education sciences

MDPI

Article

Conflicting Demands of Chemistry and Inclusive Teaching—A Video-Based Case Study

Simone Abels [1,*], Brigitte Koliander [2] and Thomas Plotz [3]

[1] Leuphana University Lüneburg, Lüneburg, Germany
[2] University of Education Lower Austria, Baden, Austria; Brigitte.koliander@ph-noe.ac.at
[3] University of Vienna, Vienna, Austria; Thomas.plotz@univie.ac.at
* Correspondence: simone.abels@leuphana.de

Received: 27 November 2019; Accepted: 26 February 2020; Published: 28 February 2020

Abstract: Almost every country in the world is obligated to implement education policies to enable an inclusive school system. However, implementing techniques to be inclusive in schools is a major challenge to teachers, especially to those teaching a subject at secondary level and higher. Most of the literature concerning inclusive science education was published in recent years, and is more normative than empirical. Teachers struggle to transfer these normative demands to their accustomed way of teaching science. In this study, we analyze conflicts a teacher experiences when teaching a so-called 'hard science' like chemistry at an inclusive school. On the one hand, inclusive science education should facilitate participation in science specific learning processes for all learners. This broad perspective on inclusion demands that everyone can take part in everyday classroom life. On the other hand, chemistry strives for the understanding of abstract concepts, theories and models, which forms a barrier to learning chemistry for many people. This paper presents an explorative case study focusing on these conflicting demands. To reconstruct the inconsistencies, we analyzed a videotaped teacher–student discourse on atoms. Using the documentary method, a qualitative approach developed by the sociologist Ralf Bohnsack [1] distinguishing between explicit and implicit knowledge, it was possible to reveal the orientational frameworks guiding the teacher's actions. On the surface level, traditional scientific educational approaches structure the discourse. Reconstruction of the discourse is deep, as evidence was found for a participation-oriented framework as well as for the challenges the conflicting demands of chemistry and inclusive teaching put on teaching. We implicate that future professional development courses must not only concentrate on combining chemistry with inclusive pedagogies, i.e., how to teach, but also on the reflection of implicit beliefs concerning inclusive chemistry teaching.

Keywords: inclusion; chemistry education; secondary school; participation; classroom discourse; atoms; video analysis; documentary method

1. Introduction

This paper presents an explorative case study focusing on the question: What are a teacher's difficulties in implementing inclusive practice while teaching chemistry? The research focuses on the co-construction of "inclusive teaching" in a chemistry lesson by the teacher and seven learners (two of them with additional educational needs) on the topic atomic structure and bonding. The focus was not on the development of instructional material for students with disabilities who were included in the class.

Subject teaching and inclusive pedagogy seem to be two hardly compatible cultures. On the one side, Chemistry counts as one of the 'hard' sciences; striving for the understanding of abstract concepts, theories and models. It deals with the characteristics of substances and its reactions. Phenomena are described with macroscopic concepts; characteristics and reactions of substances are explained on a submicroscopic level (molecules, ions, atoms etc.), using a specific technical language [2]. We as chemistry teachers feel that our subject is incomplete when only focusing on phenomena. We want students to understand the relations between substances and atomic structures, as required by the national curricula [e.g. 3]. However, the seemingly objective, authoritarian, rationale, male culture of chemistry—that is how chemistry is often perceived by the layman—acts as a deterrent [4]. “As a result, scientific discourse comes across not only as impenetrable and forbidding, but also as anti-democratic and elitist to outsiders” [5] (p. 1258). Interest in science as a school subject and in pursuing a career in related areas is consequently rather low [4]. The more students need to know about chemistry in their school career, the less they are interested in chemistry concepts [6]. To minimize these barriers in learning chemistry, chemistry education researchers developed several ideas on how to teach chemistry more student-centered, e.g., context-, inquiry-, problem- or project-based. “The topics should be personally relevant to the student, stem from their living environment, and gain transparence through explaining them by scientific concepts” [7] (p. 140). Activities that are investigative, networking and social are recommended [6].

Inclusive pedagogy, on the other side, suggests a change of contents, structures, methods and approaches to enable all students to participate in education [8].

