Successful Experiences in Chemistry Teaching: Has Chemistry Education Research Common Ground with Greek School Practice?

Katerina Salta and Dionysios Koulougliotis*
Technological Educational Institute (TEI) of Ionian Islands
Zakynthos, Greece
ksalta@chem.uoa.gr, dkoul@teiion.gr

Abstract

In the first part of this work, we present a brief summary on educational research related with the effects of different instructional strategies on chemistry learning by focusing on the two most common school instruction settings: the classroom and the laboratory. Subsequently, an effort is made to explore the degree of adoption of these strategies by Greek teachers via analysis of the content of a workshop carried out with the participation of 15 persons. Significant insights were provided in regard with "what constitutes a successful experience in chemistry teaching" and proposals of good teaching practices and also for the conditions required for the successful implementation of a novel teaching approach were made. Practical laboratory work, the cooperative teaching approach (despite its difficulties in implementation), the exploitation of interdisciplinarity and the targeted use of ICT have been some of the proposed good practices. The main conclusion reached is that although Greek chemistry teachers are aware of the existence and importance of student-centered instructional approaches proposed by chemistry education research, they seem to face several obstacles during practical implementation and often ignore the circumstances under which these approaches are effective for students' meaningful learning.

1. Chemistry education research

The importance of chemistry in preparing science-literate citizenry has drawn increased attention to the quality of secondary chemical education and how it can be improved. There are persistent concerns that school chemistry courses are not providing students with high-quality learning experiences, nor are they attracting and retaining students in science and chemistry fields [1]. A significant portion of chemistry education focuses on measuring the impact of instructional strategies on student learning and understanding [1]. In this work, we initially summarize research related with the effects of different instructional strategies on student learning by focusing the discussion on the two most common settings for school instruction—the classroom and the laboratory. Most chemistry education studies on instructional strategies hypothesize that students build their own understanding in chemistry by applying its methods and principles, either individually or in groups [2, 3]. Consequently, these studies typically examine the extent to which student-centered classes are more effective than traditional lectures in promoting students' understanding of course content.

The majority of studies consistently support the view that adopting various student-centered approaches to classroom instruction can improve students' learning relative to lectures that do not include student participation [1]. Instructors have a variety of options at their disposal to make lectures more interactive and enhance their effectiveness. Interactive lecture demonstrations are a strategy for encouraging student participation. Chemistry education research shows that students who were allowed to work in small groups to make predictions about lecture demonstrations showed significant improvements on tests over students who merely observed demonstrations [4]. Many transformed courses incorporate in-class activities where students collaborate with each other. Research has shown that these activities enhance the effectiveness of student-centered learning over traditional instruction [5]. Moreover, collaborative learning has been shown to improve student retention of content knowledge [6].

The evidence on the efficacy of widely used technologies such as animations is mixed. The use of animations has been studied and shown to enhance learning in some circumstances, but to be ineffective or even detrimental to students' learning in other situations. Taken together, this research demonstrates that how technology is used matters more than simply using technology. For technology to be effective,

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instructors must be aware of the conditions that support the effective use of technology and incorporate it into their lessons with clear learning goals in mind [7].
Learning chemistry takes place not just in classrooms, but also in laboratories. Well-designed laboratories can help students to develop competence with scientific practices such as experimental design; argumentation; formulation of scientific questions; and use of chemical equipment such as pipettes, and volumetric glassware. However, laboratories that are designed primarily to reinforce lecture material do not necessarily deepen students' understanding of the concepts covered in lecture [8-10]. Indeed, a review of more than 20 years of research on laboratory instruction found "sparse data from carefully designed and conducted studies" to support the widely held belief that laboratory learning is essential for understanding science [11].
Domin has characterized inquiry in chemistry laboratories as ranging from deductive experiences ("explain, then experiment") to inductive experiments ("experiment, then explain") [12]. While the label "inquiry" is often synonymous with inductive experiments, one analysis found that neither commercially published laboratory manuals nor peer-reviewed manuscripts that self-identify as "inquiry" score very high on Lederman's rubric of scientific inquiry, which was designed to assess the level of scientific inquiry occurring in high-school science classrooms [13]. Regarding the effect of laboratories on learning, emerging evidence suggests that students in an open-ended problem based laboratory format improve their problem solving skills [14].

