On the Way to Scientific Inquiry Supporting Hearing-Impaired Learners in Chemistry Classes

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Abstract
This paper deals with the promotion of scientific inquiry for deaf and hard-of-hearing students. The purpose of the project is to create teaching material to advance students' ability to scientific reasoning and working. Results of a preliminary study and information on future steps will be resumed.

Keywords: Students with hearing loss, inclusion, scientific inqury, language support, visualization

1. Introduction

An essential task of teaching chemistry is to introduce students to scientific reasoning and methods of investigation. For this matter doing experiments as well as reporting on experiments and using models to explain scientific phenomena play a decisive role. These aspects are incorporated in the National Educational Standards as ‚epistemological competence' [1] and are directed to mainstream schools and special-needs schools equally. Within the framework of this project, initial studies indicate that deaf and hard-of-hearing students need special support for achieving epistemological competence. Although, creating inclusive learning environments has become an increasingly important topic in education, so far, only a few studies exist which consider possibilities to promote students with hearing loss in science classes [2,3]. Therefore, it is necessary to look at the status quo and to think about concepts to advance an understanding of scientific inquiry. Based on the concept of *Participatory Action Research* [4], methods to enhance students' ability to report on experiments and to use models to explain scientific phenomena are tested and evaluated qualitatively [5]. In order to develop teaching material, interviews and survey studies among special education teachers and findings of a video study and participant observation were used. It is anticipated that the outcomes of the project can contribute to inclusive education and to the handling of heterogeneous learning groups.

2. Methodology

The aim of the preliminary study is to diagnose learning difficulties and to receive information to create teaching material. In order to do this, questionnaires, interviews, videography and participant observation were chosen as suitable tools.

26 chemistry teachers for deaf and hard-of-hearing students participated in the questionnaire. The survey was conducted in April and November 2011 and contained open questions which deal with issues in teaching chemistry to students with hearing loss.

Afterwards, five teachers were selected and interviewed in October and November 2011. For this purpose, an interview manual was created. The teachers were asked about their education, conditions of the school and how they let students report on experiments.

Subsequent to this, ten chemistry lessons were videotaped and observed from April to June 2012. The study took place in sixth and ninth grade at schools for the deaf and hard-of-hearing. Based on the results of the previous survey, categories were determined and an observation guide for the videography and the participant observation was created. Further categories were added, when new aspects occurred.

To transcribe both interviews and recordings of the lessons, the transcriptions software F5 was applied. In order to analyze the findings, *Qualitative Content Analysis* [6] and *MAXQDA 10* were used in each investigation.

3. Results

In the following section, results of the preliminary study will be presented.

3.1 Questionnaire

For the most part, the results of the questionnaire (figure 1) suggest that the language difficulties of the students are a main issue in chemistry classes, as stated by 19 teachers. Deficiencies in written language cause a lack of understanding of textbooks and difficulties in describing observations. Hence, the teachers are constrained to optimize their teaching material linguistically. In addition, and according to the statements of seven teachers, most of the technical terms used in science do not exist in sign language. It is clear that the absence of subject-specific sign language poses a problem for students who use sign language.
According to nine teachers, the use of models is also a problem. They mentioned that the students have difficulties in understanding and using models to explain experiments. As a result, certain topics will not be discussed or have to be highly simplified. Due to that, the explanation of experiments takes place mostly on the level of phenomena. Although the difficulty in using models is not specific but a general problem [7], it demands specific strategies for students with special needs in terms of language and communication.

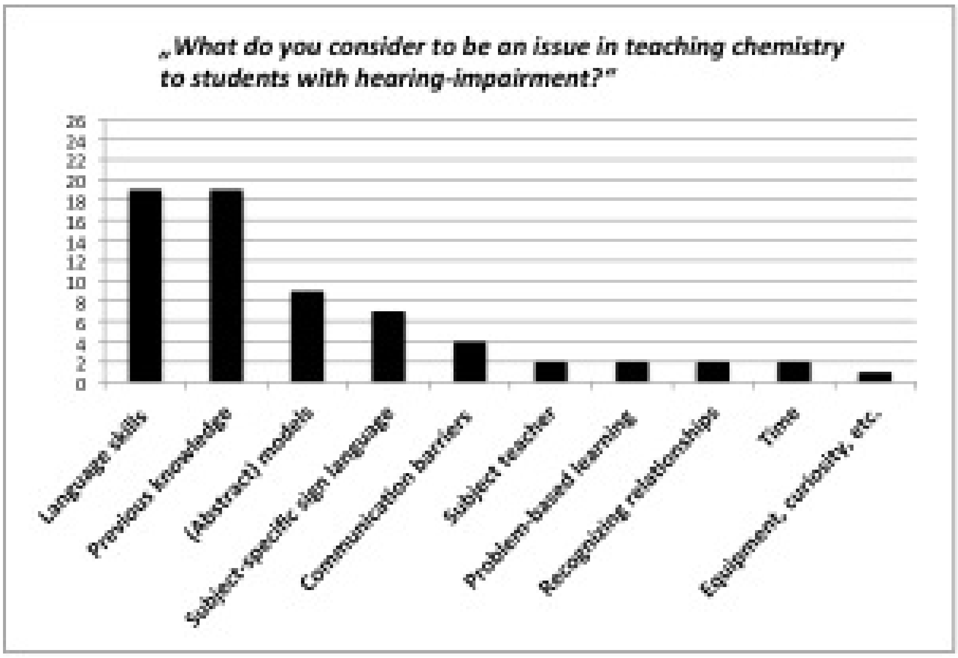

Figure 1 Examples of the results of the questionnaire

From the point of view of two teachers, there are no difficulties on the part of the students. Instead, they see problems on the part of the teachers because of the lack of trained chemistry teachers in special-needs schools. It is probable that most of the participants are teaching chemistry without specific chemistry teacher training.
The results of the questionnaire show a variety of learning difficulties. In order to receive further information, some teachers who had participated in the study were interviewed.

3.2 Interviews

The results of the investigation show that none of the participants was a trained chemistry teacher. They all studied special education and subjects like maths, physics and biology. A few of them participated in certificate courses to gain knowledge about chemistry, but most of them were autodidactics. The teachers described the students as heterogenous regarding to forms of communication and language skills. Obviously due to heterogenity, a high level of flexibility on the part of the teachers is required. But it can be assumed that technical uncertainties may occur because of a lack of teacher training in chemistry.
From the point of view of these teachers, problems in reporting on experiments are caused by language difficulties. But they mentioned problems in forming hypotheses and finding explanations as well. Based on the difficulties, the teachers prefer cloze as a tool of reporting on experiments. Other variations are graphical presentations of the experiments or lab reports formulated together at the blackboard. But the students' statements have to be supported linguistically by the teachers quite often.

Table 1 Proposals of the teachers for developing teaching material

Proposals of the teachers	Aids
Language support	- Guided and structured writing - Suggestions on sentence structures - Glossary of technical terms combined with pictures of the items/terms in sign language
Visualization support	- Presenting experiments in pictures - Glossary of technical terms combined with pictures of the items/terms in sign language
Other	- Possibilities of differentation

In order to create teaching material, the teachers proposed (table 1) guided and structured writing, suggestions of sentences and the use of a glossary of technical terms. The glossary could contain technical terms, images of items (e.g. laboratory apparatus) and images of important technical terms in sign language, if available. Concerning visualization, the teachers recommended to present the procedure of experiments in pictures. Due to heterogenity the teachers stated, that the teaching material should also give multiple options for differentiation. All five teachers agreed to a further cooperation.

3.3 Video studies and participant observation

Initial results show learning difficulties in terms of language skills, using models, finding explanations and forming hypotheses. Therefore, the statements of the teachers mentioned in previous investigations were confirmed. Apart from the difficulties on the part of the students, technical uncertainties of the teacher were also revealed.
To obtain more information about the possibilities to support the students as well as the teachers, the investigation will be continued.

4. Interim conclusion

The results of the preliminary study reveal a variety of difficulties. Thus, different perspectives and approaches arise for the handling of the issue.
This would be benefical because of the language deficiencies of the students, so they can reconstruct scientific processes by pictures.

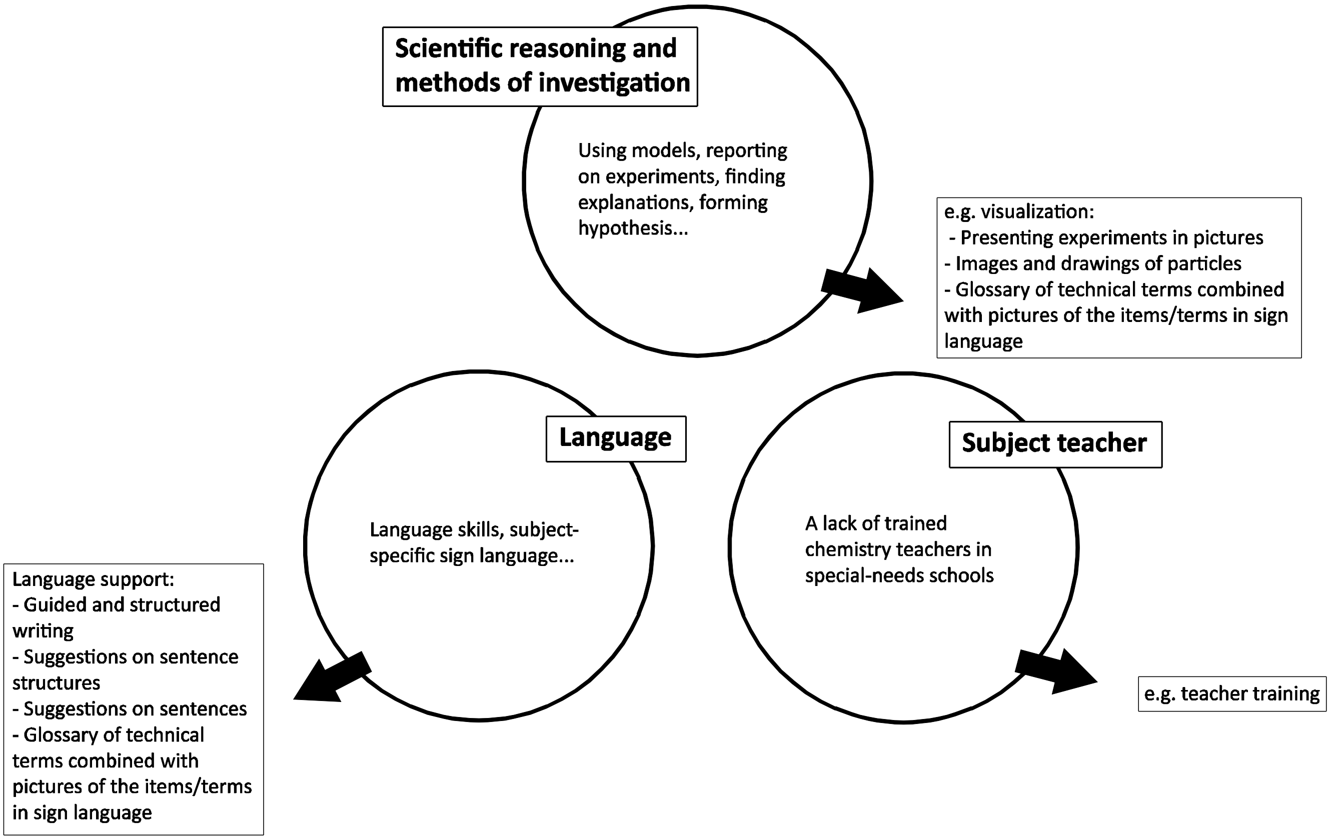

Figure 2 Ideas for developing a problem solving concept

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Maximizing Scientific Thought through the Design of a Collaborative Research-based Organic Chemistry 2 Laboratory Course

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This paper describes the collaborative research-based organic chemistry laboratory course we have developed at Ferris State University and have implemented over the past 10 years. It also explains what we've learned through the experience about engaging students in scientific thought. At Ferris, 200-250 students complete the two-semester organic chemistry sequence each year, approximately half of them bound for pharmacy school. Ten years ago we received a grant from the National Science Foundation Course Curriculum and Laboratory Improvement (CCLI) program to convert the entire Organic Chemistry 2 laboratory course into a collaborative research experience. Since then, roughly 1/3 of our Organic Chemistry 2 laboratory sections have been research-based. Our goal was to create a pedagogical and physical environment in the laboratory that would result in the development of the skills and behaviors inherent to the scientific inquiry process. Specific desired outcomes were that students would 1) learn to design and carry out experiments in response to a research problem, 2) learn to evaluate resultant data and draw their own conclusions, 3) learn to present their own findings and critique classmates' work, and 4) have improved attitudes toward the field of chemistry. A critical component of our course design is a framework that guarantees a maximum of instructor feedback throughout the process. Our two-project model allows students to apply what they learn during the first cycle of planning, synthesis, analysis, evaluation, presentation and critique to a second research project where they refine their skills as they complete a second round of the process.

Background

From the beginning of my teaching career I had engaged students in a team research project during the final 4-6 weeks of the Organic Chemistry 2 laboratory course. Students carried out a fairly well-defined investigation on a tight time line and summarized their findings in a formal report that was graded at the very end of the semester. While students reportedly enjoyed the experience, I became increasingly frustrated with the lack of scientific thought displayed in their final reports. In 2003 my frustration was translated into action resulting in the changes listed on the right half of Table 1.

Table 1 Research Lab Design Rationale

Research Projects Before 2003	2003 Collaborative Research Lab
Original Research (assigned) Cooperative Team Work (4 students/group) 4-6 weeks in Duration	Original Research (student choice) Cooperative Team Work (4 students/group) Entire Semester of Research
Limitations	**Improvements**
Old Varian EM390 NMR	FTNMR upgrade by Anasazi Instruments
Data not collected and analyzed in a timely manner	Instrument request sheets and data interpretation sheets required
Little instructor feedback before the end	Feedback given on experimental plans, instrument request sheets, data interpretation sheets, Power Point presentation and portfolio in two different research projects
Little critical evaluation by students	Students evaluate data quality on data interpretation sheets and participate in 2 oral presentation/critique sessions

In the years preceding our NSF grant, several articles were published describing the use and benefits of problem solving pedagogy, [1,3-10] cooperative learning [2,4,11,12] and multi-week research projects [13-16] in the organic chemistry laboratory. A 1996 report to the National Science Foundation "Shaping the Future," [1] outlined new expectations for undergraduate education. The report recommended that science, mathematics, engineering, and technology (SMET) faculty "build into every course inquiry, the process of science, a knowledge of what SMET practitioners do, and the excitement of cutting edge research." Additional recommendations were, "Devise and use pedagogy that develops skills for communication, teamwork, critical thinking, and life-long learning." We sought to incorporate these recommendations into our course. The work of three authors: Kharas, [14] Davis et. al. [16] and Dobrev [13] who introduced a single laboratory research project at the end of the year of organic chemistry laid the groundwork for our new research course design. Our course combines instructor-initiated original research,[14] independent problem-solving emphasis,[13,16] cooperative team work,[16] and a final oral presentation.[13] We added the following components: 1) structured research requirements (experimental plan, instrument request sheets, and data interpretation sheets) to maximize student instructor interaction; 2) a second research project to solidify what students learned in the first project; and 3) peer evaluation of interested in this research because cocrystallization can be used to modify critical properties of drug compounds. Again students submit a plan that is critiqued and returned within a day for modification and resubmission before beginning lab work. During the final week of the course, students present a Power Point p student presentations to engage students in the critique process.

Project Design and Experimental Plan

At Ferris there are thirteen 3-hour lab periods available during a 15-week semester. During the first two weeks students are introduced to the research lab and taught to use the NMR. They form teams of 4 and generate an experimental plan for the first research project. Requirements of the experimental plan include a list of chemicals with quantities, properties and hazards; a glassware and equipment list; a stepwise procedure for synthesis, purification, and analysis; and a weekly schedule. The first research project introduces students to the research process. During the first 3-week project, students investigate the effect of changing a single variable of their choosing on the yield of a reaction selected by the instructor. This first project may or may not involve original research. Experimental plans are submitted to the instructor and returned within 24 hours with suggestions for modifications to be made before the next lab period when the experimental work begins. The final draft of the experimental plan is submitted before beginning lab work the 3rd week of the course. Students carry out 4 reactions concurrently and have 3 weeks to synthesize, purify, and analyze their products. During the 6th week students present their results and conclusions to their lab section in the form of a Power Point presentation, answer audience questions, and critique each other's work. Students then apply what they have learned about the research process from the first research cycle to a second project that they plan during the 7th week of the course and carry out over the following 5 weeks of lab. In recent years the second research project has focused on molecular recognition. Teams typically devise and carry out 20 experiments investigating the influence of various factors on whether two types of compounds will recognize and selectively bind to each other forming a cocrystal. Students design experiments to investigate the effect of molecular substituent, substituent position, solvent, or reactant ratio on the type and stoichiometry of crystalline product obtained. Solution NMR provides information on cocrystal stoichiometry while IR provides information about the specific binding interactions within the crystal. Pre-pharmacy students are particularly interested in this research because cocrystallization can be used to modify critical properties of drug compounds. Again students submit a plan that is critiqued and returned within a day for modification and resubmission before beginning lab work. During the final week of the course, students present a Power Point presentation on their 2nd research project and most participate in a poster session open to all lab sections and the general public.

Instrument Request Sheets

In general, chemists select the analytical technique that will best answer the question(s) they have formulated. In contrast, a majority of our students, if allowed to, will collect analytical data without ever considering whether the data will answer the question they need to answer. In short, student behavior is often guided not by questions to be answered but rather by tasks to be completed. To train students to behave more like chemists and to avoid the time wasted in collecting meaningless data, students in the research lab course are required to explain to the instructor specifically what will be learned by collecting the desired data. In preparation for collection of analytical data, students complete an instrument request sheet showing structures of expected products, solvents, and possible impurities. Students explain why their chosen analytical method is better than other available techniques. Students requesting NMR usage are required to list the chemical shifts, splitting, and integrations expected for their product and possible impurities. For IR, students describe expected peaks and tell specifically what will be learned from their presence or absence. Students also explain what the data will NOT show. Before collecting the data, students give an oral explanation of what they have written on the instrument request sheet to an instructor who signs off on it.

Data Interpretation Sheets

Chemists often interpret their analytical data immediately after it is collected to determine if the experiment was a success. If nothing else, chemists examine the data quality to make sure it is sufficient for answering the question at hand. Students, on the other hand, often blindly collect data, planning to interpret it at a later date. Often they don't check for proper integration and the presence of TMS in an NMR or whether there are any significant peaks in the IR other than those for mineral oil. In order to encourage a somewhat timely analysis of the data, students within a week of collecting the data are required to complete a data interpretation sheet explaining what they know about the quality of the data and explaining exactly what the data tells them about the purity of the sample and the amounts of the various contaminants. Again, the student explains the sheet to an instructor and receives feedback as needed.

The structure provided by the instrument request and data interpretation sheets ensures that the data hasn't been mindlessly collected, that its quality has been properly assessed, and that it has been accurately interpreted. This structure not only serves to develop the habits of mindful data collection and timely analysis, but also increases the value of the data set and consequently the viability of the conclusions drawn. Largely because of the high number of experiments completed in the molecular recognition project, each student typically goes through the instrument request - data interpretation process 6-10 times during the semester.

Oral Presentation/Critique Sessions

Each team delivers a 10-minute oral presentation to the other students in their lab section at the conclusion of each research project. Teams explain the question they were investigating and their hypothesis; summarize their procedure and the data collected; and explain their conclusions. Students in the audience are required to write down one question during each presentation and ask a minimum of one question during the lab period. This first presentation session gives the instructor an opportunity to model critical analysis of data and conclusions through questioning the presenters. Many of the instructor questions are designed to get students to reflect on the real meaning of their data and the validity of their conclusions. For each presentation, students in the audience complete a grading rubric rating the presenters in eight categories. This serves as a tool to focus their assessment of the presenters and to catalyze improvement in their 2nd presentation.

A majority of the students participate in a public poster session at the end of the 2nd research project. There they compare and discuss their data and conclusions with students in other lab sections. They also gain experience explaining their research to people spanning a wide range of backgrounds.

Grading

The laboratory grade is determined by the identification of an NMR unknown (8%), the 3-week research project (27%), the 5-week research project (54%), and participation in the Q&A session and critique of the presenters (11%). Each project grade is composed of two parts: the Power Point presentation evaluation (70%) and a portfolio evaluation (30%). The portfolio contains both drafts of the experimental plan, all instrument request sheets, all data along with data interpretation sheets, laboratory notes, and a hard copy of the Power Point slide presentation. In order to encourage all team members to do their share of work, each student is given 16 points to divide up between the four team members for their relative contributions in each of 8 different areas. The points are collated and the score is used as a multiplier of the team score. Upon completion of the first research project, students are given their group score, their multiplier and their individual score. Also, if there is a consensus among the group that a student did less or more than his share in a particular area, he is provided with that feedback.

Results

Pre/Post Test Results

During the first two years of the pilot project, students' learning was evaluated by a pre/post test that we devised. Students were tested on their ability to understand variables in a chemical reaction, choose methods of purification and analysis, evaluate spectral data quality, and evaluate conclusions. The test was given to students in 4 different lab sections: 3 research labs and 1 control lab (a lab of more traditional structure, but with similar learning objectives.) Average pre to post test improvement for the three research labs was 24% compared to 22% in the control lab. In the research labs we saw a 22% improvement in questions related to our first desired outcome on designing and carrying out experiments and a 29% improvement on our second desired outcome on evaluating data and drawing conclusions.

Student Survey Results

Students were provided with an anonymous survey with 3 free response questions and 7 Likert scale questions during each of the two years of the pilot and during each of the past two years. Five of the Likert scale questions addressed areas of change as a result of the Organic Chemistry 2 lab experience and two questions focused on preferred student groupings for lab work and preferred lab focus. 36 (92%) of the students responded in 2003; 34 (46%) in 2004; 55 (85%) in 2011; and 46 (82%) in 2012.

In the first free response question we asked, "What were the *most important things you gained or learned* from the group research projects?" Representative responses from six of the 2012 students provided below reflect learning about various aspects of the research process as well as gaining skills in communication and team work.

"I learned how to work in groups effectively. I also gained the ability to interpret data such as IR and NMR to a huge degree."

"I learned a lot about planning out lab work. I also learned a lot about working in a group and being patient with other people."

"I learned how to analyze results much better than I ever could before. It really helped me to question the data that I collected and pushed me to figure out exactly why my data turned out the way it did."

"Ability to lead a project, proficiency in running and interpreting IR, confidence in lab, ability to explain research to someone who has little background knowledge of chemistry."

"I learned how to plan and execute a research project. I learned the importance of planning and thinking carefully about every aspect of the experiment."

"That I love lab and research."

We also asked, "What did you find *most stimulating* about the group research projects?" The top 6 responses of the 46 respondents in 2012 are as follows with frequency of response in parentheses: problem solving/critical thinking (11); the flexibility/freedom/independence (9); experiencing the research process (7); discovery (6); presentation (5) and the cocrystallization topic (5).

In the third free response question we asked, "What were the *most negative aspects* for you of the group research projects?" Table 2 compares the top responses from the 70 students in 2003 & 2004 to the responses on the same issues from 46 students in 2012. Ways in which we addressed some of the issues are included in the table as well.

