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SCIENCE EDUCATION IN THE 21ST CENTURY: CHALLENGES AND CONCERNS

Edited by
Rachel Mamlok-Naaman & Dvora Katchevich

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Institute of Education, University of Lisbon
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E-mail: sisyphus@ie.ulisboa.pt

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Sisyphus – Journal of Education aims to be a place for debate on political, social, economic, cultural, historical, curricular and organizational aspects of education. It pursues an extensive research agenda, embracing the opening of new conceptual positions and criteria according to present tendencies or challenges within the global educational arena.

The journal publishes papers displaying original researches – theoretical studies and empiric analysis – and expressing a wide variety of methods, in order to encourage the submission of both innovative and provocative work based on different orientations, including political ones. Consequently, it does not stand by any particular paradigm; on the contrary, it seeks to promote the possibility of multiple approaches. The editors will look for articles in a wide range of academic disciplines, searching for both clear and significant contributions to the understanding of educational processes. They will accept papers submitted by researchers, scholars, administrative employees, teachers, students, and well-informed observers of the educational field and correlative domains. Additionally, the journal will encourage and accept proposals embodying unconventional elements, such as photographic essays and artistic creations.

Science Education in the 21st Century: Challenges and Concerns

Introduction by Rachel Mamlok-Naaman & Dvora Katchevich (Editors)

Krajcik, Mamlok and Hug (2001) claimed, that during the twenty century, the topics about which scientists and educators were concerned were: «What is worth learning in science», or «How should students learn science»? Science and educators have continually struggled to make science teaching resemble the practice of science, and yet, there are still textbooks and classroom practices persisting in providing cookbook styles and hands-on activities. The release of the National Science Education Standards (National Research Council, 1996) served as a landmark in identifying a comprehensive set of goals for achieving scientific literacy for all American students.

The National Science Education Standards (NSES) define in broad terms the scientific concepts and processes that all students should know and be able to apply. Most importantly, they provide guidelines for assessing the degree to which students have mastered the content of the standards. In addition, the standards detail the teaching strategies and support necessary to deliver high-quality science education to all students, e.g., inquiry skills. «Inquiry» has been a perennial and central term in the rhetoric of past and present science education reforms in the United States. During the second half of the twentieth century, «good science teaching and learning» has come to be distinctly and increasingly associated with the term inquiry (Anderson, 2002).

Students learn to do inquiry in the context of science content and develop epistemological understandings about the nature of science (NOS) and the development of scientific knowledge, as well as relevant inquiry skills (e.g., identifying problems, generating research questions, designing and conducting investigations, and formulating, communicating, and defending hypotheses, models, and explanations).

The issue consists of six papers. In all the six studies there has been done an effort to find out what should be the best ways to motivate students to study science, and to gain inquiry skills. Some studies (e.g. Fraser, 1982) revealed a positive correlation and a causal relationship between achievement in science and attitude constructs, whereas others revealed no clear (or negative) relationship between attitudes towards learning science and achievement (Osborne & Dillon, 2008). International studies have shown that students' attitudes towards scientific disciplines depend on the extent of their active participation in the learning process.

The main topics of the six studies of this issue are: (1) The link between formal and non-formal learning in science education, (2) students' linguistic heterogeneity in science, (3) poster exhibition as an effective means of support for teachers to introduce contemporary chemistry topics to high school students, (4) argumentation in the chemistry laboratory, (5) chemistry, industry, and the environment in the eyes of the individual and society, and (6) the inclusion of students with special needs in science classes teaching them inquiry-based activities. All the papers deal with studies which have the similar objectives: How can we involve as many students as possible in science studies? How can we bridge the gap between formal and non-formal education? How can create a productive and encouraging learning environment?

We hope, that the variety of the topics discussed in this issue, will present a broad picture of studies in science education which have been done in different institutions and countries, aiming at improving and enhancing students' motivation and learning skills. These studies refer to a large population of students and to innovations in science and in science education in the 21st century. The papers address educators as well as to policy makers, in order to improve and to enhance science education as much as possible.

Rachel Mamlok-Naaman
Dvora Katchevich

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

Nicole Garner
ngarner@uni-bremen.de | Universität Bremen, Germany

Sarah M. Hayes
sarah.hayes@ul.ie | University of Limerick, Ireland

Ingo Eilks
ingo.eilks@uni-bremen.de | Universität Bremen, Germany

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

Nicole Garner | Sarah M. Hayes | Ingo Eilks

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 Germany, 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 societaloriented 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 upmost 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-oriented 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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heterogeneity – challenge and/or opportunity in science education?

Silvija Markic
smarkic@uni-bremen.de | Universität Bremen, Germany

abstract

The following paper focuses on a field of science research which has not yet been thoroughly researched in many countries: mixed languages in the science classroom. This area represents terra incognita in many areas of science education research. First, this paper will define the term heterogeneity and contrast it with the term diversity. According to the literature, one word stands for challenges, while the other highlights the opportunities arising from heterogeneity in science classrooms. The focus here will be on students' linguistic heterogeneity in science. The main part of this paper discusses a collaborative research and development project carried out by in-service science teachers, teachers of German as a Second Language (GSL), and science educators. The project was developed under the framework of Participatory Action Research in science education. It focuses on the development of teaching modules for early lower secondary science (grades 5 to 7, ages 10-13) on different topics, including matter and its properties and water. The teaching modules consequently implement learning content and language as envisioned in the Content and Language Integrated Learning (CLIL) approach. After focusing on linguistic heterogeneity and various means for dealing with it, the question of whether such heterogeneity in science classes represents a challenge and/or an opportunity will be raised and discussed.

key words

Heterogeneity; Language; Challenges; Opportunities.

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Heterogeneity – Challenge and/or Opportunity in Science Education?

Silvija Markic

INTRODUCTION

There is currently a high level of migration from one country to another due to worldwide economic changes («globalization»). Populations in many countries are therefore becoming increasingly diluted and heterogeneous in the ethnic, linguistic and cultural sense. These changes are noticeable in school settings around the world, since classroom heterogeneity is also on the rise. In many countries like the US and Germany, is this effect not a new one. For example, Germany has served as the crossroads of Europe for centuries and has also seen large ethnic changes in its population since the end of the Second World War. These changes have influenced the research occurring in both general and science education. However, since science education research in the US has a long tradition, this field has also affected German research efforts, especially since the publication of such international comparative studies as PISA and TIMMS. Factors covering the changes in school populations have also become much more obvious since PISA and TIMMS were published (Lynch, 2001).

There are many differences in research carried out in this field in different countries. Independent of global location, however, the special research focus almost always tends to delve into students` linguistic skills in the official language(s) of a given country. But the question remains, whether such studies are actually comparable or not. Are the results really transferable between different countries, school systems and pupils? We can use the US and Germany as an example: 1) The English and German languages are widely different, despite their common ancestry. 2) The school systems in both countries differ broadly in their sizes, amounts of resources, school laws, curricula, educational foci, organization, etc. 3) The chances for successful entry into and learning success within such systems for students with migration backgrounds vary widely at the State and national levels. 4) The ethnic, cultural, economic, educational, etc. backgrounds of both foreigners and second- or third-generation citizens are not comparable. The US currently has large numbers of Latin and South Americans, however, immigrant groups include people from all around the world. Germany has mainly Turkish, Arabic, Polish and Russian minorities with smaller numbers from Greece, Italy and Spain. 5) The «degree» of migration differs. In the US pupils tend to be mainly from either newly-arrived or refugee families. In Germany students were to a large extent born in Germany, but have parents who immigrated coming from another country.

With all of the above differences and varying national reactions to increasing diversity, the main question should be whether such heterogeneity is something that should be viewed as a burden or rather be perceived as an opportunity when it comes to science education. Furthermore, we must also recognize that the terms used to describe such differences vary widely and are not universal in their application.

This paper presents a project by the University of Bremen in which in-service science teachers and science researchers have taken up the challenge of linguistically heterogeneous classes and used it as an opportunity for continuous professional development.

CLARIFICATION OF THE TERMS

In the research literature for science education, two terms dominate the discussion dealing with varying student requirements for successful learning: h*eterogeneity* and d*iversity*. The choice of the definition often depends both on the research tradition in the country where the study originates and the overall context of the study. However, the terms are used as separate constructs, which frequently overlap and then become synonyms. Studies performed in

English-speaking countries mainly use the term «diversity». As mentioned above, this field of research has a longer tradition than research efforts in Germany. The National Education Association (NEA) defines diversity

> (…) as the sum of the ways that people are both alike and different. The dimensions of diversity include race, ethnicity, gender, sexual orientation, language, culture, religion, mental and physical ability, class, and immigration status. While diversity itself is not a value-laden term, the way that people react to diversity is driven by values, attitudes, beliefs, and so on. Full acceptance of diversity is a major principle of social justice (http://diversity.dpsk12.org/definitions).

Since educational research in this field in Germany is not that old, the terms heterogeneity and diversity are often understood to be synonyms of each other. Many different perspectives can be labelled as «heterogeneity» and «diversity». However, differences in understanding these two terms and the paradigms hidden behind them are slowly beginning to emerge in Germany's educational world. School systems are also being influenced by the decision to move schools more firmly in the direction of «inclusion». «Whereas the paradigm of heterogeneity perceives difference as a challenge to be dealt with actively, diversity as a systemic paradigm perceives difference as an asset» and a resource for learning (Sliwka, 2010, p. 213, Figure 1).

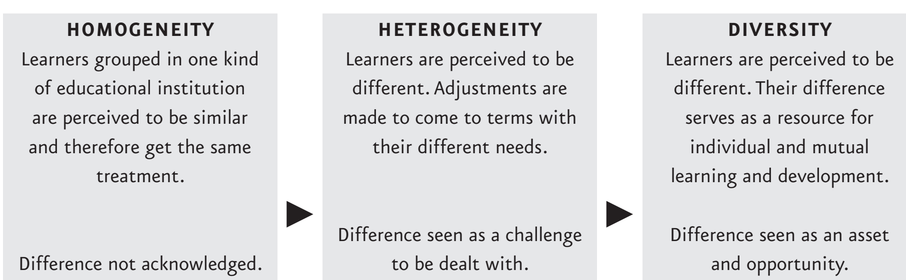

FIGURE 1 – PARADIGM SHIFT FROM HOMOGENEITY TO HETEROGENEITY TO DIVERSITY (SLIWKA, 2010, P. 214).

Looking at the possible differences which students in the classroom may bring with them, we quickly recognize a broad spectrum. Students possess many different, often highly individual prerequisites in the classroom and an ideal teacher is supposed cope with each and every one. These differences are multifarious among the student body, but they also overlap in many areas. In the American literature these differences are summarized in eight main dimensions which are represented as «The Big Eight». Krell, Riedmüller, Sieben and Vinz (2007) listed the following eight dimensions as important: age, gender, ethnicity, religion, race, sexual orientation, functional role, and mental/physical ability. Another representation commonly employed is the diversity wheel, which is mostly used for diversity management in large organizations. It distinguishes between internal and external dimensions (see Figure 2).

The different dimensions of diversity and the concepts presented by Sliwka (2010) give us one possible starting point. We might suggest that since we are concerned with the language and science classes, we should positively focus on linguistic heterogeneity instead of linguistic diversity. Language in the science classroom represents much more of a challenge than is commonly perceived, since science teachers can't use pupils` poor linguistic skills as an asset so that other students can learn more. (This is definitely not true for language classes.) However, other dimensions such as culture can be viewed as opportunities in teaching and learning. They can serve as a resource for the individual while also supporting mutual learning and development processes.

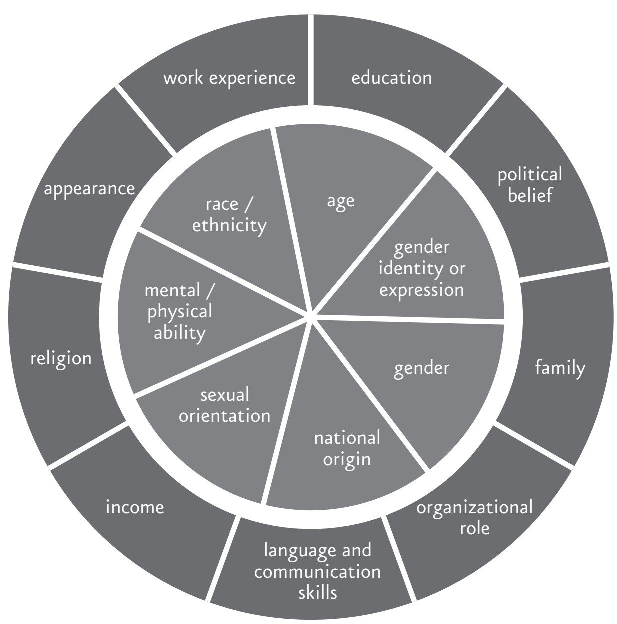

Figure 2 – Diversity wheel (retrieved January 1, 2014, from http://web.jhu.edu/dlc/resources/diversity _ wheel/)

DESCRIPTION OF THE PROJECT

About four years ago, a group of in-service teachers combined with education researchers from the University of Bremen to look at the issue of heterogeneity in the classroom. They used the difficulties faced by students with poor linguistic skills and the subsequent problems confronted by teachers when teaching in linguistically heterogeneous classes as a starting point for their study. The research and development project aims to develop both new teaching methods and learning materials for linguistically sensitive science classes. The effort includes research on the effects of such products on teaching and learning. There are different goals that newly-developed lesson plans that should attain:

1. The lesson plans should develop teaching methods and learning materials for linguistically heterogeneous classes.
2. These lesson plans should help students to develop a linguistic basis for learning and correctly employing scientific language without making linguistic mistakes.
3. The lesson plans should aid teachers in supporting communication between students by helping pupils express themselves in both proper German and scientific language terminology, for example, «mass» instead of «weight».
4. The new lesson approach and learning materials developed should combine both content and language using Content and Language Integrated Learning (CLIL) along with cooperative and autonomous learning.

From this initial starting point the main research question emerges:

> To what extent it is possible to simultaneously learn scientific methods, terminology, content matter and the German language as the students work in a cooperative, autonomous learning environment?

This project is based on the Participatory Action Research (PAR) method of science education (Figure 3) (Eilks & Ralle, 2002). PAR is a joint effort between teachers and science educators for curriculum development, educational research, and classroom innovation. This allows different competencies to meld together into new developments of teaching practices.

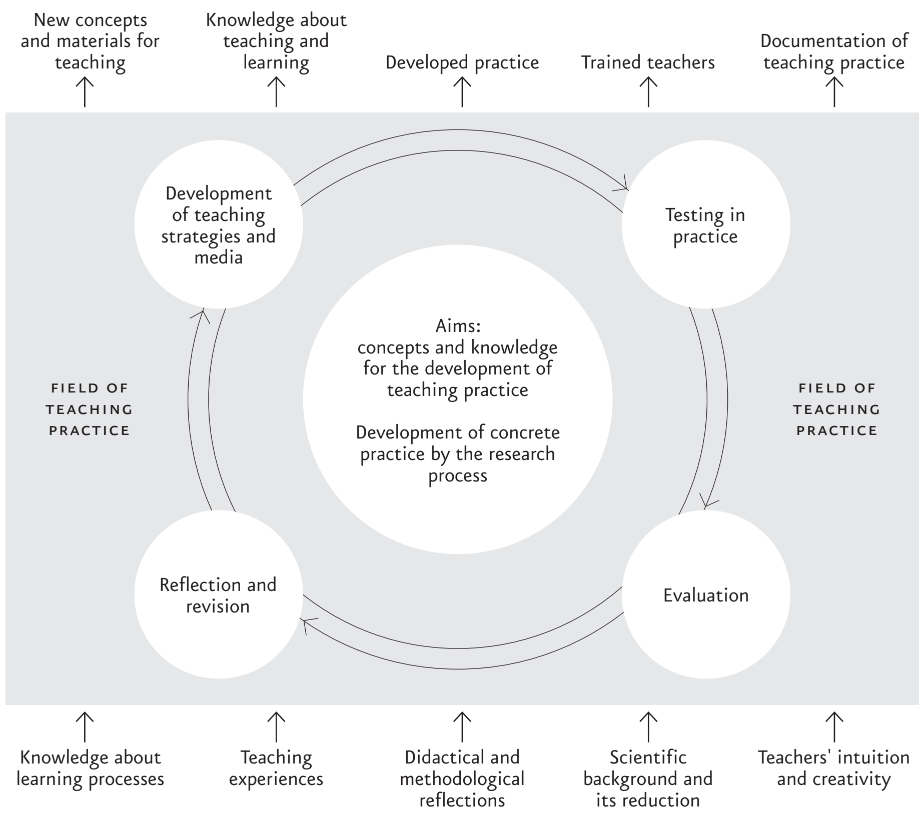

FIGURE 3 – PAR IN SCIENCE EDUCATION

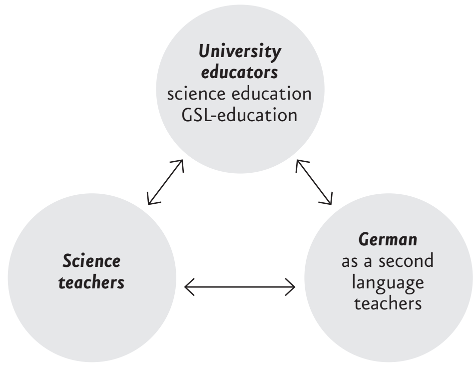

FIGURE 4 – PAR GROUP IN THE PRESENT PROJECT

Time	Activity
May 2010	analysis of relevant literature; collecting ideas for methods and experiments; first provisional structuring
End of June 2010 (Meeting of the group)	presentation of the provisional lesson plan; negotiating and restructuring the first part of the lesson plan; collecting ideas for structuring the second half
July to August 2010	revising the lesson plan
September to October 2010	testing of the lesson plan in two learning groups; observation of the lessons by one university researcher and teacher self-reflection after each lesson
Mid of November 2010 (Meeting of the group)	reflection on first experiences with the whole group of teachers; negotiating the test and students questionnaires
November to December 2010	testing occurs in another learning group; test and student questionnaires
Mid of December 2010 (Meeting of the group)	reflection in the whole group
January to June 2010	testing in another three learning groups occurs; test and student questionnaires

TABLE I – DEVELOPMENT AND EVALUATION

This paper describes the results of a group of eight Chemistry teachers and three German as Second Language (GSL) teachers from different schools, who collaborated with a university researcher (Figure 4). The group meets regularly every four to five weeks and has been developing lesson plans concerning CLIL for roughly four years. At the group meetings, changes in teaching practices are proposed, negotiated, and refined so that the resulting structures can be tested and applied in classroom situations before being reflected upon and improved.

Up to now six different lesson plans have been developed using this model. The development and evaluation of two lesson plans called «Matter and Its Properties» and «Water» will be presented in this paper as examples. Table 1 offers an overview of the development and evaluation process for the lesson plan «Matter and Its Properties».

Multidimensional triangulation was performed to arrive at an answer to our research question. All of the groups that implemented the lesson plans were continuously accompanied by and observed by university researchers, who were actively developing the lesson plan. Furthermore, after each lesson a self-reflection exercise (an interview by an observer from the university) was completed by the teachers and recorded. These experiences were regularly discussed by the entire PAR group. Finally, students were asked to write a short text based on their personal knowledge. This exercise was developed by the teacher group, based on the teachers` own experiences and knowledge. Additionally, a student feedback tool was collected, which combined an open and a Likert questionnaire.

LESSON PLAN EXAMPLES

MATTER AND ITS PROPERTIES

The lesson plan «Matter and its Properties» occurs in two phases: (I) experimentation and (II) exchange. In the first phase students are divided into two groups: chemists and physicists. Both groups must work at stations and conduct experiments on the properties of matter. The chemists focus on the chemical properties of matter and the physicists concentrate on physical properties. Both groups are structured around a research folder containing helpful materials. The folder is very similar in both cases. The first page lists all of the materials needed to carry out the experiments. As a language aid, German vocabulary and definitions are provided in the appendix, including pictures of the laboratory equipment with the definite (der/die/das) and indefinite (einer/eine/ein) articles for German masculine, feminine and neuter nouns in both the singular and plural forms. This is important, since many German words undergo both spelling and pronunciation changes and/or receive new word endings in the plural form. Every worksheet begins with a sentence describing the aim of that particular station. Linguistic aids are offered for topics which the teachers in the group viewed as necessary.

In the second phase, the original groups from the first phase are mixed to form new groups. In this phase, two chemists and two physicists must work together. Their job is to exchange the relevant knowledge which they individually discovered in their original role. They must also work cooperatively to fill in an exercise book covering both topics.

The entire lesson plan is also supported by laminated «Help Cards» (different levels) and «Solution Cards», both of which are available on the teacher's desk in case students reach an impasse.

WATER

This lesson plan is also divided into experimentation and exchange parts. In the first phase students must work on a research folder which has been constructed to cover the different properties of water. Similar to the previous lesson, the first page lists all the materials needed to carry out the experiments. German vocabulary and definitions are also provided, as well as the definite and indefinite articles for German masculine, feminine and neuter nouns in both the singular and plural forms. Students must work in groups of two in the learning at stations method. Every station is based on a single experiment and contains exercises on the station topic. However, each exercise aims at both repeating and building upon knowledge, while simultaneously improving students' German language proficiency. This is why every exercise includes a short problem requiring practice in the German language. The experiments are mainly presented as a drawings or a sequence of pictures. To acquire the necessary skills in writing a protocol, pupils are aided by «Help Cards» at nearly every station. This allows students to actively decide whether or not they need help and what learning level the help should take place.

In the second phase of the lesson plan, content matter from chemistry and biology is combined. Students must work on their research folders again, but now the method consists of «think – pair – share». First, students are required work on the characteristics of four different animals. Information concerning important details for each animal is provided. The information is specifically based on the properties of water, e.g. water striders using water's surface tension to keep themselves afloat. After working out the details, the learners must work on exercises inquiring into the characteristics of the different animals, and then combine this knowledge with the information on the properties of water. These exercises are strongly linked to exercises in the German language. In this phase students can rely on the «Solution Cards» that are offered. It is important that the learners know that they can receive aid, but that they are not forced to do so.

