

**LINKING FORMAL AND NON-FORMAL LEARNING IN SCIENCE  
EDUCATION – A REFLECTION FROM TWO CASES  
IN IRELAND AND GERMANY**

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**ABSTRACT**

This paper discusses two cases of linking formal and non-formal learning in science education. The cases concern science education in the Irish Transition Year, a facultative year between lower and upper secondary education, and a non-formal laboratory learning environment for lower and upper secondary school students in a German university. Both cases are described, compared and jointly reflected on non-formal education's potential and limitations for supporting formal science learning.

**KEY WORDS**

Science education; Non-formal education; Curriculum; Innovation.



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# Linking Formal and Non-Formal Learning in Science Education – A Reflection from Two Cases in Ireland and Germany

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## INTRODUCTION

Reform in education in general and in science education in particular is an ongoing process. Educational reform regards, among others, the curriculum, the pedagogy or the educational system. How one links formal education in school with alternative and non-obligatory settings, for example learning experiences in informal or non-formal settings, is a key element which impacts on all of the three named dimensions of educational reform. The OECD (2012) defines informal learning as out-of-school learning that is unstructured and does not follow a specific curriculum, such as a visit to a museum or science exhibit. Non-formal learning is also out-of-school learning but has a specific structure and is connected to some kind of a syllabus or curriculum. Coll, Gilbert, Pilot and Streller (2013) note that despite the terms informal and non-formal science education being both officially defined and widely used they often are not coherently applied. Quite frequently the terms are used to describe any school events that take place outside school or just even outside the regular classes.

Both informal and non-formal educational settings for science education offer broad possibilities. The potential settings range from field trips or industry visits, via specific learning environments in museums, science centres or

science departments in universities, towards non-obligatory science courses offered on or off the school campus (Coll et al., 2013; Stocklmayer, Rennie & Gilbert, 2010). Within this range, site visits or learning environments outside of the school campus clearly belong to the informal or non-formal sector although sometimes the activity in them is clearly connected to the formal science curriculum applied in the school and participation for students is compulsory. Non-obligatory courses in the school typically belong to the formal sector, but due to the fact that they are not compulsory and not always structured by a given curriculum they may have quite an informal character. Thus the distinction between formal and non-formal education is not always easy. There are types of alternative educational settings that are somewhere between pure formal and pure non-formal educational settings. Some of them are even connected to informal educational activities. One might call them partially non-formal.

All the different activities from informal, non-formal, and partially non-formal education offer specific chances to learn more or different science in addition to the regular formal science classes in school. This paper presents two such educational settings from Ireland and Germany. One of the settings is science education in the Irish Transition Year (TY), a facultative year between lower and upper secondary education. The TY is not compulsory and does not follow a formal curriculum, yet is offered in the majority of Irish schools. The other approach concerns science education modules offered in a non-formal science laboratory for secondary students in a German university called Schülerlabor (SL). The visits of the SL, in most cases, are compulsory for all students when the teachers or schools decide to visit the laboratory as an official school event and in many cases the activities follow a prescribed structure and the learning is clearly connected to the school science curriculum. Both concepts will be discussed, compared and jointly reflected upon, examining the opportunities and limitations of the respective partially non-formal educational initiatives for formal science education.

## SCIENCE EDUCATION IN THE IRISH TRANSITION YEAR

The Irish Transition Year (TY), which forms a part of the Irish second-level education system, is an anomaly, often referred to as a «delicate flower in the educational garden» (Jeffers, 2008, p. 5). The TY is a curriculum free year between the junior and senior cycle of secondary education. *The TY is designed*



to act as a *bridging year*, between the two examinable cycles of secondary level education. It was designed to enable pupils to move away from the highly structured, formally examinable education program which prevails throughout the Irish schools system (Jeffers, 2011; Smyth, Dunne, McCoy & Darmody, 2007). Students are on average 15-16 years old when they take the TY. However, schools are not obliged to offer the TY, and if they do pupils are not always obliged to take it. Each school has the autonomy to offer the TY in a fashion that they deem appropriate for their own school, schools must only adhere to a set of TY guidelines (Department of Education, 1993).