Table 2 Negatives from Students' Perspective and How They Were Addressed

Top responses in 2003 & 2004 (% of students with issue in 03 &04)	**How Issue has been addressed (% of students with issue in 2012)**
We had to wait for instructor assistance (13)	Hired student lab assistants (0)
We received too little guidance (16)	Initial guidance has increased (2)
The lab was at too high of a level (9)	Replaced conceptually difficult chemistry (0)
We didn't have appropriate background (7)	We can fill in gaps for a few students (0)
Team members didn't contribute equally (11)	Partner evaluations affect grades (13)
Too great of a time investment (44)	Equal to traditional labs, not addressed (20)

Results of the five Likert scale questions addressing perceived personal change as a result of the Organic Chemistry 2 laboratory experience are summarized in Table 3. Table 3 condenses the greatly increased and slightly increased categories of the 5 point Likert scale as well as condensing the slightly decreased and greatly decreased categories.

Table 3 Responses to Student Survey Questions about Change as a Result of the Organic Chemistry 2 Lab Experience (percentages in parentheses represent decreases)

Area of Change	2003 student responses	2011 & 12 student responses
Confidence in lab skills	77% increased (11%)	97% increased (02%)
Confidence in problem solving skills	64% increased (06%)	89% increased (01%)
Ability to interpret results	89% increased (03%)	95% increased (01%)
Interest in scientific research	50% increased (28%)	85% increased (02%)
Attitude toward chemistry	44% improved (39%)	87% improved (04%)

Presentation Assessment

We have found that student questions during the first presentation session are largely of a clarification nature. While some students begin to question whether the data presented actually supports the conclusions, a majority of such questions are initiated by the instructor. During the second round of presentations at the end of the semester a noticeable change is observed in the ability of students to critically analyze the meaning of their own data as well as the data and conclusions of others.

Discussion

Overall the pre/post test results and the student survey results point to significant positive movement toward the objectives. In 2012, students found the most stimulating aspect of the experience to be the problem solving/critical thinking component. Also in 2012, 97% of the students reported increased confidence in lab skills, 89% increased confidence in problem solving skills, and 95% increased ability to interpret data. The first free response question points to group work, interpreting data, and planning lab work among the most important things gained or learned. The 3rd free response question, however, unearthed some underlying issues in 2003. The first four issues listed in Table 2 are closely related to each other and can be summarized as follows. The students didn't understand enough of the chemistry that they were carrying out to trouble shoot on their own and couldn't readily get the help they needed. We suspected this was a major contributor to the decreased interest in scientific research reported by 28% of the 2003 students and a poorer attitude toward chemistry reported by 39%, as seen in Table 3. Two major factors come into play here: the high student/instructor ratio and the difficulty of the chemistry. In analyzing the 2004 surveys, which gave similar results, we were able to make a direct connection between the negatively responding students and the projects that they were involved with. The chemistry in these projects was more challenging, products were difficult to isolate and it was difficult even for the instructor to draw conclusions from the data collected. Even while team teaching, the instructor supervising the more challenging projects had trouble keeping up with the needs of the students. When we applied what we learned from the surveys in the following years, the first 4 complaints on Table 2 and the poor attitude displayed in Table 3 all but disappeared.

We have been impressed over the years by the depth of thought demonstrated by the type of questions students ask each other and by the responses during the final presentation/critique session. The instructor questions during the first presentation session generally catch the students off guard as they have, at that point in the course, put little critical thought into whether their experimental results really justify their conclusions. The first Q&A session sets the standard for the second research project and serves as a catalyst for more critical examination of experimental design, data, and conclusions.

Often a pedagogical innovation requires a surge of time, energy, and creativity that cannot be maintained indefinitely. In order to maintain the research lab over the years, we've had to address several issues of sustainability. The biggest threat to the research lab upon expiration of the grant period was the return to the normal laboratory student/instructor ratio of 24/1. One instructor can't keep up with student questions, instrument requests, and data interpretations while still addressing instrument issues that arise. Fortunately we have been able to hire students who have successfully completed the research lab as teaching assistants. The extra instructor in the lab makes it possible to address the high number of required student/instructor interactions.

Another sustainability challenge is the need for continuous generation of ideas for new research projects. One of the ways that we maintain a flow of new ideas is to maintain a spread sheet of all of the results of the experiments completed by previous students. Students and faculty can peruse the spreadsheet, which now consists of results from over 3000 cocrystallization experiments, and can build on the findings of previous students with new ideas.

Conclusions

In short, we've found that the success of our collaborative research-based laboratory course rests on a few simple principles. Maximizing feedback throughout the process is probably the most important component of our lab design. When students carry out research over an extended period of time, continuous intentional instructor feedback greatly increases the learning and the understanding of the research process. We found out the hard way that it only takes one or two frustrating factors to sour students' attitudes toward the research experience. Keeping the chemistry simple helped the students to more fully understand what they were doing in lab. This greatly improved students' attitudes toward the experience and consequently their learning. Formalizing the critique process forces the students to look at each part of their work critically and teaches them how to critically evaluate the work of others. It is a stretch to carry out two research projects in a single semester, but the experience of learning to critically evaluate each other's work during the first oral presentation session contributes greatly to the ability of teams to effectively design, carry out, and assess the results from experiments in the 2nd project. We have learned the importance of balancing freedom and structure. Students enjoy the freedom to design their own experiments and set their own schedule, but in the end, the structure is essential for meeting educational objectives. Pre/post test data, student surveys, student presentations, and student critiques of each others' work all point to significant progress toward our four objectives. Also in line with the "Shaping the Future" recommendations of using pedagogy that develops skills for communication and teamwork, our students report gains in teamwork and presentation skills among the most important things gained through the experience.

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'Interpretive frameworks' Supporting argumentation processes in pre-service chemistry teachers: the role of meta-theoretical ideas

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Abstract
In this paper, analysis on part of the data corpus generated in an exploratory investigation is presented. In the piece of research that we conducted, two 'interpretative frameworks' were proposed to account for the 'fundamentals' selected and applied by chemistry teachers when envolved in argumentation processes. Those interpretive frameworks are instructional ideas and common-sense ideas. To this, a meta-theoretical perspective of analysis was added, considering the ideas about science employed by teachers when arguing. The methodology of data collection included: 1. participation of a group of pre-service teachers in a video game with science content; 2. application of post-game survey and semi-structured interview; 3. preliminary analysis of the results obtained (via constant comparative method) in terms of the original interpretive frameworks. In this paper, we discuss and re-interpret selected fragments from the interviews conducted; we focus on a third interpretive framework, of meta-theoretical character. This addition allowed us to characterise teachers' argumentation processes through two 'key ideas' coming from philosophical reflection on science; such ideas can be labelled as representation (the way in which science 'captures' reality with symbolic artifacts), and correspondence (the relationship between what science 'predicates' and reality). Results of our re-interpretation led us to consider that chemistry teachers often rely on these two meta-theoretical ideas when developing argumentative processes, since they talk about the complex, interactive relationships between symbolic entities and the phenomena modelled.

Keywords: argumentation processes, interpretive frameworks, meta-theoretical perspective, philosophy of science, realism.

1. Introduction

Characterising argumentation processes in educational contexts requires the adoption of specific theoretical frameworks that would allow the demarcation of methodological aspects, i.e., what will be considered and how, and what will be disregarded. In this sense, a number of investigations in didactics of science (i.e., science education as a research discipline) are available [1-3] in which it is apparent that the theoretical approach *determines* the methodological approach.

In this paper we are interested in the generation of argumentation processes among teachers, within a learning environment that implies interaction with a technological tool: a video-game, Kokori[1], that is designed as a set of seven 'missions' of a microscopic spaceship inside an animal cell.

The choose of a technological tool was made with the aim of critically investigating the use of such kind of resources in real classroom settings; specifically, in a classroom of pre-service chemistry teacher education. In this respect, we follow Inés Dussel [4], who claims that school and its functions are being re-defined at the beginning of the 21st century, and that educational action within the schools should be conducted taking into account the variety of modes of communication and dissemination currently availa-

1. The videogame Kokori was developed by the Universidad Santo Tomás in Chile (see www.kokori.cl). It simulates an environment representing the interior of an animal cell; it inspects cell functions related to key biological processes in different situations: the attack of a bacterium, a virus invasion, shortage of energy, etc.

ble. Nevertheless, we consider that the incorporation of those modes cannot be done without critical reflection on the ways in which they affect classroom dynamics and represent an actual improvement on more traditional classrooms.

Our focus has then been the argumentation processes produced following the interaction of two groups of student-teachers with the video-game Kokori as an innovative tool. We have interviewed the participating teachers after their interaction with the video-game; the context in which they 'played', and in which data was collected, was designed with the aim of generating *dialogical processes of argumentation* between each teacher and the researcher (Natalia Ospina).

One of the premises of our piece of research has been that, during the development of argumentation processes, student-teachers base their arguments on a variety of what we call *interpretive frameworks*. In the preliminary categorisation of the data obtained from the interviews, we initially proposed two interpretive frameworks: *instructional ideas* and *common-sense ideas*. Further analyses have led us to propose a new set of categories, coming from a meta-theoretical perspective; those categories are the object of this paper.

2. Theoretical framework

This section is devoted to describing the theoretico-methodological frameworks for our work with pre-service chemistry teachers around argumentation. Firstly, we define our stance on argumentation processes, then we introduce the meta-theoretical perspective.

2.1. A characterisation of argumentation processes

We understand the generation of dialogical arguments as a *process*, as depicted by Deanna Kuhn [5]. Arguing understood as dialogue demands cognitive effort, since participants need to process each other's contributions and anticipate their own response in the dialogical situation [6].

In chemistry teaching, the aforementioned argumentation processes can be fostered in real classroom contexts, starting from the presentation of some phenomena that allow proposing and discussing two positions that need to be defended and supported by students. The selected phenomenon should be 'reachable' from students' conceptual capacities, so that argumentation does not present itself as the mere repetition of an oral or written text that only complies with the constraint of having a 'sound' structure from the point of view of argumentation theory. If this requirement of meaningfulness of the phenomena to be argued on is fulfilled, rich, complex argumentative processes can be found even from common sense (i.e., without the introduction of scientific ideas).

In Figure 1, we have called *interpretive framework* to the set of referential aspects that guide an argumentation process in a distinct setting (scientists' science or school science). The interpretive framework would more or less play the role of what Stephen Toulmin [7] calls *warrant* and *backing*; we have created this construct to acknowledge that the substantive content of an argument is always construed from a distinct and organised set of beliefs and premises. In our preliminary analyses of data obtained with two populations of pre-service chemistry teachers, we found that their arguments to account for complex cellular processes could be seen as based on common-sense ideas (i.e., ideas coming from their everyday experience) or on instructional ideas –whether these would be accepted scientific ideas or misconceptions.

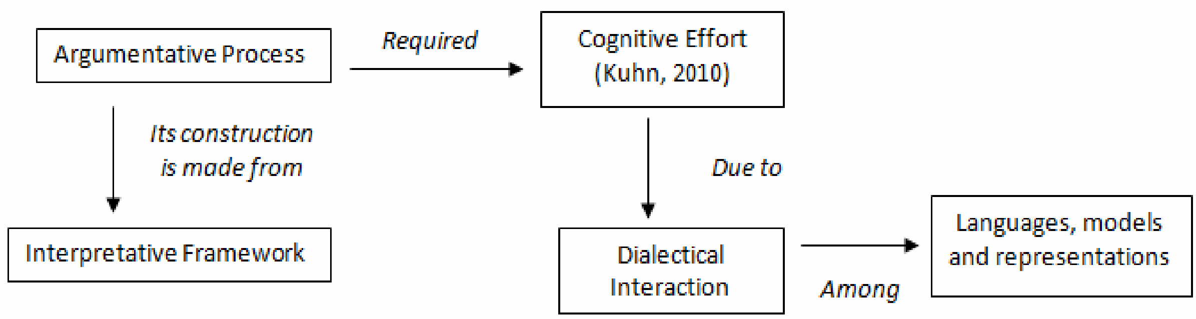

Figure 1. A characterisation of argumentation processes. Adapted from [8].

2.2. Meta-theoretical analysis of arguments

As we have stated in the introduction, revisiting data of our piece of research convinced us of the need to acknowledge the possibility that a 'meta-theoretical' interpretive framework exists as support of some of the argumentation processes that we were studying. Such acknowledgement brought up the need to characterise this third framework through reflection on the *nature of science*. Such reflection is done from the discipline of philosophy of science.

Accordingly, this section intends to present the most relevant characterístics of our positioning in the philosophy of science. Our meta-theoretical choices permitted the construction of the 'key' philosophical ideas on science and chemistry with which student-teachers arguments were examined.

Among the variety of philosophical schools that have emerged in the last century (e.g., logical positivism, received view, historicism, evolutionism, naturalised epistemology) the current *semantic* –or *representational*, or *model-based*– view of scientific theories provides, according to some specialists, refined meta-scientific tools to think about the structure, dynamics and products of the scientific enterprise [9-10]. The semantic view is represented by authors such as Fred Suppe, Bas van Fraassen, Ronald Giere, and those inscribed in the so-called meta-theoretical structuralism.

The semantic view gives a secondary role to the formal and linguistic aspects of a scientific theory, which were emphasised by the axiomatic view that reigned in the first half of the 20th century. 'Semanticism' puts in the centre of epistemological analysis the construct of 'scientific model' [9-12].

The core notion of the semantic view is that a scientific theory is best characterised when it is portrayed as a set of models, rather than as a set of axioms (the classical 'scientific laws'). Such notion is recovered in the philosophy of science [cf., 11-12] and in didactics of science, in the very few cases in which this school is used [cf., 13-14]. In general, members of the semantic view agree, to different degrees, with the following statements:

1. The most basic component that constitutes the identity of a theory is a *class* of models.
2. When characterising a theory, part of the task consists in identifying the phenomena that the theory is aimed to account for.
3. A theory defines its models with the pretension of adequately representing the aforementioned phenomena; thus, there exists a substantive relationship between theoretical models and empirical systems.

Starting from the most fundamental statements of the semantic view, which we have here only very superficially presented, we identified and characterised two key meta-theoretical ideas –*correspondence* and *representation*– that we find extremely fruitful in didactics of science. In the next section we go deeper into these latter ideas.

3. Key ideas from the philosophy of science

Key ideas can be characterised as those structuring ideas that allow organising content from the philosophy of science with didactical purposes [15]. We recognise in these key ideas structuring, analytical, and evaluative purposes. These key ideas have been extensively examined by different epistemological schools.

3.1. Approach to the ideas of correspondence and representation

For the purpose of the present paper, we have concentrated on the key ideas of correspondence and representation, which are closely linked to the issue of *realism* [15]. We will now briefly define these two ideas having in mind their utility for our work in an educational context.

Correspondence refers to the way in which scientific theories relate to the items of reality they intend to account for. Form a semanticist point of view, and particularly using Giere's [16] ideas, the relationship between theoretical models and the real world is a relationship of *similarity*. In this sense, theoretical models 'resemble' reality without capturing it completely. The degree of resemblance of models and real systems can be specificied in what Giere calls 'theoretical hypotheses'.

Representation refers to the way in which items of reality are 'captured' with symbolic means, i.e., re-presented 'in absentia' for scientific purposes. Although this idea was tackled in different ways by the philosophical schools that preceded the semantic view, semanticism has treated in depth the operation of representation in the dynamics of science. In this sense, semanticists consider that the real world is represented through abstract, non-linguistic, mainly imaginistic, models, which are then defined or described using different semiotic tools.

3.2. Operationalisation of the key ideas for our investigation

Based on the previous characterisation, we have reconstructed these two ideas so that thay can fit the context of our investigation and function as criteria of analysis in order to study the arguments of the teachers under study.

Correspondence is here applied to describe the multiple ways in which teachers relate the theoretical entities that they know from biology and chemistry and the different elements of real living beings that they recognise in the Kokori environment. This would be done through the use of what are usually called 'theoretical terms', which function as 'bridges' in teachers' identification of the represented features and transformation of those feature employing their knowledge about them.

Representation is here applied to describe the way in which teachers decode the symbolic processes of mediation between the objects and phenomena that they know in biology and their stylised representations in the Kokori environment.

4. Methodology

The piece of research from which this paper stems is of qualitative nature. In it, we intended to generate theoretical criteria to analyse the arguments contained in the survey questionnaires and semi-structured interviews with the teachers we were working with. The methods of data analysis used in our research are based on *symbolic interactionism* [17], and are usually referred to as *constant comparative analysis*. This kind of analysis allows the construction of categories 'from' raw data and the development of diverse hypotheses during the different phases of research.

The population of our study is constituted by teachers (N=35) in their pre-service education in two higher level institutions in Colombia and Argentina. These teachers were surveyed and interviewed after their interaction with the video-game Kokori. The questionnaire and the interview script related to structural and functional aspects of the video-game and to the cellular processes that were supposedly represented therein.

Our first categorisation of some selected fragments of the interviews allowed us to situate teachers' arguments as based on two main interpretive frameworks: they either support their inferences in their everyday knowledge, or they make explicit reference to 'academic' knowledge that they have learnt. As we have stated, the latter, which we have called instructional ideas, may or may not correspond to accepted disciplinary knowledge from chemistry and biology.

After this first categorisation, we approached data with the hypothesis that teachers also often talked about meta-theoretical issues. Instead of completely 'surrogating' the real cell with the analogue provided by Kokori, they went back and forth connecting these two realms, and extensively commenting on the advantages and disadvantages that arose from the work with the model. Accordingly, we proposed the existence of a third interpretive framework, and we tried to inspect teachers' utterances from a meta-theoretical point of view. We found recurrences that, in our opinion, could be captured with the key ideas of correspondence and rationality. The following section is devoted to presenting some results of this new analytic approach.

5. Teachers' arguments and the meta-theoretical interpretive framework

In this section we provide a few fragments of the teachers' responses to survey and interview that we have selected as the most significant to support our introduction of the new interpretive framework. In our opinion, the excerpts –when revisited from a meta-theoretical point of view– provide evidence of teachers' concerns about the use of models. The ideas of correspondence and representation have proved powerful to look into these excerpts in order to find their some hints around teachers' perspectives on the nature of science. Using the excerpts, we exemplify the kind of analysis we have performed on the data.

Pre-service Teacher C: […] it helped me to see that [the cell] is three-dimensional, this is what I most, what I most noticed, and how it works; you can well see that the cell is a unit in fact […].

Pre-service Teacher D: […] lysosomes performed a function, but it wasn't what it [really] does, because it traps a… something virtual, and this is really not in the cell… [but then] what is real and what is not real […].

Pre-service Teacher A: […] it helps to see what is more structural, the structural cell, and furtheromore to erase a little bit the imaginary that one has about the cell –plane […].

Pre-service Teacher B: […] exactly, that's it, like the grape that I take from the cluster and the raisin, that's the comparison that I make for you between the living cell and the one that is frozen […].

The combined use of the constant comparative analysis and our system of epistemological categories allowed us to go again through the corpus of data in order to construct a second 'layer' of interpretation. This new codification can be understood as a 'mapping' of our 'contextualised reconstruction' of the ideas of correspondence and representation (section 3.2) onto some of the core elements in teachers' statements. Mapping is done through the identification of some linguistic 'indicators' in those statements, which we now highlight (using italics):

Indicators for correspondence:
- You can well *see* that the cell is a unit *in fact*[2].
- It was [...] something *virtual*.
- What is *real* and what is *not real*.

Indicators for representation:
- It helps to *see*.
- *Erase* a little bit the *imaginary* that one has about the cell.
- *Like* the grape [...], that's the *comparison*.

The mapping that we have explified here relies on linguistic elements (modals and metaphors) that are traditionally linked to the epistemological topic of realism. This gives plausibility to our re-interpretation of teachers' arguments in terms of the meta-theoretical framework.

6. Final remarks

In our opinion, considering argumentation processes as grounded on some justifying elements, which we have here called 'interpretative frameworks', adds to the the discussion about the crucial aspects that guide school scientific argumentation. Our proposal in this paper focused on one of these frameworks, constituted of meta-theoretical elements. By looking into the arguments built by our students-teachers, it becomes apparent that one of their concerns revolves around the nature of science. Concretely, they think and talk about how a model-representation (the Kokori 'cell') stands for a real system (an animal cell). According to our interpretation, teachers' responses: 1. explicitly establish relationships between real entities and the symbolic elements that are used to model those entities; and 2. pose questions concerning the extent of these relationships.

We consider that further, more refined, studies of the interpretive frameworks of meta-theoretical nature that support teachers' argumentation processes could lead to new insights on the ideas about science that they maintain.

2. n Spanish, the teacher uses the expresión 'en realidad' (lit., 'in reality'), which might be translated as 'really', 'as a matter of fact', 'after all'.

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The Effect of Discovery Learning Method on High School Students' Understanding of Daily Life Chemistry Concepts

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Abstract
The purpose of the study is to investigate the effectiveness of discovery learning model on high school students' understanding of some daily life chemistry concepts such as organic and inorganic compounds, soaps, detergents and other cleaning agents. A quasi experimental design was used in order to examine the effectiveness of the intervention designed and the results were compared with the results of the conventional teaching that is constructivist in nature. An open ended questionnaire was designed so as to uncover students' ideas related to the nature of organic and inorganic compounds used in daily life. Students' written responses to the questionnaire were analyzed in ideographic terms. The findings indicated the feasibility of the teaching daily life chemistry concepts based on discovery learning theory.

Keywords: Constructivism, Discovery Learning Method, Chemistry Education, Misconceptions, Chemistry in Daily Life

Introduction
Constructivism has been the underpinning philosophy for many current reform efforts in education [4]. Educational reform in Turkey launched in 2004 has emphasized constructivist instructional approaches leaving the knowledge transfer view behind. Traditional learning model suggests the transmission of knowledge from teacher to learner whereas constructivist model gives value to learner's construction of knowledge from their experiences; making meaning from the interaction between existing knowledge or beliefs and new ideas [5]. Discovery learning requires active involvement of the learner [3]. Hammer [2] defined discovery learning as designed activities to engage students in inquiry guided by teacher through materials that they discover. Discovery learning also states that student finds discovery more meaningful than just learning about the subject. Joolingen [3] emphasized the importance of cognitive tools as instruments in learning environments for performing discovery skills. Thus, it is a suitable way to practice constructivist philosophy in class and it is often used in teaching skills via inquiry rather than scientific concepts. According to Castronova [1], teachers thought that discovery learning cannot be used in learning science concepts. However, concepts can be taught in the line of discovery learning principles. Students can be provided a range of examples that are representative of the key concept to be learnt. They examine the examples and find out the basic properties of the concept. Thus, they discover the meaning of that concept. During this personal discovery process, students are able to compare and contrast illustrative examples and generalize it toward a general meaning. In this way, they also use the scientific process skills such as comparing, classifying, making a decision via inductive reasoning [2].
Even though the constructivist paradigm has been adopted in educational arena, Turkish teachers have a tendency to transmit knowledge to their students in "Daily Life Chemistry" unit concepts. This unit involves the concepts of organic and inorganic compounds, soaps, detergents and other cleaning agents. The reasoning behind this tendency might be the appearance of these concepts in chemistry textbooks. They are presented in the form of knowledge to be transferred. However, the concepts aforementioned can be thought via instruction based on discovery learning where problems are posed to encourage investigations and examples are presented for promoting inductive reasoning.

