Learning and Instruction 38 (2015) 43–52

Contents lists available at ScienceDirect

Learning and Instruction

journal homepage: www.elsevier.com/locate/learninstruc

Effects of a science center outreach lab on school students' achievement – Are student lab visits needed when they teach what students can learn at school?☆

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ARTICLE INFO

Article history:
Received 16 September 2014
Received in revised form
14 March 2015
Accepted 24 March 2015
Available online

Keywords:
Achievement
Educational setting
Science education
Science center outreach lab (SCOL)
School intervention

ABSTRACT

This study examined the effectiveness of labwork settings in science education with a pretest-posttest design. Sixty-eight ninth-grade classes ($N = 1773$) were randomly assigned to three experimental conditions and a control condition. The first condition was taught the topic of the chemistry of starch in *School only*, the second condition was taught in the *Science Center Outreach Lab (SCOL) only*, the third condition was taught in a combined setting encompassing both a SCOL visit and classroom learning (*SCOL & school*), and the fourth was a control condition. A multilevel analysis investigated differences in achievement with experimental conditions as predictors on the class level and gender, language spoken at home, and pretest scores as predictors on the student level. The intervention was effective in all three experimental conditions with higher achievement than the control condition. Students in the combined setting (*SCOL & school*), our reference group in the multilevel analysis, learned more than the students in the control condition. However, since students' achievement in the *SCOL only* and *School only* conditions did not differ significantly from the *SCOL & school* condition, it seems that the learning goals of the SCOL can also be achieved at school (at least when labwork is provided).

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1. Introduction

Boosting achievement scores in the so-called STEM (science, technology, engineering, mathematics) subjects is a goal that ranks high on the priority lists of several countries (European Commission, 2007; National Research Council, 2011; OECD, 2011). It is often argued that long-term economic growth depends on a country's success at fostering young people's achievement in science and other STEM subjects (Sawyer, 2008).

However, increasing student competencies in science subjects is not an easy task. Several reports have stated that deductive, teacher-led lessons are still the norm (e.g., Andrés, Steffen, & Ben, 2010). This traditional approach has been criticized, and there are many calls for a more "active" familiarization with scientific contents (see Schroeder, Scott, Tolson, Huang, & Lee, 2007) that is assumed to be more likely to result in long-lasting engagement and higher achievement (Swarat, Ortony, & Revelle, 2012; Yager & Yager, 1985).

The call for more "active" elements in science education has highlighted the role of labwork in and outside of students' regular science classrooms. The present article focuses on visiting a *science center outreach lab* (SCOL) as one prominent example of recent endeavors to improve science education. SCOLs can be described as extracurricular science laboratories that can be visited by secondary-level classes, in which students have the opportunity to

☆ Heike Itzek-Greulich is a member of the "Cooperative Research Training Group" at the University of Education, Ludwigsburg, and the University of Tübingen, which is supported by the Ministry of Science, Research and the Arts in Baden-Württemberg.

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http://dx.doi.org/10.1016/j.learninstruc.2015.03.003
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study a scientific research question for which they prepare, conduct, and review experiments in inquiry-based learning environments (Domin, 1999; Hempelmann & Haupt, 2014). The distinguishing feature of SCOLs is that students carry out research by themselves, guided by a researcher. With its specific features (e.g., workshop-like teaching unit instructed by scientists and experimental hands-on activities to answer a research question), a SCOL is similar to science or university outreach programs. SCOLs are believed to provide students with excellent opportunities for active learning and hands-on activities, and they have spread around the world, including Germany. Visits to SCOLs are seen as a valuable addition to learning in the classroom (e.g., Tal, 2012). Some have claimed that SCOLs have a positive impact on the acquisition of knowledge and competences, especially because they can supply the necessary infrastructure (Luehmann & Markowitz, 2007). However, other researchers have warned that SCOLs may have limited impact on achievement when they are not closely tied to the regular science lessons at school (Glowinski & Bayrhuber, 2011; Hofstein & Rosenfeld, 1996).

So what are the effects of SCOL visits? Surprisingly, the impact of SCOLs on learning is still hard to gauge because the empirical evidence for the assumed positive effects of SCOLs for academic achievement is small and inconclusive, and several of the existing studies have suffered from methodological shortcomings (Hofstein & Kind, 2012). In the present study, we therefore capitalized on both a conceptual innovation (a learning condition in which learning at school and SCOL were coupled) and a comparably complex study design. More specifically, we (a) randomly assigned 68 classes to four experimental conditions, (b) implemented a design with similar timing and contents across three experimental conditions, and (c) investigated several achievement outcomes.