Initially the TY was introduced as a 'top-down' initiative, with little planning and limited support for schools (Smyth, Byrne & Hannon, 2004). The TY has been characterised by uncertainty, from its initial inception, to its current day form. This characterisation is both in terms of monetary provision and in terms of the attitudes of parents, teachers, pupils and policymakers towards the TY (Jeffers, 2002, 2008, 2011). Much of this is due to the autonomy and the ambiguity of the TY guidelines. With teachers and schools free to design their own programmes, the guidelines state that:

The school should ensure therefore that, in all areas studied, there is a clear distinction between the Transition Year programme and the corresponding Leaving Certificate syllabus. A Transition Year programme is NOT part of the Leaving Certificate programme, and should NOT be seen as an opportunity for spending three years rather than two studying Leaving Certificate material (Department of Education, 1993, p. 2).

The educational categorization of the TY is complex and it is difficult to define the type of learning or educational setting which occurs during this year. Under the OECD guidelines the TY has aspects of formal, informal and non-formal learning embedded within it. It encompasses both non-formal and informal learning in a formal setting. The learning is not necessarily linked to a syllabus or curriculum (although sometimes it is in a non-formal fashion), it tends to take place in the formal school setting, yet many informal field trips are encouraged. Perhaps the term partially non-formal may be most appropriate, as elements of informal, non-formal and formal all ensue throughout the year.

This lack of certainty has characterized the TY. The educational freedom is not always embraced by schools, teachers or policy makers. Change in practices

can often be met with resistance (Dalin, 1993). The TY is an important example of school and curriculum reform in Ireland, despite its initial beginnings as a ‘top-down’ initiative; it is a prominent example for its notable opportunities for innovation and development. The autonomous nature of the year has meant that school culture has had a very prominent role to play in the development and delivery of the TY among schools. Every school and department has its own specific character conditioned by «its history, staffing and the school in which it was set» (Donnelly, 2000, p. 272). Hayes (2011) and Smyth et al. (2004) found that provision of the TY varies dramatically across school types and school gender intakes. The highest levels of provision have been found in single-sex female schools, particularly in secondary and community and comprehensive schools. The lowest levels of provision are in vocational schools. The size of the school has also been found to be a factor in whether the year is offered to pupils, with the highest level of provision occurring in large schools. Schools also differ in whether they offer the program as an option to their pupils, or whether they made it compulsory. Co-educational secondary schools are more likely to offer the program on a compulsory basis than other schools. In addition, where small schools offer the year they are also more likely to make it compulsory, as they may not have adequate facilities or staffing to do otherwise, while a compulsory TY make it a viable year in small schools. Currently, the TY is offered by over 80% of the schools and uptake of the TY raised from 40% to over 60% of the students in recent years. We can infer a number of reasons for this, such as pupils staying in school longer due to the economic crisis Ireland has been experiencing or people valuing the TY and the opportunities it offers to a greater extent.

For science education, the TY provides a unique opportunity for teachers to teach science in an imaginative and authentic way without the confines of a syllabus or central examinations. It offers teachers the exciting prospect of changing pupils’ views of science through teaching interesting and authentic material: «Transition Year is an opportunity for pupils to become familiar with a broad range of Science activities. Pupils should be encouraged to study areas of Science not heretofore encountered» (Department of Education, 1993, p. 27). The TY guidelines state that any science module taught in the year should «explore the links between science and society» (Department of Education, 1993, p. 29). As a result, the TY has given rise to curriculum innovation in many subject areas including science (Hayes, Childs & O’Dwyer, 2013; Regan, 2005). The TY guidelines (Department of Education, 1993) suggest that schools place particular emphasis on negotiated learning, personal

responsibility in learning, activity-based learning, integration of appropriate areas of learning, team teaching approaches, group work, discussion, debate, interview, role play, project- and research-based learning, visiting speakers and seminars, study visits and field trips, or work experience, work simulation, community service. The use of a wide variety of learning theories is advocated, like situated cognition (Greeno, 1988; Smith & Matthews, 2000) or inquiry-based science education (Childs, 1994; Hofstein, Kipnis & Abrahams, 2012). TY Science, with its partially non-formal nature offers an opportunity for teachers to contextualize science in a different way and put science education research into practice without the time or content constraints of a formal curriculum and the pressure of formal exams. Previous interventions to utilize the year to promote the uptake of science at senior cycle have been relatively successful (Childs, Hayes, Lynch & Sheehan, 2010; Matthews, 2010; Smith & Mathews, 2000).