> “Inclusive pedagogy focuses on extending what is ordinarily available as part of the routine of classroom life as a way of responding to differences between learners rather than specifically individualizing for some. It represents a shift in thinking about teaching and learning from that which works for most learners along with something ‘different’ or additional’ for those who experience difficulties, to an approach to teaching and learning that involves the creation of a rich learning environment characterized by lessons and learning opportunities that are sufficiently made available to everyone so that all are able to participate in classroom life” [9] (p. 370).

This wide perspective on inclusion is difficult to enact in the current school system, as long as students are still stigmatized with having special education needs or a migration background. There is still a gap between inclusive pedagogy in theory and classroom practice [10,11]. Chemistry teachers struggle to transfer inclusive demands to their teaching [12,13]. Overall, teachers have little to no training in inclusive teaching and therefore no experience to connect their knowledge in science teaching to inclusive teaching [14]. There are some studies that show possible ways to prepare teacher students and teachers so that they become able to handle diversity and heterogeneity in a chemistry or science classroom [15,16]. Those approaches are, for example, based on video stimulated reflections [16].

One reason for the practice and research gap may be that researchers in the field of chemistry education have only been dealing with the topic of inclusion in research and practice for a few years. Mostly, studies focus on certain diversity dimensions like gender, age, or (dis)ability [17]. The latter is often seen as being equivalent to studies in the field of inclusion. This represents a narrow view on inclusion, which is, however, currently the position taken in the Austrian and German school system. Considering a wider perspective,

> “science education fosters inclusion by facilitating participation in science specific learning processes for all learners. By appreciating the diversity and individual prerequisites, science education involves individual and joint teaching and learning processes to promote scientific literacy” [18] (p. 270).

This definition was established in the Network for Inclusive Science Education, which is currently funded by the German Research Foundation (NE 2105/2-1). So far, several studies have shown that inquiry-based learning has a potential to enable all learners to participate socially and academically, provided that it is adequately scaffolded [13,19–27]. During inquiry-based learning approaches, the focus often lies on phenomena and practical experiences. Teachers struggle to integrate scientific explanations and teaching abstract concepts like the atomic structure.

> "Implications for practice include the need for general education preservice and in-service professional development on differentiation for students with LD (learning disabilities) in science inclusion classrooms, especially when utilizing an inquiry-based curriculum." [28] (p. 140)

Teachers should be better prepared, because they are challenged in an inclusive setting to facilitate social and academic participation. We agree with this demand, but it is necessary to investigate why teaching chemistry inclusively is so difficult for teachers.

In this paper, that is based on [12], we show a teacher's difficulties in implementing inclusive practice while teaching chemistry. We conducted a video study at an inclusive middle school (grades 5–8) in Austria to reconstruct the challenges a chemistry teacher faces when teaching an abstract concept like the atomic structure at secondary level. At first, her teaching seems to be structured by traditional scientific educational approaches only. The teaching appears authoritarian, i.e. teacher-centered, with little room for co-construction. Analyzing her actions in depth, evidence can be shown for enabling participation. Ødegaard and Klette [29] point out how important it is to analyze classroom discourse in depth at a small scale. Nevertheless, the conflict between social and chemistry-specific participation cannot be dissolved. Consequently, we implicate to set one focus of future professional development courses on the reflection of implicit beliefs concerning inclusive chemistry teaching.

2. Data Source and Methods

2.1. Data Source

The research field is an urban, inclusive middle school (grades 5–8) in Austria. Here, students with and without special educational needs visit the same classroom. As we have described, the Austrian school system still has a narrow view on inclusion, as students are still diagnosed with additional educational needs. On average, 25 % (ca. five out of about 20) of the students per class have the diagnosis of additional educational needs, primarily in the areas of mental development, learning, language and emotional and social development. Some students have the diagnosis only in individual subjects [30]. Although this procedure corroborates the narrow view on inclusion, the school established a school development team to implement an inclusive school program more than 20 years ago. The idea was to get closer to the wider view on inclusion by establishing courses, e.g. on dyslexia, learning to learn, equestrian vaulting and interdisciplinary science [23].