Purpose of the Study

The purpose of the study is to investigate the effectiveness of discovery learning model on high school students' understanding of the nature and properties of organic and inorganic compounds used in daily life. In this respect, the research questions can be stated as:

1. Is there a difference between the conventional teaching method and discovery learning model on students' understanding of "Daily Life Chemistry" unit concepts?
2. What are high school students' (conventional teaching method group) ideas concerning the organic and inorganic compounds?
3. What are high school students' (discovery learning model group) ideas concerning the organic and inorganic compounds?

Method

The study was planned in the light of constructivist/interpretive paradigm and a quasi experimental design was benefited in order to examine the effectiveness of the teaching intervention designed. The results were compared with those obtained from the conventional teaching method. The teaching intervention was put into practice in a first year upper grade secondary (grade 9) Turkish class. Forty four high school students (21 female and 23 male) participated in the study. An open-ended questionnaire concerning the nature and properties of organic and inorganic compounds used in daily life was designed. Some of the questions asked students to explain a range of concepts such organic compounds, inorganic compounds, whereas some of them asked students to distinguish the hydrophilic and hydrophobic parts of the molecules and to define polar and apolar compounds. Also, in the questions, high school students were asked to write down the open formula, hydrophilic and hydrophobic parts of some organic compounds such as propane, methanol and benzene. After piloting the questions, the questionnaire was distributed to students in both groups (experimental and control) before and after the instruction carried out. The participants' open ended responses to the questionnaire were analyzed in ideographic terms and the statistical relationship was investigated by nonparametric test.
The study is designed on the bases of socio-cultural constructivist view. In line with this view, discovery learning method was also benefited in designing the teaching intervention. Teaching activities involved daily-life stories, case studies and primary and secondary sources to help students construct their own knowledge. In the first activitiy, the students worked in pairs and examined examples of organic and inorganic compounds. They were asked to figure out the differences between the two and define the two term. This was followed by questions where they had to classfy given compounds as organic and inorganic. In the second activity, stduents were presented organic compounds with their names. They were then asked to find out how organic compounds were named. Afterwards, they examined presentation of some properties (such as melting point, bonding type, water solubility) of organic and inorganic compounds. Having completed the aforementioned conceptual part, students were asked some questions about cleaning agents, they designed open-ended experiments and tested their hypotheses. These questions were:

1-Is there a difference between soap and detergent on cleaning grease spot?
2-Do you use hot or cold water when you are doing the laundry? Which one clean faster?
3-Do you use powder detergent or liquid detergent? Compare the cleaning rate of the two cleaning agents.
At completion of the inquries, students designed posters where they explained the cleaning mechanisms of some cleaning agents. The teaching intervention was lasted for four weeks in total in accordance with the existing curriculum. Both of the groups received instruction by the same teacher. The effectiveness of the teaching intervention was taken to mean to enrich scientificity of students' explanations.

Findings

The effectiveness of the discovery learning method on students' understanding

The students were administered the same questionnaire prior to and after the instruction so as to know the status of the two groups prior to the teaching. In this way, it was possible to know whether the experimental and control groups were equivalent (i.e. equivalent only in terms of the variable focused on by the pre questionnaire) at the outset of the study. The responses of the two groups were similar in nature. The results of the Mann Whitney U test (as the test distribution is not normal) carried out showed that there was no significant difference between the two groups of students indeed in terms of the grades obtained the questionnaires. It can be said that the groups are equivalent to each other prior to instruction statistically.

The same questionnaire was used again to trace the development of the students' understandings. The findings were analyzed by SPSS programme. Mann Whitney U test results regarding post test scores of groups can be seen in Table 1.

Table 1: Mann Whitney U test results of the groups' understanding of unit concepts

Groups	N	Mean rank	Rank total	U	p
Conventional Teaching Method Group	22	21.64	476.00	223	0.665
Discovery Learning Method Group	22	23.36	514.00		

It can be said that the teaching intervention based on discovery learning was as successful as the conventional teaching in helping students to gain knowledge concerning the daily life chemistry concepts. This means that students who were not imparted knowledge by the teacher could construct the knowledge related to the concepts tested.

The two groups of students were similar statistically. Yet, they differ in their performanses in individual questions. For instance, they differed in acquisition of their definitions of organic and inorganic compounds. The results of the analyses of these questions can be seen in Table 2 and 3.

Table 2: The Conventional Teaching Method Group Students' definitions related to organic and inorganic compounds

	Organic	**Inorganic**
Correct definition	12	11
Inadequate definition	-	-
False definition	8	9
Uncodeable/No answer	2	2
Total	**22**	**22**

Table 2 shows that 12 students out of 22 (54%) defined correctly organic compounds and 11 students out of 22 (50%) gave the correct definition of the inorganic compounds. The number of students who incorrectly define the two concepts (8, 9) is noteworthy. These students (%36, %41) failed to learn the definition of the concepts.

Table 3: The Discovery Learning Method Group Students' definitions related to organic and inorganic compounds

	Organic	**Inorganic**
Correct definition	16	17
Inadequate definition	4	4
False definition	2	1
Uncodeable/No answer	-	-
Total	**22**	**22**

Table 3 shows that 16 students out of 22 (72%) defined correctly organic compounds and 17 students out of 22 (77%) gave the correct definition of the inorganic compounds. Even though there is no significant difference between the mean ranks of the two groups, it can be seen from the tables that the ratio of discovery learning group who gave the correct definition is higher than the conventional teaching group.

Results and Conclusions

The findings indicated the feasibility of the teaching daily life chemistry concepts based on discovery learning theory. They also revealed that the teaching intervention based on discovery learning was as successful as the conventional teaching in helping students to gain knowledge concerning the daily life chemistry concepts. The discovery learning method can be used as an alternative teaching intervention in teaching the science concepts even if they seem to be knowledge-based in nature.

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How to Improve Learning Activity of Students in Chemistry Education

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Abstract
Today learning activity of students becomes a great significance for success of both education and life. There are at least two concepts of learning activity. One of these concepts considers learning activity as characteristic of personality. The second concept considers that learning activity is an action. Russian researches T.Shamova and G.Shchukina supposed what learning activity as characteristic of personality includes three levels. First level is a reproducing activity. If students have some knowledge of chemistry they can achieve second level was named interpretative activity. Third level is creative activity.
Researchers in chemical education consider mainly learning activity as action. Many methods of stimulation learning activity have been developed, but the problem of improving learning activity as characteristic of personality in chemical education has not been resolved.
Theoretical and experimental research allowed us to develop the pedagogical model for improving learning activity of students. Reproducing activity requires stimulating motives for learning. Motives «interestingly» and « usefully» are very helpful for this aim. Improving of interpretative activity requires that a success in learning was achieved. The concept of cognitive strategies is very useful to improve a creative activity. There is difference between terms «cognitive strategy» and «method». «Method» is a particular way of doing something. «Cognitive strategy» is a mental technology of thinking.
We tried to help all teachers realize the model. We had formulated 7 simple rules with the aim of improving learning activity of students.

Key words: chemistry, learning, activity, students, to improve

Learning activity

There are at least two concepts of learning activity. One of these concepts considers learning activity as learning work. Russian researches T.Shamova and G.Shchukina supposed what learning activity as characteristic of personality includes three levels. First level is a reproducing activity. If students have some knowledge of chemistry they can achieve second level – interpretative activity. Third level is creative activity. Learning activity as characteristic of a student may be improved in education.
Reproducing activity students begin to study chemistry. They haven't a positive experience of solving problems. Their motives for learning depend on teaching methods. To take an interest in chemistry they need a fun. These students have not ability to study without teachers' help.
Interpretative activity students have already some knowledge of chemistry. They can take a part in heuristic education, solve chemical problems. These students want to understand essence of chemical phenomena. They want to master new skills. These students know that problems solving gives a feeling of success, a feeling of bliss. They have a some clash of wills to study. These students want to have a learning success, therefore they try to overcome learning difficulties.
Creative activity students have high level of learning interest. They can understand essence of chemical phenomenon. These students can find new way to solve problems. They have a high clash of wills and a persistence. These students can orginize and can plan their process of learning chemistry.
Researchers developed various methods for improve learning activity. These methods are: problems solving; learning games; a chemical experiment; to improve a motivation; a positive emotional education; an entertaining learning; a heuristic methods of teaching; to use a fiction; using of an information on interactions between chemistry and human life; prepare a sutuation of learning success.

At the same time a way of improving learning activity as charateristic of personality at teaching chemistry was not developed.

The model for improving of learning activity in chemistry education

We created this model on the basis of A. Maslow concept of self-actualization. From our point of view human motives for an activity includes learning motives. According to the model teachers should choose methods of teaching that depending on learning activity level. Development of students' reproducing activity requires stimulating motives for learning. Motives «interestingly» and « usefully» are very helpful for this aim. The development reproducing activity need using such methods as chemical experiments, visualization, educational games, an using a fiction, art, film clips, history of chemistry, the media, interactions between chemistry and life.

Improving of interpretative activity requires that a success in learning was achieved. Students need an opportunity to choose a kind of activity, methods for solving problem. Gradual development of chemical concepts, problems solving are conditions for learning success. Chemical problems need to be set in the context of a human life and the real importance of a feeling or experience. Metaphors have a great importance to many students. Metaphors help students to understood difficult chemical concepts. Repetitive feelings about learning success improves learning activity and clash of wills.

Improving of creative activity requires a lot knowledge has gone into making a leraning success. This level students need careful thought about their thinking. A reflection, understanding of own style of thinking helps students to find a creative way to solving problems. These level students need other advanced pupils, teamwork in a classroom, overcoming of learning difficulties. Project activity, learning research, participation in chemical competitions need creative activity of students.

The concept of cognitive strategies is very useful to improve a creative activity. There is difference between «cognitive strategy» and «method». «Method» is a particular way of doing something. «Cognitive strategy» is a mental technology of thinking.

Seven rules for improving learning activity of students

All teachers want their students have good knowledge and skills. Learning activity of students should improve for this purpose. Teaching methods need to conforms with level of students' learning activities. It is hard to choose best teaching methods for many teachers, because they have not enough knowledge of psychology and didcactic methods. We are suggested only seven easy rules for chemistry teachers.

Rule №1«Firstly, students need to take an interest in chemistry, and just then they'll wish to study chemistry»

No strong actvity,
without pesonal interest.
Lev Tolstoy

In the Russian fairytale that reflects the wisdom of the people, it had told: «Firstly, feed me, give me a drink, lay me to sleep, and just then - ask me!". Motives are the basis of some activity. It is important that these motives were internal. For improving students' interest on chemistry lessons teachers should use: chemical experiments; educational games; teamwork; information about the history of chemistry; interconnection between chemistry and art (poetry, prose, fragments of movie, painting, sculpture), other subjects (physics, mathematics, biology and others), the media (TV, radio, Internet, magazines, newspapers); an interconnection chemistry with human life.

Rule №2«Firstly, students need to learn substances, secondly, they'll want to study their structures»

From living perception to an abstract thought,
and from it to a practice
V. Lenin

Substances and their properties are the subject of chemistry. Firstly, students need to learn substances, secondly, they'll want to study their structures, chemical formulas and chemical equations. This rule applies to both the method of constructing an initial course of chemistry, and the method of constructing each individual topic.
If we ask students: "Where do we find chemical elements?" We can hear the answer: «In the Periodic Table!». This answer is the indirect indication that the rule №2 has not been realized. The expected response can be like this: «Chemical elements exist all around us and into our body. All material world, including you and me are made from tiny particles called chemical elements. More than 100 chemical elements well known».

Rule №3 «Firstly, students need a practical experience, secondly, they can learn a theory»

Grau, teurer Freund, ist alle Theorie,
Und grün des Lebens goldner Baum
Johann Wolfgang von Goethe

What majority of students prefer, to learn theory or practice? We think that the answer is clear. A theory is a scientifically valid way to solve problems of human life. Theory as an instrument to solve practical problems is significant and full of meaning. But a theory without practice hasn't significance, not uderstandable for students. They need to encounter life' problems then this theory will be important, easy to understand.

Rule №4 «Interconnect chemistry with human life»

Teachers need to use information from other areas of life: a history of chemistry; an art (a poetry, a prose, the cinema, painting, sculpture); daily life (health, a household, professions); media (TV, a radio, the Internet, newspapers, journals); other subjects (biology, geography, physics, literature, mathematics and others).
Example of chemical problem: «Alchemists didn't know about the chemical composition of substances. They used words instead of chemical formulas and equations. Goethe in "Faust" wrote an example of the alchemical procedures:

Da ward ein roter Leu, ein kühner Freier,
Im lauen Bad der Lilie vermählt,
Und beide dann mit offnem Flammenfeuer
Aus einem Brautgemach ins andere gequält.

We can suppose that the «roter Leu» is a red mercuric oxide (HgO), and the «der Lilie» is hydrochloric acid (HCl).
1) Write the equation of chemical reaction between "roter Leu" and "der Lilie".
2) What mass of «roter Leu» will react with 100 g 36,5% "der Lilie" solution?

Rule №5 «Learn chemistry deeply»

It is necessary to combine a hearing
and a vision, a talk with activities of hands
Comenius

A teacher shouldn't begin a new topic until students achieved success in learning. It is necessary to ensure that students: in their thoughts have seen substances, and their structure, be able to demonstrate structures of substances using models and formulas, know how to describe their internal representations by words. Visual, auditory, kinesthetic, digital styles of representation should integrate into a common image. Students should use these styles to think.

Rule №6 «Students should use chemical calculations to understand chemical formulas and chemical equations»

Chemistry is fundamental science. Chemistry is the scientific study of the structure of substances, but formulas and equations have great importance for understanding chemistry. If students hadn't understood what is "chemical formula", "chemical equation", purpose of teaching chemistry is not achieved.
Students need to use mathematical calculations for the understanding of the concepts of "chemical formula" and "chemical equation". Difficulty of chemical calculations should be increased gradually.

Rule №7 «Prepare a success in learning of chemistry»

If teachers have performed six previous rules students will be ready to self education. Teacher should explane easy way of solving problems to students. Because of students can use different cognitive strategies, they will any way for solving chemical problems or offer on their own. It may happen that a one student will choose a one method of solution, and an other student will choose a second way, and a third student will propose his own method. In this case students can discuss various methods of solving chemical problems without a teacher. A content of the course can be depends on what the students would like to study. Following teaching methods can be used:

- an heuristic conversation;
- a best choice content of course, methods and ways to solve chemical problems;
- educational research activities;
- self reflection of cognitive styles and cognitive strategies;
- training students for competitions and conferences;
- solving chemical problems should interacts with problems of human life.

Conclusion

Our experimental research showed that using of these rules increases learning activity of students. For example we found that chemical problems with a life context had increased the number of participants in the regional Chemistry Competitions for 2 years in more than 2 times.

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Chemistry competence based curricula: a comparative analysis of the implementation in Germany and Italy

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Abstract
The introduction of chemistry competences based curricula at compulsory school level in Italy lead to make a comparison with Germany, whose theoretical framework has similarities with the Italian one but according to international surveys results in better learning outcomes. The hypothesis is that, despite the similarities in the theoretical framework, the implementations in the two countries are different. A comparative analysis of the implementations has been done using the German outline as a lens through which to observe the Italian one. The analysis highlighted that, whereas the German framework comprehends detailed description of the areas of competences and learning outcomes, the Italian framework and guidelines are holistic, and that the area of the competence epistemology is less addressed in Italy. The results support the importance of a systematic description of the area of competence epistemology to enhance this area in the Italian school.

Keywords: chemistry curricula, competences.

Theoretical background

The introduction of Chemistry Competence-Based Curricula (CCBC) in Italy, at compulsory school level, initiated an analysis of the documents in the countries in order to have a larger vision of how competence-based curricula were interpreted and implemented. It is important to go beyond the national vision and interpretation, which can be narrowed and biased by the local mental habit and traditions, to have a larger perspective that enables to individuate the points of strength, to be stressed, and those of weakness, to be recovered.
The analysis of the documents that introduced the competence-based curricula in the educational systems revealed that German theoretical framework has similarities with the Italian one, but has different results concerning learning outcomes in science on the bases of the international PISA surveys [1].
The hypothesis is that, despite the similarities in the general theoretical frameworks, the implementations in the two countries are different, and this led to make a comparison to find out what makes the differences and how can the Italian teachers be supported to improve students' learning outcomes.
Design of the study and Methods
To carry out the comparison between the CCBC implementation in the two countries the study encompasses two steps: a) the comparison of the theoretical frameworks for CCBC; and b) the investigation of their practical implementation.

a) The comparison between the theoretical frameworks involved the analysis of the Italian and German documents for the CCBC implementation, which are the Italian National Educative Norms [2] and Guidelines for CCBC [3] and the German National Educative Standards for Chemistry [4, 5]. The well organized structure of the German areas of competences has been used as a lens through which observe the Italian one.

b) The investigation of the practical implementation was based on the information collected by using a questionnaire, which was created by the authors. It was pilot tested. To validate the results the observation of two teachers, one in Italy and one in Germany, was added. The observations were documented. The investigations have been carried out in the Italian region Emilia Romagna, and in the German state North Rhine Westphalia. The Italian teachers engaged in the study teach at Technical Institute, while the German at Gesamtschule. The choice of those types of schools allowed the comparison between situations in which chemistry is taught at grade 9-10 (the two last year of compulsory school) as a separate subject for a comparable amount of periods per week (three hours in Italy and two in Germany). The investigation had been conducted in the school year 2010/2011.

Results

The comparison of the theoretical frameworks showed that the German standards refer to Weinert's definition of competence [4, 6], which encompasses the cognitive, practical and social spheres, and the same spheres are addressed by the Italian definition of competences that refers to the one released in the European Qualification Framework [2, 7]. The definitions of competence used by the two countries overlap broadly, but the comparison of the guideline for the implementation showed differences. In Italy de descriptions of the guidelines are based on knowledge and skills and refer almost exclusively to the cognitive area. Furthermore, the learning outcomes are generic. Whereas the German competences refer both to knowledge and skills: they are interrelated, and the operative description of the learning outcome standards is present for the different areas of competence. The comparison showed that the Italian guidelines are holistic whereas the German are systemic and refer directly to the areas of competence.
The investigation of the practical implementation showed differences between the approaches of the Italian and German teachers to CCBC especially concerning the competence area of epistemology. Following are reported three Lickert items from the questionnaire and their answers. The items are part of those that investigate the competence area of epistemology. Figure 1, 2, and 3 show the results of three interrelated questions that investigate if the teacher offers students opportunity to carry out experiment and to design them. The questions are respectively: 1-Do you make students carry out experiments?; 2-Do you make students design experiments? And 3- Do you make students carry out experiments designed by them? Both the Italian and German teachers let students carry out experiments but unlike the German teachers more than 50% of the Italian never make students design experiments, and what is worse, 77% never make students carry out experiments designed by them. The German teachers provide students with more opportunity to regard the experiments not only as a hands-on training activity but also as a mind-on activity. This fosters the students' capability to formulate hypothesis and to test them, and with it addressing some important aspects of epistemology.
The results of the questionnaire were confirmed by the direct observation of the teachers at work in the class.

Conclusion and Implication

The results reveal differences in the implementation of CCBC. Especially the competence area of epistemology is underestimated in Italy. Furthermore, the Italian teachers' approach is more traditional and transmissive. This support the idea that a clear and systematic description of the competences, their constituents and the learning outcomes, like the one present in Germany, can help the teachers to foster the implementation of CCBC. Due to this a proposal had been developed and presented to a group of experienced Italian chemistry teachers, and the results had been discussed in a workshop. The feedback was positive; the Italian teachers appreciated the schematic approach, and especially the operative description of the learning outcomes, which is helpful to design curricula and to select teaching activities.

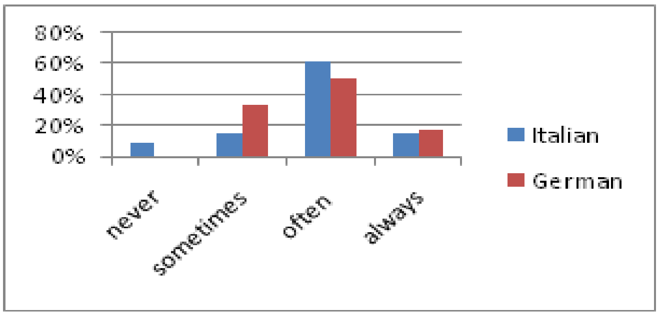

Figure 1: Percentage of answers given by the Italian and German teachers to the question: Do you make students carry out experiments?

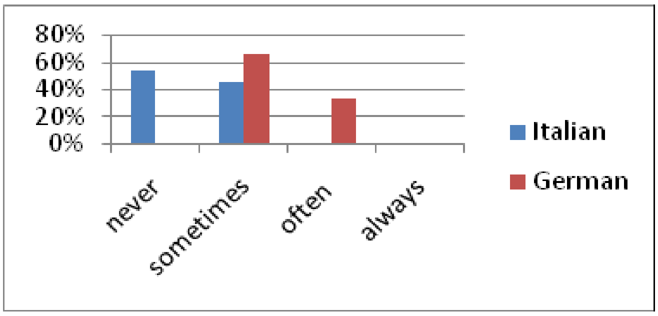

Figure 2: Percentage of answers given by the Italian and German teachers to the question: Do you make students design experiments?

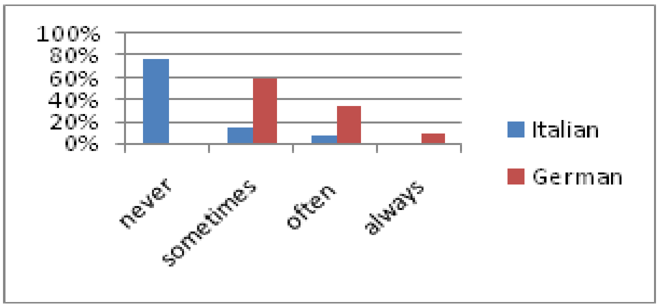

Figure 3: Percentage of answers given by the Italian and German teachers to the question: Do you make students carry out experiments designed by them?

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Study of the Relationship of Student-Teacher Dialogical Interactions in a Brazilian School from the Perspective of Toulmin's Argumentation Framework, Cyclic Argumentation, and Indicators of Scientific Literacy

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Abstract

This research has the main objective to present the results of how the student-teacher dialogical interactions [1] contributed to the development of the arguments of 25 students from the 10th grade of a Brazilian school, in a investigative laboratory work to solve a problem related to the following question: "Where does the energy come from in chemical changes?" This study shows the results of the first six meetings, whose arguments were divided into 10 episodes. The classes were video-audio recorded and the arguments identified in the transcriptions were analyzed according to Toulmin's Argumentation Pattern [2]. The levels of students' argumentative reasoning related to the teacher dialogical interactions were also analized, as well as the presence of the Indicators of Scientific Literacy (ISL) [3]. The results indicated that the type of question asked by the teacher affects directly the students' answers and the intensification of the presence of the Indicators of Scientific Literacy, evidencing a cyclic argumentation to solve the main question of the problem, which was resumed by the teacher several times, always in a deeper way.