Different methods borrowed from German as a Second Language lessons were employed in the lesson plans. From the vast available repertoire some examples are (see for more in Markic, Broggy & Childs, 2013):

- Simple phrasing (1-sentence constructions);
- List of Vocabulary (with article, plural);
- Words for helping to write observations and discussions;
- Beginnings of sentences provided;
- Connecting the parts of sentences;

- Example sentences as thought provokers;
- Drawings as explanations instead of words;
- Cloze-sentences.

SAMPLE

The testing and evaluation phases were carried out using six learning groups (grade 5; age range 10-11) with a total of 119 students for «Matter and Its Properties». The lesson plan «Water» was tested in four classes (grade 5; age range 10-11) in different schools in the city-state of Bremen, Germany. All of the schools who took part in the study are located in the suburbs of Bremen. This is significant, since the residents in these areas tend to have both a lower than average educational background and social class and generally include a large percentage of people with migration backgrounds. Table 2 presents some of the characteristics taken from the sample.

Table 2 makes it clear that many students come predominantly from migration backgrounds and that a very high percentage of students do not speak the German language at home. Unfortunately, further information about students with a German background cannot be given. Some information about the pupils' competency in the German language could be provided by the science teachers in cooperation with their German language colleagues. The German students taking part in our study generally show poor German language proficiency, particularly when it comes to expressing their own knowledge in writing and creating proper sentences. They tend to come from families with low levels of education.

Characteristic		Matter and its properties (N=119)	Water (N=93)
Sex	Female	72 (60.5%)	35 (38%)
	Male	47 (39.5%)	58 (62%)
Students with a migration background		67 (56.8%)	63 (67%)
German not spoken as the home language		45 (37.8%)	56 (60%)

TABLE 2 — SAMPLE CHARACTERISTICS

RESULTS

The final knowledge test was pre-structured by the teachers according to their personal teaching experiences. Scoring was based on the pre-structured pattern for evaluating the test. The majority of students passed the test successfully, thereby achieving scores higher than 50% of the total available points. A high percentage of all student groups had scores of «good» or «very good». A total of 84% of the participants achieved more than 80% of the total points possible. Such achievement was considered to be a quite remarkable factor by the teachers.

When starting to develop the lesson plans, the teachers were very reluctant to use autonomous teaching strategies for students with language shortfalls. The teachers also expressed considerable fears about leaving pupils alone in a cooperative learning environment, particularly because of the linguistic issues faced by many students. This was not merely due to the specific scientific topics, but also because their learners would simultaneously have to deal with difficulties arising from their deficient German language skills. Nevertheless, the teachers were open to experimentation when it came to applying the scheme. After teaching and reflecting upon the lessons, the teachers' attitudes towards teaching linguistically heterogeneous classes in cooperative, autonomous lessons changed quite considerably. They were happy with the end-product, with the openness of the lessons, and with the overall motivation of their students. This reaction consistently fits in with the feedback given by the students. The learners judged the lessons to be remarkably good, especially concerning aspects such as: help in verbalizing of their own ideas and knowledge, the autonomy of learning, and structured cooperation and communication. In particular, they mentioned that the materials had helped them to better understand the topic both by themselves and within their peer-group. During the lesson plan it was easy to observe that students were proud of themselves and of their own work. They also agreed that their ability to express their own ideas and results in proper German had grown commensurately.

During the development process of the lesson plans, it was easy to observe how the teachers directly influenced the learning process. They considered the potential difficulties which they would encounter in the overall approach and suggested appropriate corrective changes. Furthermore, the differing competencies and experiences combined by teachers of science and GSL during the process complemented one another. The teachers did not focus solely on developing materials which increased the students` scientific knowledge. Instead, they allowed the researchers to sufficiently address and undergird additional factors. These included the simultaneous enhancement of the learners' German and scientific language skills while the pupils were actively engaged in assimilating specific, scientific content knowledge. More details about the studies are to be found in Markic (2011, 2012).

CONCLUSIONS AND IMPLICATIONS

Although the knowledge test in the present study is limited in its scope in terms of judging long-term learning effects, the short-term results provided a good baseline for measuring whether students can understand topics on their own. Students' comprehension of topics includes their ability to express themselves more easily and correctly in the German language. The initial data seems very promising for implementation of further lesson plans and units which combine the learning of scientific knowledge, German language skills and cooperative learning methods.

Despite the process of collaborative development being new for both teachers and students, each group dealt with it in an autonomous fashion, aided by the newly-created teaching materials and aids. This also held true for the aspects focusing on teaching the German language and the teaching methods selected. The students were able to cooperatively manage the lesson plan, despite initial doubts expressed by some of the teachers. The expectations of the teachers, which had been recorded in a pre-structured test, were exceeded by the pupils, most of whom achieved unexpectedly positive cognitive results.

Cooperative efforts between science and GSL teachers appear to provide attractive possibilities for developing new teaching materials which support linguistic heterogeneity in Chemistry lessons. Researchers also had a chance to exchange their personal experiences with linguistic difficulties, their knowledge of their students, and any pertinent interdisciplinary information, including methodologies. Furthermore, cooperation between experts stemming from multiple disciplines offers a promising path for creating motivating, highly attractive learning environments. This can bolster science teachers as they attempt to aid their students in simultaneously mastering both scientific content knowledge and German language skills.

After summing up the ideas above, our question still remains: If heterogeneity is viewed solely as an overwhelming challenge for science education, can we ever move forward from the negatively-focused paradigm surrounding such a viewpoint? This becomes especially relevant in light of the fact that classroom heterogeneity will only become more pronounced in a globalizing world, whether we recognize the problem or not, whether we like it or not, and whether we adequately address the issue or not. In Germany, for example, one person in five is either a foreigner or is a German national from a family with a migration background. This fact will not simply go away. The modern cultural and linguistic complexity in our schools will continue to increase, regardless of which country you live in.

The above question is also of paramount importance, because the general goal of education in many countries has been shifting increasingly towards «inclusion», which starts from the idea of diversity. Inclusion programs add such factors as physical, emotional and mental disability, often severe psychological and behavioural problems, general learning difficulties such as dyslexia, ADD, etc. to the mix. These factors will further combine with background linguistic issues to make the teaching and learning landscape in our schools even more complex and unnavigable.

It is our belief that heterogeneity should not be ignored as a possible challenge to current teaching methods and practices. However, such heterogeneity can also serve as an opportunity and a catalyst to spur on educational decisions and more effective classroom practices for the future. The project described here shows that it is possible to view linguistic heterogeneity as a negative challenge, if the definition in the opening paragraphs is selected. However, the project also reveals that linguistic heterogeneity in science classes can also serve as a door of opportunity in different ways. First of all, poor linguistic skills can help science teachers to redefine the aim of their science lessons and to rethink their teaching materials. Furthermore, it offers science teachers an opportunity to reflect on their own teaching behaviour when it comes to teaching in a language-sensitive manner. This is very important for most teachers, since they (especially in the German context) tend to be mainly monolingual. Different studies have focused on this point. In her study, Moore (2007) interviewed three teachers. She came to the conclusion that the teachers she interviewed were sensitive to the influence of language on students` language. However, this was the case because interviewees were all Native Americans who had experienced exactly the same thing during their own time at school. The teachers in Moore's study see language as a barrier for students to learn and understand science. Studies from Cho and Mc Donnough (2009) also support this. However, the science teachers in their study were specially trained to teach English Language Learners (ELL).

The project also shows that the issues addressed by linguistic heterogeneity in the science classroom can (or to put it more provocatively *should*) be seen as an opportunity to «look past our own noses» and see what is happening in other teaching domains like linguistic science. The tools and methods which are used in the above-mentioned lesson plans are not new for GSL teachers, but they do represent largely uncharted territory for science teachers. This paper shows that cooperation between science and language teaching provides us with an opportunity to see what is happening in other teaching domains and to adapt this knowledge for our own classrooms (compare also Verplaetse, 1998).

Finally, this project also reveals that dealing with linguistic heterogeneity in science classrooms can be an opportunity for continuous professional development (CPD). As Mamlok-Naaman and Eilks (2012) have shown, the Participatory Action Research method is good for promoting continuous professional development. The current study presented here supports this idea and shows that collaboration between teaching colleagues is a good way for science teachers to develop more sensitivity to their students` poor linguistic skills, while simultaneously developing their own competencies for dealing with this issue in their classes. On the other hand, the exchange cuts both ways. This is also an opportunity for GSL teachers to gain insights into science lessons and to use this knowledge in language lessons by focusing on the language of science.

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CHEMISTRY TEACHERS INTRODUCE HIGH-SCHOOL STUDENTS TO ADVANCED TOPICS USING A POSTER EXHIBITION OF CONTEMPORARY ORGANIC CHEMISTRY

Ron Blonder
ron.blonder@weizmann.ac.il | Weizmann Institute of Science, Israel

Inga Meshulam
inga777@bezeqint.net | Weizmann Institute of Science, Israel

ABSTRACT

The 21st century presents many challenges for chemistry educators. Chemistry as an evolving entity is not reflected in the existing high-school chemistry curriculum. The goal of the current study is to examine teachers' perceptions regarding introducing advanced topics in chemistry for high-school students by using a poster exhibition of contemporary organic chemistry. Four different groups of chemistry teachers participated in the study. The groups differ in their Content Knowledge (CK), and their experience in using the poster exhibition. The poster exhibition served as an effective means of support for teachers when high-school students were introduced to contemporary chemistry topics. CK was found to be an important component that positively influences teachers' self-efficacy for using the poster exhibition in their class. However, the teachers' CK was insufficient; the feelings of ownership and mastery experience are also important influential components that should be considered.

KEY WORDS

Chemistry education; Professional development; Modern chemistry; Poster exhibition; Teacher knowledge; Ownership; Teaching efficacy.

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Chemistry Teachers Introduce High-School Students to Advanced Topics Using a Poster Exhibition of Contemporary Organic Chemistry

Ron Blonder | Inga Meshulam

INTRODUCTION

Chemistry as an evolving entity is not reflected in the existing traditional high-school chemistry curriculum. The existing curriculum usually presents chemical concepts that were developed more than 100 years ago. However, different attempts have been made to integrate contemporary scientific content and methods into high-school chemistry: (1) Advanced laboratories invite classes of high-school students to use modern instrumentation (Blonder, Mamlok-Naaman & Hofstein, 2008); (2) Scientists come to schools and lecture about their research (Kapon, Ganiel & Eylon, 2009); (3) Science educators use adapted research literature (Yarden, Brill & Falk, 2001). These three methods, which are used for integrating contemporary chemistry (and science) into the existing curriculum, represent the role of scientists: They perform experiments in their laboratory, and communicate their results at scientific conferences (lectures) and in scientific journals (articles). However, scientists also use additional communication channels to present their research: scientific posters. The poster is a visual means that is used to briefly present scientific research at conferences (Stephen, 2011). The current study focuses on teachers' content knowledge, which supports them in using poster exhibitions of contemporary science in their classes.

The critical role of teachers in attaining the goal of quality education in the sciences is highlighted in the research literature on education. A recent international policy document written by Osborne and Dillon (2008) reflects a consensus on the importance of teachers:

> Good quality teachers with up-to-date knowledge and skills are the foundation of any system of formal science education. Systems to ensure the recruitment, retention, and continuous professional training of those individuals must be a policy priority in Europe (Osborne & Dillon, 2008, p. 25).

The notion of teachers' knowledge first came to prominence a quarter of a century ago (Shulman, 1987), and there has been a plethora of literature on what teachers know and do in order to carry out their work (Mulholland & Wallace, 2005). By acknowledging the central role of teachers in teaching, the teachers' use of knowledge places the practicing teacher at the heart of attempts to reform classrooms and improve student achievement. However, although there is much agreement about the importance of teachers' knowledge, there has also been numerous discussions, debates, and concerns regarding how teachers' knowledge is constructed, organized, and used (Kennedy, 2002; Kind, 2009; Munby, Russell & Martin, 2001). Many teachers completed their formal education a long time ago. As a result, their science knowledge and knowledge of important recent developments regarding science teaching (pedagogical knowledge and knowledge of new learning environments) are rather limited. This inhibits their ability to implement curricula that require contemporary scientific and pedagogical knowledge and to teach at an appropriate level and with the appropriate methodology (Van Driel, Verloop & De Vos, 1998).

Research findings on the effectiveness and professional development of teachers underscore the importance of teachers' knowledge and professional enthusiasm, as well as their pedagogical knowledge (Munby, Russell & Martin, 2001). What teachers know and how this knowledge distinguishes them from other knowers of particular subjects was defined by Shulman (1986, p. 9) as Pedagogical Content Knowledge (PCK), «which goes beyond knowledge of the subject matter… to the dimension of subject matter knowledge for teaching». Since then, PCK has come to be thought of as a special amalgam of subject matter knowledge and knowledge of pedagogy, long considered as separate, used in a type of professional understanding unique to teachers (Shulman, 1987).

In many respects, the work of Dewey (1902) foreshadowed the concept of PCK. According to Dewey, teachers' subject-matter knowledge differs from that of other individuals. The teachers were concerned not with subject matter for its own sake, as were other scholars, but rather, with subject matter as only one part of the whole spectrum of educational experiences that a learner undergoes. So important has the notion of PCK become, that in more recent times, researchers have called for subject matter knowledge to be taught to teachers as PCK in order for teachers to more readily transform their own understandings, so that they are suitable for teaching (Marks, 1990). Researchers have long debated the knowledge categories to be included as part of PCK and various definitions of it have evolved since Schulman's initial description (Van Driel et al., 1998). However, the notion of PCK has come to epitomize the computer or the knowledge-based metaphor of teachers' knowledge. In the two ensuing decades since Schulman's early work, the knowledge base movement has developed into a major effort to study the essential components comprising the knowledge base, and with the aim of determining how they affect it. Lists of such knowledge types, clustered in different ways and with different emphases, abound in the literature. They include content knowledge, general pedagogical knowledge, curriculum knowledge, pedagogical content knowledge, knowledge of learners, knowledge of educational contexts, knowledge of educational aims, purposes and values, and moral dispositions. However, it is difficult to isolate specific elements of teachers' knowledge in research situations, because teachers have a holistic or integrated understanding of their work (Loughran, Milroy, Berry, Gunstone & Mulhall, 2001). The concept of PCK, for example, has fuzzy boundaries, which presents a challenge to those who attempt to add knowledge to its categories (Gess-Newsome, 1999). One of the difficulties associated with making more use of PCK lies in its elusive nature. According to a recent review by Kind (2009), pedagogical content knowledge is a 'hidden' concept, although it is a useful construct, and determining what it comprises and using this knowledge to support good practice in teacher education is not easy. Moreover, inconsistencies and disagreements persist concerning PCK, resulting in no overriding consensus about how this can best be used to describe effective science teaching. In Kuhn's (1962) terms, the PCK research field is still at the 'pre-science' stage; therefore, despite having been researched for over twenty years, it is not ready for wider dissemination (Kind, 2009).

OUR STUDY

Based on the above, a program for enhancing chemistry teachers' content knowledge as well as their pedagogical content knowledge was initiated at the Weizmann Institute of Science in Israel. The Rothschild-Weizmann Program for Excellence in Science Teaching was established for the academic and professional development of science and mathematics teachers in Israel. A two-year program for earning a M.Sc. degree in science teaching was established within the Feinberg Graduate School at the Weizmann Institute of Science.

The chemistry program consisted of three main topics: chemistry, science education and laboratory experience. The chemistry courses were specifically designed, and included three stages in which the teachers attended (1) the course lectures, (2) a 'follow-up' tutoring lesson, which was prepared especially for them by one of the staff scientists and was aimed at elaborating on the course lecture, and (3) a workshop coordinated by a researcher from the science teaching group, in order to apply the scientific knowledge to the educational field (Mamlok-Naaman, Blonder & Hofstein, 2010). The model reduced the teachers' anxieties resulting from taking academic scientific courses; they gained modern and advanced scientific content knowledge, and succeeded in applying it in their teaching. The chemistry courses were chosen to represent advanced and modern chemistry topics that are associated with the chemistry curriculum (e.g., medicinal chemistry, nanotechnology, materials, advanced organic chemistry, and chemistry of proteins). The science education courses included issues such as an introduction to chemistry education, inquiry-type teaching and learning, the diversity of assessment methods, etc. In addition to the courses, a laboratory experience was scheduled for the summer vacation. Every chemistry teacher spent two weeks in one of the laboratories, was involved in specific research, and wrote a report. The teachers were also asked to suggest how the research, in which they were involved, could be applied in their classes.

COURSE DESCRIPTION

In the current study we focused on the product of the third stage of the three-stage model: adapting the scientific knowledge to the field of education in the 'Organic reactions used in the total synthesis of natural products' course.

The three-stage model in this course included the following stages:

Stage 1 – Lecture: An advanced course in organic chemistry was given by Prof. Hassner in the form of conventional lectures. The course was open to M.Sc. students (the course was given three times at the Weizmann Institute of Science) whose work focuses on organic synthesis as well as to those chemistry teachers who were engaged in the M.Sc. program for chemistry teachers. The lectures included oral explanations that were taught together with organic chemistry equations that the lecturer wrote on the blackboard. A written exercise was given after every lesson. The evaluation of the course used a test that consisted of questions that were similar to those that were given in the exercises.

Stage 2 – Follow-up: a tutoring lesson was given after each lecture by an assistant staff scientist in the organic chemistry department of the Weizmann Institute of Science. This lesson was given separately to the teachers; the chemistry M.Sc. students had a different tutor.

Stage 3 – Adaptation to education: This session was conducted by the author, a researcher in the chemistry education group; she has a PhD in chemistry. The emphasis of this session was on applications in two dimensions: applying the advanced chemistry content to the field of education, and using the material to solve the exercises. Adaptation to education sessions was carried out as workshops in which the students (the chemistry teachers) usually worked in pairs and an educational guide aided their learning.

Assignment of stage 3 – The assignment was changed for the three cohorts that took the course. In the first cohort the teachers were asked to produce a poster that presents one concept or one synthesis that they learned in the course, which is appropriate for high-school students. As a result, seven posters were designed and printed. The second cohort was asked to design an activity for high-school students using the exhibition of the seven posters. The third cohort was asked to design an activity and to use the poster exhibition in their class. The posters in the poster exhibition are described in Table 1 (see next page).

Poster preparation and poster components

The posters were part of the course assignments of the first cohort; each teacher had to choose one of the course topics and to produce a poster. These posters were

Poster title	Advanced subject matter	Basic concepts	Connections to everyday life
β-Lactam rings: the key for new antibiotics	Staudinger reaction	Synthesis of β-Lactam Penicillin structure	Antibiotics and its role in modern medicine
Carbocation equivalents and the secret of the orange smell	Acyl anion equivalents Asymmetric reactions	Chirality	Fragrances
The connection between retrosynthetic analysis and the way detectives solve crimes	Retrosynthetic analysis of a complicated example	Simple organic reactions	Crime Scene Investigation (CSI), reflective thinking
Mimicking nature using chemistry	Robinson annulation reaction	Chirality	Chemical ingredients used by man
Hydroboration in serving mankind	Hydroboration	Alcohols and their properties	Commercial medicines: Ventoline, anti-cancer treatment, antifungal cream, and more
What is the connection among organic chemistry, umpolung, and vitamin B12?	Acyl Anion Equivalent, the Umpolung principle	Carbonyl group, aldehydes, Krebs cycle	B12 Vitamin
Chemical dartboard	Directed aldols, Asymmetric reactions, protection groups	Functional group, enolate inion, nucleophilic addition	Mimicking nature by chemical synthesis

TABLE I – DESCRIPTION OF THE POSTER EXHIBITION ACCORDING TO ITS COMPONENTS

intended to help them teach the specific topic to their high-school students. The teachers were guided by the course tutor and by the educational guide regarding (1) choosing a topic, (2) finding a component that was connected to students' everyday life, and (3) integrating basic chemistry principles and concepts. The teachers (the first cohort only) presented their posters to those colleagues who participated in the program. Table 1 presents an analysis of the posters, showing different parts: the advanced subject matter that they chose, the basic concepts, and the connection to everyday life. The posters are shown in Figure 1.

RESEARCH QUESTIONS

Concerned with the lack of instructional materials for introducing cutting edge chemistry to high-school students, we were interested in determining whether this poster exhibition could be used by teachers other than those who developed it. Therefore, we investigated the following research question:

1. What knowledge do teachers need in order to be able to use the poster exhibition in their class?
2. What influences teachers' self-efficacy beliefs regarding their ability to use the poster exhibition that presents cutting-edge chemistry to high students?

The study will focus on different components of teachers' knowledge and their beliefs regarding their ability to present the poster exhibition to high-school students.

FIGURE I — THE SEVEN POSTERS IN THE POSTER EXHIBITION, PRESENTED IN THE SAME ORDER AS IN TABLE I

METHODS

Participants: Four teacher groups participated in the study, as presented in Table 2. All the teachers in the study are experienced chemistry teachers (having more than 10 years of experience). The first three groups of teachers were students in the Rothschild-Weizmann Program for Excellence in Science Teaching. The first cohort of teachers took the course and created the posters for the exhibition. The second cohort took the course and planned a student activity based on the poster exhibition. The third cohort took the course, planned a student activity, and performed it with their students. The last group includes leading chemistry teachers with second degree in chemistry. Teachers in this group did not participate in the course.

Teachers' group	Number of teachers	Took the advanced course	Created posters	Used the poster exhibition
(1) First cohort	7	+	+	-
(2) Second cohort	18	+	-	-
(3) Third cohort	11	+	-	+
(4) Leading teachers	17	-	-	-

TABLE 2 — CHARACTERIZATIONS OF THE DIFFERENT GROUPS OF TEACHERS

DATA COLLECTION AND ANALYSIS

Teacher Interview

Semi-structured interviews were conducted with the first cohort of teachers (group 1) at the end of the year. The interviews (60 min each) included two parts (Fontana & Frey, 1998). In the first part they were requested to freely describe how they apply their academic learning. The second part was semi-structured and guided the teachers to focus on and to express their opinion regarding the poster exhibition that they created. This part included the following questions:

- Do you plan to use the organic poster exhibition with your students? Please explain.
- What support do you need in order to use the exhibition in your class?
- In your opinion, what could the students gain from this kind of activity?

