International Journal of Science Education

ISSN: 0950-0693 (Print) 1464-5289 (Online) Journal homepage: https://www.tandfonline.com/loi/tsed20

Conceptions of second year university students of some fundamental notions in chemistry

Danièle Cros , Maurice Chastrette & Michel Fayol

To cite this article: Danièle Cros , Maurice Chastrette & Michel Fayol (1988) Conceptions of second year university students of some fundamental notions in chemistry, International Journal of Science Education, 10:3, 331-336, DOI: 10.1080/0950069880100308

To link to this article: https://doi.org/10.1080/0950069880100308

INT. J. SCI. EDUC., 1988, VOL. 10, NO. 3, 331–336

Conceptions of second year university students of some fundamental notions in chemistry

Danièle Cros, Université des Sciences et Techniques du Languedoc, Montpellier, Maurice Chastrette, Université Lyon I, Villeurbanne, and Michel Fayol, Laboratoire de Psychologie, Université de Dijon, France*

This research is a follow-up to our earlier study in which we assessed the knowledge and conceptions of fundamental notions in chemistry of first year undergraduate students at the time of entry into university. It examines to what extent, after one year of study at university level, the conceptions of the students have evolved and how their knowledge of scientific theory has progressed. We have found that the conceptions of the students are often modified in the right way, but sometimes in the wrong way as well, and the results obtained seem to indicate that the ambitious aim of teaching (better acquisition of important notions by students) is far from being attained. The study also shows that for some notions the teaching of chemistry has too formal a character. To rectify this situation, we propose that practical work must include problems that are not only chemical in nature.

In an earlier paper, the conceptions of first-year students of the constitution of matter and the conceptions of acids and bases were described (Cros *et al.* 1986). The aim of the present research was to determine the evolution of the knowledge and the notions of students in order to see how after one year of university study their concepts and ideas of scientific theory in chemistry had progressed.

Method

The interviews and semi-directed interviews, which were used previously to set up the questionnaires, were not repeated in this study. However, the questionnaires used in the earlier work (Cros *et al.* 1986) were slightly changed for this study. The questions which were shown to be ambiguous were either eliminated or modified.

Table 1 gives the distribution of the two questionnaires (dealing with atomic structure and the acid/base area, respectively) to students.

Since differences between the answers from students following the baccalaureate **C** specialization and those of the other baccalaureate programmes were previously noted, the analysis was divided into baccalaureate **C** and the other baccalaureate specializations. However, the results from the universities of Lyon I and Montpellier II were not separated since no significant differences were detected during the previous investigation (Cros *et al.* 1986).

* Corresponding author.

Table 1. Distribution of questionnaires.

Notion \ Baccalaureate	Number of students Baccalaureate C	Other baccalaureates	TOTAL
Atomic structure	57	142	199
Acids/bases	40	105	145

Analysis of the questionnaire returns

The analysis of the questionnaire results was carried out with the help of a computer. Firstly, percentages were obtained for each answer as a function of the nature of the baccalaureate (BAC) with no cross-references. Later, the responses to two questions were cross-referenced in order to verify certain hypotheses suggested by the preliminary analysis.

Results and discussion

Only significant differences in the answers given by BAC **C** and the other students are mentioned.

Atoms

Atomic structure: The answers to questions 1 and 3 – what kind of particles are contained in an atom, a nucleus? – had evolved somewhat. The students' knowledge of the constituents of the atom and of the nucleus, which was already very good at the completion of secondary school education, had progressed for BAC **C** (93% correct answers, compared with 81% for the constituents of the atom, and 98% compared to 91% for the constituents of the nucleus). However, little progress was noted for the students holding a BAC other than **C**.

Regarding the interactions between the particles within the atom (question 2), the notions of the students had evolved slightly. Thus, the electrostatic model seemed to be better understood (average progression of 11%, but 16% for the BAC other than **C**). The Bohr model seemed to have receded a little, but it must be noted that the reply, 'electrostatic interactions', certainly overlaps with the planetary model.

Concerning interactions between the particles that make up the nucleus (question 4), it is striking to observe that the percentage of non-responses had decreased by 9% (i.e., from 40% to 31%) and that some 16% of the students (compared to 21%) thought that there was no interaction. In addition, the answers remained rather varied.