In 2011, Hayes presented a broad analysis focusing the place of science in the Irish TY, by viewing it through the eyes of the key players: the pupils, teachers, and schools. The study focused on the implications for teaching science in a partially non-formal learning environment. The results indicate that the type of classroom activities experienced by TY pupils (when compared to junior cycle pupils) are more varied. The traditional classroom activities of writing in, answering questions from, or reading of a science textbook are experienced by Junior Certificate pupils with a far greater frequency than TY pupils, although not at a significant level. Significant differences were found that TY pupils experience more frequent working with apparatus or materials, group work, pupil presentations, watching TV/DVDs/Videos on scientific phenomena, use of computers and internet, listening to visiting speakers, or taking part in activities such as science fairs. These trends are also noted in terms of assessment, with Junior Certificate pupils experiencing quite traditional assessments, such as written and oral tests with a far greater frequency than their TY counterparts, however once again not at a significant level.

One of the key findings in the study was that two thirds of teachers are teaching from the Leaving Certificate/Senior Cycle Science syllabi. This practice is carried out, in the main, to allow pupils a taste of science subjects for their Leaving Certificate; although close to a fifth of teachers do so in order to decrease their workload for the Leaving Certificate program. The teachers, although working in schools that have above average levels of science uptake for senior cycle, added a further insight into their rationale: they believed



that it aided the pupils, due to the time constraints in the senior cycle science syllabi, to prepare themselves better for the Leaving Certificate course.

The teachers were asked about their own degree and subject background. The majority had a background in the biological sciences, either alone or in combination with another subject. Perhaps this explains the high levels of the biological sciences taught in the TY, and the pupils' significantly more positive perceptions of the biological sciences. The body of research surrounding this area indicates that a teacher's background and subject specialism affects their self-efficacy and practices (Kind, 2009; Shulman, 1987; Van Driel, De Jong & Verloop, 2002). Research has indicated the importance of subject specialists teaching within their own field (Davis, 2003; Hashweh, 1987; Kind, 2009). The teachers who took part in this study believed that it is of vital importance that teachers teach within their subject specialism in TY Science, in order to allow their pupils a better experience of the subject, and to encourage better uptake of the subjects at the Leaving Certificate level. It seems that the biological sciences are the most popular science subjects among TY pupils because the majority of teachers have a respective background, and therefore feel more comfortable teaching these topics. Thus, the TY is currently doing little to reduce the dominance of biology at the senior secondary cycle.

The experiences with TY science allow us to derive some of the important elements to a successful partially non-formal science education program. School culture, teacher 'preparedness', and pupils' perception of science and scientific careers all have a part to play. There can be a tendency for schools to 'domesticate' the TY. This is an understandable, but potentially dangerous practice as it may lead to the TY becoming 'colonized' by the Leaving Certificate curriculum (Jeffers, 2007). Science is considered to be a 'vital', 'essential' and 'important' element of the TY programme. Overall, the subject is held in high regard among science teachers and TY co-ordinators, though many teachers struggle to develop their own curriculum for the subject. Biology, in particular is taught by the largest proportion of teachers. Perhaps the higher number of biology specialists in schools contributes to this or it may be due to the schools' timetabling and organisation of the subjects.

