MOTIVATIONAL SECONDARY AND TERTIARY EDUCATION: THE PROFILES PROJECT

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This paper reports about a European didactic project, PROFILES, that aims at disseminating inquiry-based science education. To this end, the PROFILES partners are using and developing innovative learning environments and long-term teacher training programmes.

1. INTRODUCTION

Over recent decades, students' interests and achievements in chemistry have declined in many countries. According to Aikenhead (1, p. 103) the reason is that "chemistry and physics are irrelevant and boring, mainly because their instruction is out of synchrony with the world outside of school". It may be interesting to consider the reasons why we are at this point, and then to suggest some alternatives. Contrary to the situation at the beginning of the 1950s when science was viewed as important, interesting and exciting, the image of science today has to compete with many other interests. It is therefore reasonable to assume that these competing interests can hinder students' motivation to become involved in science studies.

In a report to the Nuffield Foundation, Osborne and Dillon (2, p. 27) concluded "The irony of the current situation is that somehow we have managed to transform a school subject which engages nearly all young people in primary schools, and which many would argue is the crowning intellectual achievement of European society, into one which the majority find alienating by the time they leave school."

In an extended study about the school science curriculum, involving 144 students, 117 parents and 27 teachers, Osborne and Collins (3) found that science was considered to be an important subject of study by all students and their parents, but that science education was valued by students only as a topic to achieve career aspirations rather than as a subject of intrinsic interest, and "The subject that attracted the most antipathy was, surprisingly, chemistry. This was seen as abstruse and irrelevant to contemporary needs." (p. 5) The lack of relevance most probably leads to both low levels of motivation and interest in chemistry, and can also be one of the reasons for the decline in enrolment in science courses in upper secondary and higher education.

As science teachers, we are trained to transmit to the students the products of "the context of epistemological justification", that is to transmit 'what we know', rather than 'how we know what we think we know' (4, p. 407). Schwab argued that science is “taught as a nearly unmitigated *rhetoric of conclusions* in which the current and temporary constructions of scientific knowledge are conveyed as empirical, literal and irrevocable truths” (5, p. 24). Science in schools is commonly taught from a “positivist perspective” as a subject in which there are clear “right answers” and where data lead without any doubt to agreed conclusions. Such presentations of scientific progress constitute a rhetoric of conclusions, based on immutable truths and fail to show the tentative nature of scientific theories and this can be one of the causes of chemistry’s lack of relevance in chemical education. (4, 6-8)

Motivation is an important construct and one of the foremost challenges in education. (9-15) According to Brophy, “Motivation to learn refers primarily to the quality of students’ cognitive engagement in a learning activity, not the intensity of the physical effort they devote to it or the time they spend on it. For most tasks, there is a curvilinear relationship between motivational intensity and degree of success achieved. That is, *performance is highest when motivation is at an optimal level rather than either below or above this optimal level*.” (16, p. 16)

Scholars distinguish between “*intrinsic motivation,* which refers to doing something because it is inherently interesting or enjoyable”, and “*extrinsic motivation*, which refers to doing something because it leads to a separable outcome.” (17, p. 55) Extrinsic motivation can be triggered up by the teacher, as long as the teacher enjoys the subject and the teaching of it. Because of their position of authority in class, teachers play a fundamental and influential role in education. Arguing about models in teaching chemistry, Bent (18) concluded “that *the most important models in teaching chemistry are chemistry teachers themselves*. The most important models in classrooms are real role models using chemical models to talk about real chemistry.”

The teacher is the central character when education is concerned: if we are not interested in the subject and in the way our student learn meaningfully, nothing is possible, and we know we can be the major barrier to the learning of chemistry: “As a student, I hated chemistry. .. The teacher ... appeared to dislike chemistry as much as he disliked the students.” (19)

Because of the disappointing results of the international comparative assessments, such as the *Program for International Student Assessment* (PISA; since 2000, 20-23), it is necessary to rethink the goals and pedagogy of science education. Reflection might well begin with the conclusions of recent reports and studies on science education: the content of school science and its associated pedagogical approaches are not aligned with the interests and needs of both society and the majority of the students. (1-3, 7, 8, 24, 25)