In spite of the decrease in the number of non-responses (from 38% to 26%), there was relatively little progress with regard to the relationships between the constituents of the hydrogen atom (question 5). The proportion of students who persisted in simply listing the constituents of the atom remained at 13%. Some 44% of the students (compared to 30% previously) gave an acceptable answer, and of these 36% (i.e., 16% of the total) referred specifically to the planetary model. Overall, this represents little change from the findings of the previous investigation. The nature and names of the constituents of the atom and of the nucleus were well-known to the students, and this knowledge had even progressed somewhat. However, it was quite evident that they did not have a clear understanding of the interactions associated with the atomic model. Although the students had followed courses where their discussion of the Bohr atom and of the Schrödinger model had been quite extensive, their notion of the atom had changed very little. Free interviews of advanced students showed that the persistence of the Bohr model is remarkable even to the point where the answer to a question on the atom is given by a circular motion of the hand, showing the planetary system, before any word is spoken!

Question 6 dealt with the release of nuclear energy as a result of collisions. The results obtained for all of the students at the end of secondary school education and also at the end of the first year of university teaching are given in table 2 without distinction as to baccalaureate.

The most striking aspect of these results in the weak progress shown by the answers to subquestions *c, d* and *e*, where there was an increase of about 10%, but even then the response to *e* did not exceed 50%. In addition, the number of students who thought that collisions between atoms do liberate energy (*b*) decreased by 13% (from 70% to 57%). This result seems to indicate that the role of the nucleus in the atom is still not well understood (cf. colloquial expressions such as 'atomic war', 'atomic bomb', 'atomic power station').

In general, the degree of confidence in the answers to the preceding questions varied little. Thus, the correct answers of which the students are certain still, made up an average of 32% only.

Radioactivity: In response to question 7 – What does radioactivity signify for you? – there were, in general, few variations in the answers. The idea of danger linked with radioactivity had almost disappeared (from 15% to 6%). Some 45% (compared to 50%) of the answers mentioned the radiation associated with radioactivity, and only 9% (compared to 12% earlier) cited the connection with the liberation of energy. On the other hand, the number of students mentioning the notion of disintegration had increased by 17%. It

Table 2. Answers to question 6: Nuclear energy can be released during collisions...'.

Sub-question	Scholastic level of student	End of secondary school correct answer (%)	End of first year of university correct answer (%)
a)	between molecules	86·6	86·1
b)	between atoms	69·5	56·6
c)	between nuclei	69·0	77·5
d)	between nuclei and particles	78·4	89·1
e)	between atoms and particles	39·1	49·6

may be concluded that the notion of radioactivity is fixed and continues to have a descriptive character. The association with the production of energy is, however, not realized at all.

Molecules and crystals: The question asking for the constituents of a molecule (question 8) did not cause *any* problems; there were 94% correct answers – a molecule is made up of atoms –, which represented a slight increase.

The interactions between the constituents of a molecule (question 9) were much better known than they were at the end of secondary school education (2% non-responses compared to 38%, i.e., a difference of 36%). Some 63% (compared to 33% before) mentioned covalence, i.e., 30% better. The notion of the chemical bond within the molecule has changed very considerably.

The students knew a little more about the make-up of crystals (question 10); there were only 13% non-replies compared to 42% previously. We have to bear in mind here that there is no teaching of the structure of crystals at the secondary level, and that it is generally, but not always, taught at university. Some 45% mentioned the notion of a well-defined arrangement or lattice, compared to only 27% earlier. It appears, however, that molecular crystals are almost as poorly understood as previously noted (only about 10%).

The interactions between the constituents of a crystal (question 11) appeared to be somewhat less mysterious to students than before (42% non-replies, compared to 80%). The notion of ionic bonds between the constituents (19%) appeared for the first time, and the idea of electrostatic interactions had progressed from 8% to 18%.

Acids-bases

The definition given for an acid (question 1) had become more scientific, for 82% of the students (compared to 52% previously) mentioned the Brønsted definition (an acid releases or can release H^+), whereas at the same time the descriptive definition (pH less than 7) almost completely disappeared (5% compared to 23% a year earlier).

The same tendency towards a more scientific definition was also observed for a base (question 3). The citations of the purely descriptive definition decreased from 23% to 5%, but the mention of the Brønsted definition (a base may accept a proton) had increased from only 47% to 63%. The Arrhenius definition (a base releases OH^-) was again given more frequently than before (a change from 14% to 25%). The notion of a base as a donor of OH^- still persisted and was even more in evidence, despite the fact that during the first year course attempts are made to fight it. It is fortunate that the Arrhenius definition is no longer part of the secondary school programmes, for it is very difficult to eliminate.