The results of the study by Hayes (2011) begs the question as to why do teachers, teaching TY science, use the particular teaching methodologies and teach the content reported in this study? Many activities, such as discussion, debate and self-directed learning, which are integral to becoming a scientifically-literate citizen and to understanding the nature of science (Eilks, Prins

& Lazarowitz, 2013), are not being experienced to a great extent by pupils in either the TY or Junior Certificate science classrooms. It is proposed that the answer lies within the area of teacher preparedness. The question of how prepared teachers are to teach TY science was not one of the initial research questions, however, as the study progressed the theme of ‘teacher preparedness’ was one which could not be overlooked. There were many indications that there is a severe lack of preparation for teachers involved in teaching in TY science. Nearly three-quarters (71.3%) of teachers believe that they did not receive adequate pre-service education in order to teach in or design a TY science curriculum, and only a third of teachers had ever attended such in-service education. The more experienced the teacher (the longer they have been teaching), the more likely they were to have attended these sessions. Perhaps in-service education that was provided concerning TY science was not equal in terms of geographical location, or perhaps education has not been provided in more recent years. This unequal provision of education leaves teachers inadequately prepared to take on the mantle of curriculum development, and teachers appear to have become entrenched in familiar and traditional practices (Halton, 2004; Hargreaves, 1996, 2003).

The question arises, how are our teachers to teach in an informal, non-formal or partially non-formal learning environment if initial teacher education and continuous professional development for teachers is so inextricably bound to the curricula and syllabi of the time? As Ross, Lakin and Callaghan noted «At best they (pupils) have a scientific system that is good enough to pass examinations. But after the crops have been harvested the land is bare, the ideas are lost and everyday life is unaffected» (2004, p. 56). Science in the TY is in a state of continual flux, and teachers appear to be undecided about what it and the attributes of the year should be. This is in part due to the ambiguity of the guidelines (Department of Education, 1993), which while explicitly stating on one hand that the TY is ‘NOT’ a part of the Leaving Certificate program, and teachers’ should not teach Leaving Certificate material, it then also states that the TY does not need to exclude Leaving Certificate material, but the Leaving Certificate material should be chosen with a view to «augment the Leaving Certificate experience, laying a solid foundation for Leaving Certificate studies» (Department of Education, 1993, p. 5).

It is easily seen how teachers and schools receive mixed messages. This ambiguity has led a majority of science teachers to teach from the Leaving Certificate Science courses in the year. It has become the ‘norm’ to teach aspects





of the Leaving Certificate in the TY, with teachers not wanting their pupils to fall behind. Teachers are also wary of departing from familiar practices and express concern regarding teaching outside the box, without the security of routine practices and a familiar syllabus to rely on. Previous research in schools (Fullan, 1993, 2001; Fullan & Hargreaves, 1992; Hargreaves, 1989, 2003; Hargreaves, Earl & Ryan, 1996) tells us that change is difficult and leaving familiar and ‘cosy’ practices to change traditions is not an easy task.

Like the TY itself, science education in the TY has the potential to be a relevant, imaginative, and challenging innovation. The subject is enriching for pupils, teachers and the whole school. However, there are undertones of resistance. This resistance is not explicit, but is recognizable and detectable as inadvertent and unconscious practices and attitudes. The TY and teaching science within the year asks much of science teachers, particularly without them having adequate preparation for teaching their subject within the year. Teachers in Ireland have been trained to prepare their pupils to pass examinations, not to develop lessons which link to socio-scientific issues and contribute a societal perspective on science as it is demanded for a well-developed scientific literacy (Hofstein, Eilks & Bybee, 2011). The links to authentic science education are not made explicit and teachers are ill-equipped to fully utilize the partially non-formal nature of the TY. Braund and Reiss (2006) argue that we need to reconsider the site of learning in science education in order to revitalise the subject and provide authenticity and meaning. The Irish TY offers the opportunity to do just this, bridging the formal and informal/non-formal gap, yet is a cautionary tale, if teachers are not prepared and educated beyond the narrow confines of the school curriculum they may well be unable to fully utilise this opportunity in any meaningful way.

## SCIENCE EDUCATION UNDER INCLUSION OF A NON-FORMAL LABORATORY IN GERMANY

For about twenty years, there has been trend in Germany to establish non-formal laboratory environments for primary and secondary school students at universities and research institutes. In Germany, these laboratories are named «Schülerlabor» (Haupt et al., 2013) which can be translated as student laboratory (SL), where ‘Schüler’ in German means the school student and not the university student. More than 300 of such laboratories exist all over Ger-



many, however, every laboratory has a specific focus and thus not every science domain is available at every regional environment.