The focus of the study at hand was on one of the school's two eighth grade chemistry classes. The lessons were always organized in semigroups (max. 10 students per group), the other half being taught in computer science. The chemistry teacher studied at a teacher education college and had 27 years of professional experience at the time of data collection. She has a degree in chemistry, physics, computer science and mathematics for lower secondary education.

During the school year 2013/14, participant observations were conducted by the first author. About 20 chemistry lessons were videotaped and the teacher's voice was additionally audiotaped to ensure sound quality. For this study, a double lesson with one semigroup was chosen and analyzed in depth by the documentary method [1]. Seven students of the semigroup (4 boys, 3 girls) were present. To make the analysis more accessible in the group of researchers, and to fix the verbal and non-verbal communication, the video was transcribed following the rules of [31]. The whole process was performed collaboratively. The interdisciplinary researcher team (i.e., the authors of this article) regularly met over the course of months to analyze the data together. Every interpretation session was audio recorded and a technical as well as a content memo was written, to be able to reconstruct the preliminary results in later sessions.

The project was authorized by the responsible Austrian education authority in accordance with the school education law, §46(2). The first author signed the declaration of commitment to data secrecy. The head of school officially approved the project as well; the chemistry teacher agreed in writing that she welcomes the research project. All parents received a letter about the study and got the assurance that data would be used only for scientific purposes and in an anonymized way. They signed an agreement. All students were informed about the project focus as well as the use of the video data for research purposes only.

2.2. Method

The documentary method is rooted in general educational research [1], and was lately used in science education research projects [32,33]. During the analytical steps, researchers have to distinguish between explicit knowledge, the immanent understanding on a matter-of-fact level, and implicit knowledge "underlying and orientating habitualized social action" [34] (p. 21). Due to the distinction in these two levels, the method was chosen. Transferred to our research study, this means that the way chemistry lessons are orchestrated does not only depend on technical knowledge that a teacher is able to explicate. Teaching as a social phenomenon is substantially influenced by unwitting beliefs and orientations ("orientational frameworks" [35]). It is possible to identify orientational frameworks by shifting the perspective from the question of what happens to the question of how this practice is produced [28]. In line with the documentary method, three major steps are taken during analysis:

1. A formative interpretation
2. A reflective interpretation
3. Reconstructing orientational frameworks

To strive for a formative interpretation, firstly the "what" of the discourse is noted. The formative interpretation structures the data and helps the researchers to distance from the case. In our study, the discourse between teacher and students was categorized in main topics and subtopics [36]. During the formative interpretation, we focused on the chemistry content, which was targeted during the double lesson, categorizing what was said. Additionally, we wrote down the social forms that different episodes of the lesson were orchestrated in.

Secondly, habitualized social action becomes visible through the reflected interpretation of the discourse. The idea is to reconstruct patterns in the observable verbal and non-verbal language acts that are invisible at first glance. In order to detect and systematize the patterns, the documentary method relies on additional ways of analysis. In general education, methods such as discourse analysis are usually used. We as science educators were looking for a framework providing a possibility to focus more on content and chemistry specific aspects. Otherwise, there is a risk of losing the subject specific perspective during reflective interpretation. We found a useful tool in Erickson's idea on analyzing lessons [37], also used by Bonnet [32]. "Teachers and students engaged in doing a lesson together can be seen as drawing on two sets of procedural knowledge simultaneously; knowledge of the **academic task structure** and of the **social participation structure**" [37] (p. 153, original emphasis). Patterns regarding the academic task structure (ATS) illustrate the way subject content is taught. Patterns regarding the social participation structure (SPS) represent the form of interaction, as well as rights and obligations of the discourse members [32,37].

To summarize, we strived for the reconstruction of content-related interaction patterns in the inclusive chemistry lesson.

The patterns found in the data were sharpened and abstracted in comparison with theoretical models used in chemistry education, like 'the Johnstone triangle' [2]. The triangle represents levels of description and explanation in chemistry. It helps to understand the basic difficulty students have in learning chemistry, that is, to explain macroscopic phenomena on a submicroscopic level (Figure 1), i.e., it helps to clarify the academic task structure.