Most students do not find their science classes interesting and motivating mainly because the school science program is overloaded with content and the curricula exclusively emphasize the fundamental content of the science disciplines. (26-31) “It would seem that teachers continue to teach the content of the subject for a variety of reasons. One important factor is that textbooks, for the most part, ignore non-conceptual areas, preferring to include applications within the society of science concepts studied, rather than starting from society's way of utilising science" (26, p. 15)

If a change is needed, we should know the direction to follow to implement a more engaging curriculum. According to Rosalind Driver and co-workers, "what is required is a reconsideration of the role of science education, commonly seen as an introductory *training* in science, emphasizing basic methodological skills and practices, to one that sees its function as an education *about* science, which seeks to empower young people and develop their scientific literacy." (32, p. 289)

Contextualizing the teaching and the experiments brings beneficial effects on students' understandings. "Advocates of context-based courses often cite two particular features which should enhance the understanding of scientific ideas. The first of these is the motivational aspect of the approach: if students can see the point of what they are studying, they will engage with the materials and they are likely to learn more effectively. The second relates to the 'drip feed' approach: the revisiting of ideas at different points in a course provides more opportunities for students to develop their understanding of scientific ideas." (33, p. 172)

As a result of actual practice, learning in the sciences has a tendency to be linear and boxed, often with isolated concepts detached from their scientific origins: students fail to make connections between learned facts and concepts with applications because they unable to recognize the science's relevance. The learned science does not become applicable knowledge, useful in the students' lives to be citizens able to participate successfully in discussions with their peers, and so it no longer meets their needs, interests and aspirations. (28, 34-37) The learned concepts and facts become *inert knowledge*, only connected to the context of being part of 'school science'.

Many students now arrive at university poorly prepared and motivated towards learning. For example, a Friedel-Maloney (38) questionnaire presented during the first lessons for students enrolled in the first year of an engineering university course typically shows poor results (less than 50% correct on any question). The Friedel-Maloney questionnaire consists of four questions: A1) How many oxygen atoms are present in a container with 288 g of O_3? (molar mass of O_3 is 48.0 g); A2) There are $1.8x10^5$ atoms in a sample of P_4. What is the mass of this sample? (Molar mass of P_4 is 124 g); A3) How many atoms of sulfur are in a sample of 963 g of S_6? (gram atomic weight of S is 32.1 g); A4) There are $2.41x10^{24}$ atoms in a sample of S_8. What is the mass of this sample? (gram atomic weight of S is 32.1 g). Five response choices are provided for the last question, and four for questions 1, 2, and 3. Only 10 students out of 75 solved the four problems correctly, while 24 answered all the four problems wrongly.

2. THE PROFILES PROJECT

The European Commission is currently funding, through the 7th Framework Programme for research and technological development, some international projects, which address the issues of education and teaching of mathematics and natural sciences. One of them is the PROFILES (Professional Reflection Oriented Focus on Inquiry-based Learning and Education through Science) project. (39-41) It is a large project consisting of a consortium of 21 partner institutions in 19 different countries. This project will go on for four years and promotes motivational inquiry-based science education (IBSE) by supporting science teachers to develop more effective ways to teach students, involving them actively in their learning.

The initial focus of the programme is the teachers, and the professional development needs of the participating teachers are ascertained by the use of a so called ‘gateway’ questionnaire. The interests and needs of the teachers are the basis for repeatedly organized, professional development and collaborative interaction meetings, in which IBSE strategies, inclusive of student motivational teaching alternatives, are developed and tried out in the classroom setting. The intention is that enhancing their professionalism in a collaborative setting will raise the self-efficacy of science teachers to take ownership of more effective ways of teaching students. Because of the strong relation between a teacher’s sense of efficacy and the commitment to teaching, it is important to sustain a long-term professional development programme, based on the challenges of implementing student relevance in the learning of scientific subjects. (42)

Teachers can implement already-developed, exemplary context-led, IBSE focussed, science teaching materials: the modules were developed as part of an FP6 project on which PROFILES builds called PARSEL (43). PARSEL stands for ‘popularity and relevance of science education for scientific literacy’. The PARSEL project, based on a philosophy of increasing students’ intrinsic motivation and student involvement in learning using an education through science approach, produced teaching modules in a range of science subject areas. (44) There are now available about 55 modules on biology, chemistry, physics, mathematics, science, and some are interdisciplinary. They are of different levels of complexity, ranging from grade 6 to grade 12. Each module comprises four documents: the front-page; the material for students; the material for teachers, and the assessment of the students. A few modules contain a fifth document: a questionnaire, or the teacher’s notes.