The SL were founded in order to support science learning by offering out-of-school experiences and practical work that is not possible to implement in schools due to lack of equipment, high costs, or poor facilities. The rationale behind this scheme was to improve students' motivation to undertake further studies in science and engineering. Visits typically include half- or full-day excursions to excellently equipped laboratories where a practical lesson takes place. Quite often the programme is prescribed, but the laboratory visit is not necessarily connected to the school curriculum. Thus these laboratories belong mainly to the non-formal educational sector (Haupt et al., 2013).

If the programme in the SL is not attuned to the learning in school the students frequently do not link experiences and knowledge gained in the non-formal setting with their formal learning in school. Also, the motivational effects are slight if students visit the non-formal learning environment only once for half a day. In such cases, the educational effectiveness of a trip to an external laboratory might sometimes not be worth the effort (Orion & Hofstein, 1994). Thus, a good connection between in- and out-of-school learning is needed to benefit from the multifaceted advantages (Griffin, 2004).

Hofstein and Rosenfeld (1996) or Rennie (2007) explain that non-formal learning, if it is to be connected to formal education, needs to coincide with the syllabus, and it should be flexible so that it can be adopted to individual teachers and learning groups' pre-requisites. The out-of-school experience has to be accompanied by preparation and post-processing elements in school, and all materials used as part of non-formal laboratory environments need to be consistent with the students' abilities and prior knowledge.

The project «Sustainability and chemistry in non-formal student laboratories» tries to follow these suggestions exactly (Garner, Lischke, Siol & Eilks, 2014). The project is a cooperation of two SL located in Bremen and Saarbrücken, Germany. Experts in chemistry, environmental sciences and chemistry education are working closely together within the project in order to develop half- and full-day non-formal laboratory-based learning environments for the SL. Issues of sustainability in chemistry related contexts are chosen as a topic because chemistry is seen as prototypical domain to learn about sustainability issues and contribute to Education for Sustainable Development (ESD) (Burmeister, Rauch & Eilks, 2012). For the whole range of secondary education in grades 5-13 (age range 10-19) modules that fit in specific



lesson units from the governmental syllabi are offered. The topics offered in the learning environments range, e.g., from usage of renewable raw materials (in grade 5/6), via chemistry of the atmosphere (in grade 7/8) and biofuels (grade 9/10), to modern technologies and synthesis strategies in the chemical industry (senior high school level).

Similar to the Irish TY this project also links formal and non-formal education by making the non-formal activity part of the school curriculum. As such the visit of the SL becomes a compulsory learning activity for all students where the teachers or schools decide to make the laboratory visit part of the science teaching in their classes. So here we have a setting which is essentially the reverse of the Irish TY. The setting is non-formal, but nevertheless has partially a formal character.

One of the central aims of this SL-initiative is to link non-formal and formal learning in a meaningful manner, thus making the out-of-school experience a component of formal school education and contributing to fulfilling the school curriculum. For this purpose, flexible and individually adaptable teaching and learning modules related to the governmental syllabus were created. 10-20 experiments for each topic are offered in a handbook from which the teacher can make a selection according to the curriculum applied in school. In negotiation with the accompanying university staff, the teachers select those experiments and materials that fit best to their objectives, their individual teaching style and the students' abilities. Additional information and working materials are also offered for preparation and post-processing the laboratory visit in school (Garner et al., 2014).

During the SL-visit, emphasis is placed on contextualized, inquiry-based and student-orientated learning (Garner et al., 2014). Laboratory instructions offered within the project use different degrees of openness and complexity. Tasks in the laboratory allow variation from structured to open inquiry (Abrams, Southerland & Evans, 2007). The students work in small teams and solve their tasks cooperatively and autonomously. Situated cognition (Greeno, 1988) suggests learning to be most effective if it is embedded into meaningful contexts. Contexts that are bound to chemical technology, research and industry (e.g. Hofstein & Kesner, 2006) as well as to societal relevant issues (e.g. Hofstein et al., 2011) are among the most promising frameworks through which to connect chemistry learning with all the different dimensions that make the learning of science relevant (Stuckey, Mamlok-Naaman, Hofstein & Eilks, 2013). Accordingly, this project operates a context-based and societal-

oriented approach to science learning. The contexts are current and authentic practices of research and industrial applications of chemistry to promote a more sustainable development for the future. The spectrum of examples ranges from daily-life, natural and industrial products (such as vanillin, plastics and fuels) and authentic and controversial societal issues (such as climate change and renewable energy supply) to research relevant emphases (such as click chemistry and zeolites as highly selective catalysts). Overall, the activities aim to support practical learning of science content, better understanding of the nature of science, and development of positive and critical attitudes and motivation towards science and technology.