1.1. A way to enhance science achievement in students: SCOLs

Science as taught in school, in particular chemistry, has often been shown to have a low appeal to students (Osborne, Simon, & Collins, 2003). One way to increase students' acceptance of science is to conduct labwork, which has been found to have positive effects on students' interest and achievement in science education (e.g., Hofstein & Lunetta, 2004). However, labwork at school is often restricted because of a lack of infrastructure. Therefore, visiting student labs outside of school, such as SCOLs, offers students the opportunity to explore new topics in a well-equipped learning environment where hands-on activities and experiments can be conducted easily by the students themselves. Consequently, extra-school science laboratories are believed to increase students' acceptance of and achievements in science education (Reiss, 2012; Rennie, 2007).

Several arguments have been made in support of SCOLs. SCOLs offer exploration, discovery, and original experiences. Although SCOLs can be considered as an out-of-school learning facility, they have additional features distinguishing them from other extracurricular learning settings. For instance, SCOLs offer students the opportunity to conduct experimental hands-on activities themselves (McClafferty & Rennie, 1993; Rennie & McClafferty, 1995). A typical SCOL offers more structured lessons than other extracurricular learning settings, as it consists of a workshop-like teaching unit in which students are instructed by scientists in order to enhance their understanding of a certain topic of the natural sciences (Hausamann, 2012). Moreover, students may perform experiments in a research area they received input on before, with equipment that might not be available in school (Hausamann, 2012). Typical characteristics attributed to SCOLs, therefore, are experiences of experimental methods, context-based cooperative learning, team work, exploring and problem-solving, and embodied experiences in a well-equipped environment. Although schools may provide such a learning environment, a SCOL typically offers a better equipped environment, instruction by scientists (accompanied by the teacher), and longer lessons, for example four or eight hrs (Guderian & Priemer, 2008). Overall, these features indicate that SCOLs are more similar to science or university outreach programs (e.g., Bleicher, 1996) that also feature "hands-on inquiry-based science activities in an authentic, real-world setting" (Markowitz, 2004, p. 396). University outreach programs (e.g., Jeffers, Safferman, Safferman, & Asce, 2004) were found to have positive effects on students' science-related attitudes (e.g., Heinze, Allen, & Jacobsen, 1995) as well as on students' interest in science careers (e.g., Markowitz, 2004). Moreover, via qualitative and quantitative analyses, Rodriguez, Jones, Pang, and Park (2004) showed that a six-week university outreach program advanced tenth-grade students' engagement and competencies in science learning.

1.2. Effects on student achievement

Is there empirical support for the value of visiting science laboratories for students' achievement outcomes? Reviews have pointed to differences in students' achievements when they were taught out-of-school as compared with when they were taught in school (DeWitt & Storksdieck, 2008; McClafferty & Rennie, 1993; Rickinson et al., 2004). More specifically, students achieved more when they took part in out-of-school learning compared with students who were taught in the classroom (Seybold, Braunbeck, & Randler, 2014; Sturm & Bogner, 2010). On the other hand, formal educational settings have been found to lead to higher knowledge after treatment than unstructured out-of-school learning (Randler, Kummer, & Wilhelm, 2012). However, prior reviews and studies have primarily focused on informal learning in museums and on field trips (Fallik, Rosenfeld, & Eylon, 2013; Hofstein & Rosenfeld, 1996; Salmi, 2012; Stocklmayer, Rennie, & Gilbert, 2010). Consequently, these findings have to be carefully put into context when studying the effects of SCOL visits.

Moreover, some authors have argued that the majority of studies investigating the effects of SCOL visits (Hausamann, 2012; Thomas, 2012) on students' learning performance have had some limitations: Several studies were based on small sample sizes, in particular regarding the necessary number of classes in treatment groups; did not include a control group or randomization; or did not apply a multilevel analysis to hierarchically nested data. In sum, there is surprisingly little evidence for positive effects of SCOL visits on achievement.

1.3. A way to obtain more insight into the effectiveness of out-of-school learning: integrating a SCOL visit with traditional classwork

To enhance out-of-school learning, Adams, Gupta, and DeFelice (2012) advocated that out-of-school learning facilities and schools should be able to create collaborative science learning practices, thereby enabling students to be part of the practicing scientific community. Moreover, several researchers have claimed that field trips are most effective when they are integrated into the curriculum instead of when they are isolated as a one-day occurrence (Falk & Storksdieck, 2005; Fallik et al., 2013; Hofstein & Lunetta, 2004; Orion & Hofstein, 1994).

Integration into the curriculum encompasses preparing and reviewing out-of-school learning (Falk, 2004). However, Griffin and Symington (1997) found that few teachers prepared their classes for visits to museums and those that did prepare them mainly concentrated on organizational issues. Additionally, teachers often only have limited information on the extracurricular learning

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