Keywords: Toulmin's Argumentation Framework, Dialogical Interaction, Literacy

Introduction

Argumentation has been widely used in science teaching as a way of presenting a scientific explanation of a particular concept, whose arguments and evidences presented are focused on the teacher. However, it may restrict the development of the students' skills, such as, arguing, critical thinking, reflecting and making judgments of values in the pursuit of problem solving.

Researches have shown that cognitive skills and reasoning can be better developed in environments in which students participate actively in the construction of concepts, expressing their ideas, and participating in discussions during science classes [3-4-5-6].This research identified and analyzed ten arguments transcribed during investigative and experimental science classes about the energy involved in chemical changes. This analysis was based on Toulmin's Argumentation Pattern (TAP)[2]. Students should reflect on the following problem question: "Where does the energy come from in chemical changes?". The objective was to investigate the levels of student's argumentative reasoning related to the student-teacher dialogical interactions (STDI) as well as the occurrence of indicators of scientific literacy (ISL).

Theoretical background

Toulmin´s Argument Pattern (TAP)[2] is used by some authors as the basis for their investigation in the discourse analysis in science classes [3-4-5-6]. This pattern is composed by the following elements: data (D), warrant (W), conclusion (C), qualifier (Q), and rebuttal (R). Although Toulmin´s framework does not have the specific goal of the field of education, it has been used in research about science education [5]. However, it has some limitations, such as: the arguments are not contextualized, the warrants are not explicit, it requires a long discourse to identify the elements of his pattern, and sometimes there are ambiguities of the elements when used to categorize the argumentative discourse [4-5-6].

Sasseron describes a methodology using the Toulmin´s Argumentation Pattern [3]. This author formulated the idea of cycle in argumentative discourse in science classes, setting the argument as *"the ability to*

relate data and conclusions, evaluate theoretical statements in the light of empirical data or from other sources." [3]. Therefore, through epistemological operations, such as induction, deduction, causality, the discourse of science classes is drawn, thus making the argument more complex.
In an argument cycle, it can be observed some Indicators of Scientific Literacy (ISL). These indicators are skills or actions that students and teachers use during the argument, such as, raising hypotheses, classification, organizing the information, construction of an explanation, justification to support the ideas, logical and proportional reasoning.
The identification of these indicators in the discourse of science classes allows an investigation of scientific literacy process of students. However, there is no hierarchy among indicators, so, they may arise during the speech in random order and there are no degrees of importance or chronological order, they are all equally important in the learning process [3].
Another important aspect related to investigative experimental activities that may contribute to the development of cognitive skills is that the student role is not passive during the learning process, because there are not only procedures and observation. Students have the opportunity to participate, for example, proposing hypotheses to explain the problem, collecting data, analyzing, and developing conclusions based on their ideas, participating in the construction of a concept or scientific knowledge. The investigative activities at the same time arouse curiosity and guide the students on the relevant variables of the phenomenon studied, and provide them the chance to raise their own hypotheses and propose possible solutions [1-7].

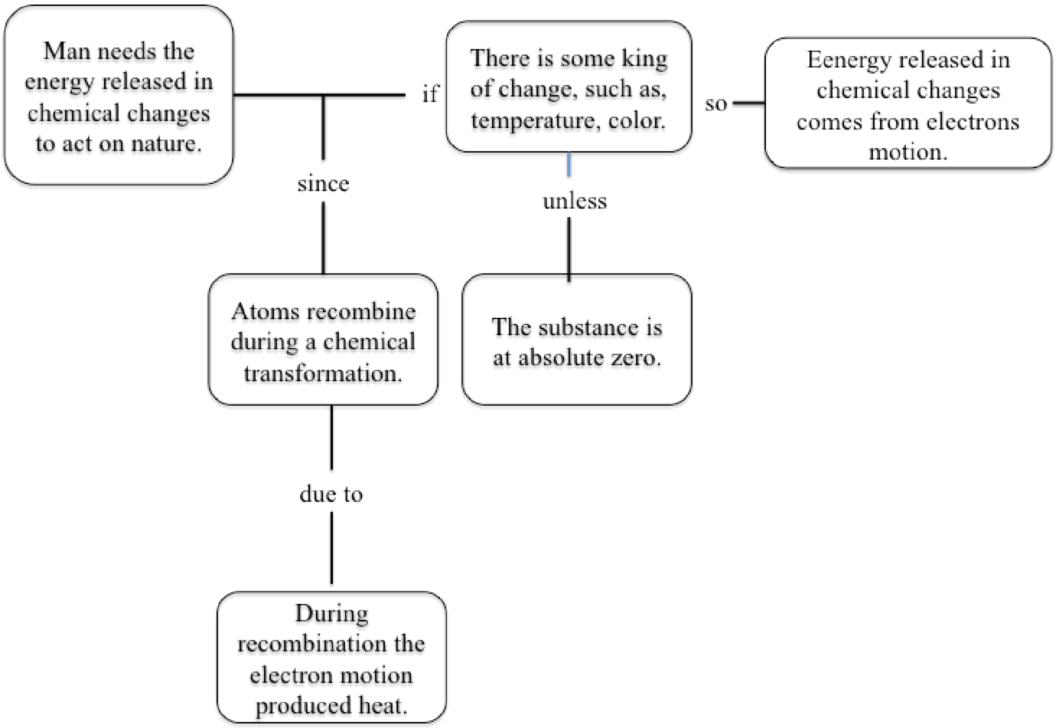
Methodology

The aim of the researchers was to investigate the ideas of 25 students, 14-15 years, of the 10^{th} grade in a Brazilian school about the heat released during chemical changes. The classes were audio-video recorded and the transcript was analyzed. This study presents the results of the first six meetings of fifty minutes each, whose arguments were divided into 10 episodes after transcription of audio-video recordings.
During the meeting, the teacher guided a discussion to investigate the students' ideas about chemical changes and heat. Through this discussion, the teacher came up with the following question for the students: "Where does the energy come from in chemical changes?" It was possible to infer that the students were able to establish relationships about chemical changes, energy and heat. After that, two experiments were carried out by students, for them to realize the elevation and lowering of the temperature involved in a chemical change. Experiment 1: (sodium hydroxide + water), experiment 2: (potassium nitrate + water).
Finally, students and teacher discussed about the experiment and drew conclusions about it.

Data analysis and results

Ten arguments were observed based on Toulmin's Argumentation Pattern (TAP). For the analysis of the arguments we elaborated levels of Dialogical Interactions (DI), levels of Students' Argumentative Reasoning and identified Indicators of Scientific Literacy (ISL).
On episode 2, it was possible to find three of the six Toulmin's elements: data, warrant, and conclusion, and the student-teacher dialogical interactions analyzed were level 2, in which the teacher accepted what students spoke, discussed their answers, requested more examples. However, the teacher changed the subject without continuing the discussion. As it was observed, the teacher did not encourage students to link their own ideas, in order to permit further reflections. The level of students' argumentative reasoning was low, level 1: students interacted expressing views based on stored data and expressed demands to recall or remember. They did not estabilish conceptual connections neither raised hypothesis to solve the problem question, though. Only three indicators of scientific literacy were observed: organization of information, explanation, and logical reasoning.
On episodes 5, 6, and 7 rebuttals were identified, which indicated better quality of arguments emphasizing the dialogical interactions and the level of students' argumentative reasoning. This also indicates an increasing of epistemological operations performed by the students, which implies the presence of

indicators of scientific literacy, observed as predictions and justifications.
On episode 9, only four Toulmin`s elements were identified: data, warrant, qualifier, and conclusion. The student-teacher dialogical interactions were the highest level, which is level 5, teacher accepted what students spoke, discussed their answers, encouraged them to think and used their own ideas for further reflection. Moreover, the level of students' argumentative reasoning was 4, because the students were able to establish conceptual connections, and raise hypothesis in order to solve the problem question. It was possible to identify five indicators of scientific literacy: organization of information, explanation, logical reasoning, justification, and raising hypothesis.
On episode 10, a final argument was built connecting all students' ideas, as shown in picture 1:



Picture 1: final argument

The level of students' argumentative reasoning was 4, because they could connect the concepts, and raise hypothesis in order to solve the problem question. Furthermore, five indicators of scientific literacy were identified: organization of information, explanation, logical reasoning, justification, and raising hypothesis.
According to the analysis of the arguments, as the student-teacher dialogical interaction advanced, the level of students' argumentative reasoning became more complex and also students were able to establish connections between concepts, raise hypotheses, make predictions in order to solve the problem question proposed by the teacher.
During the analysis of the arguments, we observed that when the teacher asked questions that only required the recall or exemplification of a fact or concept, the level of the student's argumentative reasoning in the construction of the concept was the lowest, and fewer Indicators of Scientific Literacy emerged. However, when the questions were more elaborated, better levels variables appeared. Besides, there is no relationship between the quantification of the presence of Toulmin's elements, the student-teacher dialogical interactions (STDI), the level of students' argumentative reasoning and the presence of indicators of scientific literacy (ISL). Although, on episodes 1 and 8 there were many of Toulmin's elements, the level of student-teacher dialogical interactions ranged from 1 to 5.

Conclusion

This study showed that the activity developed presented characteristics of an investigative approach, since the students could participate in the process of developing hypotheses, analyzing data, drawing conclusions, discussing ideas for the construction of scientific knowledge at school [1-7]. Argument contributed to the conceptual development, since students have built their arguments to explain phenomena using their own ideas and appropriating more of a critical thinking to a better understanding of scientific ideas.

It was possible to infer that the teacher role is extremely important, because how he/she asks questions and guide discussions may affect the level of students' argumentative reasoning with implications for the level of learning of concepts. This implies the need for the teacher to prepare his/her teaching plan, reflecting on these needs, especially if the activity is interactive and with dialogue [6].

The answer to the problem question was built collectively, so that, the discussion allowed students to build together the concept to resolve the given problem: "Where does the energy come from in chemical changes?". This construction was given in a cyclic manner, *i.e.*, the problem was taken up the issue several times and always getting deeper by the teacher.

Generally, there were some indicators of scientific literacy throughout the discussion, such as, raising hypothesis and making a prediction. These indicators are meant to organize the reasoning and reformulate new conclusions, as data was introduced into the discussion, structuring an argumentative cycle [7]. Thus, the students could understand some concepts and terms involved in the scientific exploration of the theme energy and heat in chemical changes.

Although quantification of the presence of Toulmin's elements did not have a direct relationship with the level of student-teacher dialogical interaction, their presence, especially qualifiers and rebuttals, may assist the teachers to reflect and understand about their actions in an argumentative context.

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The role of science in a fragile world

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Abstract
Science and technology permeate more and more the human society. Some scientists have pointed out that the development of science increases the fragility of our world. The most important, but not unique, reason is the strict connection between science and military establishment. Limiting and controlling scientific research is a difficult problem, but a democratic society must collectively take decisions on the development of science. Honest and clean science communication is extremely important to foster democratic decisions. Complexity is a common feature of all problems facing mankind and in such a complex world we need science to propose solutions and wisdom to choose among them. Progress of science and availability of a powerful energy source like fossil fuels have led to the present epoch, anthropocene, where human beings are no longer passive passengers of spaceship Earth. The shortage of fossil fuels, the extensive damages caused by their use, and a new consciousness of living in a resource-limited world require a transition from fossil fuels to renewable energies, from wastefulness to efficiency, and from consumerism to sustainability. Besides teaching good science, we should teach and discuss with our students other not less important topics, like to be aware of the limitations of science and technology, to remember that science has to be guided by ethical values, to pay attention to the needs of the society, to become authoritative and concerned citizens, and to like disconcerting truths better than reassuring lies.

Key Words: anthropocene, energy, complexity, scientific research, teaching science.

End of Science?

Science has developed so much in recent years that one may wonder whether it is close to its end. In the last page of the book "The Theory of Everything" [1] it is written that "... If we will be clever enough to discover such a unifying theory, we will decree the definitive triumph of human reason, since we will know God's thought". One of the strongest ambitions of some scientists is indeed that of becoming like God. It is much better to recognize that our knowledge is very limited, as pointed out, for example, by John Maddox, in his book entitled " What remains to be discovered " [2]. A few years ago *Science* tried to make a list of the 25 most important questions that are waiting for answers. After having realized that it was impossible to stop at 25, the list went on up to 125 questions before concluding that it was an impossible task since "The highway from ignorance to knowledge runs both ways: as knowledge accumulates, diminishing the ignorance of the past, new questions arise, expanding the area of ignorance to explore" [3]. The same concept had been expressed, more than two centuries earlier, by Joseph Priestley in a poetical way: "As the spotlight increases, the dark edge around it increases too. The more we make light, the more we have to be grateful because this means that we have a larger horizon to contemplate".
Other scientists believe that one day, perhaps in a few centuries, the scientific age, like the stone age and the iron age, will come to an end. Not, however, because we will know everything, but because science will reach the border of what it can explain [4]. From a philosophical viewpoint there are indeed four types of "things": (i) things we know we know: e.g., H_2O; (ii) things we know we don't know: e.g., the chemical basis of conscience; (iii) things we don't know we don't know; (iv) things that we cannot know due to intrinsic limits of human mind: there may be some aspects of reality we cannot understand or some question we cannot pose [5].

Science and scientists

Will it end or not, science has limits and boundaries. Science rationalizes the occurrence of natural phenomena, but it does not explain *why* they take place. For example, we know the law that governs the force of gravity, but we do not know why masses act on each other at a distance. Science has no answer for the so-called *questions of sense* like: which is the meaning of my life? Why there is a mystery of evil? Does God exist? Answers to these questions should be found in other fields of the human culture, such as philosophy and religion. Science permeates but does not fill up the space of mankind culture.
Science is important and useful not only because it brings us material benefits, but also because it trains people to democracy teaching the correct method that should be used in dealing with any kind of problem: listening, collaborating, acting with rigor and objectivity, avoiding dogmatism, keeping doubt alive, exchanging ideas. Exchange of ideas is, indeed, the basis of any kind of human progress. A famous aphorism of George Bernard Shaw says: "If you have an apple and I have an apple and we exchange these apples, then you and I will still each have one apple. But if you have an idea and I have an idea and we exchange these ideas, then each of us will have two ideas". This aphorism has been recently updated by Dan Zadra using dollars instead of apples.
We often tell our student that science is important and useful, but generally we do not care to explain them that science is beautiful. Sometimes the job of a scientist is compared to that of an artist, but there is a fundamental difference that can be illustrated with a simple example. Looking at a superb tree, a poet can take inspiration to write a beautiful poem, and a painter to create a marvelous picture. A scientist too is admired looking at a beautiful tree, but his mind does not stop at beauty, it goes on to consider that there would be no tree without the Sun. Better, to use the words of Richard Feynman [6], "A tree is essentially made of air and sun. When it is burned, it goes back to air, and in the flaming heat is released the flaming heat of the sun which was bound to convert the air into tree". The two most important natural phenomena, photosynthesis and combustion, that we often explain with many boring words, look so interesting after reading these few Feynman’s lines! A scientist understands, and is deeply amazed, that a tree is essentially made of air and sun and wants to know more. He images a much simpler scene and asks himself some questions: why light is needed to grow a tree? How does a tree use light energy? What is light? Scientists are curious people, science is indeed based on curiosity. In an attempt to satisfy his curiosity, a scientist tries to interrogate Nature. His questions are presented in the form of experiments, which must be carefully planned and executed. The more intelligent is the question, the more important will be the answer. Perhaps, the greatest surprises in the field of science will be answers to questions that we are not yet ready to formulate. Then the scientist analyzes the results of the experiment, that is Nature’s answers. He has to look at these answers with great attention and passion because, as Albert Szent-Gyorgyi said, "Discoveries consist in seeing what everybody has seen and thinking what nobody has thought" [7]. The results obtained with the experimentslead to knowledge, and knowledge leads to astonishment, exciting new curiosity that leads to the formulation of new questions and the design of new experiments. One might think that this merry-go-round of questions and answers will end after a few cycles, but this is not true, because discoveries add new questions to the list of those that remain to be solved. This is the reason why a scientist can never say to be satisfied. As it happens in a Tale of Chassidims written by Martin Buber, to the question “You got knowledge, what do you need?”, the answer of a wise scientist is: “Indeed, only if you get knowledge you know what do you need” [8].

Science and war

Nowadays, society depends more and more on science and science and technology develop at a growing rate. Should we fear this development? A first reason of fear is the tight connection between science, technology, and war. According to a recent report by the Stockholm International Peace Research Institute (SIPRI) eight states possess about 4400 operational nuclear weapons, nearly 2000 of these are kept in a state of high operational alert [9]. Furthermore, the present political conditions do not allow taking operative decisions on biological weapon control, and Russia and the USA have declared that they were unable to complete the destruction of their chemical weapon stockpiles by the final mandated deadline of

29 April 2012. For 2011, the military expenditure is estimated to have been $1738 billion, representing 2.5 per cent of global gross domestic product or $249 for each person. Joseph Stiglitz estimated that, apart from its tragic human toll, the true final cost of the Iraq conflict will be three trillion dollars [10].
As soon as something new is discovered or invented by science, the military establishment tries to catch it. For example, when nanotechnology began to develop, the US Army and the famous MIT joined together to make the Institute of Soldier Nanotechnology. The military establishment is looking carefully to any technological development, as shown by what happened to me some years ago. We were working on artificial photosynthesis and we published a couple of papers on decanuclear ruthenium dendrimers, which we used as antennas for light harvesting [11]. One day a got a letter from the US Army inviting me to attend a meeting on military applications of dendrimers. I did not go, but it was appealing because attending the meeting would have resulted in getting money for our research.

The development of science makes our world more fragile

As science develops, we can say with Newton that we can see further, but nowadays seeing further can generate fear. Scientists have pointed out that the development of science increases the fragility of our world. In his book “Our last hour” Martin Rees writes that there is no more than 50% probability that our civilization will survive until the end of this century because of bad or incautious use of the most recent developments of science and technology [12]. Other scientists have warned about further development of science: there is not much time to decide what we should do and what we should not do [13]. It has also been noticed that the new technologies have the ability to change the very essence of our beings and that we are overcoming the boundary between enough and too much [14]. Several scientists have emphasized that our finite planet cannot sustain an endless expansion [15] and that we should take ecological constraints as a given, not a hindrance but a source of long-term economic security [16]. According to Stephen J. Gould [17], the fragility of the world can be summarized in the great asymmetry principle: “The essential human tragedy lies in a great asymmetry in our universe of natural laws. We can only reach our pinnacles by laborious steps, but destruction can occur in a minute fraction of the building time. A day of fire destroyed a millennium of knowledge in the library of Alexandria and centuries of building in the city of London”. Such an asymmetry between our capacity to build up and destroy becomes, of course, greater and greater as science and technology develop. Nowadays, a nuclear war could destroy almost completely our planet in a few hours. An Italian philosopher, Umberto Galimberti, has summarized his pessimistic feeling about the development of science and technology in two sentences: "Man is powerless against science, because science is stronger than man. The question is no longer what can we do with science and technology, but what science and technology can do of us [18].
Recently, creation of a highly contagious form of the bird flu virus by Dutch and American scientists has raised a debate about whether the work should be published in full to aid pandemic preparedness or redacted to prevent misuse by terrorists [19]. According to some scientists, that work should never have been done, whereas others say that there should be a system of prior review and approval for potentially dangerous experiments. Concern is also generated by genetically modified microbes with tailored functions and presently in the US there is a debate about the approval of a genetically engineered salmon that grows to the market size in 16 months instead of 30. It would be the first genetically-engineered animal in the human food supply. Another controversial issue is that related to the production and use any kind of pills. There are trust pills because it has been discovered that some compounds (e.g., oxytocin) have effects on trust. A trust nasal spray is also available on internet. The use of these substances can give unfair social advantages [20]. Studies are in progress on compounds capable of modifying moral behavior. Who should decide about their use?.

Limits to scientific research?

Since the progress of science makes our world more fragile, should we stop or limit scientific research? This is a very difficult question indeed. The aim of Science is to increase knowledge, to discover *the truth.* Therefore it seems unreasonable, in principle, to limit scientific research. It is true that discoveries

can have a dual use, but at the beginning of a research this point is often unclear and, in any case, *the truth will out*: it will simply be discovered later, perhaps by a less scrupulous scientist. Therefore, most scientists maintain that science should be free to expand. But there are problems that cannot be overlooked. To know a scientist must act. Knowledge is indeed entangled with action: knowledge presupposes action and action presupposes knowledge. A scientist, like any other person, acts on the basis of his ends and values that, by definition, are not neutral. If a scientist has no personal ends and values, he will play into ruling class' hands, as it happened in Germany during Nazism. Science is not neutral, it has a profound social dimension; furthermore, since knowledge can hardly be separated from its use, another difficult question arises: who is responsible for the applications of scientific work?
Several years ago, at an important meeting, Robert Oppenheimer said: "If you are a scientist, you believe that it is good to find how the world works … and, as a citizen, you know it is good to turn over to mankind the power to control the world and to deal with it according to its values" [21]. Perhaps this is the best way: to employ a collective responsibility, just as for other important issues like education and health care. Therefore, a democratic society must discuss the role of science and must collectively take decisions on the development of science. Collective responsibility, of course, relies on science communication. Honest and clean science communication is extremely important to fill the fracture between science and society and to foster democratic decisions. This is the reason why in the University of Bologna we have activated a course of lectures on *Scienza e Società*, opened not only to students, but also to citizens. Such a course aims to construct a cultural bridge between the university and the town. There is a need to discuss the relationship between science and society with students and a need to explain science to laymen. Even more important would be to educate politicians on the most important scientific issues. Books like Physics for Future Presidents [22] can play an important role in this regard and an analogous book on Chemistry would be necessary since going towards a sustainable world needs a stronger advisory role of chemists.

Complexity, science and wisdom

Several years ago Hannah Arendt observed that "Reality has the disconcerting habit of confronting us with the unexpected, for which we were not prepared" [23]. This is even more true today because the world is a system whose complexity increases further year after year. A simple example of increasing complexity related to chemistry is the following: two decades ago, a typical household owned products that altogether depended on less than 20 elements of the Periodic Table, whereas today a typical smart phone contains up to 60 different elements [24]. Complexity is a common feature of all the problems we have to solve: we need science to propose solutions but we also need wisdom to choose among them. Unfortunately at the universities all over the world we teach a lot of science, but not much wisdom, even here in Rome where Wisdom is the name of the University. Teaching wisdom should be the mission of the University and the background of science education.

Spaceship Earth and the energy problem

People believe that the four most important problems of mankind are food, water, wealth and environment. In reality, behind these problems there is an even more important issue: energy, because food, water, health and environment depend on energy. In fact, everything around us and whatever we do depends on energy.
A famous Italian writer, Italo Calvino, was used to say that if you really wish to understand an important problem, you should first look at it from far away. Let's follow Calvino's suggestion, looking at the energy problem from very far away, from Saturn's rings, about 1.5 billion km from Earth. Seen from there, Earth looks like a dot. Before trying to solve the energy problem, we should acknowledge that the Earth is a spaceship [25] travelling in the infinity of the Universe: a very special spaceship that cannot land or dock anywhere for being repaired, a complex spaceship with seven billion passengers. They have to live altogether: white, black, and yellow people, poor and rich, no one can go away. After being aware of that, we can begin examining the energy problem with a quick look at the history of energy

consumption. Several thousands years ago, at the beginning of the human civilization, the few people living on the Earth got energy from man and animal power, wood and wind. Nothing changed for millennia, but about 200-300 years ago mankind discovered fossil fuels, an abundant, very powerful, and easy to use source of energy. The industrial revolution exploded and in a couple of centuries we have changed the world. We have mined coal and minerals, extracted oil and gas, constructed industries, built up and destroyed cities and roads, manufactured cars and machines, caused air pollution, accumulated enormous amounts of waste, and lighted the planet at night [15].