A non-mandatory part of each SL-module is a field trip into research laboratories in the university or branches of industry that fit the thematic issue of the SL-lesson and that operate sustainability strategies in an authentic research or industry context. These trips are intended to make the context of learning even more authentic and allow for career orientation. Finally, all the modules are structured in a way that contents and contexts are in line with the national German science education standards as well as the regional syllabi in question.

The various SL-modules within this project were prepared from February 2012 onwards. More than 600 students visited the non-formal chemistry laboratories of the project partners so far. In all the SL-visits, both teachers and students are invited to contribute to a survey prior to and after visiting the university laboratory. The questions focus the prior expectations of the teachers and students towards the visit in the SL and into their experiences and reflections thereafter (Garner et al., 2014).

In the responses, the teachers supported a need for more intense practical work in science classes. The following two exemplary statements reflect the teachers' expectations towards SL visits in general:

The students should have the opportunity to experiment in several ways. Interest needs to be promoted. (Answer to the question regarding what needs to be done by SLs to be worthwhile)

The offered topic was focused in class. Because of the high expenditure of time and materials experimentations were not possible in the schooling context. Therefore, the visit in the SL supplements formal learning in school. (Answer to the question regarding the function of SLs for teaching purposes)



The teachers indicated that it is difficult for them to conduct appropriate experiments in their schools because of time constraints, insufficient equipment, and overloaded curricula. There was hope that the visit to the SL would enrich the practice of laboratory work in their classes. The teachers expected the SL to also contribute to promoting motivation in science learning. The teachers attributed motivational potential to the societal relevant aspects of the experience, such as providing students with insights into university education as well as chemistry which is relevant to everyday life. A large number of participating teachers stated that SL-modules should be easy to integrate into formal learning. These teachers believe non-formal learning environments can support school learning. The project enables this by connecting all SL-modules to the regional science syllabus and thus to the school curriculum. Although all the SL-modules were clearly connected to the school curriculum, only a few of the teachers expected content learning to fulfil part of the school curriculum and governmental syllabus. From the teachers' perspective support with practical work would be most welcome. The teachers believe that the visit to the SL should have other benefits beyond cognitive school achievement. This offers a contrast when compared with the students' point of view, in that they expected better marks after visiting the SL. More than 80% of the students agreed partly or fully with this statement. Almost 90% of the students expected to have a pleasant laboratory and research experience in the SL. They look forward to do more experiments than in the regular school context.

Only one percent of students were not excited to visit the SL. This finding indicates that visiting the SL has the potential to affect students' attitudes and motivation towards chemistry and science learning. The students connected their positive expectations mainly with their hope to do interesting experiments; especially those that cannot be done in schools (e.g. experiments with ozone in a module on the chemistry of the atmosphere where ozone is no longer allowed in German school laboratories). Students seem to be aware that school laboratory conditions are far from perfect for doing inquiry-type and open experiments. They suggested a major difference between formal and non-formal learning is the frequency of experimentation before visiting the SL. Practical work seems to be an important element of chemistry lessons from the student's point of view. They would like to conduct experiments in order to advance their own learning process.

The lack of availability of equipment and chemicals in schools was criticized by many students, as was the 45-minutes slots allocated to the science lessons,

which they believed hinders inquiry and open practical work. The students explicitly expressed their view that there is a gap in open and problem-based experiments in school and their hope for a different experience in the SL. However, the students also hoped to gain a better understanding of chemical content having visited the SL and as a result expected to later improve upon their grades in school. The majority of students did not want to see the SL separated from formal learning in school. They expected something more tangible, particularly in terms of getting better marks in school, however, that is inevitable.

