in chemistry education (excluding reviews and perspectives focussing solely on aspects of chemistry education research)

Topic	Citation
Clickers in the classroom	MacArthur and Jones (2008)
Teaching chemical equilibrium	Raviolo and Garritz (2009)
Green chemistry	Andraos and Dicks (2012)*
Use of dataloggers	Tortosa (2012)*
Transfer of learning	Dori and Sasson (2013)
Chemical triplet (Johnstone's triangle)	Taber (2013)*
Learning progressions	Sevian and Talanquer (2014)*
Teaching thermodynamics	Bain *et al.* (2014)
Solutions/electrolytes	de Berg (2014)*
Hydrogen bonding	Weinhold and Klein (2014)
Education for sustainable development	Burmeister *et al.* (2012)* Juntunen and Aksela (2014)
Quantum chemistry	Greca and Freire (2014)*
Graphical representations of orbitals	Barradas-Solas and Sánchez Gómez (2014)* Clauss *et al.* (2014)*
Chemical bonding	Dhindsa and Treagust (2014)*
Implicit knowledge	Taber (2014)*
Distinguishing abstraction and complexity	Blackie (2014)*
Organic chemistry	Graulich (2015)
Capturing student reasoning	Sevian *et al.* (2015)*
Flipped learning	Seery (2015)
Chemical kinetics	Bain and Towns (2016)
Learning difficulties leading to misconceptions	Tümay (2016)*
Symbolic expressions in chemistry	Liu and Taber (2016)*
Pre-laboratory activities	Agustian and Seery (2017)
Reasoning about structure–property relationships	Talanquer (2018)*

topic. Of course, identifying key aspects of what is known and where the gaps are is a typical opening gambit in any research article; the intention here is to highlight to authors the breadth of the audience reading that section, and how it can be useful in unintended ways for non-experts.

The above discussion excludes review articles, which by their nature aim to survey a field, and there are a number of reviews available on a range of topics in CERP (Table 1). In addition, perspectives will typically offer a more extensive literature as authors situate their own perspective in a broader field. Where suitable, these are useful to cite in introductions to research articles, as they will be useful sources of information to those looking to find out more about a topic. The journal also has a back catalogue of special issues on particular themes (https://pubs.rsc.org/en/journals/journalissues/rp#!themedcollections).

Evaluating and implementing approaches

Readers considering a particular approach being described in an article are likely to assign a value to the described approach based on how authors described the research and evaluation in their article. While authors cannot control for the variety of biases and ontological perspectives of our variety of readers, clearly explained methodologies and well-presented and discussed results are more likely to be *persuasive*. Readers will naturally aim to consider what is being described in the context of their own practice, so elaboration on the context of the article is imperative. Research questions, clearly phrased, are very powerful, as they allow readers to identify exactly what the article is considering, and how that might relate to their own context. Clarity of language in discussing an innovation or describing a research finding is helpful to non-expert readers, and more likely to lead to a decision to consider adopting similar approaches in a reader's own practice.

Implementation in reader's own settings is known to be one of the pinch points in adoption of teaching approaches. It is known from work in physics education research that when adopted, approaches described in the literature are often changed and tweaked to the local setting, which may result in important aspects of the approach not being included. Therefore full detail of implementation is useful, with inclusion where possible of any associated learning materials or examples of classroom structures (most usefully included as Appendices).

However, in work on this topic, Henderson and Dancy (2009) advocate moving from *how* a particular approach can be implemented or used to the elaboration of *why* a particular approach leads to results described in any article. This is an important aspect in any discussion of results, and is likely to empower readers in understanding more about the underlying pedagogy and/or theory of an approach, with consequent improved likelihood of *confirming* the use of that approach in their own practice. Elaborating on limitations of a particular study setting can also be a powerful way to enable readers to consider the reality of a particular approach in their own setting.

Influencing practice

A common request at review stage to authors of research articles in CERP is to elaborate further on implications for practice. This section is usually set aside at the end of articles, alongside implications for further research. While this is important in its own right, and useful as a summary, what I intend to demonstrate in this Editorial is that this section is not stand-alone. It should draw from a consideration of practitioner readers throughout the article, and act to summarise and highlight key considerations for practitioners looking to use the outputs of the work described.

The above discussion raises an overarching question about where the *duty* lies for improving the practice of chemistry education. Education researchers will naturally be focussing on incremental advances in understanding the field, with a primary audience of other education researchers in that field. While the responsibility is clearly with practitioners to update their knowledge of pedagogical aspects of teaching their discipline, authors of articles to CERP can make that task much easier. Infusing the article with a consideration of practitioner readers in a

Table 2 Incorporating Roger's (2003) stages in diffusion of innovations in education research articles

Knowledge	Introduction setting context for work, linking to key literature that informed authors, and reviews where possible. Clearly articulated summary of state of field and gap in which this work is situated.
Persuasion	Identification of gap in knowledge where this work is situated (*e.g.* through clearly articulated research questions). Well explained methodology and clearly presented, well-explained results.
Implementation	Provision of detail on implementation of any approach – learning materials used (*e.g.* in Appendices), details of instruments/questionnaires, classroom structures, context of students.
Decision	Discussion section elaborates on the key aspects of any implementation, linking back to introductory literature and/or theoretical frameworks. Elaboration on why particular results may have been observed, rather than descriptive summaries.
Confirmation	An *Implications for Practice* section can be a useful summary in articles summarising aspects outlined above, with key messages written clearly. Limitations that explicitly consider practitioner aspects, such as extent of training of those involved in implementation, or unusual context for a given set of students should be highlighted.

manner described above will likely be of benefit to all readers, and indeed the overall impact of the field. An outline of how to consider incorporating key messages for practitioners throughout an article, guided by Roger's work is summarised in Table 2.

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