The use of the modules attempts to awaken students’ intrinsic motivation as a stepping stone to engaging them in tackling scientific problems and making socio-scientific decisions. The approach is from a socio-scientific situation seen as familiar and motivational by students, while the teaching is challenging, inquiry-based and student-centred. “Socio-scientific issues are controversial social issues with conceptual and/or procedural links to science. They are open-ended problems without clear-cut solutions; in fact, they tend to have multiple plausible solutions.” (45, p. 4) The intent is that such modules are meaningful and captivating to students, engaging in dialogue, discussion, argumentation, and debate, requiring the use of evidence-based reasoning, and providing a context for understanding scientific information.

Many studies have suggested inclusion of a personal and societal component as a necessary dimension of education for the acquisition of scientific and chemistry literacy. (46-49) In order to educate future citizens "the inclusion of societal issues into science education should be enhanced in order to raise the potential of science education to promote scientific literacy for all students." (50, p. 1477) There are important didactic advantages in using Socio-scientific issues (SSI), because "Given the status of SSI as ill-structured, open-ended problems, SSI are ideal contexts for scientific argumentation, and advocates for SSI education have frequently suggested that SSI-based instruction can support development of argumentation practices." (51, p. 805) In this way, we can promote reflection on scientific questions "inserting authentic and controversial debates on socio-scientific issues into chemistry teaching, which provoke and allow for open discussions and individual decision-making processes." (52, p. 231) Societal issues chosen for science education purposes should meet certain criteria: "The criteria should be authenticity, personal and societal relevance, openness of the societal debate, the possibility of open discussion, and the relation to science and technology." (50, p. 1477)

Such didactic material can provide to science teachers at the secondary level an environment where conceptual learning can take place, making the learning relevant and interesting and, at the same time, encouraging students to develop problem-solving skills both geared to education for all and as a conceptual base for tertiary and lifelong learning. The 'true' nature of science education needs to put the learning of science into an educational framework (44).

3. PROFILES in Italy

The programme for professional development includes coverage of active learning methods such as cooperative learning, the use of concept maps, scientific problem-solving plus support in the development of specially designed didactic modules for use in the classroom. The goal of the professional development is to develop teacher self-efficacy in motivational IBSE with an ultimate goal of transforming teachers into leaders, able to take ownership of the use of a socio-scientific learning environment for motivating their students in relevant science learning. The demanding task is to guide and support teachers in being able to scaffold students towards self-directed learning.

Although examples of modules developed according to the philosophies of PROFILE are available for every scientific subject, the teachers have preferred to enact their learning to develop their own teaching modules. With the aim of increasing interest and active student involvement in the processes of learning and studying, three teachers have developed a didactic module suitable for learning important concepts in Biology and Chemistry, entitled "Chemistry ... What a Pizza!!!". The idea was to develop a teaching module focussing on increasing the intrinsic motivation of students, thus overcoming students' hostility towards science, which can make it difficult for students to learn complex concepts.

Pizza is a food, very popular among teenagers and featuring strongly, together with pasta dishes, in Italian gastronomy. The module starts from a well-known food and seeks to analyse, from a scientific standpoint, the main chemical changes, physical and organoleptic characteristics that occur during its preparation by reflecting on the parameters that can affect the quality of the final product. This activity also stimulates observation and reflection skills of students by requiring them to face a practical problem (how to make a good pizza) using a scientific method of investigation and an experimental approach.