The interviews were audio-recorded, transcribed, and then analysed by the first author of this paper according to three main categories that emerged from the teachers' interviews: (1) their «feelings» towards the poster exhibition, (2) their perceptions regarding the content of the poster, and (3) their perceptions regarding using the exhibition in their classroom. The initial analysis was followed by a secondary analysis conducted by an expert in science education research who re-read the interview transcription and commented on unclear category attribution. Then, the two researchers discussed the results until they reached a consensus. Interviews were analysed to determine the extent to which the teachers planned to implement the poster exhibition in their chemistry lessons. Finally, those factors that influenced their plans were identified.

Reflective Report

The assignment that was given to the teachers in cohorts 2 and 3 (groups 2 and 3) was to develop an activity in which they will implement the poster exhibition in the chemistry lessons. Group 2 was only requested to design the activity, whereas group 3 was requested to design an activity and to try it out in class. Teachers in the two groups were requested to describe the activities that were developed and to identify the following:

- The goals of the designed activity
- The pro and cons of using the poster exhibition with high-school students
- If they plan to use the poster exhibition and try your activity with your students next year

Teachers in group 3 that tried the activity in class as part of the course assignment were also asked to evaluate the success of their activity and to bring evidence to evaluate its success.

The three categories that emerged in the interviews were used to analyse the reflective reports.

Questionnaires

One of the teachers from the first cohort (the second author) designed an activity based on the poster exhibition for her students. A group of 17 leading chemistry teachers (group 4) were invited to participate and learn about this activity. This activity lasted two academic hours and included a guided reading of the posters, which were hung on the wall of the classroom. Then the leading teachers were requested to choose one of the posters and to deepen their understanding by following a student's work sheet. After the activity, the leading teachers were asked to fill out a questionnaire. In the questionnaire they were asked to describe their professional background and to answer the following questions:

- Did you find the poster exhibition activity to be interesting for you as a learner?
- Would you like to introduce this activity to your students? Please explain.
- What are the pitfalls of such an activity?
- What are the advantages of introducing high-school students to the poster exhibition?

In addition, the questionnaires were analysed according to the categories that emerged from the interviews.

Follow-up Short Interview

All the teachers from the four groups were interviewed one year after the third cohort completed the MSc program. The 30-minute short interviews were audio-recorded and transcribed. The goal of the follow-up interview was to learn whether the teachers actually used the poster exhibition in their class. The teachers were first asked to describe their feelings and what they have done in school since the last time that they have been at the Weizmann Institute of Science. Then they were asked if they made use of the poster exhibition as they had planned. These interviews were used for collecting technical information and therefore inter-rater validity was not required.

RESULTS

The results will be presented according to the different teacher groups in order to identify differences between teachers' knowledge and beliefs.

THE FIRST COHORT

The teachers in this group took the advanced organic course and designed the posters in the «adaptation to education» stage of the course.

(1) Teachers' «Feelings» Towards the Poster Exhibition

Most of the teachers in this group exhibited positive attitudes towards the poster. They created the posters, they are very familiar with them, and they even like them, as reflected from the following examples:

> One of the activities I plan to do with my students next year is to use the poster exhibition. I am familiar with the posters…

> I really like the posters – they are really good considering their content and their design.

> The colours of the posters make the exhibition very attractive and I love to see them all together creating a rainbow.

> I worked very hard to prepare my poster and the result is beautiful. Actually, I think that all the posters are great and very appealing for students.

A question regarding teachers' feelings or attitudes towards the poster was not asked directly in the interview. However, only two teachers did not reveal their feelings towards the posters, whereas the others described positive feelings. In addition, the teachers expressed their sense of ownership regarding their own poster and even regarding the entire poster exhibition.

(2) Teachers' Perceptions Regarding the Content of the Poster

The teachers described different components of the posters' content. They discussed the advanced organic content that was derived from the advanced course; they referred to the connection to students' lives and also discussed the pictures in the posters, as shown in the following examples:

> They [the posters] give the students access to cutting-edge science that are outside the chemistry curriculum and connect this advanced knowledge to their everyday life.

> I'm not afraid of the high level of the posters. On the contrary, students will learn some of the content. They will know – parts are too high for me – I need to learn more chemistry in order to understand them all.

> We had chosen photos of familiar objects (like the grapefruit) to explain chemistry concepts like enantiomers. We integrated examples from students' everyday life to connect them to the posters.

> Although the advanced organic-chemistry concepts that are presented in the

> posters are very complex, I understand them well and therefore will be able to mention them to my students.

(3) Teachers' Perceptions Regarding Use of the Exhibition in their Classroom

The teachers were directly asked if they plan to use the poster exhibition in their class, and therefore all of them referred to this aspect:

> Next year I will use the poster exhibition. I really like to do the activity with them. I will just need to receive them and I'll do the activity.

> There is no doubt about that – I am going to use the poster with my students.

> One of the activities I plan to do with my students next year is to use the poster exhibition. I know the posters (…) The poster exhibition will introduce the students to the methodology of using posters for scientific communication whereby scientific knowledge is succinctly presented.

> I plan to use them when I'll teach functional groups because their content is connected to this chemistry content. They give the students access to cutting-edge science that is outside the chemistry curriculum and it links this advanced knowledge to their everyday life.

> I really like the posters – they are really good, considering their content and their design. I plan to use them when I'll teach functional groups because their content is connected to this chemistry content.

Only one teacher explained why she did not plan to use the posters with her class, as indicated in Table 3:

> I am not sure that I'll bring the poster exhibition to my class. My students are not so strong and usually I don't have time for enrichment.

Four teachers from the first cohort actually took the printed posters and used the exhibition in their class (Table 3). These four teachers stated in the follow-up interviews that they plan to use the poster exhibition again.

Teachers' group	Planning to use the poster exhibition	Actually used the poster exhibition	Stated that they will re-use the poster exhibition
First cohort	6/7	4/7	4/4
Second cohort	10/18	2/18	2/2
Third cohort	8/11	8/11	6/8
Leading teachers	5/17	0/17	-

TABLE 3 – IMPLEMENTATION OF THE POSTER EXHIBITION: PLANS AND ACTUAL USE

THE SECOND COHORT

Teachers from the second cohort took the advanced chemistry course and were also asked to design an activity for their students using the poster exhibition. Ten out of the 18 teachers in the group stated in the interview that they will use the exhibition but only two teachers actually did so, as presented in Table 2.

(1) Teachers' «Feelings» Towards the Poster Exhibition
The teacher found the exhibition to be very aesthetic but did not reveal any personal connection to the posters, as indicated from the following examples:

> I think that the posters are very beautiful.
>
> The design of the exhibition is appealing; together the posters create a rainbow of colours.

The teachers who chose to express their feelings regarding the posters described them as a group. They did not express any sense of ownership but rather, related to the way the poster exhibition is designed.

(2) Teachers' Perceptions Regarding the Content of the Poster
For most of the teachers the content of the poster seemed to be highly complex and very difficult for high-school students. They stated that even for them the advanced course was very difficult and they could not distinguish between the advanced course and the poster exhibition, as indicated from the following examples:

> It was very difficult for me to develop an activity for my students using the poster exhibition. The advanced course was not easy for me, although

> I received a high score, and I almost can't imagine an activity using these materials that will be suitable for high-school students.

> The posters, which expose the students to high-level chemistry, emphasize the organic synthesis and the chemical industry. The connection of the advanced content to students' everyday life is prominent.

About half of the teachers in this group saw mainly the advanced organic content, which is included in the posters. The other half related to the additional components of the posters (e.g., their connection to students' life, their connections to industry) and were less threated by the content of the posters.

(3) Teachers' Perceptions Regarding Use of the Exhibition in their Classroom

The teachers could be categorized into two groups, regarding their perceptions of the content of the poster. Those teachers who mainly noted the difficult content had difficulties in explaining why they would not be able to use the poster exhibition in their class. In contrast, those teachers who emphasized other components of the poster content described the advantages of using the poster with their students, as reflected in the following examples:

> Usually I don't have time for enrichments – and this activity will take a lot of time because the posters are so difficult to understand.

> It was very difficult for me to develop an activity for my students using the poster exhibition (…) I don't believe that the activity can work well with my students because the posters are too difficult.

> Bringing the poster exhibition to my class and doing the activity I prepared creates a unique opportunity to show my students the cutting edge of scientific research, and it shows them the connections to their life and to industry.

> There is no chance that will not do the activity. It is a great opportunity for me to share what I learned in my MSc degree and to introduce the advanced content in such a way that students will understand.

THE THIRD COHORT

Teachers from the third cohort that took the advanced chemistry course were asked to design an activity using the poster exhibition and to pilot the activity in their class. Ten out of the 11 teachers in the group used the exhibition (it was the course assignment for this group), and most of them stated that they planned to reuse the poster exhibition.

(1) Teachers' «Feelings» Towards the Poster Exhibition

After developing and piloting the students' activity in class, the teachers developed positive feelings and attitudes towards the posters, as was indicated in their reflective reports:

> The posters are so beautiful; actually I discovered this when I worked on my assignment and had to look carefully at the poster.

> I can't find any pitfalls in the posters – they are great. Each poster presents a different work in the cutting edge of organic chemistry and connects it to students' life and also shows the students that there is still what to discover.

However, three teachers in this group asked not to pilot their activity in class, since they taught middle-school students the same year and not high-school students for whom the posters were designed. These teachers received the same assignment like the first cohort of teachers, namely, to design a poster. This poster was designed but was never printed and therefore was not part of the poster exhibition. The third teacher received the assignment of the second cohort, namely, to design an activity for her students without piloting it in school. The two teachers had negative attitudes towards the posters. They felt the assignment was not relevant for them and was very demanding, as reflected from the report they submitted with the poster:

> I don't think that these posters can be really used in school. They are much too difficult and I don't think that young students will be connected to them, since even I can't learn from them.

(2) Teachers' Perceptions Regarding the Content of the Poster

The teachers could distinguish between the high level of the advanced course and the content of the posters. They highlighted the ways in which the posters aid high-school students to learn the difficult organic chemistry content:

> The organic chemistry course was the most difficult course for me – the poster gave me an opportunity to rebuild my confidence. I like organic chemistry after all.

> The posters are not so complex as the course; they expose the beauty of new developments in chemistry research.

> The poster exhibition shows the connection between real life and advanced organic chemistry – the posters are appealing for students and for me too.

(3) Teachers' Perceptions Regarding Using the Exhibition in their Classroom

The teachers in this group actually used the poster exhibition in their classes. Therefore, their perception regarding use of the posters is based on reflective evaluation of their activity. The three teachers who did not complete the assignment explained that the posters were too difficult for their students and that they lacked time to include in their teaching an activity that is outside the chemistry curriculum. Most of the teachers who used the posters in their class were very surprised by the success of the activity, as indicated from the following examples:

> The pedagogy is really student-centred; they could choose the poster they want to focus on and they don't have many opportunities like this in school.

> I was amazed by my students' reactions – they were so enthusiastic and cooperative. There is no doubt that that I'm going to do that again next year!

> My students really liked the posters. They read them carefully and asked me a lot of questions regarding them.

> I was sceptical, because I thought they are too difficult for them. But they [my students] were very interested in them. First, they looked at the exam-

> ples that were connected to their life, and then they started to surf the internet to lean new concepts. I was very surprised.

LEADING TEACHERS

Teachers from this group did not take the advanced chemistry course; however, they all hold at least an MSc in Chemistry and therefore they had taken an advanced course in organic chemistry. They were exposed to the poster exhibition and a workshop for leading chemistry teachers. In the workshop they performed the activity that was designed by the second author (as learners) and were asked to fill out a questionnaire. Five out of the 17 teachers in the group thought that they will use the exhibition. They were not asked about their «feelings» towards the poster exhibition because this category emerged from analysing teachers' interviews only after they had completed the activity. Therefore, we do not have direct evidence regarding their feelings and of their sense of ownership regarding the posters.

(1) Teachers' Perceptions Regarding the Content of the Poster
The leading teachers indicated that they learned a lot from the activity. They learned new directions in organic synthesis, and found new connections to everyday life and industry.

> My knowledge regarding organic synthesis stopped ten years ago when I finished my MSc degree in chemistry. The poster exhibition provided me with the opportunity to learn new developments in the field.

> I know that chemistry is everywhere and I also tell that to my students, but I never realized that even organic chemistry is so connected to everyday life; for me it was always an area that stays in the laboratory.

> It was not easy for me to fully understand the advanced content – I need more time for that.

(2) Teachers' perceptions regarding use of the exhibition in their classroom
The teachers were asked whether they like to introduce this activity to their students and to describe the pitfalls and the advantages of such an activity.

Most of them referred to the advanced organic chemistry content, which would be too difficult for their students, as the main reason for not using the activity in class. The content knowledge of this group of teachers, who had not taken the advanced course, was lower than that of the teachers in the other groups.

> I liked the activity but it was not easy; I think that my students can't do that.

> This is too hard for high-school students.

> I don't have time for enrichments; I must prepare them for the external exams.

However, the leading teachers are very experienced teachers and were impressed by the pedagogy underlying the poster exhibition.

> The poster exhibition uses a pedagogy that put the student in the centre of the learning. The student will feel like he is at a scientific conference in which the researchers can choose which poster to read.

> I can imagine myself using the posters with my students in an activity that will summarize functional groups in organic chemistry. They don't have to fully understand all the details in the posters. They will the opportunity to see how organic chemistry in connected to everyday life.

DISCUSSION

The discussion is based on integrating the results from the different research tools consisting of (1) interviews with teachers, (2) a reflective report, (3) a questionnaire, and (4) follow-up short interviews conducted a year after the end of the course. The discussion will be presented according to each research question.

(1) *What knowledge do teachers need in order to be able to use the poster exhibition in their class?*

Only five teachers from the leading teachers' group wrote in the questionnaire that they planned to use the poster exhibition with their students. In contrast to the teachers from the first three cohorts, who took the advanced organic course, the leading teachers indicated that their previous knowledge was not enough to completely understand the posters' content. Moreover, none of the leading teachers actually used the posters. This supports the notion that teachers' content knowledge is a necessary condition to introduce the poster exhibition activity to the class. When Shulman (1986) distinguished three kinds of knowledge that lie at the heart of the teaching profession, he started with subject knowledge content knowledge: «the amount and organization of knowledge per se in the mind of the teacher» (Shulman, 1986, p. 10). Shulman continued and emphasized that «The teacher needs not only [to] understand *that* something is so; the teacher must further understand *why* something is so» (Shulman, 1986, p. 9), namely, the content and its context. The leading teachers did not know the content of the poster exhibition and a fortiori they did not know the context of the advanced knowledge. It is therefore reasonable that lacking the relevant content knowledge, the teachers did not feel capable of using the poster exhibition in their class. There are many evidences that show the relationship between the teachers' subject knowledge and their attempts at implementing this knowledge in their lessons (e.g., Smith & Neale, 1989).

Ball, Hoover, and Geoffrey (2008) distinguished between «pure» content knowledge unique to the task of teaching and specialized content knowledge, which is distinct from the common content knowledge needed by teachers and non-teachers alike. Therefore, «pure» content knowledge is not enough. Not all the teachers who took the advanced course felt they could handle this activity with their students. Teachers' interviews and their reflective reports indicated that the third group who designed an activity for their students and piloted it in school was the group that adopted the activity at a higher percentage rate than the other groups, even after the course. A more careful look at the results shows that teachers from all groups who tried the activity once (voluntary or obligatory) repeated it again. The knowledge that they developed while piloting the activity was an important factor that influenced them to use the poster exhibition again. Examining what they said and wrote after the activity revealed that they emphasized their success in using this pedagogical technique and the ways to connect the activity to the chemistry curriculum (namely, pedagogical knowledge and curriculum knowledge) (Shulman, 1986).

Although advanced and modern scientific contents and their technological applications are appealing and have the potential to positively influence and motivate students to enrol in science courses, they are absent from most high-school curricula, mainly because of the hierarchical nature of science (Kapon et al., 2009). If one wishes to incorporate contemporary science contents, such as the content in the poster exhibition, into high-school science lessons, one must develop a teaching pedagogy that can bridge the gap between students' pre-knowledge and the advanced content. The poster exhibition provides an opportunity to use student-centred pedagogy that is rarely used in high-school chemistry teaching (Blonder & Dinur, 2011). The concept of student-centred learning has been credited to Dewey's work (Dewey, 1902). Carl Rogers, the father of client-centred counselling, is associated with expanding this approach into a general theory of education. In his book *Freedom to Learn for the 80s* (Rogers, 1983), he described the shift in power from the expert teacher to the student learner, driven by a need for a change in the traditional environment where in this so-called educational atmosphere, students become passive, apathetic, and bored. The student-centred approach is based on the hypothesis that students who are given the freedom to explore areas based on their personal interests, and who are accompanied in their striving for solutions by a supportive, understanding facilitator, not only achieve higher academic results but also experience increased personal values, such as flexibility, self-confidence, and social skills. This approach also allows the students to have a free choice (Jenkins, 2006). They can choose the poster they would like to learn more about – an element that is rarely found in a school learning situation. The combination of advanced content knowledge and teachers' beliefs will support the teachers in using this unique poster exhibition in class (Blonder, Benny & Jones, 2014), as will be discussed in the second research question.

(2) What influenced teachers' self-efficacy beliefs regarding their ability to use the poster exhibition, which presents cutting-edge chemistry in class?

We found that teachers who developed a sense of ownership regarding the poster exhibition (the first cohort) or to the activity they introduced to their class (mainly cohort three) were most likely to use the poster exhibition. One conclusion that arose from decades of studying the success and failure of a wide variety of curriculum innovations is that imposed innovations are generally ineffective (Pintó, 2005), and that innovations succeed when teachers feel a sense of ownership of the innovation, or that it belongs to them and that it is not simply imposed on them (Ogborn, 2002). Pintó, Couso, and Gutiérrez (2005) also insisted that only if teachers feel some sense of ownership of an innovation, will they effectively carry it out in the classroom. Although a sense of ownership plays a central role in education and in teachers' professional development, not many studies have dealt with this issue. A study that followed the adaptation of European modules to the context of chemistry teaching was conducted in Israel (Blonder, Mamlok-Naaman, Kipnis & Hofstein, 2008). It was found that when the teachers were involved in developing or adapting the teaching program, they developed a high sense of ownership toward the program as well as positive attitudes. These results are correlated with our results. The teachers that were involved in developing the posters (the learning materials) or the in designing the activity with the poster exhibition developed a high sense of ownership.

However, we found a difference between the second cohort and the third cohort, although both groups developed a poster-exhibition-activity for their class. The third cohort, which was asked to pilot the activity in their class, exhibited a higher sense of ownership, more positive attitudes, and repeated the activity even when it was not part of the course requirements. One of the components for teachers (especially in implementing new activities) is teaching self-efficacy (Bandura, 1986). Teachers' self-efficacy was found to contribute to their development and sustainable changes (reference). The contribution of teachers' attitudes and more specifically, teachers' self-efficacy to changes in their teaching emerged in their first interview. Therefore, we looked for indications of teachers' self-efficacy in the follow-up interviews.

In the cyclic model for teaching-efficacy, Tschannen-Moran, Woolfolk, Hoy, and Hoy (1998) emphasized that the major factors that influence self-efficacy beliefs are cognitive interpretations of the four sources of efficacy information (namely, mastery experiences, vicarious experience, verbal and social persuasion, and emotional and physiological states). In the current study, the third cohort of teachers experienced the first source (mastery experience), which is known to be the most influential source for developing efficacy beliefs (Bandura, 1994; Usher & Pajares, 2008) of information, as was mentioned in the interviews. In addition, the teachers were asked to evaluate their teaching reflectively (in the reflective report). We would like to stress that the reflective evaluation process that the teachers underwent provides a mechanism for cognitive interpretations of the sources of efficacy information. Therefore, it supported the development of high self-efficacy beliefs.

It is therefore important to provide teachers with opportunities to develop their efficacy beliefs as well as their knowledge if one wants to introduce to schools innovative teaching materials and especially advanced up-to-date subject content.

CONCLUSIONS

The current paper presents a unique method for teaching up-to-date subject content in school science by using a poster exhibition that was designed by the teachers. The poster is a visual means that is used to briefly present scientific research at conferences (Stephen, 2011), and scientists also use the poster as a means of communicating their research. It was found that teachers were able to implement the poster exhibition in their classes and were able introduce their high-school students to cutting-edge organic chemistry. However, not all the teachers, who differ in knowledge and efficacy beliefs, actually used the poster exhibition.

The current study focuses on teachers' knowledge and beliefs that supported them in using the poster exhibition of up-to-date science in their classes. It was found that the first component that teachers need in order to introduce the poster exhibition is content knowledge (CK). Teachers (leading teachers) who lacked adequate CK found the poster exhibition to be an interesting learning experience for themselves but they did not use them in their classes. The pedagogical knowledge that accompanies the poster exhibition, namely, student-centred pedagogy was found to be less influential.

Teachers' sense of ownership and their self-efficacy beliefs were also found to be influential factors. Teachers who developed a sense of ownership during the process of designing the posters or when developing the activity for their students and piloting it in class had a higher sense of ownership towards the poster exhibition and were more likely to reuse the posters in class the next year.

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THE CHARACTERISTICS OF OPEN-ENDED INQUIRY-TYPE CHEMISTRY EXPERIMENTS THAT ENABLE ARGUMENTATIVE DISCOURSE

Dvora Katchevich
dvora.katchevitch@weizmann.ac.il | Weizmann Institute of Science, Israel

Rachel Mamlok-Naaman
rachel.mamlok@weizmann.ac.il | Weizmann Institute of Science, Israel

Avi Hofstein
avi.hofstein@weizmann.ac.il | Weizmann Institute of Science, Israel

ABSTRACT

One of the key goals of science education is to provide students with the ability to construct arguments – reasoning and thinking critically in a scientific context. Over the years, many studies have been conducted on constructing arguments in science teaching, but only a few of them have dealt with studying argumentation in the science laboratory in general and in the chemistry laboratory in particular. Our research focuses on the process in which students construct arguments in the chemistry laboratory while conducting different types of inquiry experiments. The experiments that were assessed for their argumentation level differed in their level of complexity. It was found that the more complex experiments served as a better platform for developing arguments as well as regarding their relative numbers. Moreover, we identified a number of characteristics during the discourse that serve as a catalyst for raising arguments: asking questions and unexpected results obtained in the experiments.