Many students were capable of naming three acids (question 2). The acids most often given were the same ones as before (Cros *et al.*, 1986) (HCl: 86%, CH_3COOH: 69%, H_2SO_4, 67%), but there were some notable changes in the number of times that they were cited.

In contrast, the situation was very different for the bases. Indeed, 41% of the students (compared to 43% previously) could not name more than two bases. The number of times that particular bases were mentioned, changed considerably. While sodium hydroxide and ammonia were still given very often, potassium hydroxide had come to the fore (59% compared to 15% earlier) and now occupied second position. It is to be noted that the citations of bases that do not contain OH^-, such as water and the ethanoate ion, had in general not progressed. However, another possible explanation for the students' improved performance regarding the names of acids may be a linguistic one; namely the fact that in French the acid name is always preceded by the word acid (e.g., acid nitrique), whereas the base name is never preceded by the word base.

These results confirm the permanency of the Arrhenius definition and show that university teaching in this regard has remained far too abstract. It is also possible that the teachers have paid more attention to acids than to bases.

The students' knowledge of the scientific definition of pH (question 5) had progressed from 48% to 71%, but the descriptive definition (measure of the degree of acidity) had hardly changed (17% to 13%). Overall, the concept of pH seemed to be better mastered than at the time of entry into university.

As to the responses regarding the difference between weak and strong acids (question 6), there were no notable changes.

Question 7 concerned the practical aspect of the acid-base reaction. Two parts of this question were modified and reported under question 8. One of the important aspects of this reaction, namely, the evolution of heat that occurs, was very poorly understood. Only 47% of the students (compared to 41% in the previous year) thought that there was a release of heat and 31% (in contrast to 46%) believed that there was none. A likely explanation for this is that the reactions between acids and bases usually studied by students experimentally, involve only dilute solutions where the heat release is not easily observed.

The foregoing remarks are confirmed by an examination of the results obtained regarding the degree of confidence of the answers: Only 12% of the students were sure that there is a release of heat during acid-base reactions. In contrast, about 70% are certain about their correct answer to the question on the changes in pH during acid-base reactions.

The evolution of heat during the reaction of a weak acid with a strong base (question 8) was even less well understood than for the case of a strong acid. Some 23% did not know how to answer this question, and the remainder were equally divided between release and non-release of heat. This corresponds to the idea that a weak acid cannot perform in any way as well as a strong acid.

Comparison of the answers to question 9 (on the pH of drinks) after an interval of one year showed that the students still take few risks: Only 50% would drink a solution with a pH of 6.

This study, confirmed by numerous systematic observations, shows that the students do not perceive the relationships between the scientific notions they master (often well enough) and their applications, not only in the daily practices of chemists, but also in everyday life.

Conclusions

Our study has shown that the conceptions of students are modified in the right way (but sometimes in the wrong way too!) by the university teaching. However, the extent to which this happens can be disappointingly low. Although the aims of university teaching are justifiably ambitious so as to ensure a better acquisition of important notions by the students, our study suggests that this objective is far from being attained.

It is our view, based on the current investigation, that for some important notions the chemistry teaching at both the university and secondary school levels is too formal in character. The students are almost incapable of applying these notions to chemistry and to daily life. In order to rectify this situation it is essential that practical work be developed and opened up to problems that are not only chemical in nature.

Acknowledgment

The authors express their gratitude to B. T. Newbold for discussions and linguistic help.

References

CHASTRETTE, M. and CROS, D. 1985, Enquête sur la maîtrise de la notion de mole et son évolution entre 16 et 20 ans. *Actualité Chimique*, No. 3, pp. 69–76.

CROS, D., AMOUROUX, R., CHASTRETTE, M., FAYOL, M., LEBER, J. and MAURIN, M. 1986, Conceptions of 1st-year university students of the constitution of matter and the notions of acids and bases. *European Journal of Science Education*, Vol. 8, No. 3, pp. 305–313.

NOIZET, G., and CAVERNI, J. P. 1978, *Psychologie de l'Évolution Scolaire* (PUF, Paris).

VIENNOT, L. 1978, Le raisonnement spontané en dynamique élémentaire. *Revue Française de Pédagogie*, No. 45, pp. 16–24.