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Perspective

The laboratory in science education: the state of the art

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Abstract: For more than a century, laboratory experiences have been purported to promote central science education goals including the enhancement of students' understanding of concepts in science and its applications; scientific practical skills and problem solving abilities; scientific 'habits of mind'; understanding of how science and scientists work; interest and motivation. Now at the beginning of the 21st century it looks as if the issue regarding learning in and from the science laboratory and the laboratory in the context of teaching and learning chemistry is still relevant regarding research issues as well as developmental and implementation issues. This special CERP issue is an attempt to provide up-to-date reports from several countries around the world. [*Chem. Educ. Res. Pract.*, 2007, **8** (2), 105-107]

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Introduction

Laboratory activities have long had a distinctive and central role in the science curriculum and science educators have suggested that many benefits accrue from engaging students in science laboratory activities (Hofstein and Lunetta, 1982; 2004; Tobin 1990; Hodson, 1993; Lazarowitz and Tamir, 1994; Garnett et al., 1995; Lunetta 1998; Hofstein, 2004; Lunetta et al., 2007). At the beginning of the twenty-first century we are entering a new era of reform in science education. Both the content and pedagogy of science learning and teaching are being scrutinized, and new standards intended to shape and rejuvenate science education are emerging (National Research Council, 1996; 2000). The *National Science Education Standards* (NRC, 1996) and also the 2061 project (AAAS, 1990) reaffirm the conviction that inquiry in general and inquiry in the context of practical work in science education is central to the achievement of scientific literacy. Inquiry-type laboratories have the potential to develop students' abilities and skills such as: posing scientifically oriented questions (Krajcik et al., 2001; Hofstein et al., 2005), forming hypotheses, designing and conducting scientific investigations, formulating and revising scientific explanations, and communicating and defending scientific arguments.

Learning in and from science laboratories

Over the years, many have argued that science cannot be meaningful to students without worthwhile practical experiences in the school laboratory. Unfortunately, the terms *school laboratory* or *lab* and *practical* have been used, too often without precise definition, to embrace a wide array of activities. Typically, the terms have meant experiences in school settings where students interact with materials to observe and understand the natural world. Some laboratory activities have been designed and conducted to engage students individually, while others have sought to engage students in small groups and in large-group demonstration settings. Teacher guidance and instructions have ranged from highly structured and teacher-

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centered to open inquiry. The terms have sometimes been used to include investigations or projects that are pursued for several weeks, sometimes outside the school, while on other occasions they have referred to experiences lasting 20 minutes or less. Sometimes laboratory activities have incorporated a high level of instrumentation, and at other times the use of any instrumentation has been meticulously avoided.

Many research studies have been conducted to investigate the educational effectiveness of laboratory work in science education in facilitating the attainment of the cognitive, affective, and practical goals. These studies have been critically and extensively reviewed in the literature (Hofstein and Lunetta 1982; 2004; Blosser, 1983; Bryce and Robertson 1985; Hodson, 1993; Lazarowitz and Tamir 1994). From these reviews it is clear that in general, although the science laboratory has been given a distinctive role in science education, research has failed to show simple relationships between experiences in the laboratory and student learning. Hodson (1990) has criticized laboratory work and claimed that it is unproductive, and confusing, since it is very often used without any clearly thought-out purpose, and he called for more emphasis on what students are actually doing in the laboratory. Tobin (1990) wrote that: "*Laboratory activities appeal as a way to learn with understanding and, at the same time, engage in a process of constructing knowledge by doing science*" (p. 405). He also suggested that meaningful learning is possible in the laboratory if students are given opportunities to manipulate equipment and materials in order to be able to construct their knowledge of phenomena and related scientific concepts.

Research on learning in and from science laboratories: looking to the future

Laboratory activities have been used in many natural science disciplines to teach students of many age spans in very different cultural and classroom contexts. In the many studies and varied research settings important issues and variables intersect. However, there have been many substantive differences in the laboratory settings and in other variables reported. To develop research in the field, the science education community and especially the research community must be careful to provide detailed descriptions of the participating students, teachers, classrooms, and curriculum contexts in research reports. Among the many variables to be reported carefully are (based on: Lunetta et al., 2007): learning objectives; the nature of the instructions provided by the teacher and the laboratory guide (printed and / or electronic and / or oral); materials and equipment available for use in the laboratory investigation; the nature of the activities and the student–student and teacher–student interactions during the laboratory work; the students' and teachers' perceptions of how the students' performance is to be assessed; students' laboratory reports; the preparation, attitudes, knowledge, and behaviors of the teachers . What do the students perceive they are supposed to accomplish in the laboratory activity? How do they perceive their laboratory performance will be assessed? How important do the students and the teachers perceive the laboratory activities to be? Studies should clearly report the amounts of time students spend in laboratory activities, and how those are integrated or separated from other work in the science course. They should distinguish clearly between long-term and short-term student investigations, and indicate clearly the numbers and roles of students in each laboratory team. Since substantial differences are often present in different laboratory settings, detailed descriptions of the subjects and contextual details are especially important. To support the development of knowledge that can advance science education by informing curriculum development, teaching and assessment practices, and education policy, it is essential to define technical terms precisely to explicate knowledge in the field; it is also important to use those terms consistently in research reports and in scholarly writing.

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This special issue of CERP is totally devoted to the issue of theoretical, practical, and research issues regarding the laboratory in the context of secondary and tertiary education in the chemical sciences. This special issue consists of twelve contributions from seven countries, representing different educational settings and different student backgrounds. The editors of this journal and the guest editors of this special issue sincerely hope that this contribution will provide more insight into our knowledge regarding the laboratory as a unique learning environment.

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