

## The mechanics of computation and human thought (Note †)

Thousands of students throughout Australia are preparing for chemistry examinations in June. An unresolved debate is whether they should be permitted to use graphics and programmable calculators in those examinations. Some educators like Michael Phillips, winner of the 2010 Victorian Education Excellence Award for Outstanding School Leadership, and principal of Ringwood Secondary College, have not only advocated the use of graphics calculators, but have also pointed to the Danish system in which students are permitted to use computers in senior school examinations.<sup>2</sup>

Assessment in education is a very emotional and emotive issue. There are perceptions of what is considered “fair and equitable”, which obscure the fundamental questions of what is being assessed why it is being assessed, and the use of technology in education. Often, a conservative approach is implemented in trying to be fair to all.

In some Australian jurisdictions, graphics calculators are permitted in year 12 mathematics examinations, but not in chemistry examinations. The reasoning is that information or methods of solving numerical chemical problems can be stored in the memory of graphics calculators, giving some students an unfair advantage. This means that chemistry students either have to learn how to use (and buy!) two types of calculators or, if they only have one calculator, are disadvantaged in using non-programmable calculators in mathematics examinations.

The use of technology (or its lack thereof) can limit how and what students learn. “The mechanics of computation and human thought” is an allusion to Asimov’s short story, “A Feeling of Power” in which, overuse of technology has caused people to forget how to do simple arithmetic.<sup>3</sup> In our current assessment system, the insistence that students must be able to do simple chemical calculations has led to underuse of available technology. The misperception is that the ability to do calculations is linked to understanding of concepts.

19<sup>th</sup> century textbooks used the quadratic equation to solve equilibrium problems,<sup>4,5</sup> because calculators did not exist. Although graphics calculators can solve polynomial equations of any order, the retention of manual calculation means that modern textbooks still use the quadratic equation, which in turn, limits the study of equilibrium to second-order or bimolecular systems. Students are subtly brainwashed into believing third- and higher-order equilibria do not exist.

In the early 20<sup>th</sup> century, pilots built and repaired their own aircraft, and as late as the 1980s, quantum chemists were expected to be able to solve the Schrödinger equation to obtain the Legendre polynomials and spherical harmonic functions describing the hydrogenic atomic orbitals. The use of modern technology has changed that. No one expects a 21<sup>st</sup> century pilot to know the nuts and bolts of a jet aircraft, while graphic user interfaces (GUIs) enable high-school students to perform quantum computations.<sup>6,7</sup> Technology enables students to grasp qualitative concepts, by calculating a large number of numerical solutions, but without the tedium of working the mechanics of the mathematics.<sup>8,9</sup> The power of programmable and graphical calculators should not be feared; technology empowers students to do more and learn more.<sup>5,10,11</sup> Instead of relying on questions that

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focus on chemical calculation, examinations can take calculations for granted and ask probing questions that probe conceptual understanding.

“Technology can enable important changes in curriculum, even when it has no curricular content itself. What matters most are educational strategies for using technology.”<sup>12</sup>

Stephen C. Ehrmann

Why should the ability to store textual information in calculators be something to be feared and avoided? In an examination, students are generally busy reading, thinking and answering examination questions; the only students, who have sufficient time to access information in calculator memory, are those with insufficient chemical knowledge and ability to attempt questions. For these latter students, stored information might result in a few extra marks, but will not convert a fail score into a pass mark.

Graphics calculators, programmable calculators and computers are tools. The old adage that “a bad workman blames his tools” also applies here. Instead of banning or limiting technology, we should take the opportunity to rethink what is being assessed and how it is assessed. It is the proper use of technology, by combining the mechanics of computation and human thought to deepen understanding and to ask probing questions that truly leads to a feeling of power.

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