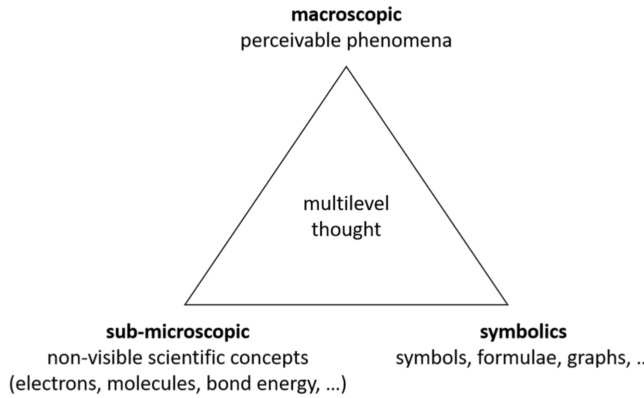

Figure 1. The multilevel thought in chemistry education [38]

Finally, orientational frameworks of the teacher were derived based on the findings of the reflective interpretation.

3. Results

In the following, findings are presented and discussed for each analytical step of the Documentary Method.

3.1. Formative Interpretation

The formative interpretation was conducted by allocating main and subtopics to the transcript, which allow for splitting the double lesson into three major phases (Table 1). Each is characterized by a certain content and a certain social form. In the first 20 minutes, the teacher instructed the students to work in small groups and recall the atom structure from their notes. Then, they were asked to share their knowledge with their classmates. Afterwards the teacher revised the Bohr Model conducting a teacher-led classroom discussion (duration: 50 min). The quick pace of the discourse between teacher and students let us interpret that the double lesson was a revision of the atomic structure. After 70 minutes, the speed reduced, so in the third phase (15 min), the teacher introduced a new topic (atomic bonds), while the social form, the teacher-led discourse, did not change.

Table 1. Structure of the double lesson.

Phase	Time [min]	Social Form	Subject Matter
1	20	Individual work	Atomic structure
2	50	Teacher-led classroom discourse	Atomic structure
3	15	Teacher-led classroom discourse	Atomic bonding

3.2. Reflecive Interpretation

As there is little interaction during phase 1, the reflective interpretation concentrated on phase 2 and 3. The analysis showed a different ATS and SPS for the two phases, which can be contrasted with each other to work out the different patterns of habitualized action.

3.2.1. Reflective Interpretation—Lesson Phase 2 on Atomic Structure

The reflective interpretation focuses on the "how" of the discourse. The interpretation is interested in the way the discourse is set and in the way the participants interact with each other.

The first thing we noticed in the reconstruction of the social participation structure in phase 2 is the following overall pattern: The teacher dominates the discourse with convergent teacher questions that lead to short answers from the students. Often those answers consist only of sentence fragments or individual words. The topic or questions will be continued when the correct answer has been given by the students. The teacher acts as a judge or expert, deciding the correctness of the answer. This kind of discourse has been characterized by Mortimer and Scott [39] as the IRE-pattern. The teacher asks a question (=initiative, I), the students respond (R) and the teacher then evaluates (E) the answers in terms of their correctness according to scientific knowledge. Mortimer and Scott [39] classify this classroom discourse as an authoritative-interactive one, because the teacher is heading at a specific scientific objective and controls the discourse with the questions asked to get to this goal. The task of the students is to follow the teacher's path and provide the correct answers to the teacher's questions (see the following transcript excerpt) to signal that they are up to speed. (The teacher is abbreviated with a T, students with an S. Sex is indicated by f for female and m for male.)