Anthropocene

By using fossil fuels mankind entered a new era that scientists call anthropocene [26], characterized by a profound impact of man on the Earth. It is indeed a new phase in the history of both humankind and of the Earth. For centuries, natural forces have been stronger than human forces, so that humans were essentially passive passengers of spaceship Earth. The powerful energy of fossil fuels and the progress of science have reversed the situation: now human forces are stronger than natural forces and human beings are no longer passive passengers of spaceship Earth. They have power over Nature and have changed the rules by which the Earth systems operate. This is the reason why the world is fragile

Reinventing fire: from fossil fuels to renewable energies

Using fossil fuels was and still is easy and very convenient, but, as everybody knows, now there are problems. First of all, fossil fuels are going to be exhausted. Second, the use of fossil fuels causes severe damages to human health and environment. Therefore there is a need to save energy and to develop alternative energy sources. The requirements needed for an ideal energy source capable of taking care of spaceship Earth would be the following: abundant, inexhaustible, well distributed on the entire planet, not dangerous today as well as in the future, capable of supporting economic development, reducing disparities, and fostering peace. The solutions presently proposed by scientists are essentially three: (i) going on with fossil fuels by extracting unconventional oil and gas, (ii) expanding nuclear energy, and (iii) developing renewable energies. To make the right choice, we need wisdom.

Unconventional oil and unconventional gas are relatively abundant and economically convenient in some nations like USA and Canada, but their exploitation will cause much greater damages to our spaceship than those already caused by conventional fossil fuels. These extreme attempts to obtain fossil fuels raise novel environmental concern, including the large volumes of water employed, water pollution and geological consequences of hydraulic fracturing [15]. In any case, unconventional fossil fuels cannot solve the energy problem for more than a few decades.

Nuclear energy is a dream that failed, although many people are not yet convinced. It failed because it is too expensive, but it should be discarded for several other, more important, reasons: safety problems, production of radiative waste dangerous for thousands of years, difficulties related to decommissioning and dismantling of the plants, proliferation of nuclear weapons, international political problems, increased disparities among nations [15].

The best solution for solving the energy crisis is to develop renewable energies, particularly solar energy since (i) the Earth receives from the Sun in one hour the amount of energy consumed by mankind in one year, (ii) the Sun will continue to shine for 4,5 billion years, and solar energy is fairly well distributed on the Earth. Solar energy indeed possesses all the requirements needed to take care of our planet and to supply energy for the future generations [15].

The transition from fossil fuels to renewable energies is something like reinventing fire [27]. It is expected to create a stronger economy and a healthier environment, but it will be not easy, because to exploit solar energy we need to convert sunlight into useful energies, namely heat, electricity and fuels. This holds true also for the exploitation of the other types of renewable energy.

Back to the Periodic Table

To convert renewable energies into the energy forms we need, we must use equipment, machines and devices: e.g., photovoltaic cells, wind turbines, pumps, batteries, etc. To make such devices we must start from metals and other available materials, which means that we must go back to what we have on our spaceship Earth: the chemical elements of the Periodic Table. We know that some elements are abundant, but others are relatively scarce. The most advanced technologies, including those used for energy conversion and storage, make extensive use of several elements that are or will become scarce. For example, lithium used for light batteries, transition metal elements like platinum, iridium, rhodium and cobalt used for fuel cells and catalysts, indium and tellurium used for photovoltaic devices, and rare earth elements like neodymium used for making permanent magnets, lanthanum for rechargeable batteries, cerium for TV screens and europium for lasers. The scarcity of several elements gives important research opportunities to chemists: on one side there is much to do concerning supply of such elements, which means to develop new technologies for extraction, conversion, processing, and recycling. On the other side, a new field is opened, that of substitutional research.

Resource efficiency

Concern about criticity of some materials used for energy conversion and advanced technologies are based non only on scarcity, but also on geographic, economical and political factors. For example, essentially all mining of rare-earth minerals occurs in China [28]. Therefore it could happen that we will have plenty of renewable energies, but limited availability of materials to convert them into useful energy. This is the reason why we need a completely different approach concerning not only energy, but any kind of resource of our planet: food, minerals, land, etc. [29] A new consciousness of living in a resource-limited world requires a transition not only from fossil fuels to renewable energies, but also from wastefulness to efficiency and from consumerism to sustainability. We need to create a more sustainable world by decoupling economic growth from resource consumption. The first rule for succeeding in a resource-limited world concerns waste: reduce waste, reuse and repair things as much as possible, and recycle any kind of material. Maintenance, repairs and overhaul offer enormous opportunities when combined with technological advancements such as 3D-printing, wireless networking, interchangeability through standardization, making parts in such a way that they already address the assembly and disassembly processes.

Education: disconcerting truths and reassuring lies

In closing, what should we teach our students? Of course, to solve problems, to be careful in planning experiments, to be open to sharing ideas and collaborate, to publish results that can be replicated, to write papers and proposal easy to read, to follow safety regulations, to be able to communicate. But we should also teach our students, or at least discuss with them, others not less important topics, like to be aware of the limitations of science and technology, to remember that science has to be guided by ethical values, to pay attention to the needs of the society, to become authoritative and concerned citizens.

After all that, we should not forget to remember that there are three disconcerting truths: (i) we live in a crowded spaceship that cannot land anywhere, and there are no places to which our species can migrate; (ii) the resources available on the surface or stored in the holds of our spaceship are limited; we must use them with much care and creativity, and recycle them as much as possible (iii) the resources should be more fairly distributed among all the spaceship passengers if we wish to live in peace.

Discussing with students these disconcerting truths is particularly important in a world where most people prefer to listen reassuring lies such as: there is no reason to stop using fossil fuels, there is no need of saving energy, technology will solve all problems, “trickle-down" policies will make poor people happy, and war will eliminate terrorism.

We live in a spaceship that has been damaged and needs to be repaired by motivated young people. Their work can take inspiration from two sentences of two very different personalities of our civilization: Concern for man himself and his fate must always constitute the chief objective of all scientific endeavors. Never forget this in the midst of your diagrams and equations” (Albert Einstein), and “If I have the gift of prophecy, and can understand all secrets and every form of knowledge, and if I have absolute faith so as to move mountains but have no love, I am nothing" (Saint Paul).

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ICT in chemistry teaching on various levels of education

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Abstract
Common application of Information and Communication Technologies (ICT) in almost every life's domain shapes the contemporary society. It alters the manner in which people communicate, spend their spare time, acquire information and also learn. Modern educational system has to comply with occurring changes and new conditions. The usage of information and communication technologies in educational process enables to improve the efficiency of delivering didactic contents and to enhance lessons' and activities' attractiveness. The paper also presents exemplary possible methods of chemical contents' presentation in teaching nature sciences supported by information and communication technologies.

Keywords: chemistry, nature, ICT, blended-learning

The computer and the Internet have become integral elements of the contemporary young people's natural habitat. They communicate with each other by means of social networks; they meet new friends, they learn new things and broaden their interests. Digital Natives is a generation which cannot imagine their life without the Internet [1]. Five years ago, Polish parents declared that 72% of children aged over three use the computer [2]. Furthermore, the average monthly amount of time students aged 7-14 spend in front of the computer screen amounts to 49.5 hours [3]. Research carried out on a group of high school students in their senior year pointed to the fact that 72% of them do not see any point participating in regular in-class lessons, and 79% of these students find their lessons not very interesting [4]. The situation is similar in Polish schools. Thus, a question arises how to make the school more interesting for the digital natives. What can we do to motivate them to make more effort to learn? How to bring the school closer to their interests and their life outside the school?

One of the answers to the above questions could be platform-assisted learning. It can be used for:

- teaching natural sciences (Biology, Physics and Chemistry) by asking questions and carrying out discussions with the teacher concerning the animations prepared and placed on the e-learning platform [5]. The lesson begins with an open-ended question asked by the teacher after watching videos. Students provide responses The teacher then provides follow-up comments or questions built on each other. Discussions result and students are able to consider the author's point as well as student's point. Teachers are able to model the QtA approach by discussing aloud their thoughts about the questions they ask while reading [6,7]. Project *e-Science Tutor* has been realised in primary and secondary schools for 2 years, since September 2011. In the project take part: 9 schools [1].

1The ETOS project is run by Adam Mickiewicz University in Poznań in collaboration with Boulder Language Technologies, USA. Project managers and principal investigators are Prof. Katarzyna Dziubalska-Kołaczyk, Prof. Ronald Cole and Dawid Pietrala, M.A. The project is funded by the European Social Fund within the Human Capital Operational Programme (priority 3, call for proposals: 4/POKL/2009).

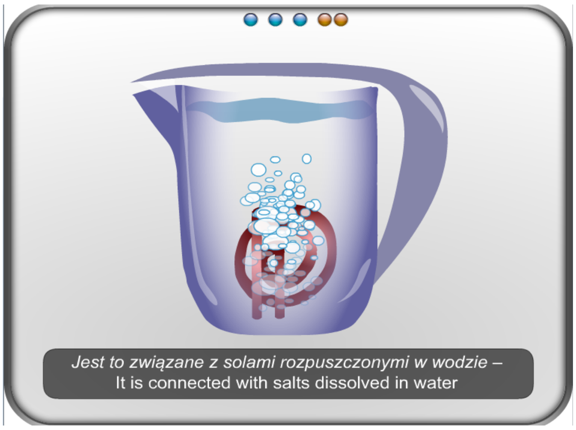


Figure 1. Tutorial

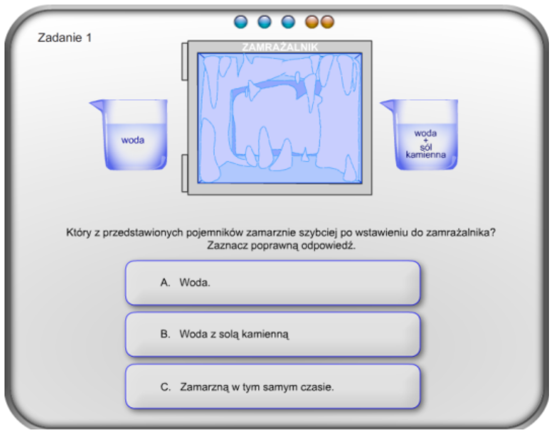


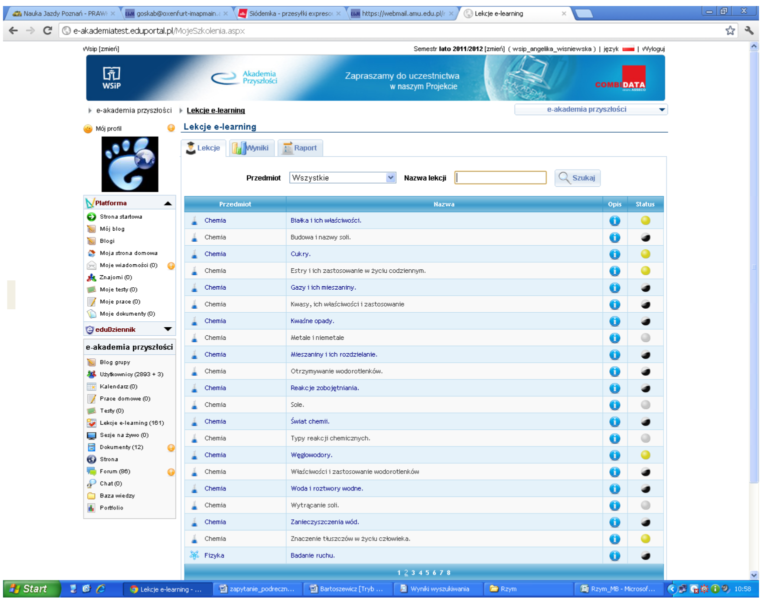
Figure 2. Test

- teaching Chemistry by developing key competences; e-learning units have been prepared as situations experienced by the avatars in the real life as well in laboratory situations [6].

  Future's e-Academy authors' main assumption is shaping Key Competences on the basis of Middle School Forming Key Competences Programme, during lessons of science, English, IT or business. Key Competences were defined in recommendation of the European Parliament and the European Council on key competences for lifelong learning as:

  1) Communication in the mother tongue;
  2) Communication in foreign languages;
  3) Mathematical competence and basic competences in science and technology;
  4) Digital competence;
  5) Learning to learn;
  6) Social and civic competences;
  7) Sense of initiative and entrepreneurship;

Creating Key Competences takes place during lessons, optional courses and pupil's individual activities.



Organisation

Project has been realised in schools for 3 years, since September 2010. In the project e-Academy Future: 200 schools, 1600 teachers, 19000 pupils, take part.

Project is implemented during math, physics, biology, geography, English, IT and business lessons. Especially to enable caring out the project an e-learning platform on which pupil's and teachers materials are uploaded , was launched.

Substantial content – creating Key Competences in the framework of chemistry lessons

Creating Key Competences in the framework of chosen subject will take place will take place by using 168 e-learning units, including 21 regarding chemistry.

Figure 3. Communication in the mother tongue
Avatar: Read the text carefully and then I am going to check your level of reading comprehension. Purpose: increasing the level of reading comprehension [8]

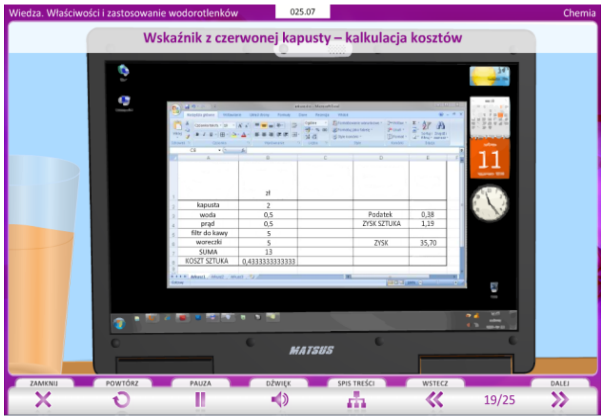


Figure 4. Sense of initiative and entrepreneurship
Indicator from red cabbage - calculation of costs. Purpose: To estimate the cost and sell the cabbage indicator paper on the online auction site [8]

Project's implementation in the school year 2010/2011and 2011/2012. Every e-learning unit consists of three modules: knowledge (pol. *Wiedza*), revision (pol. *Utrwalenie*) and test (pol. *Test*). The chart presents the number of logins in particular months:

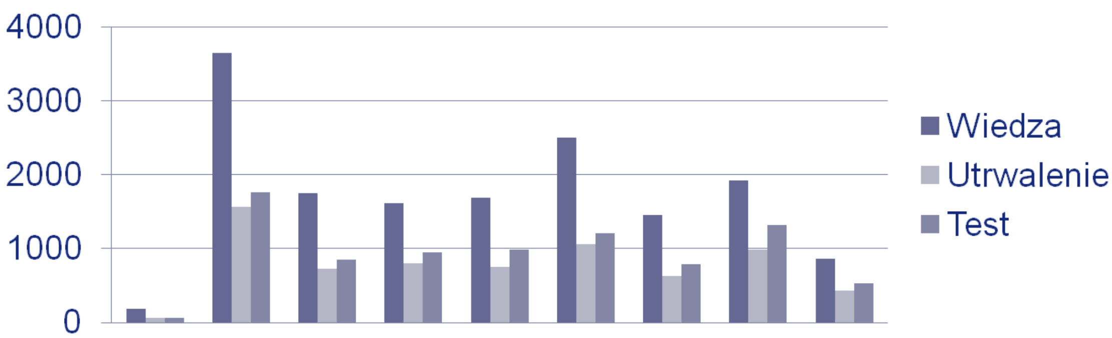


Figure 5. The number of logins – teachers
IX-VI 2011/2012
knowledge (pol. Wiedza), revision (pol. Utrwalenie) , test (pol. Test)

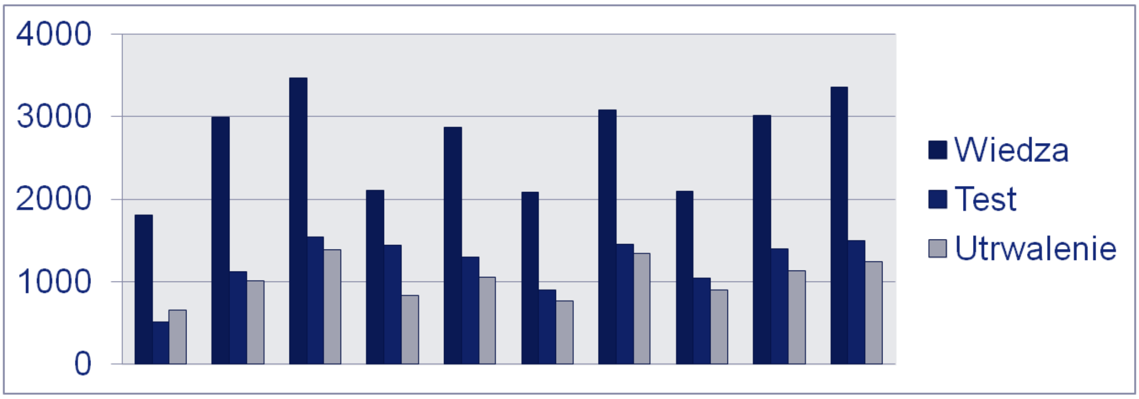


Figure 6. The number of logins – teachers
IX-VI 2010/2011
knowledge (pol. Wiedza), revision (pol. Utrwalenie) , test (pol. Test)

In 2011/2012 on average, teachers spend 8.4 hours on the platform of a month and students spent 8.2 hours on the platform of a month.
In 2010/2011 on average, teachers spend 2.0 hours on the platform of a month and students spent 2.4 hours on the platform of a month.

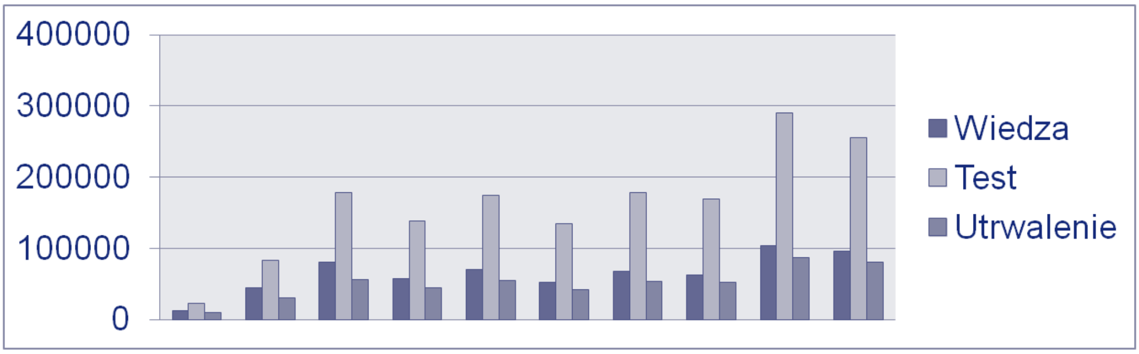


Figure 7. The number of logins – students
IX-VI 2011/2012

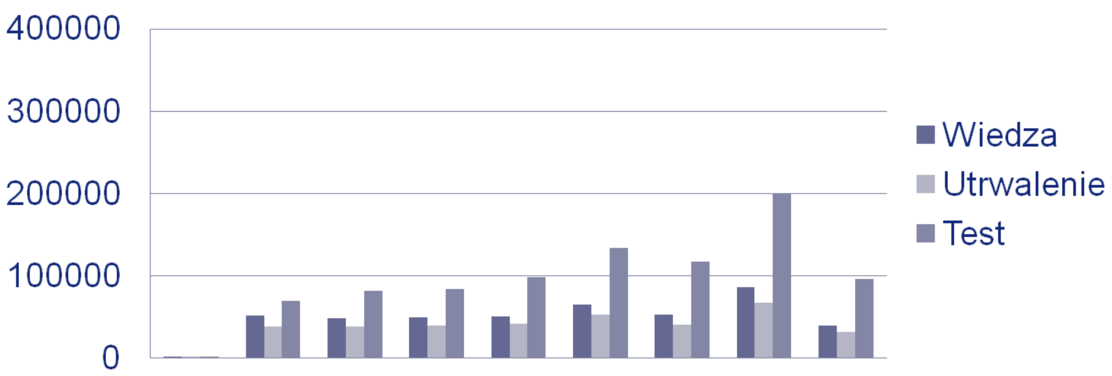


Figure 8. The number of logins – students
IX-VI 2010/2011

Working methods related to units regarding separate subjects:a supplement to the lesson;

- ❖ knowledge module is presented by teacher during a lesson while at home students prepare notes on the subject;
- ❖ knowledge module is presented by teacher during a lesson, revision & test modules are used by student at home;
- ❖ knowledge module is presented by teacher during a lesson, revision module is used by student at home, while the test is taken in a paper form in the class;
- ❖ students prepare themselves for a lesson using knowledge module; during the lesson the issue is presented and then under teacher's supervision a test is taken;
- ❖ whole units are used as homework;
- ❖ units are applied during extra lessons in a computer class [9].

- teaching Chemistry is started even before the traditional lesson starts; by means of the Google apps platform, students prepare for classes according to the instructions received from the teacher, which allows them to discuss the topic at school in a problem and multi-contextual manner. The preparatory process is managed and inspected by the teacher via the platform. Students store the materials in their files and then create their individual digital portfolios [10]. The teacher does not present the material but elaborates on it, interprets, systematizes, explains doubts, and answers the questions that the students might have. After the lesson, students have to decide what else could have been added, what sources have been forgotten, how they could have improved the structure of their work or what has changed in their knowledge of the subject since they time they started working on it.

Project *Collegiums Śniadeckich* has been realised in high schools since September 2011. In the project take part: 2 schools.