KEY WORDS
Argumentation; Chemistry laboratory; High-order learning skills; Inquiry-type experiment; Complexity of inquiry-type experiments.

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The Characteristics of Open-Ended Inquiry-Type Chemistry Experiments that Enable Argumentative Discourse

Dvora Katchevich | Rachel Mamlok-Naaman | Avi Hofstein

THEORETICAL BACKGROUND

Learning science in a laboratory has a number of features that have contributed to establishing its centrality in the learning and teaching of science in general and chemistry in particular (Hodson, 1993; Hofstein & Kind, 2012; Hofstein & Lunetta, 2004; Lazarowitz & Tamir, 1994; Lunetta, 1998; Lunetta, Hofstein & Clough, 2007). Clearly, the science laboratory, if structured properly, has the potential to develop many important high-order learning skills (Hofstein, Navon, Kipnis & Mamlok-Naaman, 2005; Katchevich, Hofstein & Mamlok-Naaman, 2013; Kipnis & Hofstein, 2008; Tobin, 1990) such as asking questions, developing critical thinking, problem-solving, and developing metacognitive and argumentation skills (Hofstein & Kind, 2012). It provides a unique opportunity to collaborate, deliberate, and communicate with peers. In a nutshell, it provides an opportunity to learn science by doing hands-on as well as minds-on science.

Over the years, the educational effectiveness of science laboratories as a unique learning environment that enables meaningful student learning has been emphasized in many research studies (see, for example, Abrahams & Millar, 2008; Hodson, 1993; Lazarowitz & Tamir, 1994; Lunetta et al., 2007; McElhaney & Linn, 2011). Moreover, the laboratory provides support for high-order learning inquiry skills that include observing, planning an experiment, asking relevant questions, hypothesizing, and analysing the experimental results (Bybee, 2000; Hofstein, Shore & Kipnis, 2004).

In this paper we define science laboratory activities as learning experiences in which students interact with materials to observe and better understand the natural world. Note that assessing the educational effectiveness of the laboratory and its related learning skills requires distinguishing between the different modes of instruction, namely, the nature of the experiments in which the students are involved. Laboratory experiments can be classified into four types: confirmatory, inquiry (various types such as guided inquiry and open-ended type inquiry that can differ in their degree of complexity; see for example, Hofstein & Kind, 2012), discovery, teacher's demonstrations, and conducting an experiment around a specific problem.

In this paper we will focus solely on the issue related to the degree of complexity of inquiry-type experiments. Domin (1999) suggested criteria to define experiments according to the type of results obtained from the experiment: the inductive vs. deductive approach to the activity and, according to who wrote the procedure, either the teacher or the student who must perform the experiment. Other researchers (Fradd, Lee, Sutman & Saxton, 2001; Herron, 1971; Schwab, 1962) suggested characterizing experiments according to their degree of open-endedness. «Open» in this sense means that the experiment is performed entirely by the student and «closed» means that it is performed entirely by the teacher (e.g., a demonstration). A confirmatory experiment is considered «closed» when the students, after learning in the science classroom, perform an experiment that is planned by the teacher. Its approach is deductive and the results of the experiment are known to both the teacher and students in advance. In contrast, an inquiry experiment is considered «open» when the students plan how it will be carried out. Its approach is inductive and the results are not known in advance to the students and sometimes to the teacher. For a more comprehensive discussion regarding this issue see Hofstein, Kipnis and Abrahams (2013).

ARGUMENTATION IN THE CONTEXT OF TEACHING AND LEARNING SCIENCE

One of the goals of science education is to provide students with the ability to formulate arguments – reasoning and critiquing in a scientific context. Progress in science is partially based on arguments and their related rebuttal. Formulating arguments is a particular genre of discourse in which a central epistemological framework is formed as a result of scientific actions. Upon examining the type of activities, it was found that formulating arguments is central and significant in developing and conducting science activities. Consequently, it is reasonable to assume that imparting the meaning of scientific content and the essence of developing a scientific concept would be a way to formulate arguments (Erduran, Simon & Osborne, 2004; Hofstein & Kind, 2012; Hofstein, Kipnis & Kind, 2008). Scientific language is based on arguments; therefore, students should be provided with opportunities to «talk science» (Lemke, 1990). We believe that argumentation in a scientific context should be an integral part of this process. In a classical science lesson teachers ask questions, expect certain answers, and immediately evaluate the students' replies (Cazden, 2001). In contrast, working in small groups, in which the members are exposed to scientific tasks, provides them with an opportunity to become involved in a debate and to be supported or rejected by their arguments. During a group debate, sometimes with the teacher's intervention, the group has an opportunity to construct individual as well as group knowledge. Formulating knowledge in this manner is an example of constructivist socio-cultural knowledge, as described by Vygotsky (1978).

According to Jiménez-Aleixandre (2008), the characteristics of an optimal learning environment for constructing arguments that relate to students, teachers, curriculum, assessment, reflection, and communication are as follows: (1) the students must be active in the learning process; they must assess knowledge, establish their claims, and be critical of others; (2) the teachers have to adopt to student-centred learning, act as a role model regarding the way they verify their claims, support the development of understanding the nature of knowledge among students, and adopt learning strategies such as inquiry; (3) the curriculum should incorporate an authentic problem-solving approach, which will require the students to learn by inquiry; (4) students and teachers should be skilled in assessing claims, and assessing the students should go beyond written tests; (5) the students should be reflective about their knowledge and understand how it was acquired, and finally (6) the students should have an opportunity to conduct a dialogue in which cooperative learning will take place. Combining these six elements encourages the implementation of an argumentative, interactive learning environment.

From a cognitive perspective, formulating an argument is a conceptual process that can aid in developing an understanding of these concepts.

Furthermore, the skill of reasoning, which requires creating a link between claims and evidence, is developed (Osborne, 2010). In general, students often have difficulty in formulating arguments; they also have difficulty in selecting and connecting findings that can be used as evidence in supporting their claims (Sandoval & Millwood, 2005). Furthermore, students do not formulate high-level arguments on their own. It is therefore necessary to initiate activities that encourage and support formulating arguments, especially with controversial-type activities that have diverse types of solutions (Andriessen & Schwarz, 2009; Duschl & Osborne, 2002). Osborne, Erduran and Simon (2004), for example, offered a number of strategies to develop argumentation skills, e.g., exposing students to several explanations regarding a particular scientific subject and dealing with claims that the students may accept or reject. They based their assessments on appropriate professional criteria and expose students to two opposing theories that can explain a particular phenomenon. The students should: (1) explain what evidence supports each of the theories, (2) construct arguments using structured patterns that include guiding questions, and (3) predict the experiment's results, based on appropriate arguments, (4) observe the experiment and explain its results (Predict, Observe, and Explain), and (5) design an experiment, carry it out, and discuss the results. Chin and Osborne (2010) claim that questions (posed by students either to their peers or to themselves) are an excellent trigger for raising arguments.

Other researchers suggested using socio-scientific dilemmas because these dilemmas are ambiguous and enable students to practice the process of simultaneously posing claims and counter claims (Dawson & Venville, 2010; Jiménez-Aleixandre, Rodriguez & Duschl, 2000; Sadler, 2004; Zohar & Nemet, 2002). Building an argument has significant social importance for students, in addition to their learning scientific concepts and high-order learning skills. While students are engaged in activities in which they are provided with opportunities to develop argumentative skills, they learn how to conduct a meaningful conversation with peers. Needless to say, these skills are useful for overcoming life's challenges and are not used solely in the context of science learning (Jiménez-Aleixandre et al., 2000).

In recent years, several researchers have used Toulmin's model (Toulmin, 1958) in their studies. This model includes three basic components: a claim, evidence, and a warrant for formulating grounded and rational arguments (Bell & Linn, 2000; Driver, Newton & Osborne, 2000; Erduran et al., 2004;

Jiménez-Aleixandre et al., 2000; Kind, Wilson, Hofstein & Kind, 2010; Sandoval, 2003). The claim is an assertion whereby the one who suggests it believes it to be true, e.g., a conclusion, an answer to a question, or a problem. Evidence is scientific data that support the claim. Scientific data consist of information, such as observations and measurements. The claim should be based on evidences and the warrant justifies the link between the findings and the claim. A higher level of argumentation includes a theoretical basis or explanation at an elementary level, namely, it also includes backing. Similarly, a conditional (qualified) argument or counter claim is intended to refute a particular argument. A rebuttal makes a claim about why certain claims are incorrect and uses additional evidence and reasoning to justify it.

It is assumed that teaching science through the inquiry method is an effective teaching strategy for teaching and developing the ability to expand argumentation skills (Duschl & Osborne, 2002; Kind et al., 2010; Wilson, Taylor, Kowalski & Carlson, 2010). It is also assumed that an inquiry activity stimulates the students to better understand the research process that scientists undergo. Scientists seek answers to unclear phenomena; they try to explain them by collecting evidence and by constructing arguments. The construction of arguments is a sort of discourse that creates an epistemological framework within the scientific process. When considering the type of activities in which scientists engage, one realizes that building significant arguments is central to the development of science (Hofstein et al., 2008). Therefore, it was reasonable to assume that we would find evidence for argumentation in the laboratory.

Argumentation in the science laboratory

Several researchers (e.g., Gott & Duggan, 2007; Sampson & Gleim, 2009) who focused on the issue of argumentation suggested that the inquiry-type laboratory in science education can provide opportunities for students to develop argumentation skills (see also the detailed discussion in Hofstein & Kind, 2012). However, only a few research studies were conducted with the goal in mind of accepting or rejecting this assumption.

For example, Tien and Stacy (1996) found that students who participated in guided inquiry-type laboratories were better at evaluating evidence obtained from their research. Kelly, Druker and Chen (1998) analysed the discourse in a physics laboratory and found that claims accompanied by justifications are generally given in response to the claims of a colleague in light of the experiment's findings or of the instructions, which may require an explanation or reasoning on the part of the student.

Richmond and Striley (1996) claimed that the development of argumentation skills in the laboratory depends on the type of group. They presented a study, conducted among 10th grade students, who performed a series of experiments dealing with the ability to cope with the disease cholera. The students worked in small groups; the researchers found that the argumentation skills that developed depended on the group leader's personality. In the groups that had an inclusive leader, all the group members contributed in developing the argumentation, whereas in the groups that had a persuasive leader, it was the leader who developed the argumentation.

Other researchers (Hohenshell & Hand, 2006; Keys, Hand, Prain & Collins, 1999) suggested a strategy of best practice in the laboratory whose outcome is a written report: Science Writing Heuristic (SWH). The lab reports, which are written in this way, should replace the traditional way in which students prepare laboratory reports (usually after performing the laboratory experiment). The students receive written guidelines that make connections among the components of the inquiry process: observations, posing questions, data collection, and evidence-based claims. The construction of knowledge and the building of relationships are done by inquiry questions, which help students establish their claims for the data that they gathered. This strategy enables the students to become more active, especially in classroom group discussions. Yoon, Bennett, Mendez & Hand (2010) elaborate on the optimal conditions and specifications needed for classroom discussions using the SWH strategy. They claim that a non-threatening learning environment, where students feel comfortable to express themselves, to accept criticism, to listen to others, and to observe teachers who serve as models, provides MODIFIES ENVIRONMENT optimal conditions for encouraging discourse, thus leading to the development of argumentation.

Sampson, Grooms, and Walker (2011) explored how a series of laboratory activities designed using a new instructional model, called Argument-Driven Inquiry (ADI), influences the ways students participate in scientific argumentation and the quality of the scientific arguments they craft as part of this process. They found that the students had better disciplinary engagement and produced better arguments after the intervention.

ARGUMENTATION AND THE NATURE OF THE EXPERIMENTS IN THE CHEMISTRY LABORATORY

Two recent studies reported in the literature discuss the nature of the experiments as a platform for evoking argumentation both quantitatively (the number of arguments) and qualitatively (the level of arguments). Kind, Kind, Hofstein and Wilson (2011) in the UK investigated the quality of argumentation among 12 to 13-year-old students in the UK in the context of the secondary school physical science program. Their study explored the development of students' argumentation regarding who undertook three different designs of laboratory-based tasks. The tasks described in their paper involved the students in the following: collecting and making sense of data, collecting data for addressing conflicting hypothesis, and paper-based discussions in the pre-collected data phase about an experiment. Their findings showed that the paper-based task (the 3rd one in the above task list) generated the larger number of arguments in a unit of time compared with the two other abovementioned tasks. In addition, they found that in order to encourage the development of high-level and authentic argumentation, there is a need to change the practice that generally exists in the science laboratories in England. They suggested that more rigorous and longitudinal research is needed in order to explore the potential of the science laboratory as a platform for developing students' ability to argue effectively and in an articulated way.

The second study was conducted in Israel in the context of 12 years of research and development of inquiry-type laboratories in the context of upper secondary school in grades 10-12 (for more details about the philosophy and rationale of the project, see Hofstein et al., 2004). The implementation and effectiveness of this project were researched intensively and comprehensively and were reported in a series of manuscripts (Barnea, Dori & Hofstein, 2010; Dkeidek, Mamlok-Naaman & Hofstein, 2011; Hofstein, Levy Nahum & Shore, 2001; Kipnis & Hofstein, 2008).

The is highly relevant to our current paper (Katchevich, Hofstein & Mamlok-Naaman, 2013) focuses on the process in which students constructed arguments in the chemistry laboratory while conducting different types of experiments. It was found that *inquiry-type* experiments have the potential to serve as an effective platform for formulating arguments, owing to the special features of this learning environment. The discourse conducted during inquiry-type experiments was found to be rich in arguments, whereas that during *confirmatory-type* experiments was found to be sparse in arguments. In addition, it was found that the arguments, which were developed during the discourse of an inquiry-type experiment, were generated during the following stages of the inquiry process: hypothesis-building analysis of the results, and drawing appropriate conclusions. On the other hand, confirmatory-type experiments revealed a small number of arguments. In addition, the arguments that were posed in the confirmatory-type experiments had low-level characteristics. Whereas the study reported in Katchevich et al. (2013) was mainly comparative in nature (inquiry vs. confirmatory-type experimentation), the research described in this manuscript focuses on the degree of complexity of inquiry-type chemistry experiments.

As mentioned in previous studies, based on a detailed analysis of the discourse in the chemistry laboratory, we can conclude that the open-ended inquiry experiments stimulate and encourage the construction of arguments, especially the stages of defining hypotheses, analysis of the results, and drawing conclusions. Some arguments were raised by individuals and some by the group. Both types of arguments consist of explanations and scientific evidence that link the claims to the evidence. Therefore, it is suggested that learning environments of open-ended inquiry experiments serve as a platform for raising arguments. In this study we wanted to point out the main factors that stimulate raising arguments in open-ended inquiry experiments, as well as to characterize situations in which argumentation develops significant discourse.

METHODOLOGY

The research method used and described in this manuscript is mainly based on the use of qualitative tools. Some of the qualitative findings were analysed quantitatively. The qualitative approach enabled us to describe in detail the phenomena and processes that occurred in the laboratory and that are related to constructing arguments. Quantitative analysis of the qualitative findings enabled us to describe the magnitude of the phenomena that we identified.

RESEARCH POPULATION

The research population consisted of five classes of 11^{th} and 12^{th} grade chemistry students (N=82) in 5 different high schools in Israel. Note that each class was taught by a different teacher. The students study in an advanced placement chemistry program that consists of a laboratory unit (about 20% of the total program including students' final grades in the matriculation examination). All teachers involved in this study underwent a continuous and intensive professional development program. The laboratory unit lasts two years and includes a series of twelve experiments, some of which are open-ended-type inquiry experiments, whereas others are more confirmatory experiments. In this study we will report only about the open-ended-type inquiry experiments.

ACTIVITIES IN THE LABORATORY

The open-ended inquiry experiments include the following: Students perform open-ended-type inquiry experiments in which they are exposed to a phenomenon; they ask questions about it, select the research question, write a hypothesis related to the research question, plan an experiment in order to examine their hypothesis, and then perform the experiment, organize their results and draw conclusions, as well as analyse and summarize the inquiry experiment (please see instructions for this type of activity in appendix 1).

RESEARCH TOOLS

The research tools consisted of the following: criterion-based observations in the laboratory and semi-structured interviews with the students.

Observations in the laboratory

Laboratory observations were conducted during laboratory sessions and focused on the discourse related to the experiments that took place in the laboratory while students performed the experiments. The discourse was audio-taped and the parts «constructing a rational hypothesis», «analysing the results», and «drawing conclusions» were transcribed. These parts included interactions between the group members, and sometimes interactions between the group members and the teacher, who approaches and interacts with them.

The discourse was analysed according to the following criteria: the components of the basic argument: claims, evidence, and scientific explanations. The analysis to identify the components of the argument was performed using Toulmin's model (Toulmin, 1958).

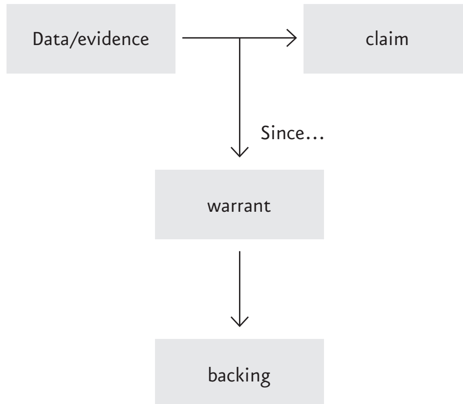

Figure 1 – Toulmin's model for the components of an argument

Toulmin's model places more emphasis on the generic features of the argument, in line with our interest in argumentation in general. In addition, Toulmin's model has been used to characterize argumentation in science lessons and is implicit in using the coding system of others (Bell & Linn, 2000; Driver et al., 2000; Erduran et al., 2004; Jiménez-Aleixandre et al., 2000; Kuhn et al., 1997; Sandoval, 2003). Following these authors, we therefore used the Toulmin framework to focus on the epistemic and argumentative operations adopted by students. In order to assess the level of the arguments, we chose a tool that refers to the various elements of an argument (see Table 1). This tool was chosen from among many assessment tools appearing in the literature; it was reviewed in Sampson and Clark's (2008) paper. This tool is in line with the discourse style of the laboratory experiments and with Toulmin's model; it is based on other tools suggested in former studies (Erduran et al., 2004; Osborne et al., 2004; Simon & Johnson, 2008). During the discourse, the students suggest different explanations for the various phenomena that they observe during the experimental procedure and then analyse the data and present arguments. The reliability of the coding of the argumentation discourse components was tested in two ways: encoding the components of the argumentation in 20% of the transcribed discourse, by three experts. The percentage of agreement between the experts ranged from 85% to 90%. For encoding in which the experts do not agree, the judges discuss the matter until they reach a consensus. In addition, the researcher repeated the encoding after a while; the correlation between the early and late coding system was 0.95.

The components	Symbol	level	Examples of arguments at different levels
Claim	C	1	Nurit: The more powder there is the faster the raisins move, and over time [claim].
Claim + Data or Claim + Warrant	CD CW	2	Nira: The more reactants that there are in the system, the greater the concentration of solution B, more products will be obtained, more gas will be generated, more bubbles will be created, and more raisins will rise [claim + explanation].
Claim + Data + Warrant or Claim + Data + Rebuttal or Claim + Warrant + Rebuttal	CDW CDR CWR	3	Moriah: As we increased the concentration of the solution, there was a greater amount of sediment [evidence]. Gil: The more we increased the concentration of the solution, the more the quantity of the products increased. We found this by analyzing the quantity of the solid [claim + evidence]. Moriah: Because the reaction has more reactants, there are more collisions between the particles of the reactants and consequently, there are more fertile collisions [explanations]. Gil: And then more of the product that forms the solid that we obtained is created and the solution obtained is more turbid [continued explanation combined with evidence].
Claim + Data + Warrant + Backing	CDWB	4	Noam: I want to state that a higher temperature will result in a more frequent occurrence of the reaction [claim]. [He draws a graph] there is an increase in ΔH since this is an endothermic process [evidence]. Alon: There is an increase in ΔS as gas is generated; thus, this is a descending graph [evidence + claim]. Noam: At a higher temperature ΔG is more negative and the reaction will be more spontaneous, according to the graph [he points to the graph that was drawn in the report]. Alon: The spontaneity will be expressed in a broader dispersion of the gas and, as a result, the gas spreads more, because it has greater energy. Ohad: The greater dispersion of the Iodine will be expressed in a greater area that crystallized on the large test-tube [explanation + backing].
Rebuttal that includes Claim + Data + Warrant	CDWR	5	Yarden: In the first system, there was no reaction at all [claim] Bennie: Not so! There was a reaction, but not like in the other systems. Insufficient gas was generated in order to raise the raisins [refutation based on evidence + explanation].

TABLE 1

The levels of the arguments posed by the students are presented in Table 1. Two major aspects are referred to: (1) those components that form the basis of the argument (claim evidence and scientific explanations), and (2) the presence of rebuttal or counterclaims. When the argument includes many components, its level is higher. An argument at level 3 includes the classic elements of an argument: a claim, evidence, and a scientific explanation that connects them.

On the other hand, during an argumentative discourse, there is an additional dimension that includes a counterclaim or refutation, the presence of which serves as evidence of a high argumentative discourse level. Consequently, this element is taken into account when determining argument levels. The highest level of an argument, level 5, includes a refutation based on accompanying scientific evidence and explanations. The discourse analysis was validated by 3 experts. Note that during the analysis of the argument components, we used a scientific explanation expression instead of a warrant because students tend to explain the evidence supporting their arguments by using scientific explanations based on their previous chemistry content knowledge.

The discourse during the experiments was transcribed, and used for two additional goals: (1) Finding evidence of students' wiliness to explain their arguments, and (2) tracking students' questions during the dialogue.

The experiments conducted by the students were categorized according to the following criteria: (1) simple / complex experiments, and (2) experiments in which the students obtained results that matched or did not match the suggested (posed) hypotheses. An experiment was defined as complex based on the above criteria, namely, consisting of one of the following: The experiment is not aligned with the concept or topic taught at that time in the chemistry classroom, and/or is based on a scientific background that is not part of the compulsory chemistry curriculum in Israel.