18 T: […] and how is the core [of an atom] charged? **(I)**
19 Sf7: Positive. **(R)**
20 T: It is positive, ok. **(E)** So I have a positive charged core in the middle and then
21 I have around the... **(I)**
22 Sm3: Negative **(R)**
23 T: The... **(E)**
24 Sf7: Electrons. **(R)**
25 T: Electrons and where can they be found **(I)** … where do we imagine this…
26 Sf9: In shells. **(R)**
27 T: In shells, exactly. **(E)** […]

This form of conversation seems to be known to the students: The various speakers respond quickly and the discourse turns very fast. It was between five and six speakers per ten seconds which is a very high rate compared to other situations. The content of the conversation must also—at least in broad terms—be known to all participants, since with this high number of turns no time for logical reasoning remains. The students either reproduce facts and/or guess the answers. It seems therefore to be a repetition of the previously developed content knowledge.

What we realized by analyzing the evaluative answers of the teacher was that she consistently avoids devaluations and rejections. She waits for the answers and only evaluates when a suitable keyword is delivered. She uses reinforcements, repetitions, or gapped sentences (see line no. 20–21 and 23). She almost never acts as a teacher who instructs the students directly. In the evaluation step, she does not make any content-related statements until the correct answers are given by the students (line no. 21–24). She even sticks to this strategy when the students have problems in giving the right answers to her questions.

The second result we encountered in the reflective interpretation is the teacher's use of logics. In order to help the students and lead them to the right answers despite their difficulties, the teacher operates with logic to provide a kind of scaffolding. To ensure that the logic provided encourages the students to answer, the teacher selects logics from many fields of knowledge. For example, mathematical logics, discursive logics (T: If I'm asking that question …) and linguistic logics are used. The following transcript shows how the teacher leads the students to the statement, that neutrons are not charged.

28 T: […] in the core there are protons and neutrons. What can you identify within
29 the word neutron?
30 Sm2: neu
31 Sm3: tron
32 T: neutr - al
33 Sm3: neutral.
34 T: What is the meaning of that word?
35 Sm3: It is neither positive, nor negative.
36 Sm2: It is not charged. Neutral—it is in the middle.
37 Sf9: It is something like a filling.

38 T: Exactly. It is something like a filling, so that it becomes heavier. And how is
39 the core charged then?

In addition to the two previously described results, a third pattern regarding the social participation practices became apparent in the analysis: the communication of the participants in the discourse is prevailed by indefinite terms instead of defined statements. The students leave chemical entities (electrons, protons, atoms, etc.) unnamed most of the times that they talk. In their answers, the students replace those entities with pronouns. Rarely, the teacher or a student asks for an explication of what is vague in a previous statement. These vague statements came mostly from the students, but also partly from the teacher.

Focusing on the ATS, the teacher's questions concern atoms, protons, neutrons, electrons, the atomic nucleus and atomic shells. The teacher represents a theoretical perspective, and the conversation in phase 2 takes place at the sub-microscopic level of the particles [2,40]. This is difficult to access for the students in the observed lesson. To contribute in the discourse, they reproduce the vocabulary—e.g., the name of the particles—but the meaning of these entities is not captured. They constantly confuse the three kinds of sub-microscopic particles (example: T: So which particles do I have in the core? Sm2: Protons and electrons). On the other hand, there is no opportunity for the students to link their everyday life concepts with the scientific concepts provided by the teacher. This can be seen in the following example.

40 T: Look at Neon.

[…]

