1 Introduction

Laboratory-centred instruction has a long tradition in both school and higher education settings and is generally regarded as a vital component of the science curriculum (Hofstein & Lunetta, 2004; Reid & Shah, 2007). Most of the time educators highlight its nostalgic value or emphasise that educating skilled practitioners works best through hands-on experience (Cooper & Kerns, 2006; Elliot, Stewart, & Lagowski, 2008; Reid & Shah, 2007). One major problem with contemporary laboratory courses, however, is that nowadays their purpose seems self-evident. In consequence, in the last two decades laboratory courses have gained a lot of attention from science education research and their role in teaching students has been critically discussed since (Eilks, Bäumer & Byers, 2010; Hilosky, Stuman, Schmuckler, 1998; Hofstein & Lunetta, 2004; Tobin, 1990; Reid & Shah, 2007).

Hofstein and Lunetta (2004) summarize how important for the twenty-first century it is to "conduct more intensive, focused research to examine the effects of specific […] laboratory experiences […] on students' learning" (p. 33) suggesting a lack of scientifically clean investigations in this regard. Although these authors are primarily referring to school contexts, their demand holds true for higher education, as well. Eilks et al. (2010), for instance, have raised the issue of a strong need for methodological innovations in German higher education chemistry, including laboratory-supported instruction. Voices that are more critical even urge academia to provide substantial evidence that practical work indeed has additional benefits for chemistry learning over lectures and seminars. This is mostly because laboratory courses are far more demanding in terms of facilities, resources and time for both faculty and students compared to the other course formats (Hawkes, 2004; Reid & Shah, 2007; van den Berg, 2013). Hawkes (2004), in particular, criticises that the poor return in chemistry content knowledge gains cannot justify these expenses. In addition, even though educators have recourse to an already well-founded knowledge about different types of laboratories and their intended purposes (Domin, 1999b; Kirschner & Meester, 1988), descriptions of these purposes appear to be very vague or they are not even defined at all (Reid & Shah, 2007), which leaves the impression that some laboratory activities are arbitrary or at least non-meaningful to the students. Against these statements it is becoming increasingly harder to justify the inclusion of laboratory courses in the undergraduate chemistry curriculum.

This study specifically focuses on introductory chemistry laboratory courses, not only because of their questionable standing in the science education community, but also because research has mostly disregarded them in investigations about chemistry-specific study success. Using the example of a typical traditional laboratory course in general chemistry this study has three major aims. The first aim is to measure alignment between the intended learning goals of faculty for this laboratory course and students' perceptions of the lab course's learning goals. This information alone would help faculty assess the effectiveness of their lab course. Second, the study investigates the prediction of lab course success. Establishing a valid predictive model for lab course success can contribute to a general deeper understanding of the laboratory as a learning environment, but also encourage faculty to reconsider their current lab practices and reflect on their intended learning goals if there are any at all. As little research related to the prediction of lab course success has been performed so far, this investigation is very exploratory in character, where possible influencing factors are deduced from the available literature on laboratory-supported learning. These two factors, the students' prior knowledge and learning goal alignment, are framed in a prediction model and encourage further investigations in this regard. The third aim of this study is to establish the significance of success in introductory laboratory courses for overall study success during the first year of studying chemistry. These findings can be useful to adequately evaluate the cost-benefit ratio of laboratory courses in the undergraduate curriculum and inform chemistry educators about ways to improve or reconstruct it.

2 The Nature and State of the Undergraduate Chemistry Lab

The laboratory is a well-established learning environment in school and higher education alike. Nevertheless, history has shown that the way it is utilised is often influenced by current developments in learning theory and new ideas about learning processes. Its original purpose of training skilled and accurate lab practitioners in a predominantly behaviouristic fashion has evolved to a constructivist education of responsible scientists capable of using their competencies to find solutions to complex science problems and participate in everyday discussions about STEM issues. These changes regularly challenge the chemistry science education community to take a critical look at their current lab practices, put them in perspective and ask themselves whether they are viable for the future. Over twenty years ago already, Abraham et al. (1997), from whom the title of this chapter is also inspired, quite fittingly summarize this situation for the context of higher education as follows:

> "In recent years there has been renewed interest in renovating general chemistry courses in colleges and universities. The National Science Foundation has a program designed to upgrade beginning chemistry courses and the American Chemical Society has a task force looking into improving general chemistry. Much of this interest has focused on the laboratory. As curriculum and instructional strategies used in laboratory will potentially change over the next years, it would be useful to learn where we stand now. How is general chemistry laboratory taught and managed? What varieties of practices are being used?" (p. 591)

Today, these questions are relevant once again in the light of an increasing interest in renovation of and innovation in higher education chemistry in Germany, including the undergraduate laboratory (Eilks et al., 2010). In order to understand the strong need for new directions, it is helpful to revisit lab course instruction styles and their popularity among chemistry faculty, current implementation practices of laboratory courses into the undergraduate chemistry curriculum as well as major challenges and issues that urge chemistry faculty to rethink the way they utilize the undergraduate chemistry lab.

2.1 Lab Course Instruction Styles

Laboratory courses at university are a unique form of instruction with their own underlying design principles that distinguish them from other course formats, such as seminars and lectures. While lectures focus on demonstration of theories and ideas, where the learner takes the role of a recipient, the laboratory requires them to take direct action and apply their knowledge during experimentation. In a sense, seminars can be regarded as a hybrid of the former two, where a good balance between reproduction and application of knowledge is desirable. Depending on the kind of laboratory course curriculum designers envision, labs may also vary greatly in terms of their instruction style. The literature provides various documentations of these instruction styles, each one using their own approach and terminology. While some authors define various types of laboratories by emphasising the differences between them (e.g. Domin, 1999b; Kirschner & Meester, 1988), others focus on a set criterion, such as the level of inquiry, to describe them systematically (e.g. Bruck, Bretz & Towns, 2008). Regardless of the approach, however, they all describe similar archetypes. *Table 1* presents the most common categorisation schemes accepted in the chemistry education community.

Table 1. **Laboratory instruction styles and their descriptors (Domin, 1999b; Kirschner & Meester, 1988).**

Classification by Domin (1999b)	**Descriptor**			**Classification by Kirschner & Meester (1988)**
	Outcome	**Approach**	**Procedure**	
Expository laboratory	Predetermined	Deductive	Given	Academic / formal laboratory
Inquiry laboratory	Undetermined	Inductive	Student generated	Experimental laboratory
Discovery laboratory	Predetermined	Inductive	Given	Experimental laboratory
Problem-based laboratory	Predetermined	Deductive	Student generated	Divergent laboratory

In the *(traditional) expository* or *formal laboratory*, lab instructors fully control the whole lab activity. They define the problem to be investigated with its underlying theoretical background, can anticipate student actions due to the procedures being detailed in a lab manual already, know which results the students are intended to generate and how the results need to be interpreted. The students are also aware of