RESULTS

In this section of the paper we will refer to those factors that might affect the scope of the arguments posed by the students during the discourse of an open-ended inquiry experiment. In addition, we will discuss the other features related to the level of the experimental arguments. Based on the results, we found two main factors that affect the scope of the arguments in the discourse of open-ended-type inquiry chemistry experiments.

ASSIGNMENT REQUIREMENTS AND ASSESSMENT

During the course of experimentation the students are involved in various inquiry skills such as formulating a hypothesis, analysing results, and drawing conclusions, which are categorized as high-order thinking skills. More specifically, hypothesis is a claim based on the preliminary experimentation and on relevant scientific information and explanations. Students are generally aware of the task requirements and the assessment rubric.

Table 2 presents three criteria for assessing the hypotheses that appear in the students' written reports. The total score is 10 points (out of 100) for the whole assignment.

Criteria
The students write an hypotheses regarding the research question which they chose
The students explain hypotheses regarding the research question which they chose
The students base their hypotheses on a scientific and relevant knowledge

TABLE 2 — CRITERIA FOR ASSESSING THE HYPOTHESES

We found some evidence in the discourse for the students' awareness of the task requirements. A discussion between two students will serve as an example (among many others). One of the students claimed: We discussed our hypothesis, and even wrote it in our report. Her colleague answered: «It is not enough! In the instructions it was written that we need to reason and explain each hypothesis.» Even from the above minor episode, we can conclude that the students developed an awareness of the requirements and instructions of the assignments.

THE DEGREE OF COMPLEXITY OF THE INQUIRY-TYPE EXPERIMENT

It is suggested that if the task presents a more complicated phenomenon than is found in other tasks, it provides a higher probability for posing arguments. In addition, if the inquiry experiment consists of scientific concepts that are not an integral part of the formal syllabus or the experiment, then once again, it may provide a wider and more articulated argumentative discourse.

In attempting to characterize the experiments according to their complexity (simplicity), we adopted the categories detailed in the methodology section of this paper. The level of the complexity was content validated by several teachers and science educators in the Department of Science Teaching. This enabled us to conclude which experiment could be declared a simple chemistry experiment and which a more complex one.

All together, the researchers conducted fourteen classroom laboratory observations on a group of students, of which eight were conducted in complex inquiry-type experiments and six in more simple ones. The average number and level of the arguments in simple and more complex experiments are summarized in Table 3 using the Kruskal-Wallis test (nonparametric test).

	Mean level of the argument(*SD*)	Number of arguments per experiment (*SD*)
complex inquiry-type experiment	2.3 (0.54)	6.5 (0.75)
simple inquiry-type experiments	2.5 (0.11)	2.7 (0.82)
Ÿ^2(1) (p)	2.5 (N.S)	10.2 (0.001)

TABLE 3 – THE AVERAGE NUMBER AND LEVEL OF THE ARGUMENTS IN SIMPLE AND COMPLEX EXPERIMENTS

Note that regarding the level of the arguments, no significant differences were revealed when comparing simple and more complex experiments. It is assumed that the level of arguments in the rather simple experiments is related to the students' background knowledge to which they were exposed in the chemistry classroom. Thus, they do not have to build a new knowledge gestalt (or framework).

THE NATURE OF THE DISCOURSE IN WHICH THE ARGUMENTS WERE POSED

In addition to the factors identified as affecting the argumentation during the open-ended experimental discourse, we found two features of the inquiry process that influenced (developing) and posing of arguments: asking questions and unexpected results.

Asking Questions

The nature of the discourse in which arguments were posed is highly based on the questions that were posed during the experimental discourse. During the discourse conducted among the students themselves and between the students and their respective teachers in the small group, one can identify three distinct types of questions: questions that stimulate discussions, questions aimed at clarification and understanding the issues related to the experiments, and questions posed for the purpose of obtaining information (in most cases technical ones). In this paper we will refer to the first two, where it is suggested to initiate and drive the group's discourse and thus have the potential for developing arguments or enhancing the development of more high-level-type arguments. The following are examples of these two types:

> Questions that stimulate a discussion: «What would happen, in your opinion, if we continue to heat up the beaker?»
> Questions aimed at clarification: «What did you mean you said we need to extend the level of the concentration?»

Altogether, sixty-two questions were revealed during the observations that included fourteen experiments (six groups conducted simple open-ended inquiry experiments and eight conducted more complex open-ended inquiry experiments) with small groups of students who were involved in conducting open-ended inquiry experiments. Forty-one questions were categorized for discussion or were questions for the purpose of understanding. In those groups conducting simple experiments, seven questions were posed, whereas in the more complicated one thirty-four questions were posed. In addition, high and significant correlation (Spearman correlation) was obtained ($r=0.80$ $p< 0001$ was found between the number of questions asked and the number of resulting arguments). Thus, we assumed that there is a clear relationship between these two variables.

Unexpected Results

The experiments were classified into two categories: experiments in which results that correlate with the hypothesis were obtained and those in which the results were unexpected and are not aligned with the hypothesis. An analysis of the discourse in these experiments revealed that the average number of arguments per group in experiments in which unexpected results were obtained was significantly higher than the number in the experiments in which the anticipated results were obtained ($\chi^2=6.7$ $p=0.017$). In the experiments in which anticipated results were obtained, only 7% of the arguments included episodes of refutation; however, about 30% of the experiments in which unexpected results were obtained included episodes of refutation.

DISCUSSION AND SUMMARY

In the experiments that were observed during the open inquiry experiment in the chemistry laboratory, the students are indeed given a platform for constructing arguments, both as individuals and as part of a group. This is the result of the special features of this learning environment: working in small groups that enable the students to conduct an argumentative discourse. It includes the need to provide explanations for the phenomena observed, select inquiry questions, formulate a hypothesis, provide results and draw conclusions, and initiate a group discussion during which arguments are raised. The arguments raised rely on the evidence collected during the experiment and are usually based on either a scientific explanation studied in classroom or knowledge accumulated during the group discussion regarding concepts that were not learned in class. Furthermore, the students are allocated time to execute all the aforementioned so that their potential can be exploited (Katchevich et al., 2013; Lazarowitz & Tamir, 1994).

In this research study we found two factors that affect the existence and extent of the argumentative discourse while conducting an open inquiry experiment. The first is the task requirements and the reason for assessing the task. The students are aware of the reason and the task requirements. The strict instructions of the work for the students and indicators for assessment dictate the conduct of the inquiry activity in the laboratory. There is evidence in the group discourse for this argument. The students read the instructions out loud and conducted the activities stage by stage. They also examined the compatibility of executing them with the indicated requirements. This awareness is the result of imparting work skills and habits by the teachers, which were also revealed in the discourse.

In order for the students to conduct a discourse that includes established arguments, they have to master the scientific background that supports the arguments relating to the experiment (Von Aufschnaiter, Erduran, Osborne & Simon, 2008). However, on the other hand, in order to conduct a productive discourse, they must include «something beyond» this scientific knowledge. The requirement in the experiment has to be in the ZPD (Zone of Proximal Development) field so that during the discourse, the group will propose possible explanations for these exposed phenomena and, while raising arguments and refutations, the knowledge of the group and its individuals will be formulated (Vygotsky, 1978).

In our study we found that when the task presents a complex phenomenon, which includes concepts that are beyond the curriculum, or alternatively, a full enquiry experiment with a scientific background that links a number of content subjects, the discourse is more meaningful and includes many more arguments. On the other hand, in experiments that are not complex (simple) and that are related directly to the concept studied in the formal curriculum material, generally, students know the answer to the inquiry question raised in advance and, consequently, the hypothesis writing, results analysis, and drawing conclusions stages are not controversial but rather, formulate an established argument with a scientific background similar to the findings of Kind et al. (2011).

Apart from those factors that encourage constructing arguments, the task requirements and their related complexity, we found additional features in the inquiry activity on which an argumentative discourse developed. We found that when students obtained unexpected results in a preceding experiment, or in the experiment that they are planning, the discourse that develops includes more arguments and even refutations. The unexpected results generate a cognitive conflict among the students, which requires them to re-examine what they already know, ask themselves why this knowledge does not form a sufficient basis for explaining the results and whether they have to expand their knowledge or propose explanations based on another scientific background that they had not thought of previously, or that was unknown to them. The conflict is resolved by the group discourse, which is sometimes guided by the teacher. This is a discourse in which the students raise empirical arguments that they perceived in the framework of the experiment (Osborne, 2010).

An additional feature associated with how an argumentative discourse develops is raising questions during the discourse. In addition to the questions that deal with receiving information, the discourse includes questions that require clarification or questions that open up a discussion. These questions generate attention from the group's members and, therefore, have a very important function in developing an argumentative discourse. We also found that in complex experiments, the students ask more questions and, consequently, many more arguments arise. This finding correlates with the *Questions and Argumentation Model* proposed by Chin and Osborne (Chin & Osborne, 2010). In this model, the investigators perceive questions as a factor that motivates discussions. Sometimes the questions are directed at the questioner himself and, sometimes at his peers in the group. However, the need for providing a reply serves as the catalyst for developing the discourse.

To sum-up, it is recommended that when teachers select experiments for their classes, it is advisable that they be aware of the potential of these experiments for constructing arguments. Furthermore, they should be aware of the additional features that are likely to contribute to argumentative discourse, such as raising questions that generate a discussion both by themselves and by the group members.

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APPENDIX – OPEN-ENDED INQUIRY EXPERIMENT THE CONTACT BETWEEN LIQUIDS

NOTE: PROTECTIVE GLASSES AND GLOVES MUST BE WORN!

GENERAL INSTRUCTIONS:

- **Read** all the instructions well before beginning the experiment.
- **Check** that you have all the necessary equipment and materials at your disposal in order to conduct the experiment.

PAY STRICT ATTENTION REGARDING:

- **fulfilling the instructions** for carrying out stage A precisely
- **recording** as many **observations** as possible
- **reporting** the **observations** clearly and in a well-organized manner
- **participation** of all the group members in carrying out the various tasks
- using correct and precise **scientific language** throughout the course

EQUIPMENT AND MATERIALS:

a Petri dish
about 30 ml of colored water
about 30 ml ethanol
3 Pasteur pipettes
A bottle of liquid soap

STAGE A: THE PRE-INQUIRY EXPERIMENTS

1. Drip colored water with a Pasteur pipette into a Petri dish until it will cover about half the area of the base of the plate. Be sure that the other regions are dry.
2. Drip Ethanol with a new Pasteur pipette into the dry part of the plate until the two fluids meet.
3. Describe all the observations. If necessary you can add Ethanol.
4. Drip a drop of soap solution into the part where the colored water meets the Ethanol.
5. Describe what is happening

STAGE B: THE INQUIRY STEP

I.

1. **Formulate** 5 varied, relevant questions that arose following the observations that were made.
   - **Choose** one of the questions that you would like to investigate.
   - **Formulate** this question clearly as an inquiry question, and to the extent possible, as a link between two variables.
   - **Clearly formulate** a **hypothesis** that relates to the question that you chose to investigate.
   - **Give reasons** for your hypothesis, based on correct and relevant scientific knowledge.

2. **Plan** an experiment that will check the validity of your hypothesis.
   - **Detail** all the steps of the experiment, including the control stage.
   - **List** the equipment and materials needed on the equipment request form.
   - **Consult** with the teacher and make changes if necessary.
   - **Submit** the list of equipment and materials to the laboratory technician.

II.

3. Get the teacher's approval for the proposed experiment.
   - **Carry out** the experiment that you proposed after receiving the teacher's approval.
   - **Present** the observations and the results in an organized form (table, diagram, graph, etc.)
   - **Analyze and interpret** the results.
   - **Draw conclusions** as much as possible based on the experimental results and rationalize them.
   - **Examine** the connection between the inquiry question and the conclusions.

4. In the summarizing group discussion
   - **Express your opinion** about all the stages of the inquiry (limitations, precision, etc.).

- To the extent necessary, **point out** the changes desirable in the inquiry process.
- **List** additional questions that arose following the whole process.
- **Prepare** your group's summary of the experiment for **presentation** before the class.

5. In the summarizing class discussion
    - **Relate** to our experiment by considering the reports of all the other work groups.

6. **Ensure** that the report is well organized, aesthetic, and readable.

Enjoy the work!

*

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ENHANCING STUDENTS' MOTIVATION TO LEARN CHEMISTRY

Yamit Sharaabi-Naor
yamitsharaabi@yahoo.com | Weizmann Institute of Science, Israel

Miri Kesner
Miri.Kesner@weizmann.ac.il | Weizmann Institute of Science, Israel

Yael Shwartz
yael.shwartz@weizmann.ac.il | Weizmann Institute of Science, Israel

ABSTRACT

The interest, attitudes, and motivation of students towards science learning decreases over time, especially during the middle school years. In order to increase students' motivation to learn chemistry, a national program «Chemistry, Industry, and the Environment in the eyes of the individual and society» has been designed to integrate three main components: (1) a competition format; (2) a context-based approach, and (3) Project-based learning (PBL). Literature supports the effectiveness of each approach in enhancing students' motivation. In this study we evaluated how the combination of these approaches influenced students' motivation to learn chemistry. In addition, we evaluated a similar project that took place in a single school. The comparison took into account students' characteristics regarding their intrinsic motivation to study chemistry as a subject in general and the nature of the project. We found that the national project increases students' motivation to learn chemistry, whereas a similar project that takes place in school does not have the same effect. Nevertheless, we noticed a small decline in interest throughout the project. Once again, this research provides additional evidence of the complexity of motivational processes.

KEY WORDS

Competition; Motivation; High-school; Chemistry.

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Enhancing Students' Motivation to Learn Chemistry

Yamit Sharaabi-Naor | Miri Kesner | Yael Shwartz

THEORETICAL BACKGROUND

Motivation affects students' learning and engagement in formal, semi-formal, and informal activities. Already in 1993, it was suggested that we should turn our attention towards motivation more than we have done before (Pintrich, Marx & Boyle, 1993). Many studies in science education investigated students' motivation by examining cognitive and affective constructs (Koballa & Glynn, 2007; Logan & Skamp, 2008; Milner, Ben-Zvi & Hofstein, 1987; Shernoff & Hoogstra, 2001).

Different definitions of motivation and theoretical frameworks have been offered by researchers and practitioners in the area. *However, most researchers agree that* «Motivation is the process whereby goal-directed activity is instigated and sustained» (Schunk, Pintrich & Meece, 2008, p. 5). Motivation is a process rather than a product. As a process, we do not observe motivation directly but rather we infer it from actions (e.g., choice of tasks, effort, and persistence) and verbalizations (e.g., «I really want to work on this»). Motivation involves both physical and mental activity. Physical activity entails effort, persistence, and other overt actions. Mental activity includes such cognitive actions as planning, rehearsing, organizing, monitoring, making decisions, solving problems, and assessing progress. Most activities that students engage in are geared toward attaining their goals. There are several different theories that are suggested in the literature that try to define and explain the nature of motivating students involved in academic contexts. We present here short examples of the four leading motivational theories in the field of education: (1) *Self-determination* theory is directed to «the process of students utilizing their will» (Deci, 1980, p. 26). In *Self-determination* theory students must decide how to act on their environment according to their basic innate psychological needs such as a sense of relatedness, ability, and autonomy in order to be internally motivated (Deci, Vallerand, Pelletier & Ryan, 1991). (2) *Attribution* theories assume that individuals are motivated to understand and master their world and will try to determine the causes of events (Kelley, 1971). In an achievement context, the most important event is achieving success or failure, and attribution theory proposes that individuals' attributions will have significant consequences on the motivational process. In Attribution theory, two general categories can influence students' attributions for success and failure: environmental (social norms and other situational features) and personal factors (casual schema, attributional bias, prior knowledge, and individual differences) (Weiner, 1986, 1995). (3) *Achievement goal* theory mainly focuses on the goal orientation in the context of the academic behaviour of students. This theory specifies two main goal orientations: mastery goals orientation, and performance goals orientation. Mastery goals orientation refers to an individual's purpose of developing competence, understanding, and skills or achieving a sense of mastery (Ames, 1992). Performance goals orientation refers to the purpose of demonstrating competence. Performance-oriented students are concerned with others' perceptions of their competence and with their ability relative to others (Ames, 1992; Nicholls, 1984). (4) *Expectancy Value* theory takes into consideration students' perceptions of the value of the task combined with their expectation to succeed in it (Eccles et al., 1983). In our research we examined students' motivation mainly through the eyes of the Expectancy Value theory; hence, in our description we elaborate more about this theory. Expectancy Value theory has two central variables such as *Expectancies* and *Values*. The expectancy construct is one of the most important mediators of achievement behaviour. *Expectancies* are individuals' beliefs and judgments about their capabilities to perform a task successfully. Most individuals will not choose a task, or continue to engage in it when they expect to fail. In colloquial terms, expectancy answers the question: «Can I do this task?» (Eccles, 1993, 2005; Eccles, Wigfield & Schiefele, 1998; Pintrich, 1988a, 1988b; Wigfield, 1994; Wigfield & Eccles, 1992, 2002). If the answer is «yes», then most students will choose to engage in the task. *Values* – they refer to the beliefs students have about the reasons why they might engage in a task. Students might have a variety of reasons why they want to perform a task. Eccles et al. (1983) proposed four major components of subjective values: (1) Attainment value or importance – the importance of doing well on a given task. (2) Intrinsic value – the enjoyment or intellectual satisfaction that one gains from doing the task. (3) Utility value or usefulness of the task – how a task fits into an individual's future plans, for instance, participating in a chemistry project to fulfil a school or teacher's requirement, or to decide whether to enrol in a chemistry class in the future. (4) Cost belief – what the individual believes that he/she has to give up while performing a task (e.g., do I spend too much time working on the project instead of spending time with my friend?), as well as the anticipated effort one needs in order to complete the task.

Expectancy Value theory has had a long-standing tradition in achievement/motivation research, and current expectancy-value models have had some of the strongest empirical support in educational settings (Eccles, 1987, 1993, 2005; Eccles et al., 1983; Wigfield, 1994; Wigfield & Eccles, 1992, 2000, 2002; Wigfield, Eccles & Rodriguez, 1998; Wigfield, Tonks & Eccles, 2004). We utilized expectancy value theory for investigating students' motivation to learn chemistry by engaging them in a national competitive project.

Recently, studies have shown that the interest, attitudes, and motivation of students towards learning science decline toward the end of elementary school and especially during the middle school years (Anderman & Young, 1994; Galton, 2009; Osborne, Simon & Collins, 2003; Simpson & Oliver, 1990; Vedder-Weiss & Fortus, 2011). In order to overcome this problem, new trends have emerged that have influenced chemistry teaching throughout the world. These trends attempt to create an appropriate curriculum suitable for general education in chemistry, and for increasing the popularity of chemistry learning. In the next section we describe two leading approaches that positively influence the teaching and learning of science, as documented by many researchers. However, the literature also points out that each approach separately is insufficient to address all needs and challenges of science teaching and learning. Accordingly, in this paper we will present a program that blends these two well-known approaches in such a way that utilizes their benefits, and minimizes the disadvantages each has individually.

THE CONTEXT-BASED APPROACH

A very popular approach in chemistry education is the context-based approach (Gilbert, 2006; Pilot & Bulte, 2006), in which the scientific content is embedded in authentic contexts that show students the importance and relevance of science, for improving their own life, and also show how scientific methods and products can be applied (Gilbert, 2006; Bulte & Pilot, 2006). However, several disadvantages of using this approach were reported. For example, students still exhibited a decrease in interest, especially in physics and chemistry. This can be explained by the fact that in many cases, the contexts were chosen by the teacher or the curriculum developer, and not by the students. Video studies have shown that teaching and learning styles are teacher dominated, and do not allow students to develop their own ideas. In other words, students did not have enough autonomy in their learning process nor in choosing the subject of their interest inside a fixed context (Graeber, 1995; PISA consortium, 2007).

PROJECT-BASED LEARNING

Another popular approach related to science teaching and learning is Project-based learning (PBL). Project-based learning (PBL) is a model that organizes learning around projects. According to the definitions found in PBL handbooks for teachers, projects are complex tasks, based on challenging questions or problems, that involve students in design, problem-solving, decision making, or investigative activities; they give students an opportunity to work relatively autonomously over extended periods of time, and this results in realistic products or presentations (Jones, Rasmussen & Moffitt, 1997; Thomas, Mergendoller & Michaelson, 1999). Other features of PBL found in the literature include authentic content, authentic assessment, teacher facilitation but not direction, explicit educational goals (Moursund, 1999), cooperative learning, reflection, and incorporation of adult skills (Diehl, Grobe, Lopez & Cabral, 1999; Thomas, 2000). In PBL, usually there are questions or problems that «drive» students to encounter (and struggle with) the central concepts and principles of science. The central activities of the project involve the construction of knowledge by the students. PBL projects require much more student autonomy, choice, unsupervised work time, and responsibility than traditional instruction does. These are all characteristics that give the students a feeling of authenticity and ownership.

The PBL approach is well known for its beneřts for students (Knoll, 1997; Koschmann, 2001; Krajcik & Blumenfeld, 2006; Krajcik, Blumenfeld, Marx & Soloway, 1994; Rosenfeld & Fallik, 2002; Ruopp, Gal, Drayton & Přster, 1993; Thomas, 2000; Thomas, Mergendoller & Michaelson, 1999; Tinker, 1997). The research literature shows that students who engage in PBL develop skills of independent learning (including problem-solving), they learn to be more open minded, remember what they learn longer, and perform better on standard achievement tests than non-PBL students do. These findings were demonstrated for PBL (Blumenfeld, Krajcik, Marx & Soloway, 1994; Ladewski, Krajcik & Harvey 1994; Marx et al., 1994, 1997, 2004; Rivet & Krajcik, 2004; Schneider, Krajcik, Marx & Soloway, 2002), and for design-based science (DBS) (Fortus, Dershimer, Krajcik, Marx & Mamlok-Naaman, 2004). From a motivational point of view, Project-Based Learning designs are viewed as maximizing students' orientation toward learning and mastery. This could be mainly due to their emphasis on student autonomy, collaborative learning, and assessments based on authentic performances. In practice, Project-Based Learning designers have incorporated additional features such as variety, challenge, student choice, and non-school-like problems in order to promote students' interest and perceived value (Blumenfeld et al., 1991).