The teachers' and students' experience was very positive throughout. It was quite similar among the different modules and grade levels of the students. After the visit, the overwhelming majority of teachers and students enjoyed the unfamiliar, non-formal atmosphere of visiting the SL. Orion and Hofstein (1991) suggested that the development of a more positive student attitude towards learning science could be fostered by visiting informal and non-formal learning environments. After visiting the SL, more than 90% of the students stated that they had enjoyed their time there, even students that had stated a dislike against the SL-visit before.

I especially liked that we did our experiments on our own. When we needed help to solve the questions, the university staff helped us.

I liked that we do thinks I never would have done otherwise. I saw those thinks just in books in school.

The students particularly highlighted the experimental approach that often is neglected in school. The staff-student ratio was also an important aspect of SL-visits. In Germany, one teacher is responsible for classes containing up to 35 students. Heterogeneous groups make individual advancement almost impossible in a school setting. In the SL the staff-student-ratio is different as there are at least three tutors per class during the SL-visit. The teacher is always supported by at least two university staff members. Therefore, students' questions are given more attention and time. Only a small minority of students was not looking forward to the visit or was disappointed after it.

Connecting science learning to authentic and innovative issues from the sustainability debate, as described e.g. in Burmeister and Eilks (2012), embedded into the non-formal learning experience was motivating and meaningful to the learners. Some students mentioned that working in the SL was exhausting. That



is why it was suggested that the SL-sessions should not exceed 3 hours. The teachers gave similar feedback. Almost all teachers were positive about the design of the SL in general and the experiments in particular. The quality of the tutors associated with the SL was noted by the students, this was also an important aspect of the experience for the teachers. Additionally and in contrast to the students the teachers placed a significant emphasis on the quality of the organization of the experience and the connection to the school curriculum and the official syllabus.

The teachers followed their students' behaviour in the SL with great interest. Several teachers mentioned during or after the SL-visit that they saw their students from a completely different angle. The lower achieving students in particular surprised the teachers with their working behaviour during the SL-visit. The teachers saw also benefits for themselves. Through visiting the SL and supervising the students they learned about new strategies of sustainable chemistry, they became familiar with new experiments, of which at least part of, can be implemented into practical work in the school science classroom, and they experienced how motivating the topics from the sustainability debate and activities of an inquiry nature can be for their students. Many teachers noted that they intended to integrate aspects from the SL into their regular classes. From this perspective there is hope that the project contributes to teacher continuous professional development and through this pathway helps in implementing issues of sustainable development more thoroughly into school science education in the future – a deficit that has been described in different studies (Burmeister & Eilks, 2013; Burmeister, Schmidt-Jacob & Eilks, 2013).

Limitations in the initiative lie in the geographical reach of the project. Only schools from the local and regional environment of the respective universities are able to participate in the programme, and only students whose teachers and schools take the initiative will be able to take part. It is also clear that the effects of such visits are short-term if the visits are only singular. As discussed in Stronck (1983), some studies in this area indicate a clear cognitive gain stemming from visits to non-formal educational environments, while others were not able to support these findings. The same applies to the motivational effects. DeWitt and Storksdieck (2008) explained this finding was due to the short term nature of most non-formal learning events which may not be suited to creating lasting cognitive and motivational effects. However, there is little research investigating whether a repeated visit in such a non-formal learning environment will have more durable effects.

## POTENTIALS, LIMITATIONS AND RISKS OF NON- AND PARTIALLY NON-FORMAL LEARNING ENVIRONMENTS IN SCIENCE EDUCATION

This paper discusses two approaches of linking formal and non-formal education. By the inclusion of expert discussions and excursions both also include aspects of informal learning. However, both initiatives are diametrical cases. In the Irish TY science learning is structured and taught by the regular science teachers in their schools. The TY is available in more than 80% of the schools and thus an almost nationally implemented initiative. The courses last a full year, but do not follow any given curriculum or syllabus. Teaching materials are rare and may be difficult to implement given the differing nature of TY science in each school. Teacher preparation for TY science is also under critique. In the German initiative curriculum development is done by scientists and curriculum experts from science education research. The teaching is supported by scientists from the university. However, the non-formal laboratories are only available in certain towns, particularly the bigger cities where universities are located. In this specific case, the modules described here are, so far, only available in the two cities of Bremen and Saarbrücken and as such offered only to schools in these two regional environments. On the other hand specific teaching materials are available that were designed based on a research-funded development strategy. The content and applied are connected to the governmental syllabus and thus to the school curriculum. Teachers get support for preparing their students for the non-formal learning visit and later connecting the learning experience to formal education in class.