2. School practice in Greek chemistry classrooms

Have chemistry education research findings been translated into instructional practice in the Greek Educational System? The discussions between the participants in the Greek National Workshop on Successful Experiences and Good Practices in Chemistry Teaching have provided significant insights to this question. The Workshop took place in March 2014 with the participation of a total of 15 people (9 teachers and 6 scientific experts). Participants were divided in small groups of 3-4 people and were asked to discuss a specific topic within a specific time interval (ca. 20 minutes). Subsequently, each group was asked to present a summary of the discussion taken place between its members via one spokesperson for a maximum period of 10 min. These presentations were taped, transcribed and content analysis was performed. The results of this analysis are subsequently presented.
In the first part of the workshop participants were asked to discuss the topic "What are the characteristics of a successful experience in chemistry teaching?" Based on the personal experiences and opinions of the participants a successful teaching approach is one that is well organized, excites students' curiosity and keeps them interested but at the same time achieves significant learning outcomes. The fact that students show enhanced interest does not guarantee that they have also understood the material taught. The teaching practice must always be evaluated both by the teacher who should closely observe students' behaviour and test their performance and by getting feedback from the students themselves. A good practice gives emphasis on how scientific knowledge can be connected with everyday life experiences and exploits as much as possible interdisciplinarity between science-related fields such as physics, chemistry and biology. Moreover, in a successful teaching experience, there is strong interaction in-between students and between the students and the teacher. The student must have acquired competences in posing questions as well as in searching ways for getting answers.
What transformations are needed in traditional instruction so that a successful chemistry teaching experience is produced? The participants' opinions to this discussion topic can be summarized as follows: The majority of participants agreed that engaging students in laboratory activities and working in small groups (2-3 people) with pre-assigned specific roles by the teacher are good teaching practices. Furthermore, a lesson introduction like a short activity which will attract students' attention and trigger motivation to learn constitutes a good practice as well. On the other hand, the circumstances under which the cooperative teaching approach can be successful are questionable. A culture of working as a team member must be taught from early schooling and more time needs to be spent in engaging students in cooperative activities during class.
Participants' proposals of good teaching practices include the following:
(a) the integration of activities aiming at popularization of chemistry research and achieving more meaningful learning;

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(b) the adoption of the cooperative teaching approach, despite its difficulties in implementation;
(c) the targeted use of Information and Communication Technology (ICT) for teaching fundamental chemistry topics such as stereochemistry;
(d) putting more emphasis on laboratory work despite existing difficulties such as the limited teaching time and infrastructure, the pressure to the teacher for "covering the material", the students' perception for lab work as a simple game which does not require any serious learning effort and the students' interest solely in performing well in the national exams for entering tertiary education institutions (taking into account the fact that these exams do not include lab-related exam questions up to this date);
(e) the appropriate incorporation of chemistry research (eg modern scientific analytical techniques) in school chemistry via interaction with academic institutions and/or chemical industries.

3. Conclusions

Although Greek secondary chemistry teachers are aware of the student-centered instructional approaches proposed by chemistry education research, they seem to face a lot of obstacles in their practical implementation and even sometimes ignore the circumstances under which these approaches are effective as successful experiences for students' meaningful learning. The results of a previous workshop related with the professional development of Greek chemistry teachers revealed teachers' obstacles to implement novel teaching approaches (eg the closed curriculum and students' evaluation methods) [15]. Furthermore, the discussion that took place during the current workshop concerning cooperative teaching and inquiry laboratory activities shed light to the difficulties encountered in the implementation of student-centered teaching approaches.

A student-centered instructional approach places less emphasis on transmitting factual information from the instructor, and is consistent with the shift in models of learning from information acquisition (mid-1900s) to knowledge construction (late 1900s) [16]. To date, the most common strategy for translating chemistry education research into practice has been to develop new teaching approaches and materials, test them via educational research, and then make the most promising ones available to chemistry teachers, primarily through conferences and workshops. Relying largely on chemistry teachers self-report data, the evaluation of this process for transferring new approaches to the teaching practice indicates that it has generally been more successful in simply making participants aware of existing research than in convincing participants to adopt new, research based teaching practices [1].

Moreover, research suggests that chemistry teachers are unlikely to change their teaching practice without opportunities to reflect on their own teaching practice, compare their practice to research-based, more effective approaches, and become dissatisfied with their own practice. This process of conceptual change for a chemistry teacher parallels the process of conceptual change to help students develop scientifically correct understanding of natural phenomena [1]. Efforts to translate chemistry education research into practice are more likely to succeed if the following conditions are met: 1) efforts are consistent with research on motivating adult learners, 2) efforts include a deliberate focus on changing chemistry teachers' conceptions about teaching and learning, 3) efforts recognize the cultural and organizational norms of secondary schools, and 4) efforts work to address those norms that pose barriers to change in teaching practice.

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