COMPETITIONS IN SCIENCE EDUCATION

The project reported in this paper is in a framework of a contextualized PBL, and took place in the context of a national competition. Our decision to choose the framework of a competition is supported by several studies, which consider competitions as an acceptable way to increase students' motivation for learning science. Competitions are popular all over the world. The chemistry international Olympiads are aimed at high-school honour students, and are mainly based on scientific content knowledge. For example, in the «Internet-symposium» 16-17 year-old students from several schools carry out a chemistry experiment and discuss their research (Internetsymposiom, 2010). Also, the «FameLab» (2010) competition is intended for graduate students who are requested to speak about scientific topics within three minutes. The IUPAC internet site (2010) also suggests a few ideas about competitions for the International Year of Chemistry 2011. This includes an essay competition «Chemistry-our life, our future», and an international pictures contest «Everything is Chemistry».

In this paper we present our findings regarding how the national competition-PBL design affected students' motivation to learn chemistry. We collected students' retrospective perceptions on their experience of learning chemistry as part of being engaged in the 'national project'. In addition, we compared these perceptions with the perceptions of another group of students that were engaged in a similar project that took place at school, named 'the school project'. This comparison better emphasizes the characteristics that a PBL design should have in order to achieve its goals of increasing students' motivation to learn chemistry while they are engaged in performing the project.

CONTEXT OF STUDY: DESCRIPTION OF THE NATIONAL PROJECT «CHEMISTRY, INDUSTRY, AND THE ENVIRONMENT IN THE EYES OF THE INDIVIDUAL AND SOCIETY»

According to the education literature, students are more motivated to study the subject matter when they find it more relevant to their lives and to the society in which they live (Bennett & Lubben, 2006). The organizers of the project found that it is important to emphasize the relevance of chemistry to daily life in order to make chemistry studies more meaningful to the students (Frailich, Kesner & Hofstein, 2007; Hofstein & Kesner, 2006; Kesner, Hofstein & Ben-Zvi, 1997). It is apparent that this context provides a very wide area of interest to the students, and allows them a high degree of freedom to choose their own subject of interest. In addition, utilizing the PBL approach enables the learning to be more student-centred and teacher facilitated instead of teacher guided. In this way, students can be more involved in the learning process and can enjoy their choice of interest inside the context-based learning.

The first round of this national competition took place in 2008. High-school students from all over the country were invited to take part in various projects, all of which are aimed at highlighting the importance and relevance of chemistry and its influence on individuals and to society.

Five parallel competitions were offered, namely: Preparing a short video; Preparing a poster; Preparing a newspaper article; Presenting a laboratory inquiry; Only in 2008: Solving a monthly riddle; Starting 2009: Preparing a photograph. The students present an artistic photograph of a phenomenon (related to chemistry), accompanied by a scientific explanation of the photographed phenomenon.

Each competition had different assessment criteria according to its unique product, but all of them required that proper scientific background and relevance to daily life be included. At the end of the project, students submitted their work for assessment. Those who prepared posters or laboratory inquiries were also asked to present a five-minute-verbal presentation in front of the judges.

THE UNIQUENESS OF THE NATIONAL PROJECT

The uniqueness of the project can be characterized as follows:

- It calls for the participation of high-school students at all levels (not only the students who take chemistry as a major).
- The fact that the project is based on a wide context area increases the students' degree of freedom in choosing a subject of their interest.
- Since the national competition is a PBL, it incorporates a good deal more student autonomy, choice, unsupervised work time, and responsibility than traditional instruction does. This also may have a positive effect on students' experiences, and they might enjoy the learning process more, and increase their internal motivation to learn chemistry.
- It offers ongoing mentors facilitation, both online and face-to-face.
- The students can meet and receive support and advice from experts in the relevant fields; these experts include scientists from chemical companies and science educators.
- Students are encouraged to participate in a one-day seminar (held in three regions) in which they participate in different workshops according to the type of product they are aiming at.
- The competitions promote peer collaboration - the chemistry students can involve students who major in other areas such as communication and multimedia according to the projects' requirements.
- The various competitions allow students with different learning styles and abilities to participate. They can prepare a specific type of product according to their interests, abilities, and talents.

- The project uses a formative assessment approach: There is a follow up process in which the outlines and interim products are checked and commented on if needed. The embedded assessment ensures that the students undergo a meaningful learning process, and helps in obtaining high-level students' products.
- All students who reach the final stage of the competition participate in a one-day national conference in which they present their work to their colleagues; they can choose their own unique way of presentation.
- The competition format enables students who reach the final stages to receive recognition for their work, and serve as their school representative. This may give students the feeling that they have a meaningful impact on their school image, and they may change their self-efficacy.

PROJECT PARTICIPANTS

Year	No. of students participating in projects	No. of students who reached the final stage	No. of participating schools that reached the final stage
2008-2009	220*	115	22
2009-2010	250	150	25
2010-2011	700	165	26
2011-2012	650	170	30

* Not including the monthly riddle.

Table 1 includes the national projects' participants over the years.

TABLE I – NUMBER OF PARTICIPANTS OVER THE YEARS

During the first two years the number of participants continued to grow slowly; however, two years later it started to grow significantly. This growth over the years serves as an indicator to the success of the national project.

SOME EXAMPLES OF STUDENTS' PROJECTS

Some students conducted *lab inquiries* on a variety of topics such as the effect of wine acidity on its colour; how do flame retardants, which are incorporated in different types of clothing, affect combustion; investigating the reaction between Coca-Cola and Mentos, as well as fermentation. Students created short *videos* on polymers, Dead Sea products, olive-oil production and its nutritional benefits, global warming, and others. Examples of newspaper *reports* are recycling, Chemistry in police work, and Chemistry used for our beauty. Examples of *Posters* topics are: Chemistry of love, acid rain, and how fuel can be obtained from water.

These examples demonstrate both the wide range of topics that students chose to focus on, as well as the socio-scientific aspects found in all the topics.

THE STUDY

The research took place in 2011-2012. Research design included the assessment of various components derived from the Expectancy-Value theory, and students' perception of a career in chemistry. We devoted a significant part of the research to the intrinsic value derived from the Expectancy-Value theory, since we consider it to be a good indicator that enables us to compare students' intrinsic motivation to learn chemistry by engaging in a project, and by approaching chemistry-related fields in their free time.

All motivational constructs were examined in two frameworks: (1) in the 'National project' competition, characterized by a free choice participation and took place in the Davidson Institute (in the Weizmann Institute of Science) and (2) in a similar 'school project' competition, in which participation was obligatory. The type of products and the assessment criteria for the 'school project' were similar to those of the national project; except that the school project was organized and facilitated by their chemistry teacher and was included in their chemistry formal scores at the end of their school year.

We examined students' perceptions of the experience of learning chemistry while they engaged in the projects, and we investigated, following their engagement in the project, whether students' motivation to learn chemistry increased.

Since the students that participate in a 'national project' freely chose to participate in it, we tended to think that they engaged in the activity for their own benefits and this falls into the authentic definition of intrinsic motivation. In the case of the 'school project', despite the fact that students were obligated to participate in the project, it was interesting to determine whether they still were internally motivated. We used this group as a control group relative to the national group. In order to overcome the possible differences in intrinsic motivation, we extracted from the two populations two sub-groups that were similar in their intrinsic motivation for *'chemistry learning at school'* and for *'approaching* *chemistry contents in general in their free time*' and compared their motivation to be engaged in the project. This will be presented in detail in the Results section.

RESEARCH GOALS AND QUESTIONS

Our main purpose was to evaluate how the 'National project' motivationally influenced chemistry learning for students. We addressed this question by collecting students' retrospective perceptions of their experience in learning chemistry through their engagement in the 'national project'. The fact that the 'national project' took place in an academic institute outside school might enhance students' motivation to learn chemistry more than if they were engaged in such a project at school. We compared the retrospective perceptions for their learning experience in the 'school project' with those received for the 'national project'.

An additional way to evaluate the success of the project is by comparing the 'intrinsic motivation' of students to learn chemistry, following their engagement in a project, with their motivation to approach chemistry contents in their free time. Hence, we examined (for each individual student) the value of 'intrinsic motivation' for chemistry learning via engaging in the project relative to that of being self-engaged in chemistry contents in general in their free time. These comparisons were conducted in both population groups: the 'national project' and the 'school project' students).

Based on the above goals, our research questions are as follows:

1) How does the 'national project' motivationally influence students to learn chemistry?
2) Are there differences in students' intrinsic motivation (for learning chemistry) while they engage in the project, relative to when they choose to be self-engaged in it on their free time and will?

RESEARCH POPULATION

'National project' Experimental group	*'School project' Control group*
N=116	N=52

TABLE 2 – RESEARCH POPULATION; STUDENTS WHO PARTICIPATED IN THE EVALUATION RESEARCH 2011-2012

Table 2 describes the two groups that were studied in the current study.

RESEARCH TOOLS

(1) A Likert-type questionnaire (1-5 scale) was developed for assessing various motivation categories. The categories were defined once for 'chemistry learning within the project', and once for 'chemistry subject in general'. The categories for 'chemistry learning within the project' are as follows: interest, enjoyment, easiness/difficulty, importance of doing well in a given task, and effort. The categories for students' perception of chemistry as a subject are as follows: interest and enjoyment while approaching chemistry contents in their free time and chemistry as a future career. The questionnaire was validated by 3 science-education researchers. Internal reliability, obtained by calculating the α-cronbach coefficient for each category, is presented in Table 3.

Category	Alpha Cronbach	No. of items	Example of an item
Chemistry in General			
Interest (free time)*	0.83	5	Chemistry-related issues evoke my curiosity
Career	0.88	5	It is possible that I'll choose a career in chemistry
Project			
Interest	0.86	6	To what extent did the chemistry project evoke your curiosity?
Enjoyment	0.8	4	Learning chemistry by engaging in the project was fun
Easiness /Difficulty	0.71	4	Learning the subject matter was easy when engaging in the project
Importance	0.85	5	It is important for me to succeed in the project
Effort	0.72	4	I made a big effort in order to succeed in the project

*This reflects students' interest when they engage in chemistry in their free time.

Table 3 – α-cronbach coefficient of categories

(2) An open-ended questionnaire allowed us to gather information regarding why students participated in the 'national project' (or in other words the utility value), the way students conducted their research, the kind of assistance that they used (or needed), some reflections regarding their learning

throughout the project, and whether the project influenced their attitude towards chemistry as a subject.

(3) 15 reflective interviews were conducted regarding students' experience and their desire to learn chemistry following their project and school studies. Triangulation was obtained by the three data sources – the Likert-type questionnaire, the open-ended questions, and interviews.

DATA COLLECTION & ANALYSIS

Lykert questionnaire: The value of 'Interest' was examined at the beginning and end times of the project (September and March 2012, respectively), all other values (such as enjoyment or difficulty) were examined at the end of the project. The mean score for each category was calculated and a paired t-test procedure was completed for comparing the students' motivation categories (or specific item) for the 'school project' or 'national project'.

The open-ended questionnaire: Students' answers were categorized according to the subject questioned. Then, all answers belong to a specific category were pooled to form a list of citations. Trends were observed and were used to support and explain data emerging from the Likert-type questionnaire.

Reflective interviews: The interviews were open in nature: students were asked to describe their experience and the process they underwent. Students talked freely and their answers were audio recorded, and transcribed. The transcripts were divided into sections by common categories. The categories emerged from students' answers. Also here, the interviews were utilized to better understand the results and to validly interpret the results.

RESULTS AND DISCUSSION

(1) How does the 'National project' motivationally influence the students' learning of chemistry?

By the end of the '*National project*' or '*school project*' we collected student's retrospective perceptions for their chemistry learning via engagement in the national project. These are presented in Table 4. Table 4 shows relatively high mean scores for all motivation categories related to the '*national project*'. All means are scored above the median (3 out of 5). The results are quite different for the '*school project*'. They had significantly lower scores than those engaged in the 'national project' in most motivational categories related to the project. This picture is reflected from all categories relating to the project except for a single category referring to 'Easiness /Difficulty'. Since both groups have similar scores for the 'Easiness/Difficulty' category (average of 3.7 in both groups in favour of chemistry being perceived as 'easy'), we claim that the '*Easiness / Difficulty' category* does not have a meaningful contribution to the differences observed in students' motivation for learning chemistry via the '*national project' relative to the 'school project*'. Our results may be interpreted as showing that the 'national project' has more of an effect on students' motivation for chemistry learning than the 'school project'. However, this effect may not be attributed only to the nature of the project.

Category	'National project' Mean	'School Project' Mean	Pr > |t|
Chemistry in general [1]			
Interest (free time)	3.3	2.8	0.0016
Career	3.2	2.1	<.0001
Project [2]			
Interest	3.6	2.3	<.0001
Enjoyment	4.0	2.9	<.0001
Effort	3.5	2.4	<.0001
Importance	4.5	3.6	<.0001
Easiness /Difficulty	3.7	3.7	NS

[1] These categories assessed the way students perceive chemistry in their free time.
[2] These categories assessed chemistry learning via students engaging in the project.

TABLE 4 – MEAN SCORES OF DIFFERENT MOTIVATION CATEGORIES FOR THE EXPERIMENTAL ('NATIONAL PROJECT') AND CONTROL ('SCHOOL PROJECT') GROUP

It might have something to do with the difference between the two populations regarding students' intrinsic motivation to learn chemistry in general. Our results show significant differences in students' motivation to approach chemistry contents in their free time for the 'national project' compared with the 'school project' population (Table 4). It appears that students that engage in the 'national project' have significantly greater interest in approaching chemistry contents in their free time than those engaging in the 'school project». Moreover, students engaging in the 'National project' reported that they are more interested in a chemistry career than those who engaged in the 'school project' (Table 4). These results may suggest that students that participated in the 'national project' were more intrinsically motivated than those who engaged in the 'school project'. In addition, the fact that students chose to participate in the 'national project', and were not obligated to do so by their teachers, could also contribute to the their greater enhancement in motivation that was observed for students participating in the 'national project' relative to 'school project'. Information gathered from interviews shed more light on how the populations of the *'national project' and the 'school project'* were motivated. It appears that they differ from each other not only regarding their motivation to be engaged in the project, but also in the way they perceive chemistry in general. Students from *'the national project'* exhibited positive attitudes for chemistry in general and for the project in particular, for example, some said:

> Chemistry is a subject that always interested me (…)
> I always liked chemistry (…)
> I enjoyed learning by myself; it is a subject of my choice.

In the case of the *'school project'* we did not observe that students spontaneously favoured chemistry, and we even observed negative impressions regarding the project itself. A sample quote:

> I think it is not fun to do a project in general (…) Since it demands investment in time which most students lack.

Considering all of the above, one can easily doubt the conclusion that the *'National project'* had more of an influence on students' motivation to learn chemistry compared with the *'school project'*. The differences in motivation may result from differences between both populations regarding their intrinsic motivation to study chemistry in general. In order to focus only on the impact that the 'national project' has on students' motivation to learn chemistry, we searched for a statistical way to eliminate the impact related to the differences in intrinsic motivation seen between both populations.

We statistically extracted two new subgroups that were similar in their intrinsic motivation, once for *chemistry learning at school* and once for *approaching chemistry contents in general in their free time*. Intrinsic motivation contains the *Interest* and *Enjoyment* values (data presented in Table 5). To achieve that, we excluded all students with scores above 3.5 in these categories from the 'national project' population. We now had two groups with no significant difference in their intrinsic motivation (see Table 5). For these two new groups, we again compared all motivational categories related to the project (see Table 6).

Category	'School Project' Mean	'National project' Mean	Pr > |t|
*Intrinsic motivation <Chemistry>**	2.56	2.57	N.S
*Intrinsic motivation <school>***	2.99	2.87	N.S

* This category includes items relating to students' interest and enjoyment of chemistry in their free time.
** This category includes items relating to students' interest and enjoyment of chemistry learning at school.

TABLE 5 – MEAN SCORES OF *INTRINSIC MOTIVATION* DATA CALCULATED FOR A CHARACTERISTIC SAMPLE BELONGING TO THE EXPERIMENTAL ('NATIONAL PROJECT') AND CONTROL ('SCHOOL PROJECT') GROUP. THE CHARACTERISTIC SAMPLES EXCLUDED DATA THAT WERE ABOVE 3.5

Category	'School project' <Mean>	'National project' <Mean>	'School project' /'National project'
Interest	2.32	3.148	<.0001
Enjoyment	2.847	3.613	<.0001
*Intrinsic motivation <project>**	2.531	3.337	<.0001
Effort	2.399	3.344	<.0001
Importance	3.625	4.311	<.0001
Easiness /Difficulty	3.71	3.554	N.S
Career	2.086	2.629	0.0079

* This category includes items relating to students' interest in and enjoyment of learning chemistry after engaging in a project.

TABLE 6 – MEAN SCORES OF DIFFERENT MOTIVATION CATEGORIES FOR THE CHARACTERISTICS OF THE EXPERIMENTAL ('NATIONAL PROJECT') AND CONTROL ('SCHOOL PROJECT') GROUP. THE CHARACTERISTICS ARE PRESENTED IN TABLE 5

Apparently there are significant differences in most motivational categories between the 'national project' relative to the 'school project', besides the '*Easiness /Difficulty* category. Even though we created two groups that have similar intrinsic motivation to study chemistry in general and for learning chemistry at school, our results did not change and explicitly show that the motivation to learn chemistry is significantly greater for those in the 'National project'. Finally, we can clearly state that the 'national project' increases students' motivation to learn chemistry significantly more than the 'school project'.

(2) *Are there differences in students' intrinsic motivation (for learning chemistry) while they engage in the project, relative to when they choose to be self-engaged on their free time and will?*

An additional way to evaluate the success of the project is by comparing students' intrinsic motivation to learn chemistry within the project to their intrinsic motivation to approach chemistry contents in their free time. We compared the values of interest and enjoyment that constitute the intrinsic motivation component. This comparison was done within each population separately ('national project' and 'school project'). Table 7 shows the results of this comparison.

Category	'National project' <Mean>			'School Project' <Mean>		
	Chemistry	Project	Pr > |t|	Chemistry	Project	Pr > |t|
Intrinsic motivation	3.25	3.72	<.0001	2.56	2.53	NS

TABLE 7 – MEAN SCORES OF THE INTRINSIC MOTIVATION (ENJOYMENT & INTEREST ITEMS) TOWARDS CHEMISTRY IN GENERAL AND SPECIFICALLY IN THE PROJECT

It appears that students of the 'national project' group have significantly higher 'intrinsic motivation' for chemistry learning both within the project and when they are self-engaged with chemistry contents in their free time.

However, there is no difference in the 'school project' group regarding their motivation to learn chemistry within the project and in their free time. Their intrinsic motivation in both cases is quite similar (and low), whereas students' intrinsic motivation to participate in the national project is significantly greater than when they are involved in chemistry in their free time. This means that there is a need for a structured framework and deadlines; this establishes a delicate balance between this need and the freedom and choice that the project should provide.

Here are some examples derived from students' reports, which support our conclusion:

1. In the case of the 'national project', students reported that it is more exciting to do the project in a research institute or an industrial facility (providing that they receive scientific, professional, and social support).

   I enjoyed the experience of going to the university and investigating the subject more deeply.

   I mostly enjoyed the interview I conducted with a doctor for nuclear medicine, meeting with professional people, elaborating my knowledge by learning new contents and working with industrial companies»

2. Students participating in the 'national project' had a chance to meet other students coming from different schools across the country and to present their work to each other. As a result, students undergo an extraordinary positive experience socially and emotionally.

   I enjoyed doing experiments related to my subject of choice and from presenting our project to other students we met.

Our main conclusion is that the national project enhances students' motivation for learning chemistry and significantly contributed to students in terms of interest, enjoyment, and importance. Students' motivation was found to be higher regarding their engagement in the 'national project' framework compared with a 'school project' framework, which was less successful. Interestingly, students' intrinsic motivation for learning chemistry is higher through engagement in the national project, and lower when they are self-engaged in chemistry contents in general in their free time, which implies the importance of an external framework. Here are some supporting quotes:

> During the project, I found out how interesting chemistry can be and I learned about new phenomena. (Interest)

> Chemistry is a much more complex subject than I previously taught. (Difficulty)

> The teamwork increased my enthusiasm for chemistry learning (Motivation)

Following a question: «Would you consider participating again next year»? Students mainly responded:

> Yes, it reflects my interests. I am curious to deal with another subject.

> Yes, it helped me better understand the lessons at school.

As was discussed in the introduction, the research literature shows that students who engage in PBL develop skills of independent learning, learn to be more open minded, remember what they learn longer, and perform better on standard achievement tests than do non-PBL students. Our research adds an additional perspective of how the national project (considered as a PBL), which takes place outside of school, contributes to students' motivation to learn chemistry. We showed here that the national project increases students' motivation to be engaged in learning chemistry, whereas a similar project that takes place within school does not have the same effect. Apparently, students participating in the 'school project' did not experience the project's unique atmosphere, especially the social interactions with experts and students from other schools, as experienced by the students of the national project.

In the future, we would like to better understand how school can enhance and maintain students' motivation to learn chemistry after they engage in the project. For example, students often reported that pressure from the school daily demands damages their functioning in the project. Since the project is time consuming, this time should be recognized by schools as a time of learning, and as such, it may replace a topic that is traditionally taught in class. As a consequence, schools may allow more time for, and put less pressure on students dealing with the project. An authentic collaboration between schools and external educational institutions should be established and implemented in order to promote students' motivation to be engaged in such a project, and to increase continuum motivation through the project as well.

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INQUIRY-BASED SCIENCE EDUCATION AND SPECIAL NEEDS – TEACHERS' REFLECTIONS ON AN INCLUSIVE SETTING

Simone Abels
simone.abels@univie.ac.at | Universität Wien, Austria

ABSTRACT

Many countries in the world signed and ratified the UN Convention on the Rights of Persons with Disabilities (2006) in order to ensure inclusive education at all levels. Nevertheless, dealing with differences in the classroom is seen as one of the biggest challenges teachers – also science teachers – face at the moment. Additionally, there is a lack of research in science education how to foster students appropriately in regard to their diverse pre-conditions. Research studies often recommend carefully scaffolded inquiry-based teaching approaches. This article is divided in two parts. The first part attempts to sum up what is known about the inclusion of students with special needs in science classes teaching them inquiry-based. The second part introduces a case study which investigates an open inquiry-based learning environment in an inclusive middle school. The learning environment is videotaped and reflected with the teachers. Ideas for change are developed. Conclusions are drawn for the facilitated competence gain for students with and without special needs.