The advantage of the Irish initiative is that nearly all students have the chance to apply for the opportunity to learn more varied and contextualised science. Unfortunately it seems that due to lacks in teacher pre- and in-service education the TY does not reach its utmost potential to support and develop science teaching and learning. It is apparent that in the German case the potential is better supported and this manifests in quality. However, this concerns only quality and not quantity. Only a limited number of students will be able to visit any of the non-formal laboratories and will experience very few of these specific topics. This is particularly true of students in rural areas where there is a significant distance to any respective SL. This fact can be viewed quite critically when the SL is made a part of formal school education as the formal educational sector has to provide equity in educational





opportunities for all students. In addition and in contrast to the Irish TY, SL-visits often remain single events and thus long-term effects are unlikely to be gained.

Another aspect that is different is the question how the initiative relates to teacher education. While the German SL, as described here, understands itself as a project to contribute quality education to students it also understands itself as providing implicit teacher pre- and in-service education. Pre-service teachers complete part of the modules during their university programme, learning new content from sustainable chemistry but also familiarising themselves with the pedagogy, such as how to gain value from non-formal educational settings like the SL. The in-service teachers accompanying their students in the university laboratory have chance to update their content knowledge and learn about new experiments and laboratory techniques. In the Irish initiative, implementation was top-down and large scale. It appears that there was an insufficient investment in teacher preparation for teaching TY science and teachers feel overwhelmed and the challenge of carrying out the curriculum development on their own is too great.

Both projects also intend reforming the way science is taught. In Ireland, teachers in the TY are asked to apply a more open, student-centred pedagogy. Single cases reported that more authentic, societal relevant and contextualized chemistry was implemented in TY science courses and inquiry-based learning was applied. Teaching materials in the form of handbooks were developed, offering teachers ideas for more open and student-oriented teaching in science. There is hope that this change in the curriculum approach and pedagogy will be more broadly applied and, in due course, also influence science teaching beyond the TY. However, there is no evidence yet. Also in the German SL project materials were developed encompassing modern approaches in science curricula and pedagogies, namely more inquiry-based, contextualized and societal-related learning in science. Part of the materials and experiments can also be applied in regular classroom learning in schools that have not the chance to visit the non-formal laboratory. There is hope that this will have a positive influence on formal science education independent from non-formal laboratory visits. However, in this instance evidence is also not available yet.

As a final note of caution it should be mentioned that in the changed curriculum approach and pedagogy applied in the TY and SL there may also be an element of risk. If teachers see TY science as something different, alien to normal science teaching they may not apply the modern more student-ori-

ented pedagogy and curriculum orientation throughout their classes outside of the TY. If they believe that TY science is the place for contextualized science and practical learning they may allocate this style of teaching there and do not develop emphasis to apply similarly modern science teaching also in the regular science classes. The same may also be true for the SL visits. Practical work during the SL visit should be an add-on to formal science teaching. Doing practical work during the laboratory visit shall not be used as an excuse to reduce or skip practical learning in regular classes.

## CONCLUSIONS

Both projects described in this paper show that a thorough connection of formal learning with non-obligatory and non-formal settings can be beneficial for the teaching of science. However, both projects show also that this can be done in totally different ways each of them having specific advantages and also limitations. An area-wide offer in schools, as is the case in the Irish TY, has potential to reach nearly every student. But it needs sufficient support and teacher pre- and in-service training to reach its utmost potential. More intense projects, like the German SL seem to work on a deeper level, but are limited in range and influence. What both projects have in common is that they have proven to have potential for the development of innovative teaching and learning ideas and materials. In the long run there is hope that ideas and materials from both of these initiatives will find their way into the more typical everyday science teaching and thus contribute to reform of the curriculum and pedagogy in science education - each in its own specific way.

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