43 Sm2: Where is Neon?

44 T: Neon?

45 Sm2: Ah// here ten

46 T: //a noble gas

47 Sm2: ten

48 Sm3: ten

49 Sm3: Neon is a gas?

50 Sm2: It has eh //

51 Sm3: // It is a color also?

52 Sm2: //It has two rings.

53 T: Yes, it has two shells.

In this transcript section, we observe a conversation on different levels. A student (Sm3) is led to the everyday life or macroscopic level of understanding by the teacher's hint "noble gas" (line no. 46) (Neon is a gas?, line no. 49) and associates the word neon with a color (line no. 51). This is not addressed by the teacher. Another student (Sm2) remains with his answers on the sub-microscopic level (line no. 52), which is taken up by the teacher and corrected in terms of the technical language (line no. 53). The macroscopic level and the sub-microscopic level are not connected to each other and the teacher does not clarify the differences. The answers on different levels stand beside each other in equality. The teacher does not help the students negotiating their everyday life experience with the concepts of chemistry. She does not explicate that she is talking about the sub-microscopic level of explanation of chemical phenomena, which is a prerequisite of students' understanding of the nature of chemical knowledge [40]. She also does not reject the idea about neon as a color other than ignore this answer. Due to the missing explanation why the rejection occurred, the students have no possibility to link the different observation levels in chemistry: the sub-microscopic, symbolic and macroscopic observation level [2]. Successful chemistry education should offer this linkage. The students in the observed lesson, like most novices in chemistry education, have difficulty distinguishing between these levels of observation. However, those levels represent a key concept of chemistry. If the students struggle in differentiating the entities electron, neutron, proton and constantly mix these entities and their characteristics on the atomic (=sub-microscopic) and phenomenal (=macroscopic) level, the teacher should put the focus on this subject.

The reconstruction of the academic task structure in phase 2 therefore confirms the impression from the reconstruction of the social participation structure. In this phase 2, the reconstruction shows a mainly authoritative subject-teaching approach. The teacher's focus is the sub-microscopic level of chemistry. This focus is motivated through the teacher's knowledge that being able to explain at the sub-microscopic level is the central goal of chemistry and chemistry education. In phase 2, the teacher does not connect this level to the macroscopic phenomena the students are familiar with. She picks up those aspects in the students' statements that are in line with the focus on the sub-microscopic level: "The teacher hears what the student has to say only from the school science point of view" [39] (p. 33). The role of the students is to supply keywords that are used by the teacher to develop the desired scientific view. The students are just following along the way but do not connect or understand the scientific view.

3.2.2. Reflective Interpretation—Lesson Phase 3

After 70 minutes there is a change of topic in the lesson. The teacher starts a thought experiment: "What happens, if, for example, an electron is missing. It may be that suddenly an electron is not there, for whatever reason." She then asks the students to share their ideas. This kind of introduction to a topic leads to a changed interaction between the students and the teacher. This change is exemplarily illustrated with the following transcript excerpt:

Sm4: (Raised his hand and points to the chemistry book in his hand) But you cannot freeze hydrogen so long till it happens, till it becomes helium.// Or is that possible?
T: Aha. No, we won´t. Pay attention! We will not convert two elements, we will ditch together two (She shows that with her hands).
Sm4: Ah, we only want that it is again…
Sm2: Making one positive and one negative.
T: Yes
Sm5: We want.
Sm2: Maybe in the heat //SM3: Yes heat .// the negative goes away and in the cold the negative stays or the other way round?
Sm3: And then it mixes in some way.
T: Okay, let's look at it.
Sm2: The one heating up, the other cooling down and then.
Sm5: Or we heat up water, and then evaporate it.
T: And the electrons evaporate suddenly?
(Sm2 laughs)
Sm4: Forget it.
Sm5: Don´t know, it is flying away?
Sm2: (laughs) No it goes.
Sm3: Why not?
Sm2: It breaks up.
Sm5: It is in a cloud.
T: And then?
Sm3: It rains.
(Everyone laughs)
Sm2: It rains electrons (laughs)

There is an obvious change in the social participation structure compared to phase 2. Now the teacher's share of the conversation is reduced massively. She formulates open and challenging questions and gives time to answer. As a consequence, the students' answers are getting longer and they formulate whole sentences and even series of sentences. Now the students' own ideas are introduced into the conversation and taken seriously by the teacher (e.g. line no 67–69). We can also observe that more students are involved in the conversation. In addition, the speed of interaction has dropped (under four turn takings per ten seconds). This could be due to the fact that the students have to think about their answers and formulate them in their own words.

In recourse to the model of Mortimer and Scott, we see two shifts in the interaction in phase 3 of the lesson. First the students switch from the role as supplier of answers to the role of the initiator. Students' ideas become much clearer in the answers (line no. 63f.), because the statements are longer and formulated in whole sentences. The second change takes place in the evaluative step. The teacher no longer acts as evaluator of the statements, but encourages the students to think for themselves (line no. 77) and to try to evaluate the statements themselves. Thus the teacher-students discourse leaves the authoritative I-R-E scheme and becomes dialogic and democratic [39].