KEY WORDS

Special education; Inquiry-based learning; Inclusion; Reflection; Case study.

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Inquiry-Based Science Education and Special Needs – Teachers' Reflections on an Inclusive Setting

Simone Abels

INTRODUCTION

Inclusion has its origin in special needs education (UNESCO, 2005). In 1994 the UNESCO *Salamanca Statement and Framework for Action in Special Needs Education* claimed that «those with special educational needs must have access to regular schools which should accommodate them within a child-centered pedagogy capable of meeting [their] needs» (United Nations & Ministry of Education and Science Spain, 1994, p. viii). In recent years the majority of the countries in the world have signed the UN *Convention on the Rights of Persons with Disabilities*[1], which means those countries have to take the responsibility to implement an inclusive school system. The right to education for every student was already set in 1948 (United Nations, 1948). In the meantime, the UN added that education «on the basis of equal opportunity» cannot be denied (United Nations, 2006, p. 16). Equal opportunity means «genuine access to learning experiences that respect individual differences and quality education for all focused upon personal strengths rather than weaknesses» (Meijer, 2010, para. 2). Accordingly, inclusion is defined as

1 http://www.un.org/disabilities/countries.asp?id=166 (Retrieved October 21, 2013).

> a **process** of addressing and responding to the diversity of needs of all learners through increasing participation in learning, cultures and communities, and reducing exclusion within and from education. It involves changes and modifications in content, approaches, structures and strategies, with a common vision which covers all children of the appropriate age range and a conviction that it is the responsibility of the regular system to educate all children (UNESCO, 2005, p. 13, original emph.).

Important is, for one thing, the idea of differentiation addressed in this definition as a strategy to provide equal opportunities. And for another thing, the attitude is crucial that the education system has to be made inclusive, not the student has to be made includable.

The perspective is that every student should be perceived as having particular learning needs. Furthermore, in many mainstream schools social developments like globalization, migration, demographic and value change are notable, increasing the diversity of students attending the same school (Krell, Riedmüller, Sieben & Vinz, 2007). Thus, all teachers should develop competencies such as individualizing, differentiating and diagnosing to meet the individual needs of all students coming together in one classroom at least partly to be supported by special educators. Education policy and teacher education have to shoulder responsibility to support teachers regarding these demands.

Empirical evidence for the normative demands is coming from the OECD. PISA has revealed that countries with inclusive school systems are more likely to be high-performance countries (OECD, 2010). One indicator for an inclusive system named by the OECD is that students are rarely transferred out of school because of special educational needs.

Despite the ratification of the policy documents and this data, inclusive education is not facilitated for every student yet, especially in those countries which traditionally pursue a segregated school system (Sliwka, 2010). For example, in Austria about 41% and in Germany almost 79% of the students with special educational needs are taught in separated settings (European Agency for Development in Special Needs Education, 2007, 2012).

This issue has not only to be discussed systemically on a macro level, but also on a micro level concerning equal learning opportunities in the classroom which are not sufficiently provided. «A resistance from practitioners to change and develop their professional practice to meet the demands and challenges of inclusive education, have led to extremely variable and often poor practice in the area» (Lloyd, 2002, p. 111). Teachers view the differences of their students as one of the biggest challenges to deal with in the classroom (Meijer, 2010). Nevertheless, it is an educational demand and political obligation to adapt teaching practices to the specific needs of all students in a mainstream school, including students with special needs. Research has to provide evidence-based implications for teachers how different students can be fostered best in one classroom.

At the same time as the inclusion movement proceeded, the «Science for All» movement was sharpened (National Research Council, 1996). School science still has the purpose to prepare students for future studies and careers in science, but this is not the only obligation anymore. «[T]he primary and explicit aim of the 5-16 science curriculum should be to provide a course which can enhance 'scientific literacy', as this is necessary for all young people growing up in our society, whatever their career aspirations or aptitudes» (Millar & Osborne, 1998, p. 9). According to the OECD (2006) scientific literacy refers to an individual's:

- Scientific knowledge and use of that knowledge to identify questions, acquire new knowledge, explain scientific phenomena and draw evidence-based conclusions about science-related issues
- Understanding of the characteristic features of science as a form of human knowledge and enquiry
- Awareness of how science and technology shape our material, intellectual, and cultural environments
- Willingness to engage in science-related issues and with the ideas of science, as a reflective citizen (OECD, 2006, p. 23).

Life-long learning and acting responsibly in a democratic society are crucial in our rapidly changing, technology-driven culture. Therefore, students need to develop the capacities «to apply knowledge and skills in key subject areas [like science] and to analyse, reason and communicate effectively as they pose, interpret and solve problems in a variety of situations» (OECD, 2010, p. 17). Methodologically and on a more practical level, inquiry-based science education (IBSE) is rated as an appropriate approach so that students can develop these capacities in science and become scientifically literate (European Commission, 2007; National Research Council, 2000).

Inquiry «refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world» (National Research Council, 2000, p. 23). Teaching inquiry-based strives for three aims:

- to construct scientific knowledge,
- to learn how to perform an investigation and
- to learn about inquiry (Abrams, Southerland & Evans, 2008).

Just like dealing with differences, teachers also struggle with the implementation of IBSE into their science teaching practice and express a lack of training in this field (Barron, Finlayson & McLoughlon, 2012; Roehrig & Luft, 2004). Teaching inquiry in a highly diverse classroom could be considered as the major challenge. The daily practice of science teachers has to be empowered for change in terms of the inclusive demands posed by education policy (cp. Lloyd, 2010). Science educators seem to be ill-equipped to teach students with disabilities while special educators are rarely trained to teach science. In addition, the important collaboration between the two professions appears as neglected (Villanueva, Taylor, Therrien & Hand, 2012).

Many general education teachers and science education researchers doubt that the performance of special needs students is sufficient to fulfil the sophisticated demands of science instruction, e.g., high level thinking, problem solving and inquiry learning (Ellis, 1993; Steele, 2004; Sullivan Palincsar, Magnusson, Collins & Cutter, 2001; Woodward & Carnine, 1988). «From studies of traditional (i.e., no inquiry, text-based) science instruction – for example, Carlisle and Chang's (1996) three-year longitudinal study of students with learning disabilities – we know that special needs students fare poorly and express doubts about their capacity to perform successfully in these classes« (Sullivan Palincsar et al., 2001, p. 16). Finkel, Greene, and Rios (2008) ENREF 6 raise concern that inquiry-based learning should not be considered as a panacea for supporting diverse students in becoming scientifically literate.

However, taking the requirement «Science for All» seriously, science education for students with special needs has to provide equal learning opportunities. Allowing for students with disabilities in the «development of classroom lessons ultimately makes the science class more inclusive. Moreover, it ensures that all students learn about science and become scientifically literate, which is a stated goal in the National Science Education Standards (NRC 1996)» (Trundle, 2008, p. 80). In addition to this normative statement, the limited number of empirical studies gives evidence positive for the inclusion of special needs students in carefully scaffolded inquiry-based science instruction.

PURPOSE AND LIMITATIONS OF THIS ARTICLE

On the basis of recent studies in the fields of science education and special education this article will show that IBSE can be an appropriate approach in inclusive settings when it is carefully scaffolded. Evidence-based practices how to scaffold an inclusive class will be introduced. Most of the research results arise from control group design studies. The case study presented here tries to give an in-depth look how two teachers deal with students learning inquiry-based in an inclusive setting. The teachers' aims and priorities, but also their difficulties and conflicts will be worked out. The first reflective meeting with the teachers will be presented here where the teachers developed solution approaches together with the researcher.

The case is an urban lower secondary inclusive middle school. The article here focuses on an eighth grade class passing through a three day open inquiry process. Five of the 20 students are officially diagnosed as having special needs.

Special educational needs are diagnosed in different areas and support is provided accordingly in form of extra resources. Key-areas are:

- learning capacity and behaviour, especially scholastic learning and the ability to cope with disability in the learning process;
- speech, speaking, the communicative act, handling speech problems;
- emotional and social development, experience and self-control, dealing with disturbances, inexperience and behaviour;
- intellectual development, handling intellectual retardation;
- physical and motor development, dealing with severe disabilities in movement and with physical handicap;
- hearing, auditory perception, the ability to handle a hearing impairment;
- vision, eyesight, visual perception, the ability to deal with a vision impairment;
- state of health and state of mind, the ability to cope with a long-term illness (European Agency for Development in Special Needs Education, 2010, para. 14).

The first four areas and the last one listed are present at the school being in the focus here. Because of the special needs areas present in the class chosen for this case study and not least because of the expertise of the author the article at hand focuses on students with the focal areas of support «learning» as well as «emotional and social development», in other words on students with cognitive and emotional/behaviour disorders. Students with these needs form one of the biggest groups of the special needs population who are included in mainstream schools the most compared to learners with other special needs (Mand, 2009; Villanueva et al., 2012). The inclusion of students who need support in emotional and social development is seen as the most challenging though (Meijer, 2010). There are almost no studies about teaching students with severe disabilities inquiry-based (Courtade, Browder, Spooner & DiBiase, 2010).

Implications will be drawn for the implementation of IBSE in an inclusive setting. In addition, the in-depth results can enhance discussions among general and special educators.

As the research project is in the starting phase, only preliminary results can be reported that have to be analysed more systematically in the future. Contrasting cases have to be found to scrutinise the results like it is conventional in a grounded theory approach (Charmaz, 2012; Corbin & Strauss, 1990). Nevertheless, the detailed insight that is possible through this project provides relevant hints for educators and researchers concerning IBSE and inclusion.

INQUIRY-BASED SCIENCE EDUCATION FOR STUDENTS WITH SPECIAL NEEDS

Students with a focal point of support in learning and/or social and emotional development face several challenges in the science classroom. For example, science textbooks «are often written 2 or 3 years above the actual reading levels of students with disabilities« (Steele, 2004, p. 20). Science vocabulary can be hard to understand and to use. Class discussions or lectures can be difficult to follow and the presented information hard to reproduce. Mnemonic strategies have to be developed with the students. Attention and concentration can be fast overburdened. The students can also be challenged to organize their notes or materials, e.g., while planning or conducting an experiment. Students with cognitive disorders often perform better in specific tasks than in situations where generalisation and transfer are needed (Steele, 2004). Scruggs and Mastropieri (2007) found that the psychometric IQ was a strong predictor for drawing inductive conclusions. Additionally, «negative attitudes can also create difficulties for students with special needs. Because of their cycle of frustration and failure, they may have trouble staying motivated and focused on a task» (Steele, 2004, p. 20). This can have effects on them establishing reliable relationships. Social skills are a developmental area which can affect group work (Steele, 2004).

These deficits are the reasons why students with special needs are often regarded as incapable of doing inquiry. This is understandable reading the list of abilities the National Research Council claims as necessary to do inquiry (table 1).

Grades K-4	Grades 5-8	Grades 9-12
Ask a question about objects, organisms, and events in the environment.	Identify questions that can be answered through scientific investigations.	Identify questions and concepts that guide scientific investigations.
Plan and conduct a simple investigation.	Design and conduct a scientific investigation.	Design and conduct scientific investigations.
Employ simple equipment and tools to gather data and extend the senses.	Use appropriate tools and techniques to gather, analyze, and interpret data.	Use technology and mathematics to improve investigations and communications.
Use data to construct a reasonable explanation.	Develop descriptions, explanations, predictions, and models using evidence.	Formulate and revise scientific explanations and models using logic and evidence.
Communicate investigations and explanations.	Think critically and logically to make the relationships between evidence and explanations.	Recognize and analyze alternative explanations and models.
	Recognize and analyze alternative explanations and predictions.	Communicate and defend a scientific argument.
	Communicate scientific procedures and explanations.	
	Use mathematics in all aspects of scientific inquiry.	

TABLE I – FUNDAMENTAL ABILITIES NECESSARY TO DO SCIENTIFIC INQUIRY (NATIONAL RESEARCH COUNCIL, 2000, P. 19)

Defining the list not as necessary abilities, but as aims in the science classroom, could offer a shift in perspective. On top of that, deficits should rather be considered as developmental areas. The core idea of this change in perspective is that the school system has to provide resources and the teachers should look for strategies and approaches so that students can make learning progressions. It is not the student who must prove to be includable. Inquiry-based teaching could provide learning opportunities for special needs students to develop some of the competencies (cp. table 1) and to foster them according to their needs. However, the positive attitude and substantial education of teachers is extremely relevant to reach this goal (Norman, Caseau & Stefanich, 1998).

The expert group of the European Commission (2007) recommends inquiry-based teaching for students across the ability range. There is a limited body of research on IBSE supporting this claim related to students with cognitive and emotional/behaviour disorders.

Bay, Staver, Bryan, and Hale (1992) compared direct instruction and discovery teaching in their study in terms of science achievement, the retention of the achievement, generalisation of science process skills and hindrance of no handicapped students. Ten students were diagnosed as having cognitive disorders, six students as having behavioural disorders. All were integrated in general education classes. The results showed no advantage for one of the approaches concerning science achievement. But «students' retention after two weeks was higher for those who received the discovery instruction» (Bay et al., 1992, p. 567). This is unsurprisingly not the case for the students with learning disabilities, because of their cognitive pre-conditions. However, the learning disabled students receiving discovery teaching scored better in the generalisation test than their counterparts with direct instruction. Against a common expectation, the achievement of no handicapped children was not hindered because of the integrated students. This study suggests that discovery learning approaches can be appropriate for students with cognitive and behavioural disorders; at least they are not obstructive for learning.

McCarthy (2005) compared a science textbook instruction with a hands-on approach in two classrooms where students with serious emotional disturbances were integrated. The researcher was interested in the effects on students' behaviour and achievement. Concerning achievement, the students who were taught with the hands-on approach performed significantly higher in the achievement tests. No difference was observable in terms of student behaviour.

In the study of Mastropieri, Scruggs, and Butcher (1997) normally achieving students were compared with students with learning disabilities and students with mental retardation (assessed by their teachers and IQ-tests) in an inquiry-based learning environment. Students were «coached and prompted to provide a general rule using inductive thinking» working on a physics task (ibid., p. 9). As expected, the students with learning disabilities scored between the other two groups of students in the generalisation tasks and needed fewer coaching than the students with mental retardation, but more coaching than the normally achieving students. The authors suggest that students with learning disorders can participate and benefit from inquiry-based learning, but need well-structured support. Ten and more years later and on the basis of many more investigations the researchers come to similar conclusions. Constructed and instructed learning approaches have both shown their applicability. The implementation is always depending on the learning aims strived for which do not have to be the same for every student. Subject-specific aims should be different while educational aims should be the same (Hinz, 1996). If inquiry-based settings are chosen, students with special needs will need an appropriate amount of coaching (Scruggs & Mastropieri, 2007). «When instruction is appropriately presented and modified, students with learning disabilities are very successful at mastering science content« (Brigham, Scruggs & Mastropieri, 2011). The case study of Sullivan Palincsar et al. (2001) contributes to understand the learning opportunities students get when participating in a guided inquiry-based setting. All students, also those with special needs, made significant learning gains when scaffolded by teachers with advanced strategies, i.e., «(a) monitoring and facilitating student thinking, (b) supporting print literacy, and (c) improving working in groups» (Sullivan Palincsar et al., 2001, p. 24).

Two reviews and a meta-analysis about studies in this field summarise that IBSE is only benefiting for students with special needs when it is carefully structured and scaffolded (Scruggs, Mastropieri & Okolo, 2008; Therrien, Taylor, Hosp, Kaldenberg & Gorsh, 2011; Villanueva et al., 2012).

One strategy of scaffolding is to implement inquiry-based learning successively to give students the chance to acquire the needed skills (see table 1) stepwise, thoroughly and without excessive demands. This procedure allows them to develop a feeling of autonomy and competence (Deci & Ryan, 2000). «It is important that learners develop basic learning techniques for autonomous study. Those have to be extended in class step by step» (Wodzinski & Wodzinski, 2009, p. 146).

To fulfil this demand in school the levels of inquiry-based learning can be applied (Abrams et al., 2008; Schwab, 1964). The higher the level of inquiry, the higher the level of responsibility placed on students. The explicit instruction of the teacher is gradually reduced with each level (table 2).

	Source of the question	Data collection methods	Interpretation of results
Level 0: Verification	Given by teacher	Given by teacher	Given by teacher
Level 1: Structured	Given by teacher	Given by teacher	Open to student
Level 2: Guided	Given by teacher	Open to student	Open to student
Level 3: Open	Open to student	Open to student	Open to student

TABLE 2 – THE LEVELS OF INQUIRY
(BLANCHARD ET AL., 2010, P. 581)

Students with no or little experience should start with an inquiry level 0 and acquire more and more competencies stepwise to work successfully on the other levels. «Instruction should gradually and systematically move from Level '0' activities with the ultimate goal being some Level '3' activities» (Lederman, Southerland & Akerson, 2008, p. 32).

However, in special education level 3 is not automatically the optimal level to be achieved for every student (Abels, 2012a). The levels should be applied appropriately in terms of context, e.g. aim, situation, students' pre-conditions and experience, topic, etc. Some students need a lot of structure and support. Having implemented a set of tools on level 0 and having enhanced the competence to draw conclusions on level 1, level 2 is often the most appropriate level in the long run offering a mixture of adapted structuring and openness. A balance between openness and structure has shown to be effective for students with cognitive and emotional/behaviour disorders (Werning & Lütje-Klose, 2007). That is why Scruggs et al. (2008) recommend guided inquiry on the basis of their studies. The following table shows a list of aims for each level which can be focused level by level. Developing the skills successively and in teamwork is supposed to increase students' feeling of autonomy, relatedness and competence (cp. Deci & Ryan, 2000).

The core skill to do open inquiry is being able to ask scientific questions. This is regarded as a complex and challenging task. Students have to be enabled to ask scientific questions to do open inquiry. Hofstein, Navon, Kipnis, and Mamlok-Naaman (2005) distinguish low-order and high-order questions. «[H]igh-level-type questions (...) are questions that can be answered only by further investigation, such as conducting another experiment or looking for more information on the Internet or in chemistry literature. These ques-

Level 0	• To be acquainted with devices (pH meter, thermometer, …) • To conduct certain practices (to titrate, to filtrate,…) • To follow safety guidelines • To follow descriptions of experiments, etc.
Additionally on Level 1	• To observe • To document observations and interpret them in the team • Apply knowledge to come to conclusions and judgements • To justify conclusions with evidence-based arguments • To present and discuss results, etc.
Additionally on Level 2	• To hypothesise • To plan and conduct experiments • To consider influencing factors, e.g., to decide about quantities, devices etc. and justify decisions • To control variables • To justify the experimental design • To match results with hypotheses • To change the experimental design reasonably, etc.
Additionally on Level 3	• To ask scientific questions • To take responsibility for the whole investigation process, etc.

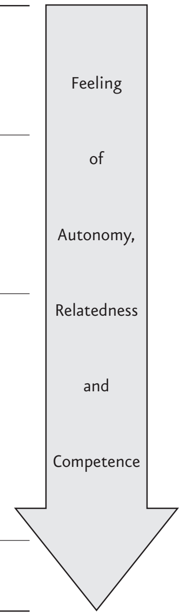

TABLE 3 – AIMS OF INQUIRY LEARNING LEVELWISE

tions are more complicated, and the student has to think critically about the research to be able to pose them» (ibid., p. 8). Question stems can help students to phrase questions which do not just ask for facts (Neber & Anton, 2008).

There are more strategies of scaffolding which can support inquiry learning. These strategies are mentioned in the following list with further reading advice.

- Teaching mnemonic strategies is effective as students can recall vocabulary and thus have more capacity to learn science concepts (Scruggs & Mastropieri, 2000; Scruggs et al., 2008; Therrien et al., 2011).
- Spooner, Knight, Browder, and Smith (2012) identified task analytic instruction with systematic prompting and feedback as well as time delay as evidence-based practices to support students with disabilities (cp. also Browder et al., 2012).
- Graphic organizers «improve the factual comprehension and vocabulary knowledge of intermediate and secondary students with LD [learning disability] in science» (Dexter, Park & Hughes, 2011, p. 210). They also facilitate longer maintenance of scientific knowledge (ibid.).
- Peer-tutoring has shown to be very successful in supporting students with cognitive disorders (Jimenez, Browder, Spooner & Dibiase, 2012; Scruggs & Mastropieri, 2007).

- Text enhancements, vocabulary learning and other language strategies support a diverse student group in comprehending a science concept and conducting an inquiry (Bakken, Mastropieri & Scruggs, 1997; Markic & Abels, 2013; Mason & Hedin, 2011). Word and picture symbol cards were also shown to be supportive (Browder et al., 2012)
- Targeted questioning by teachers or peers helps students to draw inferences and come to higher levels of comprehension compared to just providing them the knowledge (Mastropieri et al., 1997).
- Differentiated materials enable students of different achievement levels to work on the same topic (Abels & Markic, 2013; Tobin & Tippett, 2013).

Inquiry-based learning environments can be varied in length, complexity, task, responsibility etc. Groups of students can do parallel work on different levels supported by different strategies (Abels, 2012a). The teacher can provide material, guiding or targeting questions, hint cards etc. which can be used by students who need support. Using the provided help reduces the openness of inquiry, but allows everyone to participate in the task. These aspects make inquiry-based learning suitable for students with different cognitive and affective pre-conditions. Additionally, general education students are not hindered in their learning (Bay et al., 1992). Even more, what is good for students with special needs is beneficial for all students in the (science) classroom (Meijer, 2010; Steele, 2004).