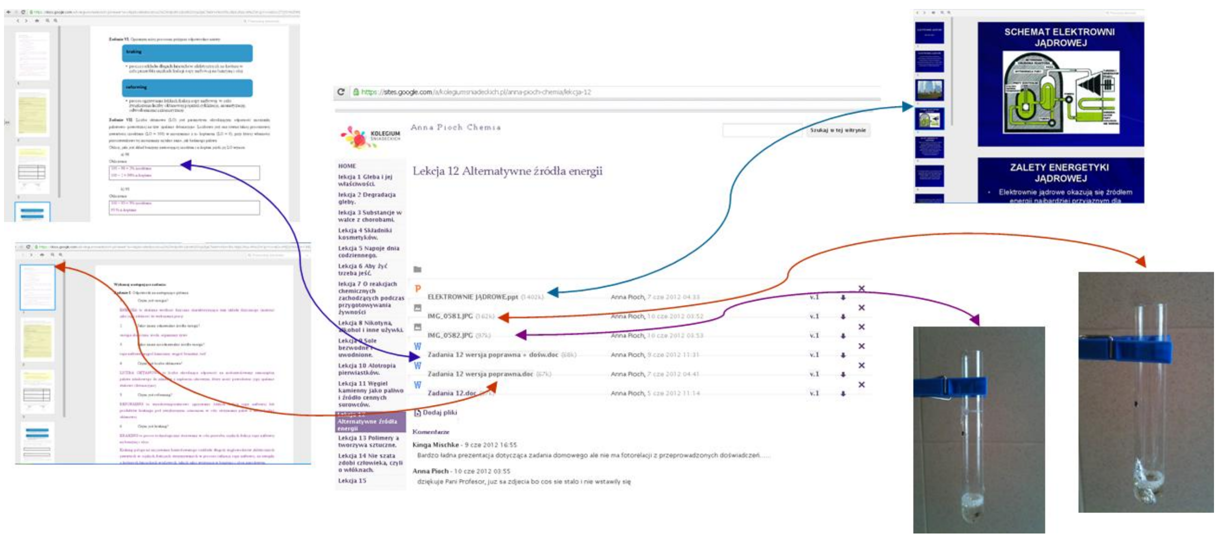


Figure 9. Digital portfolios

The educational platform-based learning may take place at various times and place which makes it possible for the users to continue their development outside the classroom and expand their interests beyond the material normally required at school.

The results, successes or failures of supporting teaching using information technology in above mentioned projects will be presented once they are completed, that is in two years

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ChemEd DL WikiHyperGlossary: Connecting Digital Documents to Online Resources, While Coupling Social to Canonical Definitions within a Glossary

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Abstract:
We are reporting on a social-semantic information literacy tool that has the potential to enhance reading comprehension, the WikiHyperGlossary (WHG), which is being developed for ChemEd DL, the Chemical Education Digital Library. The WHG automates the markup of digital documents and web pages by linking words in those documents to the content of a glossary database. This paper will discuss a strategy for improving reading comprehension of online resources in one's distill knowledge space by providing appropriate background knowledge through the coupling of content-appropriate social (wiki-generated novice level) definitions to canonical (expert level) definitions. This program not only connects these definitions to digital documents, but it allows for the social generation of the definitions at various levels of expertise, thereby expanding the educational value of canonical glossaries.

Keywords: glossaries, web 2.0, web 3.0, information literacy, online learning, digital libraries

1. Introduction

The rise of Information and Communication Technologies (ICTs) has generated an associated need for the development of digital information literacy tools. It is now commonplace for people to acquire articles that assume a higher level of reader expertise than they possess. Chemistry students, for example, would benefit greatly from the large amounts of technical material that could meet their knowledge needs if they had assistance in understanding those materials. Fortunately, the digital world provides the opportunity to develop software tools that can be deployed on the Web and meet these needs. Such tools are enabled by the computer and networking revolution where, previously, only expert tutoring could perform similar functions. The WikiHyperGlossary (WHG)[1] is an innovative example of such a software system. It is designed to assist novices in acquiring appropriate background knowledge as needed to comprehend material that otherwise would be above their level of expertise. One way this can be accomplished is by coupling socially generated, multimedia based novice-level definitions to expert-level canonical glossary definitions in a specific domain, and linking domain documents to this material through an automated markup process. Using the WikiHyperGlossary, this happens dynamically so that the software functions as a real-time assistant as the reader endeavors to understand valuable material. In the chemistry domain, IUPAC provides numerous reviewed canonical glossaries[2], and this article shows how the WikiHyperGlossary enables such expert-level glossaries to acquire new roles in online education.

2. What the WikiHyperglossary(WHG) Does

The WHG has two interfaces, an open access public one and a restricted administrative interface, with the latter providing a variety of login dependent permissions. The public interface allows any person to submit text documents and web pages to the WHG server, which returns the document in a web browser with any glossary terms within the document hyperlinked to the database content associated with that term. When such a link is activated, the associated material is then superimposed on top of the new webpage as a JavaScript overlay (Fig. 2). This overlay can present not only textual definitions with embedded multimedia objects, but through semantic technologies, chemical terms can also populate the overlay with a variety of software agents (molecular visualization and editing tools) and search services. These semantic features enable new options for document interactivity and knowledge discovery, as well as complement the strategy of using the socially generated multimedia definitions to enhance reading comprehension.

The WHG can generate a glossary through the administrative interface. When a person applies for an account they can be given a variety of permissions. The typical user would have the ability to create and edit terms, but not add people, set permissions or create glossaries. Each glossary term can have up to five definitions associated with it and figure 1 shows the TinyMCE[3] WYSIWYG editor based wiki interface that allows for the generation of social definitions (note that there are two definitions associated with this term, but only the bottom one editable). Someone with full administrative privileges can do all of the above, and in addition can set individual definitions as editable/non-editable, manage users, perform bulk glossary uploads, set citations for bulk uploaded glossaries, and perform a variety of database dump queries extracting definitions and histories.

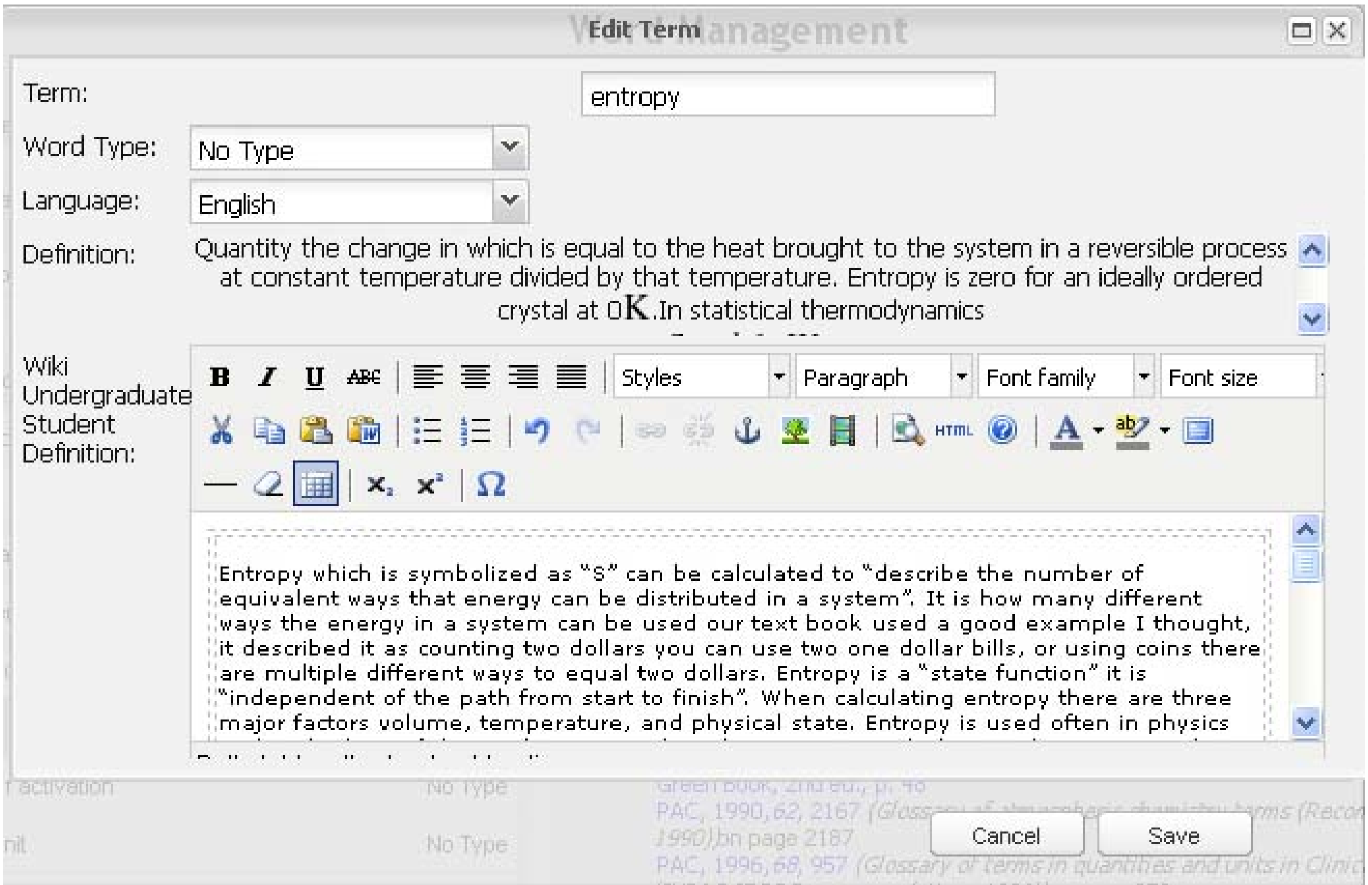

Figure 1. Screenshot of "Edit Term" interface. Note, this term is in the IUPAC Gold Book glossary, and there are two text fields. The first, "Definition" is non-editable, while the second "Wiki Undergraduate Student Definition" is editable.

3. Enhancing Reading Comprehension

To meet the goal of enhancing reading comprehension, whether the learner is a novice or has some acquaintance with the field, the learner needs to choose a glossary of both the appropriate domain, and containing definitions developed at the learner's level of domain understanding. As noted by E. D. Hirsch [4], "Cognitive scientists agree that domain reading comprehension requires prior 'domain-specific' knowledge about the things a text refers to, and that understanding the text consists of integrating this prior knowledge with the words in order to create a situation model." Hirsch further points out [5], "Researchers have discovered that what the text implies but doesn't say is a necessary part of its understood meaning. In fact, what the text doesn't say often far exceeds what it says." Thus, merely providing definitions of terms in a document in one's distal knowledge space may be inadequate to enhance reading comprehension. Rather, what is needed is a set of definitions that provide an expansion of the learner's background knowledge in the subject domain that target the appropriate learner-dependent level of expertise. To summarize the point, the author of a document assumes prior knowledge that is not explicitly stated, but is implicit in the text, and the learner who is missing this implied information will have problems comprehending the document's content. Yet, by linking to the appropriate glossary and ancillary resources like multimedia repositories, this implicit knowledge can potentially be made accessible to the learner.

For the WHG to provide this implied knowledge, it needs to generate hyperlinks at both a high term density and at the appropriate content level. We fulfill this with a glossary architecture that couples novice level social to expert level canonical definitions. The domain-expert level canonical definitions (which can be bulk uploaded) provide the required domain dependent term density and an authoritative framework for developing the coupled social definitions, which in turn can be developed at the appropriate content level of expertise. In this architecture, the WHG can associate up to four different socially created definitions to each canonical definition. A related but distinct application of this capability is that the WHG can be used to create socially defined glossary entries in another language than the canonical definition. This could be of great value for education internationally, as student understanding of documents in a non-native language can often be an issue.

IUPAC definitions clearly fit into the category of canonical definitions and are not primarily designed for education, but rather to promote the practice of science through the standardization of scientific terminology. For example, the IUPAC Gold Book definition of entropy, $S= k\ln W$ (Fig. 2) would not be of much value to someone unfamiliar with statistical thermodynamics, and by itself, would not help a large portion of the population who could be trying to comprehend a document involving thermodynamic concepts.By coupling it to the social generated definition with multimedia components like YouTube videos (figure 2) it gains new capabilities in providing background knowledge. The question then becomes, can the WHG introduce into a document sufficient glossary term density to generate the implicit background knowledge which was assumed when the article was authored?

entropy

Definition

Quantity the change in which is equal to the heat brought to the system in a reversible process at constant temperature divided by that temperature. Entropy is zero for an ideally ordered crystal at 0 K. In statistical thermodynamics

$S = k \ln W$

where k is the Boltzmann constant and W the number of possible arrangements of the system.

Source:

Green Book, 2nd ed., p. 48

PAC, 1990, *62*, 2167 *(Glossary of atmospheric chemistry terms (Recommendations 1990))* **on page 2187**

PAC, 1996, *68*, 957 *(Glossary of terms in quantities and units in Clinical Chemistry (IUPAC-IFCC Recommendations 1996))* **on page 972**

Related index:

IUPAC > Gold Book > math/physics > quantities

IUPAC GOLD BOOK

Wiki Undergraduate Student Definition

Entropy which is symbolized as "S" can be calculated to "describe the number of equivalent ways that energy can be distributed in a system". It is how many different ways the energy in a system can be used our text book used a good example I thought, it described it as counting two dollars you can use two one dollar bills, or using coins there are multiple different ways to equal two dollars. Entropy is a "state function" it is "independent of the path from start to finish". When calculating entropy there are three major factors volume, temperature, and physical state. Entropy is used often in physics and in the laws of thermodynamics. When doing entropy calculations the units are J/K (joules/degrees Kelvin).

To find the change in entropy the equation is delta S= Sfinal-Sinitial Entropy is found in out text book under chapter 18 section 3 it can be calculated and be used in many other calculations like the change in H, G, and T for reactions. Entropy is all around is from rusting of metals, fuel burning and ice melting. it is heat and energy being released. changed in entropy goes from Solid<liquid<gas and can be affected by temperature, volume, the number of molecules that are in reactants versus products.

http://www.youtube.com/watch?v=D-y73F0A02Y

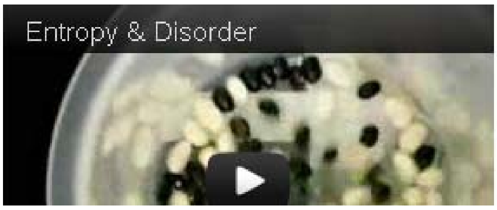

Figure 2. Screen shot of JavaScript overlay that would be superimposed on an article. This is what the public would see, and the material below the yellow "IUPAC Gold Book" can be edited through the WYSIWYG editor in figure 1 and contain multimedia objects like YouTube videos.

4. Generating Social Definitions

Because socially generated glossary material is an integral part of the learning experience that the WHG provides to learners, it is necessary to support the creation of this material. The WHG administrative interface makes it easy for learners to collaboratively create such material, and thus provides a variety of unique opportunities for contemporary chemical educators and their students. A "Get History" administrative interface has been developed and so with the WHG, teachers and students can not only develop definitions with associated multimedia content coupled to official IUPAC definitions describing concepts like entropy at their level of expertise, but the teacher can print out the work based on a variety of queries. For example, you can print all work performed by a student over a specified timeline, with the last edit printed first, followed by the rest in chronological order. This enables the instructor to see the final product, followed by its editing evolution. Students at the University of Arkansas at Little Rock have been using the editor interface of the WHG to create definitions for four semesters with some intriguing results that we plan to report in the near future.

The development site of the WHG is http://hyperglossary.org, and we soon will have it installed on the Chemical Education Digital Library website[6]. There are currently versions working on both local and cloud-based servers, and tutorials are being created for its use. We are interested in supporting multilingual glossaries and any faculty member interested in using the WHG with their students is encouraged to contact the lead author.

5. A Note on the History and Support for the WHG Project.

The WHG evolved out of the MSDS (Material Safety Data Sheet) Hyperglossary developed by R. Toreki of Interactive Learning Paradigms (ILPI) [7], which through the MSDS DeMystifier[8] connected MSDSs to static web page definitions designed to assist users in understanding MSDS. The MSDS DeMystifier went online in 2000 and in 2004 Toreki and Belford developed a collaborative project between ILPI and UALR, where students generated five-part definitions that were emailed to ILPI and manually added to the MSDS Hyperglossary.[9] In 2006 the idea of a WikiHyperGlossary was conceived[10] and in 2009 NSF (U.S. National Science Foundation) NSDL (National Science Digital Library[11]) grant 0840830 was awarded to develop a WHG for the Chemical Education Digital Library, and any opinions, findings, conclusions, or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the NSF. We gratefully acknowledge that support for the work reported here.

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Students' Proceeding in Real and Virtual Guided Inquiry Environments

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Abstract
Ever since computer-based experiments have been introduced to the science classrooms, there have been debates on the (dis)advantages, and if they can ever supersede real experiments. The focus of the project at stake is somewhat different: Is there a possibility to combine real and virtual learning environments in order to achieve a full scale advancement of students' Scientific Inquiry skills? How can the treatments advance students' skills individually based on prior knowledge of subject, topic, lab methods, and metacognitive abilities? 300 pairs of students of German intensified education schools were exposed to one out of four different combinations of experimental environments. In learning outcome based on pre-post tests, no significant differences were found. To clarify the results, process data (videotapes or log files and audiotapes) were collected. A method was developed with which both types of process data can be analyzed at in an equally fruitful way. First results are that there are differences with respect to the number of experiments conducted, and usage of strategies, although product data were not significantly different between groups. One possible explanation is that time-on-task is more important than the number of experiments conducted. Further analyses are to be conducted.

Key words
Scientific Inquiry, Cooperative Learning, Video Analysis, Computer-Based Experiments.

1. Introduction

Scientific Inquiry demands high standards of students' cognitive abilities, lab skills, and knowledge on the nature of science (Akerson, 2008, pp. 18). Nevertheless, its importance for science education is beyond debate. It is more than a mere method for gaining scientific knowledge - the components themselves can be acquired in self-regulated learning. Consequently, *Scientific Inquiry* itself as an ability to gain scientific insight based on empirical evidence and experiments is a learning goal.

2. Literature review

2.1 Learning that science is a way of thinking

For learning how to use *Scientific Inquiry*, students need more than declarative subject-specific knowledge. They should be gradually introduced to "Science as a way of thinking" (Abrams, Southerland & Silva, 2008, pp. XV.). This includes understanding scientific research as investigative processes based on hypotheses or ideas in order to explore natural phenomena, active usage of acquired methods in order to train and firmly establish what has been learned, and finally application of methods as research procedures and strategies aiming at gaining scientific knowledge (Abrams, Southerland & Silva, 2008, pp XV-XVIII.)

2.2 Scientific Problem-Solving

One way to look at scientific research processes is that of scientific problem-solving. Klahr and Dunbar (1988) proposed a model of *Scientific Discovery as Dual Search (SDDS)* According to this, in a first step one has to come up with an idea how to solve the problem (search hypothesis space), then conduct an appropriate experiment (search experiment space) and then evaluate the idea based on evidence. This is especially true for those with high prior knowledge on the task. If, however, prior knowledge is low, participants conducted experiments in order to get an idea. Then, again, they tested their idea and

evaluated them. Klahr and Dunbar distinguish between "theorists" (starting by searching hypothesis space, then doing an experiment) and "experimenters" (starting by conducting an experiment in order to get an idea what to look for) (e. g. Klahr, 2000, pp. 62-71.)
Another strategy not exclusively but characteristically applied in science is that of variable control. Tschirgi (1980) found that in everyday situations, already children aged 7 or 8 try to find the cause for a particular event by varying one variable while keeping every other variable constant (VOTAT - vary one thing at a time) which is why she claims that children of that age can be trained to use that strategy. Other strategies such as changing everything or holding one variable constant while changing every other variable (HOTAT – hold one thing at a time) are also chosen but the older children grow, the more they stick to VOTAT (Tschirgi, 1980, p. 7.)

2.3 Experimentation in the science classroom
The importance of experimentation in science is also acknowledged by several countries' education standards not because it is the distinctive feature of science but an important part of science (e.g. the German "Standards for chemistry in general education" (*Bildungsstandards im Fach Chemie für den Mittleren Schulabschluss*), 2005). Yet, experiments seem to be little helpful in constructing subject-specific knowledge, although they are often used for that purpose (e.g. the reviews of studies by Hofstein & Lunetta, 1982; Lazarowitz & Tamir, 1994; Lunetta 1998). A study conducted by Hart et al. (2000) showed that students often do not know why they run experiments at all. As they do not know what to focus on, and an experiment requires bringing together what they know, do, observe, and conclude, they focus on subject-specific knowledge (and fail as reported above.) Hart et al. instead explicitly put the emphasis on the experimentation process in order to give students the opportunity to become familiar with experimentation and lab equipment, and found that students should not only be aware of an experiment's goal but also of its aim in order to succeed (Hart et al., 2000.)

2.4 Real versus virtual experimentation
Real experiments ask for a particular level of manual skills and lab literacy. This is not necessarily true for virtual experiments because developer and programmer can decide on e.g. how fallible an experiment is, or how complex the representation of an apparatus is.
Regarding the authenticity of the lab equipment used, it is common to replace complex apparatuses, and instead just show a screen on which measured values, e.g. the pH-value or a potential, are shown. Thus, students might learn about a subject-specific content without ever having seen authentic equipment.
Another aspect is fallibility. Scientists know well of the problems possibly occurring during experimentation without making major mistakes. How does the virtual experiment deal with that? Just like authenticity of skills required, and the authenticity of equipment, this also depends on the developers and coders (e.g. Clark, 1994; Gunstone and Champagne, 1990; Triona and Klahr, 2003).

2.5 Metacognitive abilities and self-regulated learning
Apart from knowledge on how scientific insight is gained best, and a number of manual skills, being able to scientifically inquire also calls for some basic skills in self-regulation. It was proven that instructions concerning self-regulation are much more effective when not given as a note in advance but as prompts during the learning process (e.g. Thillmann, 2007).

3. Intentions and Research Questions
The project at hand tries to combine effects from real and virtual learning environments found and developed in projects of Duisburg-Essen university's research group and graduate school "Teaching and learning of science" (henceforth *nwu-essen*) (see section "Method - Experimental environments"). It also aims at finding whether a combination of real and virtual experiments is more fruitful for components of *Scientific Inquiry* by combining real and virtual experimental environments.
As the project does not only look at learning outcome but also at how students proceed when working with experimental environments, process data analyses are crucial. In former *nwu-essen* projects, these have been either run on video data or on computer-generated logfile data. As described later, the project at

stake generates both. Hence, a method has to be developed with which analyses on both types of process data can be run in order to get comparable results which can then be used for explaining product data.
The research questions (RQ) and hypotheses (H) focused on in this paper are as follows:

RQ1 How do different combinations of real and virtual experiments influence the acquisition of different experimentation sub-skills?
- H1.1 Experimentation according to *SDDS* is better trained in virtual than in real experiments.
- H1.2 *VOTAT* is better trained in virtual than in real experiments.
- H1.3 The mode of the experimental environment (real or virtual) has no influence on subject-specific knowledge gain.
- H1.4 Manual skills are better trained in real than in virtual experiments.

RQ2 Which explanations for paper-pencil-test results can be drawn from process data?
- H2.1 The number of *VOTAT* experiments conducted by individual pairs is positively correlated to scores in *VOTAT* items.
- H2.2 The number of experiments conducted according to *SDDS* is positively correlated to scores in *SDDS* items.

4. Method and Design

4.1 Experimental environments and training

As mentioned above, the experimental environments used in this project were developed and evaluated in former projects. Two disciplines have been concerned with experimentation in the science classroom: the department of educational psychology has put an emphasis on improving virtual *Scientific Inquiry* while the department of chemistry education has put an emphasis on collaborative *Scientific Inquiry* environments. The following characteristics were integrated in the learning environments used in the study at stake: well-formulated learning goals (Künstig, 2007), adaptive meta-cognitive prompts (Thillmann, 2007; Gößling, 2011; Marschner, 2011), cooperative learning (Rumann, 2005), and a training on *SDDS*-experimentation (Walpuski, 2006; Wahser, 2008).
Two topics (buoyancy, and acids and bases) can be worked on in two different modes (virtually and physically). The modes of the same topics were kept as close to each other as possible, yet there are distinctions referring to the differences between real and virtual experiments mentioned above: some aspects were simplified in virtual experiments (e.g. cleaning the Erlenmeyer flask), some mistakes were impossible to make (e.g. forgetting to note down what has been done so far). Some aspects not observable in real experiments were realised in the virtual experiments (e.g. pictures of ions in the liquids, pressures acting on solid figures in liquids), and some extra features were added (e.g. all the experiments conducted are automatically recorded and can be called up if desired).