Even though the social participation pattern of conversation in phase 3 changes significantly compared to phase 2, there are some structural features retained in a homologous manner:

- The communication remains indefinite and implicit. No participant in the conversation asks for clarification or explication of terms.
- The teacher does not act as an instructor.
- The conversation continues to be characterized by a high tolerance towards the students' statements. It seems there are no false answers for the teacher.
- The conversation is still highly interactive. Almost all participants in the discussion remain constantly in conversation.

The academic task structure, in contrast to the previous phase, also changes. The perspective of the students now dominates the conversation due to the decreased involvement of the teacher as initiator. The scientific view—which previously dominated the discourse—fades into the background. Everyday life ideas are co-constructively developed by several students and the teacher does not interfere most of the time. The problem is that the ideas developed by the students are scientifically wrong or contrary to the desired scientific knowledge.

3.3. Orientational Framework

The contradictory form of communication in phases two and three leads to the conclusion that there could be two competing orientation frameworks.

On the one hand, the actions of the teacher provide evidence that the nature of chemistry is a strong frame of reference for the academic structure. Knowledge about the submicroscopic level is indispensable in order to be able to explain phenomena on the macroscopic level. The submicroscopic knowledge is the prerequisite for understanding chemistry and has to precede the explanations on the macroscopic level. It follows directly from this that chemistry teaching has to integrate the submicroscopic level.

In phase 2, the teacher shows the clear will to offer help to the students to participate in discussions about the submicroscopic level. She uses different strategies like the avoidance of indoctrination or the avoidance of devaluation in the evaluation process. The strategy of the logics, which was used by the teacher to help, is exciting and has not been documented yet as way to help students to participate. In addition, the teacher was always respectful and very permissive towards ambiguous terms and confused concepts in the students' presentations.

In summary, the teacher has succeeded in establishing a participatory discourse in which a high density of teacher-pupil interaction can be observed. Therefore, we come to the conclusion that there has to be a further frame of orientation in relation to the structure of social participation in addition to the subject-specific frame of orientation. Chemistry teaching should not be authoritarian but should enable participation and inclusion. This orientation framework obviously contradicts the teacher's chemistry-related orientation framework.

It is easy to see the contradiction in the differences, but also in the similarities, between the actions of teacher and students in phases 2 and 3. These two phases can be interpreted as two different attempts by the teacher to convey authoritative knowledge in a participative, democratic way. In both phases, the teacher's orientational framework regarding the social participation of all students leads to a teacher-students discourse where students are eager to participate. There are no students that do not participate in some way. However, in both phases this participatory orientational framework conflicts with the authoritative orientational framework regarding the scientific knowledge. This leads to different results in the phases. In phase 2, the scientific view is imparted in an authoritative way onto the students with no possibility for them to understand the foreign concepts. So, they only participate as providers of answers to the teacher's narrow questions. The teacher does not offer the possibility for the students to link the new concepts to their existing ones. In phase 3, on the contrary, the scientific view is nearly banished from the lesson for the sake of a participatory discourse.

In both phases a participatory, dialogical way of teaching, namely the negotiation of the two perspectives—the worldview of chemistry and the worldview of the students on an equal footing—is not possible. Reasons may be the lack of content knowledge on the students' side and/or the lack of didactical knowledge by the teacher; but it may also be the interpretation of "inclusion" only as participation on the social level, ignoring the need of the participation on the level of the content knowledge. The way of teaching we reconstructed here is a superficial staging of a dialogical, democratic discourse.

4. Conclusions

The case study was performed at an inclusive middle school where students with and without special educational needs visit the same classroom. Since the school launched an inclusive school program more than 20 years ago, we analyzed chemistry lessons at this school to reconstruct some ways of educational practice that match the requirements of inclusive pedagogy with the requirements of chemical education. Although the teacher observed in the case study clearly shows a participatory (and therefore inclusive) orientation to chemistry teaching, this orientation enables only participation on the social interaction level, but failed to facilitate the negotiation of the worldview of chemistry with the worldview of the students.