The project in the schools was started a little more than an year ago, and several other modules are being developed in Chemistry, Geometry, Mathematics, and Applied Computer Science. The hypothesis is that teachers who participate in the longitudinal professional development programme experience gains in self efficacy to such an extent that they feel confident in developing their own didactic modules suitable for promoting meaningful science education competencies in students. Successful experiences will increase a teacher's self-efficacy beliefs as a key person in facilitating learning. Positive feelings will be strengthened by the ownership of the new practices, as well as by success in actual teaching accomplishments with students. (53)

I try to use the same philosophy at the university; students enrolled in a chemistry course in an engineering faculty start from the first day to work on solving problems, and the problems are logical problems. (54) The underlying hypothesis is that if students are successful in solving this type of problem, they will more easily solve stoichiometric problems. Findings confirm the hypothesis. To have some fun does not harm the learning of serious chemistry content: on the contrary, it helps.

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REFERENCES

1. G.S. Aikenhead, *Chemical Education: Research and Practice*, **2003**, Vol. 4, 115.
2. J. Osborne, J. Dillon, *A Report to the Nuffield Foundation*, King's College London, London (2008).
3. J. Osborne, S. Collins, *Pupils' and Parents' Views of the School Science Curriculum*, King's College London, London (2000).
4. M. Monk, J. Osborne, *Science Education*, **1997**, Vol. 81, 405.

5. J.J. Schwab, *The teaching of science as inquiry*, Cambridge, MA: Harvard University Press, 1962.
6. J. Van Aalsvoort, *International Journal of Science Education*, **2004**, Vol. 26, 1151.
7. J. Van Aalsvoort, *International Journal of Science Education*, **2004**, Vol. 26, 1635.
8. B. van Berkel, W. de Vos, A.H. Verdonk, A. Pilot, *Science & Education*, **2000**, Vol. 9, 123.
9. M.L. Maehr, H.A. Meyer, *Educational Psychology Review*, **1997**, Vol. 9, 371.
10. M.R. Lepper, *Cognition and Instruction*, **1988**, Vol. 5, 289.
11. C.A. Ames, *Teachers College Record*, **1990**, Vol. 91, 409.
12. J.A. Middleton, P.A. Spanias, *Journal for Research in Mathematics Education*, **1999**, Vol. 30, 65.
13. R.M. Ryan, E.L. Deci, *American Psychologist*, **2000**, Vol. 55, 68.
14. J.C. Turner, C. Midgley, D.K. Meyer, M. Gheen, E.M. Anderman, Y. Kang, H. Patrick, *Journal of Educational Psychology*, **2002**, Vol. 94, 88.
15. S.M. Glynn, T.R. Koballa, Jr., in J.J. Mintzes, W.H. Leonard, (Eds.), *Handbook of College Science Teaching*, pp. 25-32, National Science Teacher Association Press, Arlington, VA (2006).
16. J. Brophy, *Motivating students to learn*, 2nd Ed., Erlbaum, Mahwah, NJ, 2004.
17. R.M. Ryan, E.L. Deci, *Contemporary Educational Psychology*, **2000**, Vol. 25, 54.
18. H.A. Bent, *Journal of Chemical Education*, **1984**, Vol. 61, 774.
19. W.T. Lippincott, *Journal of Chemical Education*, **1979**, Vol. 56, 1.
20. Online at: http://www.oecd.org/document/58/0,3746,en_32252351_32236159_33688954_1_1_1_1,00.html (accessed March 24, 2012).
21. R. Bybee, P.J. Fensham, R. Laurie, *Journal of Research in Science Teaching*, **2009**, Vol. 46, 862.
22. P.J. Fensham, *Journal of Research in Science Teaching*, **2009**, Vol. 46, 884.
23. J.O. Anderson, M.-H. Chiu, L.D. Yore, *International Journal of Science and Mathematics Education*, **2010**, Vol. 8, 373.
24. S.J. Hawkes, *Journal of Chemical Education*, **1992**, Vol. 69, 178.
25. E.W. Jenkins, N.W. Nelson *Research in Science & Technological Education*, **2005**, Vol. 23, 41.
26. R. Millar, J.F. Osborne, *Beyond 2000: Science education for the future*, King's College London, London (1998).
27. J. Holbrook, *Science Education International*, **1998**, Vol. 9, 13.
28. W. De Vos, A.M.W. Bulte, A. Pilot, in J.K. Gilbert, R. Justi, O. de Jong, J. Van Driel (Eds.), *Chemical education: Towards research-based practice* (pp. 101–124). Kluwer, Dordrecht, The Netherlands, (2002).
29. J. Holbrook, *Chemical Education International*, **2005**, Vol. 6. Retrieved January 20, 2012, from the World Wide Web at http://old.iupac.org/publications/cei/vol6/06_Holbrook.pdf
30. J.K. Gilbert, *International Journal of Science Education*, **2006**, Vol. 28, 957.
31. A. Pilot, A.M.W. Bulte, *International Journal of Science Education*, **2006**, Vol.