4.2 Data collection

The pairs of students were randomly assigned to one of the following treatments:

Treatment	1		2		3		4	
	a	b	a	b	a	b	a	b
Experiment 1	VE Acids/Bases	VE Buoyancy	VE Acids/Bases	VE Buoyancy	RE Acids/Bases	RE Buoyancy	RE Acids/Bases	RE Buoyancy
Experiment 2	VE Buoyancy	VE Acids/Bases	RE Buoyancy	RE Acids/Bases	VE Buoyancy	VE Acids/Bases	RE Buoyancy	RE Acids/Bases

Pict. 1: Treatments used.
VE = Virtual mode. RE = Physical mode.

In concordance with the experimental environments mentioned, different tests on components of *Scientific Inquiry* were run: two different tests on scientific discovery processes, and two tests on subject-specific knowledge, a test on motivation, tests on subject-specific knowledge for both topics. All these tests were run at least twice (as a pre-test and after the intervention was completed), one of the tests on scientific discovery was also run after the training lesson. As additional control variables, a scale of Heller & Perleth's KFT (Cognitive Abilities Test) (2000) was run, and on the day the intervention took place, the classes completed a questionnaire on motivation in the morning and after they had worked on the second environment. All these tests were multiple choice tests. In order to measure the different impact real and virtual experiments have on students' lab skills, a test was developed in which students are not only asked to manually work with the equipment provided in the interaction boxes but also to answer questions on mistakes typically made when using the equipment. In this test, students have to give short answers.
Apart from the tests, process data were collected: the computer-based trainings generated log files, while students working on real experiments were video-taped. Additionally, a number of pairs working with the virtual experiments were audio-taped in order to get more information on whether or not students note every idea and conclusion due to a master thesis (Kreiter, 2010) in which it was shown that there might be discrepancies possibly influencing the calculation of learning outcome. Of those pairs working with real experiments the notes taken on experiments and the pictures of the concept maps drawn are also taken into account.
The pairs tested are year 8-students of schools of intensified general education (Gymnasium). 22 classes were tested (N=300 pairs). The first study (N=16 classes) was run September - December 2010. Another study with slightly varied material in the buoyancy box was run in spring 2012 with another 6 classes.

5. Results

Most of the tests showed an appropriate reliability (see table 1). The subject-specific knowledge tests as well as the lab skills tests contained a very limited number of items; as this might be the reason for the low reliabilities; more items were included in an additional study whose results have not yet been analysed.
The first main finding is that the differences between post- and pre-test scores for the whole sample are significant for most of the tests (see table 1), so all the treatments are successful. The test on Scientific Proceeding shows no development at all, reasons are to be clarified. The Motivation survey shows a significant decrease in motivation:

Table 1: Results

Test	N	α (Post)	Mean Pre (± SD) Mean Post (± SD)	T-test
Steps in scientific discovery	380	.823	11.38 ± 4.092 13.89 ± 3.513	$t(379)=-10.278$, $p<.001$
Scientific proceeding	380	.788	24.99 ± 4.698 24.95 ± 5.501	$t(379)=.124$, $p=.901$
Lab skills (items acids/bases)	367	.614	10.15 ± 3.591 13.37 ± 3.807	$t(366)=-16.492$, $p<.001$
Lab Skills (items buoyancy)	367	.499	6.89 ± 2.891 9.09 ± 2.627	$t(366)=-14.223$, $p<.001$
Motivation	345	.802	3.97 ± 1.13 3.54 ± 1.20	$t(344)=8.386$, $p<.001$
Subject-specific knowledge (Acids and Bases)	380	.542	1.28 ± 1.459 3.29 ± 1.953	$t(379)=-17.663$, $p<.001$
Subject-specific knowledge (Buoyancy)	380	.550	2.09 ± 1.617 2.94 ± 1.848	$t(379)=-17.663$, $p<.001$

Contrary to the hypotheses, the only significant difference between treatment groups can be found with respect to motivation. Here, group 6 shows a significantly smaller decrease than group 1.

6. Summary and Lookout

The intervention study showed that we can enhance students' experimentation skills effectively by using real as well as computer-based experiments. Thus, an important finding was replicated. However, in the analyses run so far, differences between groups were not significant. More analyses on group effects will have to be run in order to get some answers on RQ 1 (How do different combinations of real and virtual experiments influence the acquisition of different experimentation sub-skills?)

Some classes with slightly modified material have been tested in 2012. The data from this second study will have to be analysed as well in order to see if the modification leads to a higher learning outcome.

Additionally, the process data will be analyzed by using one coding manual for both videos and logfile data. At the moment, the data are prepared. The processes will be plotted in graphs which will then be categorized. The number of entries in the different categories will then be analysed quantitatively. One aim is to find whether process- and product-data results can be correlated (RQ2: Which explanations for paper-pencil-test results can be drawn from process data?)

7. Acknowledgement

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An International Comparison of Scientific Inquiry: A Video Study in Chemistry Lessons in Germany and Sweden

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Abstract

Despite the central role of Scientific Inquiry within science education, in reality it occurs rather rarely within science lessons in Germany. A comparison with a school system (such as the Swedish one) that emphasises Scientific Inquiry in a stronger way enables the identification of culture-specific teaching patterns in terms of the instruction of processes of science, in other words Scientific Inquiry. This suggests an international comparison of German and Swedish (chemistry) lessons.

The design of the descriptive study is a category-led video analysis. The video study will be conducted with a total sample of 32 video-recorded chemistry double lessons in Germany and Sweden. 20 double lessons of 10th grade (age of 15/16) grammar school classes will be video-recorded and analysed in Germany and further 12 double lessons of 9th grade (15/16) primary school classes in Sweden. The variables of the coding manual include the surface structure and the deep structure concerning Scientific Inquiry.

First results of the Swedish video sample show that the teachers focus mostly on planning and performance of investigations. Phases concerning the formulation of the research question and the hypothesis as well as the reflection of the process occur rather rarely. This leads to the conclusion that the recorded chemistry lessons demonstrate an unbalanced distribution in terms of the organisation of Scientific Inquiry. Furthermore, it indicates that Scientific Inquiry is only partly realised in Swedish chemistry lessons, despite the importance within scientific thinking. Moreover, these results clarify the relevance of further investigations in the field of Scientific Inquiry.

Keywords: Scientific Inquiry, video analysis, international comparison, Chemistry Education

1. Background & Framework

Nowadays one of the most important goals in science education is to provide a basic scientific understanding in terms of socially and politically relevant issues. This enables students to participate in these issues in a critical way [1]. One way of providing these skills is the concept of *Scientific Inquiry*. *Scientific Inquiry*, which illustrates one kind of scientific thinking, is formed of three stages [e.g. 2-4]:

1) formulation of scientific questions and hypotheses
2) planning and performance of investigations
3) data analysis and reflection of investigations

Despite the fact that these three steps play a central role in science education, in reality this occurs in less than 10% of the time [5]. Another study indicates that experiments are not often integrated within *Scientific Inquiry* [6]. These findings show an increased need for research in the field of *Scientific Inquiry* in science lessons. This can be realised through an investigation in terms of the organisation of the process of *Scientific Inquiry* in classroom situations.

Furthermore, this analysis allows a critical confrontation and reflection concerning teaching processes [7]. Thus, only the analysis of typical international teaching scripts provides an identification of teaching patterns in teaching processes and – more important – makes them changeable [8]. Consciously perceived teaching processes can be identified in a more objective way, which makes it possible to compare cultural specific patterns with the teachers' own teaching practice [7]. Consequently, it requires primarily a comparison to identify teaching patterns, due to the fact that teaching processes cannot be considered isolated. In other words, to analyse the implementation of *Scientific Inquiry* in classroom situations it is necessary to compare German lessons with lessons of a country that puts more emphasis on *Scientific Inquiry*. Internationally, there are considerable differences in the integration of the concept of *Scientific Inquiry* into different school systems [9]. There are European countries such as Sweden which integrated this concept much earlier into their curricula, compared to Germany [10]. This suggests an international comparison between chemistry lessons in Germany and Sweden to investigate culture-specific teaching processes in terms of the organisation of *Scientific Inquiry*.

2. Purpose & Research Question

The aim of the project is to analyse *Scientific Inquiry* in chemistry lessons in Germany and Sweden. In addition, a key interest of this study is to investigate influences on the level of the organisation of *Scientific Inquiry*.
The following main question is addressed in the context of this paper:

How is *Scientific Inquiry* organised in Swedish chemistry lessons?

3. Method and Design

The design of this descriptive and exploratory study is a low-and high-inference category-led video analysis. This is done with a pseudo-randomised sample of videos of German and Swedish chemistry double lessons. This video study will be implemented with a total sample of 32 video-recorded chemistry double lessons in Germany and Sweden. 20 double lessons of 10th grade (age of 15/16) grammar school classes were video-recorded and analysed in Germany and further 12 double lessons of 9th grade (age of 15/16) primary school classes in Sweden. Moreover, the teachers were asked to integrate a scientific investigation within the video recorded chemistry lesson.
To analyse the video recorded lessons there were used variables of a coding manual regarding the surface structure (classroom management, teachers' and students' statements and variables of the experimentation process), which have been developed and tested in previous investigations [11]. Additionally Björkman & Tiemann [12] constructed a coding manual for the detailed analysis of the phases of *Scientific Inquiry*. The coding manual includes 23 variables with three to twelve categories describing phases of the formulation of the research question and hypothesis, the planning and performance and the analysis and reflection of the investigation. Most of the variables of the coding manual show very good ($.75 < \kappa < 1.0$) and appropriate ($.60 < \kappa < .75$) inter-rater-reliabilities. In general, the coding manual represents a reliable tool to investigate the research question of this study. Variables with low inter-rater-reliabilities, belonging mostly to the variables of the research question and hypothesis, were better described and operationalized more precisely [12].
The video recorded lessons were analysed with the behavioral observation software Observer XT 10®, which enables the behavioral analysis as well as the statistical evaluations.
In addition, a teacher questionnaire recorded the demographic data, school climate, teaching methods and views on *Scientific Inquiry*. A student questionnaire collecting the control variables demographic data, cognitive skills, the background knowledge, the scientific interest and motivation and the views and skills in *Scientific Inquiry* was used in this study.

4. Results

This paper presents the preliminary results of the Swedish sample. Analysing the general occurrence of the phases of *Scientific Inquiry* (Figure 1), an unbalanced distribution concerning *Scientific Inquiry* is obvious. But it is not surprising that the planning and performance phase shows such a high percentage, because of the demand on the teachers to integrate an investigation within the recorded double lesson. This phase differs significantly towards all other phases of the process with high effect sizes ($r = .99^{***}$

for each phase).

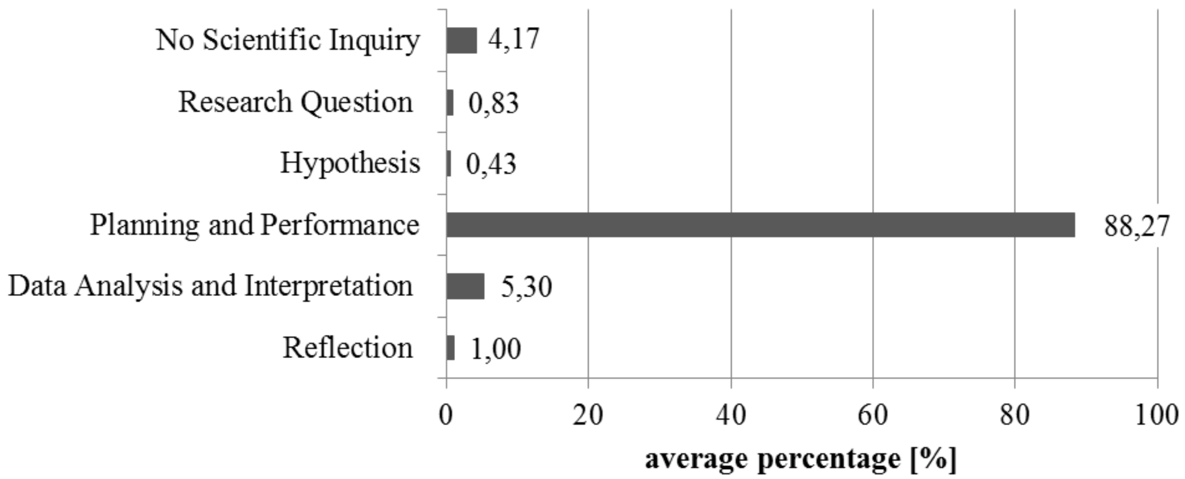

Figure 1. Average percentage of the phases of *Scientific Inquiry* in Swedish chemistry lessons (N = 12)

Furthermore, the phase concerning the data analysis and interpretation shows significant differences towards the occurrence of the research question, hypothesis and reflection with medium effect sizes (r = .68* - .77**).
The planning and performance phase can be divided in the planning phase, the performance phase and the phase of the preparation, the dismantling and the report writing (Figure 2).

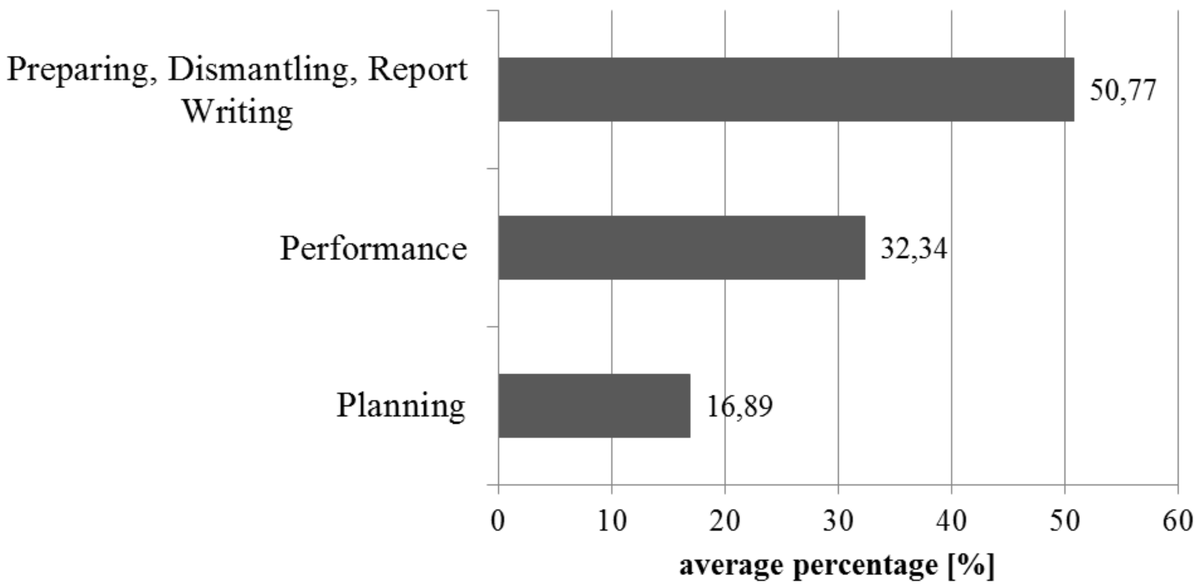

Figure 2. Average percentage of the distribution concerning phases planning, performance and preparing, dismantling and report writing in Swedish chemistry lessons (N = 12)

Figure 2 shows a high percentage of the phase, where students prepare the investigation, dismantle their equipment or write the report concerning the investigation. Furthermore, this proportion differs significantly towards the planning phase with a high effect size (.92***).
Due to the fact that this phase contributes significantly within the phase of planning and performance it is important to analyse it in detail. Thus, this phase can be divided in the categories “Students prepare investigations independently”, “Teacher prepare investigation”, “Students/Teacher dismantle equipment”

and "Students write report independently" (Figure 3).

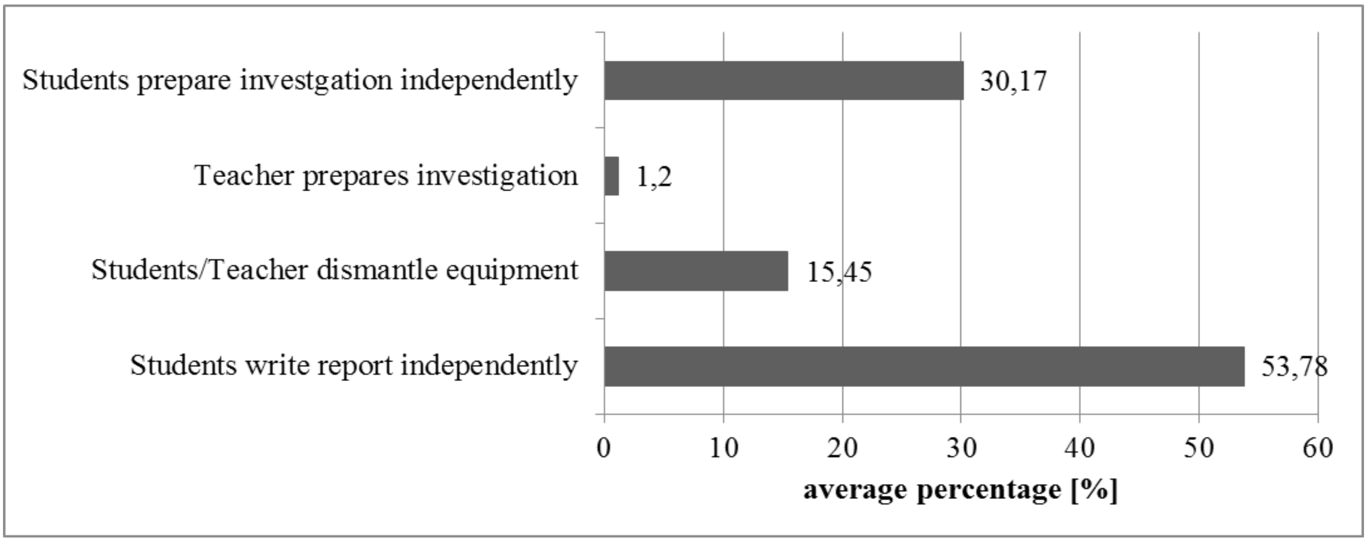

Figure 3. Average percentage of the phase of preparing, dismantling and report writing in Swedish chemistry lessons (N = 12)

The report writing along with the students' preparation phase differ significantly towards the teachers' preparation and the dismantling phase. It shows that a lot of time is given to students in order to prepare an investigation as well as to document their results. However, as figure 1 showed, a respectively low average percentage in terms of the data analysis and the interpretation can be stated.

5. Conclusion

It is of great importance to integrate the process of *Scientific Inquiry* within chemistry lessons and establish a balanced distribution concerning all phases of the process. Evaluating the video recorded chemistry lessons in Sweden, it shows that the Swedish teachers generally focus on the planning and performance phase. Whereas the formulation of the research question, the hypothesis and the reflection occur respectively rarely. An explanation for that can be found in the short amount of time, which is available for the teacher as well as the difficulties students and teacher have formulating the research question and the hypothesis.

Within the dominating planning and performance phase the class mostly performs the investigation, prepares, dismantles or writes reports in relation to the investigation. The average percentages of the preparation and the report writing show the highest amount. The high average percentage of the report writing phase and the low average percentage of the data analysis and interpretation phase support the finding that within the *Scientific Inquiry* process planning and performance are focussed instead of the discussion of results.

In summary, the video recorded Swedish chemistry lessons show a first impression of the problems and difficulties in teaching *Scientific Inquiry*.

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Development of a Training Module for Future Chemistry Teachers on Education for Sustainable Development

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Abstract
This paper reports a project of Participatory Action Research to innovate chemistry teacher education. A course module on sustainability issues and Education for Sustainable Development was developed, cyclically refined, and implemented in German pre-service chemistry teacher training. An overview on the course module will be given. Experience gained during its three-year development will be reflected upon. A short insight into the evaluation will be reported.

Keywords: Chemistry Teacher Education, Education for Sustainable Development, Participatory Action Research

Participatory Action Research for innovating chemistry teacher education

For almost a decade now the model of Participatory Action Research (PAR) developed by Eilks and Ralle [1] has been used for chemistry education curriculum development and classroom research (e.g. [2-3]). PAR seeks to thoroughly connect domain-specific educational research with curriculum development and teaching practice. PAR is performed in collaborative groups of in-service teachers and accompanying educational researchers from the field of chemistry education. The project described in this paper represents one of the first approaches for applying the PAR model to innovations for higher education.

Just like in the case of focusing school chemistry education, PAR for higher education seeks a cyclical optimization of teaching practices, which are supported by research about teaching and learning processes in the specific domain, reports of practitioners' personal experience, and the intuition and creativity of experienced people in the field. The objectives targeted in the PAR process encompass newly-developed curricula, teaching strategies and empirical evidence about teaching and learning in the field. They also include the reduction of any deficits reported from practice, and will result in better-trained professionals (Figure 1).

Every sort of Action Research is cyclical in nature. In PAR, new teaching approaches are designed, then cyclically applied, tested and revised. The objective is to improve teaching practices by applying newly-developed and cyclically improved lesson plans in different testing groups. The prototype designs are used and tested as early as possible to see if they have the potential to reduce the identified problems in classroom practice. The process of planning in a group is an important factor. This is not just because problems in evaluation can be avoided, but also because communication and reflection within the group ensure that each design is compatible with the needs of everyday teaching practices.

The research process in the PAR model is thought to be initiated when deficits in either teaching practices or empirical research are reported upon. PAR is then used to determine methods for eliminating or reducing any problems in teaching practice. This is also the case when transferring PAR to the realm of higher education. Research begins with a thorough analysis of the relevant literature. Group discussions within the research team are used to determine whether or not the problem is of general interest in authentic practice and beyond individual classrooms. The discussions also reflect whether information from the literature is considered of potential for the structuring of altered curricula or pedagogies within the specific, authentic educational settings the practitioners work in.