IBSE IN AN INCLUSIVE CLASSROOM – A CASE STUDY REPORT

The European Agency determined seven factors which are crucial for inclusive education in the secondary setting. A combination of factors makes a setting even more inclusive (Meijer, 2005, 2010). The factors are

- Co-operative teaching (i.e., cooperation between teachers in- and outside of school),
- Co-operative learning (i.e., peer tutoring),
- Collaborative problem-solving (i.e., clear class rules and behaviour strategies agreed with the students),
- Heterogeneous grouping (i.e., differentiation and absence of homogeneous grouping),

- Effective teaching (i.e., systematic monitoring, assessment, evaluation and feedback, individual education plans),
- Home area system (i.e., two or three classrooms per learning group with a consistent team of teachers), and
- Alternative ways of learning (i.e., learning to learn and teaching students to learn autonomously).

For the case study presented here an urban lower secondary school was chosen that fulfilled more than one of these factors. The school is an inclusive middle school from grade five to eight. In every class four to five students with special needs are officially integrated. Extra resources are provided in terms of an integration teacher. Help by volunteers (teacher students, retirees, other guests) is always welcome. About 20 students are grouped into one class. Every student is seen as having particular learning needs. Parents choose the school because of the effective support every student receives, not only the students with diagnosed special needs. There are consistent teacher teams responsible for one age-group level. Systematic monitoring and evaluation are organised in cooperation with the education authority and the university. Alternative ways of learning and assessment are established, also in science (Minnerop-Haeler, 2013).

The most innovative approach to establish an inclusive learning culture in science is a *Lernwerkstatt*. The concept was originally developed by Karin Ernst in Berlin, Germany, in 1980. It is mainly based on the New York workshop centre developed by Lillian Weber (Ernst, 1996; Weber, 1977). As there is no appropriate translation the term *Lernwerkstatt* will be used in the following. «A Lernwerkstatt is described as a room where learners encounter stimulating phenomena, objects and materials which are supposed to trigger questions in their own field of interest (...) to start immediately with an inquiry» (Puddu, Keller & Lembens, 2012, p. 154). *Lernwerkstatt* can be classified as open inquiry which is accompanied by coaches who scaffold students' inquiry learning process (Hagstedt, 2004; Zocher, 2000).

The inclusive middle school which is in the focus here has an own room designed as a *Lernwerkstatt* where students have access to inspiring materials, objects and phenomena (Minnerop-Haeler, 2013). Every class in the school has one *Lernwerkstatt* per year lasting three days. Given are the topic and scenery of materials and phenomena which encourage the students to find their own questions and hypotheses. This classifies the setting as an open inquiry approach.

FIGURE 1 – SCENERY WITH MATERIALS IN THE LERNWERKSTATT «LIGHT AND COLOUR»

Prescribed topics are, for example, light and colour, water, insects etc. (figure 1). Together with the coaches the students find a question, plan and conduct experiments and document their ideas and observations in a lab journal. Coaches are the *Lernwerkstatt* teachers, the classroom teachers who join the *Lernwerkstatt*, higher education students or assistant teachers. At the end a festivity is arranged by the students to present their own results (Minnerop-Haeler, 2013).

The two teachers leading the *Lernwerkstatt* were desirous of reflecting the open inquiry setting to make the learning even more effective for the students according to the aims of inquiry learning (see table 3 above). This positive teacher attitude is one of the success metrics of the school (cp. Norman et al., 1998). To have a basis for the reflection, all classes working in the *Lernwerkstatt* this school year were and will be videotaped. Additionally, the teachers wore audiotapes to record their scaffolding. Student interviews and the lab journal will function as a third and fourth database. The reflection of the video scenes is in the focus in this paper. Video sequences were chosen by the author and reflected together with the teachers to develop alternative approaches during the *Lernwerkstatt* so that the students' autonomous learning can be improved.

THE VIDEO SCENES

The research project is currently in a starting phase. First rounds of data collection and analysis have started in accordance with a Grounded Theory approach (Corbin & Strauss, 1990). The article at hand focuses on the first reflective meeting with the two *Lernwerkstatt* teachers.

FIGURE 2 – CLUSTERING OF STUDENTS' QUESTIONS

Two video scenes were chosen for this meeting recording the beginning of the *Lernwerkstatt* where students are supposed to find their research question. The topic was light and colour in grade eight who had *Lernwerkstatt* for the third time. 20 students of one class participated in this *Lernwerkstatt*, ten boys and ten girls. Five students officially had special needs, three girls and two boys, reaching from severe to mild disabilities, from mental retardation to autism to ADHD and emotional/behavioural issues. But there are more students with special needs although not diagnosed. According to the teachers every student has particular learning needs. Four coaches were present to support the students: the two leading teachers, the classroom teacher and a school assistant. The researcher and her diploma student were also fixed with scaffolding two groups of students. Every coach except the diploma student knew the class from other lessons to a different extent. One of the leading teachers is the science teacher in this class.

The first video scene selected by the researcher shows how the students presented all the questions they framed after walking through the scenery of materials and phenomena. The teachers clustered the questions among umbrella terms (green cards, see figure 2).

Each student phrased between one and about 15 questions. The students phrased, for example, the following questions:[2]

- How does a laser pointer operate?
- How far does reflected light go?
- Can light be transformed to electricity?

2 All translations were made as close as possible to the original wording.

- Why are some creatures attracted by light?
- Why is light so important?
- How fast is light?
- What would happen if the sun had another colour?
- Why is the world so colourful?
- Who discovered the colours?
- And many more …

The second video scene shows which topic or questions the students finally chose and how the decision process ran. Topics respectively questions chosen were, for example:

- What is a rainbow?
- Gain of energy out of light
- The colour blue
- How do colours affect us?
- Reflection of light with mirrors
- To build a kaleidoscope
- To dye food
- (…)

These two scenes were chosen for a first reflective meeting with the two teachers, because the phase of phrasing and finding scientific questions is regarded as extremely challenging, and at the same time crucial for starting with an open inquiry (cp. Hofstein et al., 2005).

Both phases, the collection and clustering of questions and the selection of a topic, had conducive and obstructive aspects for students' learning processes. From the researcher's point of view fostering elements were the following:

- Students phrased questions self-dependently,
- The interest of the students was pivotal,
- Some questions were already high-order questions which was made visible,
- There were a lot of why-questions making students' conceptions explicit,
- Exciting questions were posed which were all asserted and appreciated,
- The appreciative attitude of the teachers,
- The growing collection of questions on the wall as a joint project,

- The possibility to learn from each other and to get aware of each other's interests,
- To divide into groups autonomously, and
- To choose a question/topic by oneself.

From the researcher's perspective obstructive aspects were, for example, that the phase of clustering questions was very long (>20 minutes) demanding a lot of attention and patience from the students. Furthermore, the mental work was actually done by the teachers by clustering the questions on the wall and finding umbrella terms. Only one of the students was active at the moment of presentation. The others tried to stay calm or whispered with their neighbours. The students have to be praised for their perseverance, but had to be exhorted from time to time by the teachers:

T1:[3] I think it's a pity that you don't really listen and just watch there what questions people found.

T2: I believe that they are so enthusiastic about <u>their</u> questions and busy with them, you are allowed to tell them immediately, ok?

The aim of the phase of presenting questions and the added value for the students stayed unclear or implicit, especially because the majority of the students chose a topic later on to work further with instead of their original questions. Some of the students' questions were not even allowed to be chosen but it is not explicitly said why. Additionally, it was unclear how many students could work together on the same topic. A girl putting her hand up first asked how many students could work together in one group. Teacher 1 said, «We will see.» This caused problems which will be shown in the following videotaped and transcribed plenum conversation. The outtake shows the parallel negotiation about topics and group size based on implicit rules.

S_m1: I would like to with S_m2, S_m3 and S_m4, well//

T1: //in a group of four

S_m1: //the topic to make construct a laser.

3 The leading teachers are abbreviated with T and a number. Students are abbreviated with S, m for male and f for female and a number. The school assistant is indicated by Ass., while the classroom teacher is abbreviated with CT. Emphasised words are underlined, breaks are indicated by (-), one hyphen per second. Double slashes show that persons cut in.

S_m2: to construct a laser

T1: Well, in a group of four, what do you want now, my question is, do you want to construct a laser?

S_m2: Yes. We wanted to see ourselves//

T1: Eh, I tell you immediately, doesn't work.

S_m2: We want to see, well, how it is constructed and, well, we wanted to rebuild a laser ourselves.

T1: You are not able to do it here. That's not working. That that doesn't work by any means. That doesn't work. Ok, I can tell you immediately, that doesn't work. To construct a laser pointer doesn't work.

S_m5: I have a question.

T1: Yes?

S_m5: I have a question. Why does this not work?

T1: Because we do not not have (--) things for this.

Ass.: No mirrors, no lenses, no strong light//

T1: //That doesn't work.

CT: If you do not know what you are doing, it can blow up in somebody's face//

T1: //doesn't work. Well, building a laser pointer doesn't work by any means. Ok? So. Think about it, please, ok? S_f1?

S_f1: Eh, us four, we wanted to do the topic rainbow.

L2: Ok, guys, you know from last year, four people are not working.

CT: And above all, yes, there is only laughter and//

T1: //No, well, two people rainbow is ok. But four, or two times two different groups, yes, but a group of four surely doesn't work.

The aim of the reflective meeting was to see which conducive and obstructive aspects the teachers would identify as well as to develop alternatives together for the processes of presenting and choosing research questions. This reflective process is organised in accordance with the ALACT model (figure 3). Step 1 was videotaped, step 2, 3 and 4 were conducted during the meeting. Step 5 is supposed to happen during the next *Lernwerkstatt*. Reflection is seen as a key element for improvement of and for lasting changes in teaching practice as well as congruent teaching (Abels, 2012b; Swennen, Lunenberg & Korthagen, 2008; Zeichner & Liston, 1996).

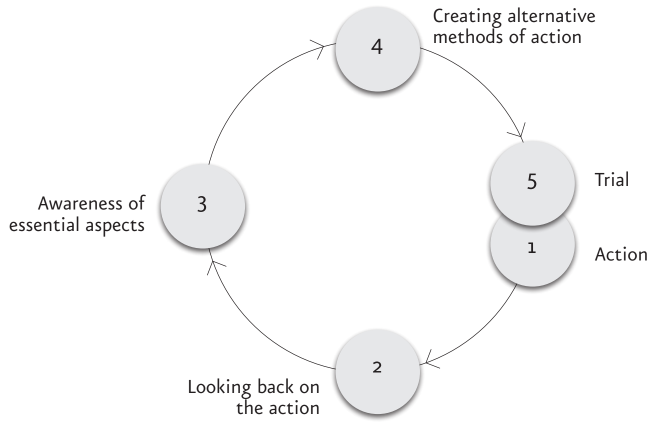

FIGURE 3 – THE ALACT MODEL DESCRIBING THE INTENDED PROCESS OF REFLECTION (KORTHAGEN, LOUGHRAN & RUSSELL, 2006, P. 1028)

THE REFLECTIVE DIALOGUE WITH THE TEACHERS

The reflective conversation with the teachers was intended to be a dialogue, not an examination. It lasted 102 minutes and took place three months after the *Lernwerkstatt*. The teachers expressed how helpful it is to see oneself with a distant view on a video. Before watching the videos, the teachers were asked to exchange what mostly returned to mind. Among other things, they highlighted two groups of male students with their research projects and the variety of questions presented especially by the girls.

Afterwards the first video scene about clustering the students' questions was watched almost in full length (>20 minutes). One teacher (T2) said right after the video started that this phase was one of the most exciting ones, but also the most difficult one. After three-fourths of the students were seen presenting their questions, she realised:

T2: This is really a long phase that demands a lot from the children. To listen. I do not really have another idea how one could shorten it.

R:[4] Shall I stop it [the video scene] here or do you want to watch it until the end?

T2: As far as I'm concerned stop.

4 R = Researcher.

The teachers were asked to express their first impression or feeling. Although they were concerned about the length of the phase, they emphasised the importance of this clustering. They assumed that the students realised what their classmates said despite mumbling. Beyond that they assumed that the mumbling students talked about the presented questions. The teachers pointed out that the exchange between the students was essential. Additionally, from the teachers' view it was important to learn to listen to each other. A conflict between appreciation and structuring occurred here. The teachers strived for valuing the ideas of every student, but felt the need for shortening the phase which was perceived as being contradictory for their internal aim of appreciation.

A first alternative approach they came to think about soon is that the students could cluster themselves and write the umbrella terms on the green cards. But this would even prolong the process of clustering. The researcher contributes a new perspective:

R: What I thought about is who is really active in this phase, who really has to think.
T2: Well, us two.
R: (laughs) Exactly. A lot of work is done by you two. You cluster and you write the umbrella terms.
T1: This means to involve the students here more.
T2: Yes, that they get an assignment. That they get an assignment.
R: Yes, the students who sit in the circle//
T2: //do not have an assignment.
(…)
T2: They really do not have an assignment. That blows my mind.

The teachers developed more and more ideas how to change this phase, e.g., one student could read his/her questions and two others would join the student and cluster the cards so that three students could participate actively. The researcher suggested the idea to present the questions not student-wise, but topic-wise. One student would read aloud a question and everyone would have to pay attention if he/she wrote a similar one that had to be pinned on the wall. The teachers picked up on this idea and developed a whole scenario how they could instruct the students during the next *Lernwerkstatt* enabling them to do the clustering themselves. Students would have to get up more often and pin their questions on the wall. Teacher 1 mentioned that this benefits especially the ADHD students.

This was the only time the teachers mentioned the students with special needs. They were mostly concerned about all students and how to handle the group as a whole.

After the approving reaction of the teachers to the first ideas the researcher mentioned another aspect.

R: What I also thought about what one really writes on the green cards. The students showed a remarkable performance (...). They almost all wrote questions.

T1: And we just slapped a headline. (all are laughing)

The teachers got aware of the fact that the green cards represented topics, not the students' original questions. Accordingly, teacher 1 suggested phrasing questions instead of headlines on the green cards. She further developed the idea to leave the cards blank and that the students should develop the core question per cluster in groups. A coach could already scaffold this part of framing the core question with a group of students who are interested in working on the associated inquiry. The teachers summed up that this change would lead to higher participation and self-dependency for the students not decreasing the appreciation. The gained time could be used to discuss with the students how they would proceed with planning and conducting an experiment. The researcher emphasised the released resources for the teachers who could concentrate more on scaffolding the process instead of doing the mental work.

These considerations led to look at the next video scene about the selection of a topic. The teachers confirmed again that the students talked about topics, not questions. Teacher 1 said that she is stressed out by the boys discussing about the laser pointer. Teacher 2 expressed her helplessness how to scaffold the students to find a question. The phase was perceived as so important that it caused a high stress level. The researcher phrased her admiration for the teachers' management of this difficult phase as in the end every student chose a topic and was able to work. Teacher 1 realised that the new ideas developed in the reflective conversation before could make the selection phase much easier.

Subsequently, the researcher formulated her observation about implicit rules. She perceived it as unclear which topics were decent and which group size was allowed. Both teachers agreed. They had certain implicit ideas and experiences how to proceed with some of the suggested topics. They did not expect the boys' idea to build a laser and foresaw a risk of injury. The teachers discovered a contradiction. Usually, in the classroom laser pointers are forbidden. In the *Lernwerkstatt* scenery laser pointers were exposed, but to work with them how the students intended to do was forbidden. Thus, it was not understandable for the students why they were not allowed to choose this inquiry as they were used to and appreciated – on their own admission – to work self-dependently in the *Lernwerkstatt*. They opposed the restriction when S_m5 launched a discussion: «I have a question. Why does this not work?» (see transcript above).

With other groups of students there was no discussion about the topic although it was not precise and although more than two persons wanted to work together. This happened especially with groups of girls and with a group of girls with mental retardation:

T1: S_f2, please.
S_f2: Eh, we want, we want//
CT: // S_f3 and
S_f2: S_f3 and S_f4 on the colour blue
T1: The colour blue, ok

The researcher's hypothesis is that the teachers know the special needs students and had ideas in mind how to proceed with them during the practical phase, mostly focusing on painting and crafting. Furthermore, they knew which groups of girls can be trusted to work in bigger groups than two. These hypotheses have to be further researched.

Another topic the researcher introduced dealt with researchable questions. During a discussion about the laser teacher 2 appealed to two boys transcribed from the video scene:

T2: I would like to say that you when you start with the group work, you have to think about which questions do you want to pursue and what can we inquire here and how eh do you really have a topic to fill two days of work.
CT: Otherwise it is such a big topic, yes?
T2: You have to think about that if that works. I put your names here and

then it is, have you thought a little bit more about it or are you only fascinated by the devices. You have to think about that. Yes? Are there enough possibilities for you right now and here to do research with our resources.

S_m5 and S_m6: Yes.

T2: Ok. (puts the names on the board)

The teachers perceived that they let the students do inquiry, but there was not an opportunity to learn something about inquiry explicitly (cp. aims according to Abrams et al., 2008; see above). They started to develop a list of criteria about «good» questions that could lead to further inquiries which were realisable with the prerequisites in the school and asked the researcher to provide some hints from the literature. They made suggestions how to integrate this meta-discussion into the *Lernwerkstatt* process.

Finally, teacher 2 summarised three alterations to be implemented next time:

T2: When we prepare the insects [next Lernwerkstatt topic] then we will talk about what researchable questions are in school. I like that. To mind the groups, the group formation. And try out this thing during the cluster round. I want to try these three things. Those will be effective, I think.

The researcher and the teachers noted that this dialogue was very intensive, but very effective as well. They agreed on meeting again after the changes were implemented (step 5 of the ALACT model, see figure 3).

Most of the ideas for change were initiated by the researcher who had time to prepare the session. The teachers captured the suggestions and developed them further. Next time the teachers should also watch the selected videos before the meeting and note their ideas beforehand.

CONCLUSIONS

Most remarkable is that the students with cognitive and behaviour/emotional disorders were not identifiable during the *Lernwerkstatt*. They worked in different groups of students and were fully included. Also the girls with severe mental disabilities could participate in this setting. Because of the teachers' experience and the possibility of intensive coaching they could also work on topics in the field of «light and colour». However, it was obvious that the teachers demanded more specific topics or questions of the general education students and students with mild disabilities. They did not treat the latter differently because of their special needs status. The *Lernwerkstatt* is a setting that facilitates equal learning opportunities for all students.

However, in terms of learning to do inquiry and learning about inquiry the learning opportunities could be improved. The teachers developed together with the researcher three important steps to increase the possible learning gain for all students:

1. Students will cluster their questions topic-wise instead of teachers doing the mental work. The students are supposed to find core questions instead of umbrella terms.
2. There will be clear rules for group formation.
3. A criteria list for researchable questions will be developed and discussed with the students.

After the implementation of these actions there will be another reflective meeting to question the success. It has to be evaluated if the level of appreciation which is so important for the teachers can stay comparably high while increasing the structuring elements.

One major observation is that the teachers struggle more with the implementation of IBSE than with aspects of inclusion. There could be a relation to their aims which are more on the educational side than on the subject-specific side.

The present research project will be extended by analysing the *Lernwerkstatt* of other classes, the regular science course as well as other cases to give more detailed insight in the field of inclusive science education.

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NOTES ON CONTRIBUTORS

Simone Abels has been a postdoc at the University of Vienna, Austria, in the field of chemistry education since 2011. She graduated in special needs education and did her PhD in chemistry education at the University of Hamburg, Germany. Her research interests are inquiry-based science education, diversity and inclusion, teacher education and reflection.

Ron Blonder is a senior researcher in the Department of Science Teaching of the Weizmann Institute of Science, in Israel. She received her B.Sc (summa cum laude, 1993) and her Ph.D in chemistry in the Hebrew University of Jerusalem. She is engage in professional development of chemistry teachers and research in Science Education. Her goal is to promote the modernization of both chemistry contents and chemistry teaching pedagogies by promoting professional development and interactions within the community of chemistry teachers.

Ingo Eilks FRSC is full professor in chemistry education of the Institute for Science Education at the University of Bremen.

Nicole Garner, MEd, studied chemistry and mathematics at the University of Bremen. She is now a PhD student of the Institute for Science Education at the University of Bremen.

Sarah M. Hayes MRSC is the Education, Training and Outreach Officer for the Synthesis and Solid State Pharmaceutical Centre based at the University of Limerick.

Avi Hofstein is an Emeritus professor at the department of Science Teaching of the Weizmann Institute of Science, in Israel. He was head of the chemistry group and head of department. Among his research interest are: learning in science laboratories, making chemistry more relevant and curriculum development.

Dvora Katchevich is a postdoc of the Department of Science teaching at the Weizmann Institute of Science, in Israel. She is conducting continuous professional development workshops for chemistry teachers and follows their development. Among her research interest are: Science teachers' professional development, and argumentation in the chemistry laboratory.

Miri Kesner is the Head of teachers' professional unit, at the Davidson Center, and Coordinator of Chemical Industry-Education Link Center in the Department of Science Teaching of the Weizmann Institute of Science.

Rachel Mamlok-Naaman is a senior research associate at the Department of Science teaching of the Weizmann Institute of Science, in Israel. She is the head of the national center for chemistry teachers. Among her research interest are: science teachers' professional development, action research and chemistry curriculum development.

Silvija Markic is a senior lecturer and researcher at the University of Bremen (Germany) since summer 2009. Her research interests include science teachers` beliefs and pedagogical content knowledge, linguistic heterogeneity and cultural diversity in chemistry and science education, cooperative learning and alternative teaching methods.

Inga Meshulam is a high school chemistry teacher for 26 years and regional guide for chemistry teachers in the Ministry f Education. She received her B.Sc in medicinal chemistry in Bar-Ilan University and her MSc degree in science education in the The Rothschild-Weizmann Program for Excellence in Science Teaching in Weizmann Institute of Science.

Yamit Sharaabi-Naor is a high-school chemistry teacher. Post-Doc fellowship of the Department of Science teaching, at the Weizmann Institute of Science, with a Ph.D in Organic chemistry. He has an Excellence Certificate for Guiding and Mentoring High school students.

Yael Shwartz is a senior scientist at the Weizmann Institute. Her research interest is focused on chemical literacy and the value for teaching chemistry to all. She also has a rich experience in designing and implementing various models of teacher's professional development programs, including on-line programs.

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SCIENCE EDUCATION IN THE 21ST CENTURY: CHALLENGES AND CONCERNS

RACHEL MAMLOK-NAAMAN
& DVORA KATCHEVICH

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