28, 1087.
32. R. Driver, P. Newton, J. Osborne, *Science Education*, **2000**, Vol. 84, 287.
33. J. Bennett, J. Holman, in J.K. Gilbert, R. Justi, O. de Jong, J. Van Driel (Eds.), *Chemical education: Towards research-based practice* (pp. 101–124). Kluwer, Dordrecht, The Netherlands (2002).
34. B.D. Pendley, R.L. Bretz, J.D. Novak, *Journal of Chemical Education*, **1994**, Vol. 71, 9.
35. J.D. Herron, *The chemistry classroom: formulas for successful teaching*, American Chemical Society, Washington, D.C, 1996.
36. D. Hodson, *International Journal of Science Education*, **2003**, Vol. 25, 645.
37. A.H. Johnstone, K.H. Otis, *Chemical Education Research and Practice*, **2006**, Vol. 7, 84.
38. A.W. Friedel, D.P. Maloney, *Journal of Chemical Education*, **1995**, Vol. 72, 899.
39. http://www.profiles-project.eu/
40. C. Bolte, A. Hofstein, J. Holbrook, M. Rannikmae, R. Mamlok Naaman, Franz Rauch, S. Streller, paper presented at the ESERA conference, Lyon, France September 2011.
41. C. Bolte, A. Hofstein, J. Holbrook, M. Rannikmae, R. Mamlok Naaman, F. Rauch, S. Streller, PROFILES: Ein transeuropäisches Kooperations- und Interventionsprojekt (PROFILES: A trans-European co-operation and intervention project). To be published in: D. Hoettecke, (Ed.), *Zur Didaktik der Physik und Chemie. Probleme und Perspektiven*, Lit- Verlag, Münster (2012).
42. T. Coladarci, *The Journal of Experimental Education*, **1992**, Vol. 60, 323.
43. www.parsel.eu
44. J. Holbrook, *Science Education International*, **2010**, Vol. 21, 80.
45. T.D. Sadler, in T.D. Sadler (Ed.), *Socio-scientific Issues in the Classroom. Teaching, Learning and Research* (pp. 1–9). Springer, Dordrecht, The Netherlands (2011).
46. A. Collins, *Journal of Research in Science Teaching*, **1998**, Vol. 35, 711.
47. G.E. DeBoer, *Journal of Research in Science Teaching*, **2000**, Vol. 37, 582.
48. J.D. Miller, *Public Understanding of Science*, **2004**, Vol. 13, 273.
49. J. Holbrook, M. Rannikmae, *International Journal of Science Education*, **2007**, Vol. 29, 1347.
50. A. Hofstein, I. Eilks, and R. Bybee, *International Journal of Science and Mathematics Education*, **2011**, Vol. 9, 1459.
51. T.D. Sadler, V. Dawson, in B.J. Fraser, K.G. Tobin, C.J. McRobbie, (Eds.), *Second International Handbook of Science Education* (pp. 799-809), Springer, Dordrecht, The Netherlands (2012).
52. R. Marks, I. Eilks, *International Journal of Environmental & Science Education*, **2009**, Vol. 4, 231.
53. A. Bandura, *Psychological Review*, **1977**, Vol 84, 191.
54. L. Cardellini, *Chemistry Education Research and Practice*, **2006**, Vol. 7, 131.