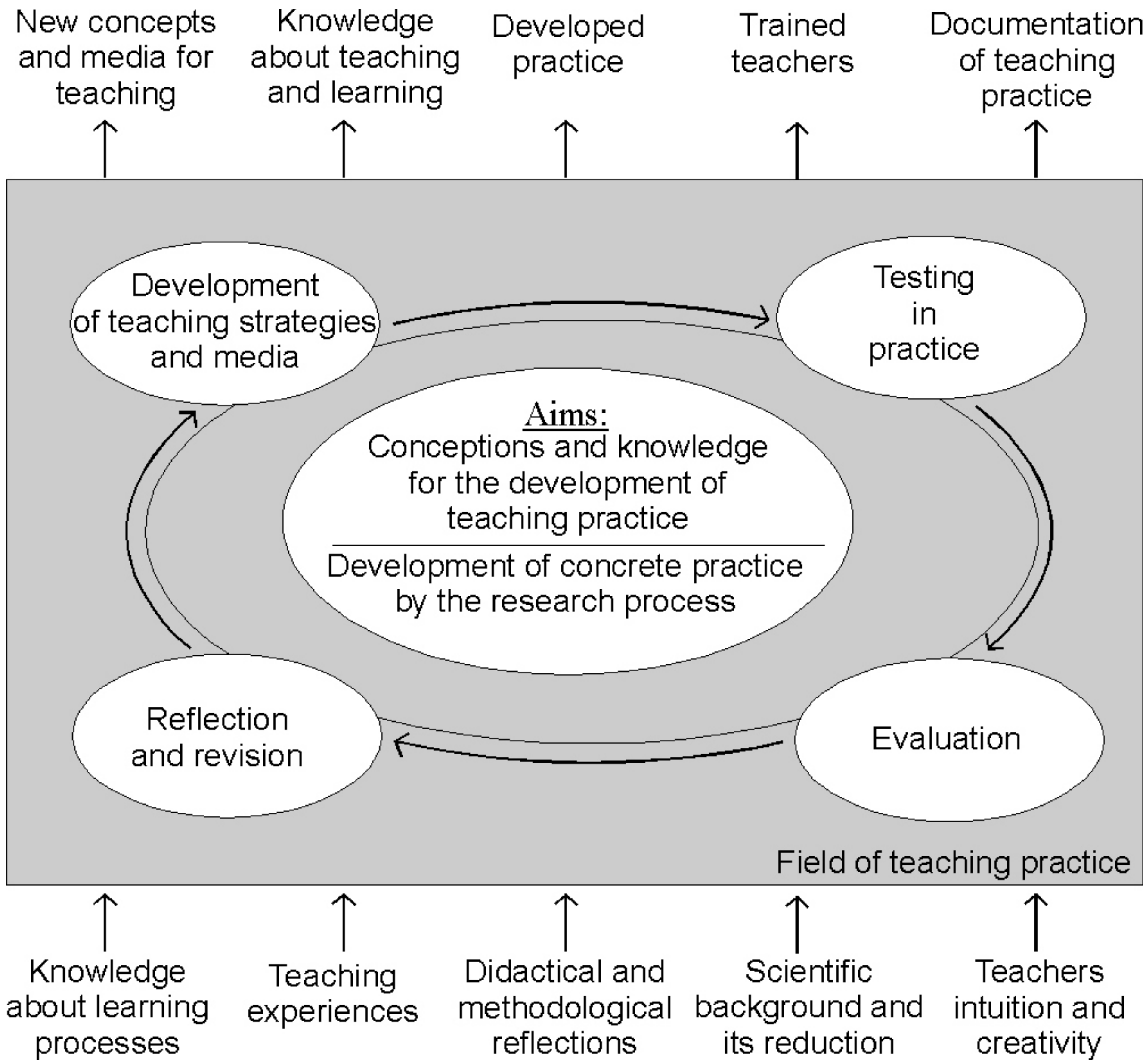

Fig. 1: Participatory Action Research within domain-specific education [1]

In the case described here, the problem analysis showed many official documents (as discussed in [4]) which called for a more thorough implementation of course content on Education for Sustainable Development (ESD) in pre-service teacher training. Literature analysis supports claims that the implementation of subject matter addressing both sustainability theories and learning about ESD in chemistry teacher preparation is insufficiently developed in many countries (e.g. [5]). This is why the cyclical PAR process was started and eventually led to three developmental cycles in three consecutive years of testing. However, hard empirical evidence and concrete information about student teachers' prior knowledge, attitudes and beliefs concerning sustainability and ESD to inform the curriculum development process in the case of German chemistry education were hard to come by at the beginning of the process. To overcome the lack in empirical support, own empirical research initiatives were started in parallel to the curriculum innovation. The empirical research was meant to interact with and influence both curriculum development and the participants' understanding of its effects.

Accompanying empirical analysis

Research on teachers' overall knowledge base, attitudes and beliefs concerning sustainability concepts and ESD is rare in the literature. Based on the few available studies from Germany and other countries (e.g. [5-7]), one can assume that German (student) teachers' knowledge of sustainability issues and the theories behind sustainable development might remain underdeveloped. The same seem to hold true for the curricula and pedagogies developed for ESD-driven chemistry teaching. Anyhow, for the case of chemistry education in the German context such documentation was not available prior to this project. That is why the development of the course module was accompanied by empirical research in order to support the curriculum development process. Two studies based on questionnaires were conducted to describe German chemistry student teachers (N= 87) and trainee teachers' (N=97) knowledge base and attitudes towards sustainability and the didactics and pedagogies of ESD.

Both studies found positive attitudes among the student teachers and teacher trainees with regard to strengthening the contemplation with sustainability issues and ESD in secondary school education. The participants acknowledged that all school subjects should contribute to ESD, but they also believed in a specific responsibility of chemistry education. Despite this positive attitude, their overall knowledge about potential topics and pedagogies was limited and poorly thought out. There seems to be a lack of theoretically sound ideas about modern concepts of sustainability, as well as about a theory of ESD. Nevertheless, many student teachers and teacher trainees were headed in the right direction when asked for their knowledge about and association with sustainability and ESD. But their ideas were raw, undeveloped and unsupported by substantial knowledge or theory. Only a small minority of the participants in these two studies was able to outline a more-or-less sound description of what is meant by sustainable development. Almost no one had heard or could repeat what a theoretically-based description of ESD actually entails.

Overall, most future chemistry teachers in the two case samples acknowledged that secondary school education should promote ESD, and that chemistry education should be a part of it. Some were able to intuitively associate topics from the chemistry curriculum with issues of sustainable development, e.g. with the question of the sustainable production of fuels. Yet ideas for using ESD in chemistry education, including how teaching might be structured by adequate pedagogies, remained very limited. Both samples explicitly mentioned that the participants had not yet been confronted with learning about sustainability or ESD pedagogies during their teacher training program. Both issues seem to play hardly any role in many of the German chemistry teacher training programs. Neither chemistry courses, nor educational and domain-specific educational courses seem to address these issues explicitly so far. The participants mentioned that the major sources of their knowledge had been from informational settings such as TV and the Internet. This strongly supports the premise of the current study that the development of explicit course content and modules to strengthen pre-service teachers' theoretical and practical knowledge for applying ESD are desperately needed in the field of chemistry education. It became clear that a theoretical foundation needs to start from the very bottom and has to include both learning about sustainability as such, the role of sustainable thinking in chemistry, and knowledge about practical pedagogies for effectively bringing ESD into the chemistry classroom.

The structure of the course module

The course module has a duration of six weeks with one ninety-minute session per week. Table 1 gives an overview of the different sessions. Inspired by the empirical findings described above, the coursework starts with a self-reflection activity. This activity makes the participants explicitly aware of their prior knowledge, their intuitive associations with the topic, and their potential lacks of theoretical foundations.

Coming from the exposure of potential deficits in the participants' knowledge, the course then focuses on three major areas of learning:

- The historical development and modern concepts of sustainability in general and their operationalization in chemistry, especially through the concept of Green Chemistry,
- The basic theories and governmental legislations concerning ESD with special focus on the practices of

German chemistry education, and
– Adequate pedagogies for acquainting school students with sustainability thinking in chemistry classes, promoting their understanding skills, and increasing their participation abilities in societal debates on questions of sustainability concerning science and technology.

Contention with the basic theories behind sustainability is introduced through a short lecture, which presents the historical development of the term, the genesis of the Agenda 21, and an overview of competing concepts for modeling sustainability as outlined e.g. in [4]. The central objectives in learning in this phase are understanding (1) that in all modern concepts of sustainability different dimension are interwoven and contain at least the ecological, economic, and social dimensions, and (2) that sustainability always is connected to balancing the interests and needs of today's society with the interests and chances of future generations.

Learning about the point of view on sustainability issues within chemistry is structured using a WebQuest [8]. The WebQuest introduces issues arising from the use of chemistry and the practice of chemical industry connected to sustainable development. It explains chemical industries' efforts to contribute to sustainable development, e.g. by the Green Chemistry initiative, but also presents critical voices. Learning by the WebQuest prepares the participants for a role-play, where both the effort required and the chances represented are talked about by different role-players. The role-play includes discussing critical roles, which question whether the efforts undertaken are carried out in the correct fashion and are sufficiently intense in nature.

Table 1. Overview of the course module structure

Session 1	Assessing students prior knowledge and attitudes towards sustainability and ESD using a research questionnaire Lecture on the historical genesis and modern concepts of sustainability Overview on the course and introduction to the WebQuest on the issues of sustainability and Green Chemistry
Session 2	WebQuest on issues of sustainability, the concept of Green Chemistry and its perception in society Role playing of different views towards Green Chemistry, prepared by the WebQuest
Session 3	Jigsaw classroom on educational policy papers about ESD in German school education
Session 4	Analyzing a lesson plan on teaching about plastics with an ESD focus, which mimics the product testing method in order to evaluate plastics in the foreground of sustainability criteria
Session 5	Facultative: Further analysis and discussion of teaching materials Facultative: A board game based on Green Chemistry in the chemical industry
Session 6	Lecture about basic models how to connect ESD and chemistry education Lecture summing up the course content Self-assessment of learning success with reference to the initial questionnaire and data about student teachers' knowledge on sustainability and ESD from the accompanying research Reflection of the course content and structure

Contention with theories of ESD takes place in a jigsaw classroom. The jigsaw classroom is based on different position papers taken from governmental bodies and educational societies, namely from the Conference of the German State Ministries of Education (KMK), the German Society for Educational Sciences (DGfE), as well as the German hub of the UN world decade of Education for Sustainable

Development (Transfer 21). This phase makes clear the importance that educational theory and educational policy gives to ESD.
The next learning phase for how to deal with ESD in school chemistry classrooms is based on a lesson plan developed by a group of teachers in another PAR project especially for this purpose [9]. The lesson plan deals with the topic of plastics and handles the basic chemistry and properties of different polymer materials. The lessons focus on ESD by combining the learning of chemistry content with information on how to evaluate chemistry products and technologies in the foreground of sustainability criteria. Within the lesson the students are familiarized with the three dimensions of modern sustainability concepts. The pupils are asked to mimic consumer test agency workers in order to experience the interconnectedness of the three sustainability dimensions when evaluating chemistry products and technologies. Within the consumer test agency method, participants are asked to evaluate different sorts of plastics (PVC, PET and TPS) currently addressed by the sustainability debate, all of which have ecological, economic and societal implications. The pupils have to weigh the impact of the different products in the various dimensions against one another, evaluate the different plastics, and make a final evaluation. Further analysis of teaching materials or an optional board game dealing with Green Chemistry principles in industrial chemistry [10] are added if time allows.
The course closes with a session reflecting on the achievement and the present status of ESD implementation in German chemistry education. For this purpose the four basic models for implementing ESD in chemistry education as described [4] are presented. This phase also refers back to the participant questionnaires, which were filled out at the beginning of the course which are now related to the empirical findings on the student teacher and teacher trainee knowledge discussed above.

Feedback from the participants

The course was applied in three cycles of development during three consecutive years of study. A total of 46 student teachers participated in the course. The different rounds of testing faced slight variations and improvements in the teaching materials. Feedback was collected by group discussions occurring after the course and written questionnaire with open-ended questions and 32 Likert-items. The evaluation was used for cyclical optimization of the course, including insights into its feasibility and effects.
Overall, the participants responded very positively to the course. The student teachers stated that the course module was interesting, important and valuable for their later profession as chemistry teachers in school. The student teachers also emphasized that they had learned a lot and that they now felt more competent in the area of sustainability and ESD.
Criticism was rare and occurred only briefly in the questionnaires and the group discussions. In the first round of testing individual students were concerned about non-optimal time management of the course and insufficiently recognizable learning objectives for each phase of learning. Some student teachers did not fully recognize the differences in some of the course materials, since some were structured as materials for teacher training while others were materials developed to be used in a secondary school classroom. The different kinds of materials, the roles they were expected to play, and the hoped-for learning outcomes were made more explicit in the second round of testing. Some criticism also arose initially, because certain phases dwelt overly long on political and societal aspects, rather than on chemistry and science factors. The emphasis was then changed by selecting different materials in a later round of testing. Due to improvements in the course structure and materials, criticism in both of these areas diminished in the third round of testing.

Conclusions and implications

Reflecting upon the findings from the accompanying empirical studies we can assume that the current implementation rate of ESD in chemistry education is still low because learning about ESD in connection to chemistry teaching is not a focus of chemistry teacher training in Germany yet. Unfortunately, hard evidence on the current state of concepts believed in and practiced by teachers in German chemistry classrooms is not yet available. Research in this field is still needed; a respective study is under way. But the fact that almost none of the student teachers brought any developed concept of sustainability with connection to chemistry topics from the school to the university is sobering. This would seem to indicate that such issues are not prominent topics in current chemistry classrooms in German secondary schools and that change is needed.

A second look upon the accompanying empirical study tends to make us assume that ESD practices will eventually be implemented in German chemistry teaching if the prospective teachers are allowed to learn about respective curricula and pedagogies. The contents of the module proved valuable for offering future teachers these ideas and pedagogies for making themselves familiar with sustainability issues. This included the connection of ESD with chemistry topics and modern pedagogies for implementing ESD in chemistry teaching. Student teachers' feedback regarding this innovation was quite positive. The statements made by the participants seem to indicate that future teachers can and will be more sensitive and competent when dealing with sustainability issues and ESD in the chemistry classroom if they are allowed to get a chance to it.

Nevertheless, there is also need that pre-service chemistry teacher training programs must be supported by training in the area of in-service chemistry teacher training with respect to sustainability and ESD. The low implementation rate derived from the empirical studies suggests change. Single parts of the course module described above are currently being used for this purpose, e.g. in-service chemistry teacher training workshops about the WebQuest on Green Chemistry and the lesson plan on evaluating plastics. Perhaps these can contribute further to reducing deficits in in-service teachers' general knowledge about sustainability concepts and ESD in the same fashion as they did for pre-service teachers in this study.

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Special Language in Chemistry Education

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In the public discussion it seems to be a consensus that scientific literacy is an important part of general education for every human being. It is also mentioned by OECD [1]:

> "*Scientific literacy is the capacity to use scientific knowledge, to identify questions and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity.*"

Students should be able to take part in relevant discussions improving their skills of communication. That contains an accurate fluency of speech, a general framework of language and a subject related word pool.

Abstract
This article delivers insight into a scientific project, which deals with diagnosis and individual support on the area of special language competencies of secondary school students. The first step of research was to develop and evaluate a tool for analyzing students' competencies. This tool consists of different parts concerning production of words (Association-test), interconnection (linking skills and Concept mapping) and awareness of the meaning of words. It has been applied in several classes in secondary schools lower level. Based on the results of this research options of language support in science classes were designed. In order to do this, cooperation between scientific coworkers and teachers was implemented in the sense of a participatory action research. The support we were aiming at is related to subject matter, language acquisition and individual qualification of the students. Finally, it was evaluated how explicit language support affects students' subject knowledge and general language competencies. Topics of this article will be the theoretical background as well as results and experiences made during developing and proving the tools.

Keywords: Special language, competencies, chemical education, language acquisition, diagnosis, individual support

1 Theoretical Background

For passing exams, being successful in education and for the academic career an appropriate language is an important factor for students to learn. But even if students are good at everyday speech they often are in trouble with this special kind of language [2]. To manage everyday life at home, on the playground or with peers Children do not have any problems to communicate to each other. If they have the intention and will to do so, a basic vocabulary and grammar is needed only [3]. The spoken language is supported by many other aspects like gesture or facial expression play. In contrast the academic language should be comprehensible detached from context and situation and should have a high grade of accuracy and specificity. A statement in this area of language should be comprehensible also for a noninvolved person.
Regarding to school education the spoken language is expected to be close to the complexity of written speech. It should be comprehensible without nonverbal interaction. A subject specific language also includes a pool of technical terms. These special languages are obligatory bound to subject matter [4]. The difficulty in school practice is that on the one hand language has to be content of learning itself. On the other hand it is the medium to learn subject matters. Thus language competencies have to be applied and shaped at the same time.

Chemistry uses special linguistic features like the other science subjects, too. This leads to a more complex grammatical structure of the written or spoken texts [5, 6]. Practicing chemistry at school we meet different types of language within the different areas of the subject. These types are characterized by a different mixture of general frame and special language [7]. The special academic language in chemical education expected from students contains a medium number of technical terms and a medium level of grammatical complexity. Additional to the criteria of academic school language students have to handle symbolic language (in relation to mathematics and chemistry).
If students understand this special language (vocabulary with chemical meaning and grammar) the arising communication will be beneficial [8]. Finally the overall aim is to be able to phrase subject matters with a little number of words, straight structure and unmistakably, for example when writing a lab report or summarizing and presenting a topic. Regarding to language demands writing a lab report is the most difficult working step in the area of scientific experiments [9].
Different groups of terms can be described according to Vollmer [7] and Rincke [10] by their meanings:

1. Words with only one meaning often seen as "real" technical terms like *molecule* or *ion*. They are commonly used only in relation to the content matters. They normally aren't used in everyday life.

2. Words with more than one meaning, which are commonly used in everyday life and in subject matters. In this field some more differentiation has to be done:

2a. Words with a modified but similar meaning in everyday life and science classes: The modification of the meaning often is a constriction or a generalization. In this case the meaning changes only a little, the connection is still visible. The usage of the technical meaning often doesn't lead to problems in everyday life, because the comprehensibility isn't reduced. The word *salt* for example in everyday life means a special substance (*NaCl* or rather *table salt*). But in science classes a special structure or a family of chemical compounds is meant.

2b. Both meanings are commonly used but the meaning differs in everyday life and science classes, according to situation and context. Because a direct link between the meanings isn't obvious, these type of words causes the most difficulties in understanding for students. On the one hand because well-known words get a second meaning; on the other hand because both meanings are coexisting and still in use. Depending on the conversation one or another meaning is to be activated. For example the word *solution* in everyday context means the result of a task or the way to solve a problem. In science classes a *solution* is described also by the dissolving of solid or gaseous matter in a solvent.

2c. The group of words with a changing technical meaning consists of words that are mainly used in a subject related context. The meaning of these terms changed in the history of chemical development [11], because new inputs were integrated by researches. *Oxidation* for example is connected to different explications. While confronting students willingly and reasoned with different conceptions for one phenomenon, some problems in understanding are initiated automatically.
Subject knowledge is the basis for development students' special language, because without this knowledge words remain meaningless. Verbalization of content knowledge in contrast is impossible without an appropriate repertoire of technical terms. Therefore words in scientific education need to be more than learning vocabulary in the sense of spelling. Additional new meanings have to be generated.

2. Beliefs and Thoughts of Chemistry Teachers about Special Language

In order to get information about the thoughts and beliefs of chemistry teachers regarding special language competencies of their students a questionnaire was conducted. It was answered by 32 teachers of lower secondary education in North Rhine-Westphalia.
The questionnaire consists of four sectors: *Importance of different aspects of special language, linguistic emphasis of different activities, difficulties regarding to groups of words* and *importance of special language for different lesson phases*.
Based on their experience teachers answered that *technical terms* and their *meanings* are the most

important aspects in the area of special language in chemical education. Especially the activities *writing a lab report* and *writing summaries* make great demands on special language competencies. More detailed results can be found in Busch and Ralle [12].

3. Diagnosis of Special Language

The intention of these tools is not to judge and mark the students; it is rather understood as an educational diagnostic aid with intention to help teachers making suitable decisions on learning assessments and support. Every tool only shows a small part of the aspired skills by itself and can suitably be used in everyday classes of scientific education. All tools were proved in lower secondary chemistry classes in North Rhine- Westphalia. It can be expected that repeated use will show development and changes of students' competencies.

Word association: Students were asked to write down as many associations to a given term as possible. By dividing the words into groups by origin, *everyday experience, science class* or *indistinctive origin,* the assessor gets an insight into the level of cross linking and direction of mental bonding. Additionally he gets information about students ability to meaningful to connect different terms meaningful. Words like *solution* commonly used in everyday life, allows a differentiation of students performance in science classes. In contrast the associations of words with only one distinct subject related meaning like *ion* or *molecule* give clear evidence if the term is known or if it is not. The tool `word association´ is suitable when a teacher wants to know what his students connect with one term or another.

Word connection: Students were asked to make up a sentence with two given words. Evaluation includes aspects regarding content *(right, imprecise, wrong or no subject related content*) and in relation to language abilities (*spelling, grammar, use of technical terms*).

Describing word meaning: In order to learn more about students' thoughts and knowledge about word meaning, it is helpful to ask them to write it down. This approach is insightful for words with more than one meaning. In this case first the everyday meaning is asked and then the subject related one. In this study the term *solution* attracts attention because two-thirds of the students (N= 56 out of 86) were not able to describe the chemical meaning correctly, although the term was linked to the verb *to prepare*. In contrast in everyday life *solution* is always connected with the verb *to find*. Besides the content evaluation the linguistic skills can be checked. In order to do so spelling and grammar can be analyzed or some aspects like personification or validity are of importance.
Every tool of its own gives information about the level of small parts of students' special language competencies. The sum of all tools shows a more extensive picture of the students' abilities. The phase of diagnosis should be complemented by some exercises. Tools for supporting content and language learning are described in the following chapter.

4. Support of Special Language Competencies

Within a working framework of participatory action research [13] every tool was proved in chemistry classes several times to support special language. A successful and lasting implementation into chemistry lessons takes place when everyone is aware of problems rising up by inexact use of technical language. Besides small tools like word lists, labeling or key phrases some other instruments seem to be useful. The following tools are developed for usage in chemistry education and were proved in several classes.

Learning poster lab report: Writing lab reports needs high demands on language skills and this often causes trouble. In chemistry lessons students are asked to write such reports regularly. Thus a learning poster was designed, which consists of two parts: on the left side there is a differentiation between the three paragraphs of a report (procedure, observation, conclusion) with special linguistic helps. On the right side are general instructions like words that help to organize the time flow or examples for adverbial phrases.
Cartoons: Concept Cartoons are well known as a tool for initiating a conversation [14]. They deal mainly

with conceptions of chemistry. In our research they were designed for discussions about the meanings of technical terms. Therefore the speech bubbles are filled with different meanings of one word and the students have to discuss which description is the right one in a given context. They learn a lot about technical terms and scientific discussion. If the students got used to cartoons and asked to create one on their own, the teacher gets special insights into the skills of his students. They can remark hypotheses and assumptions in a protected area. Students can help each other in a kind of peer assessment: find the best way to say it, correcting wrong expressions and creating a better phrasing. Especially the discussions about the best way to say it are really fruitful in the context of word acquisition. They get sensitive and aware of special language and problems that arise from imprecise use of it.

Rewriting of texts: In the area of writing texts two different types of challenges were proved: first writing a text with a special addressee like a senior expert or a younger child. The second task is the creation of a text using a different level of symbolization, for example writing a text out of a concept map or a diagram. Students have to rethink their language and to describe technical terms with their own words.

5. Conclusion

Supporting linguistic skills, especially regarding the special language competencies is an important task in chemical education. First a well grounded diagnosis is necessary. This article showed some tools to conduct this challenge. Besides the diagnosis individual support is indispensible. With the help of the described tools a teacher can support the acquisition of general and specialized language.
But this approach will only be successful if teachers and students are aware of difficulties that arise from imprecise use of language.

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