By analyzing two different situations between learners and teacher, we reconstructed two competing orientation frameworks. The first orientation framework guides the actions when the teaching focuses on the academic task of the chemical lesson. Then, the teacher pursues the worldview of chemistry. She poses narrow questions and the students provide answers that are either accepted or ignored by the teacher. However, there is no time or possibility for the students to link the new concepts to their existing ones. The second orientation framework regarding the social participation of all students leads to a teacher-students discourse where students are eager to participate. However, when students contribute and share their ideas, the scientific view is nearly banished from the lesson for the sake of a participatory discourse.

Due to the nature of chemistry and chemistry knowledge implies an authoritative orientation for her, the teacher fails to facilitate her students the access to chemistry. Moreover, even her participative strategies often prevent her students from understanding chemical knowledge and the concepts behind different phenomena. For example, for the sake of a participatory discourse, she does not correct students' statements. When students' misunderstandings are not made explicit, the students are not able to evaluate their own statements. The teacher seems to struggle to orchestrate the social participation structure and the academic task structure to reach the goal of participation and the understanding of scientific knowledge.

A possible way to enable the students to become acquainted with the worldview of chemistry is e.g., by negotiating it with the students' world view which focuses mainly on the macroscopic level. Approaches like inquiry-based learning, project-based learning and other reform-oriented pedagogies also allow for participation on the content level [15]. Conclusively, future professional development courses must not only concentrate on inclusive content-related pedagogies, i.e., how to teach chemistry, but should also focus on the reflection of implicit beliefs in inclusive science teaching. To make their implicit orientational frameworks explicit would help teachers to become aware of conflicting demands in their belief systems on inclusive science teaching. We assume this has to be a pre-requisite for a sustained improvement in their teaching practice. Though, that remains to be investigated in future studies.

Author Contributions: conceptualization, all authors; methodology, all authors; formal analysis, all authors; investigation, S.A.; resources, S.A.; data curation, S.A.; writing—original draft preparation, S.A.; writing—

review and editing, T.P. and B.K.; project administration, S.A. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Acknowledgments: We are very thankful to the teacher and the students who were participating in this study. Furthermore, we thank Christine Heidinger as a former member of the research team.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Bohnsack, R., Pfaff, N., Weller, W., Eds. *Qualitative analysis and documentary method in international educational research;* B. Budrich: Opladen, Germany, 2010.
2. Johnstone, A. H. Teaching of chemistry – logical or psychological? *Chem. Educ.: Res. Pract. Europe* **2000**, *1*, 9–15
3. Niedersächsisches Kultusministerium. *Kerncurriculum für die Oberschule Schuljahrgänge 5 - 10 Naturwissenschaften;* Unidruck: Hannover, 2013.
4. Sjøberg, S.; Schreiner, C. How do learners in different cultures relate to science and technology?
5. Sharma, A.; Anderson, C. Recontextualization of Science from Lab to School: Implications for Science Literacy. *Sci. Educ.* **2009**, *18*, 1253–1275.
6. Höft, L.; Bernholt, S.; Blankenburg, J. S.; Winberg, M. Knowing more about things you care less about: Cross-sectional analysis of the opposing trend and interplay between conceptual understanding and interest in secondary school chemistry. *J. Res. Sci. Teach.* **2019**, *56*, 184–210. doi:10.1002/tea.21475
7. Gräber, W. German High School Students' Interest in Chemistry – A Comparison between 1990 and 2008. *Educ. Quim.* **2011**, *22*, 134–140. doi:10.1016/S0187-893X(18)30125-3
8. UNESCO. Guidelines for Inclusion: Ensuring Access to Education for All. Available online: http://unesdoc.unesco.org/images/0014/001402/140224e.pdf (accessed on 11 January2012).
9. Florian, L.; Linklater, H. Preparing teachers for inclusive education: using inclusive pedagogy to enhance teaching and learning for all. Cambridge *J. Edu.* **2010**, *40*, 369–386. doi:10.1080/0305764X.2010.526588
10. Florian, L.; Black-Hawkins, K. Exploring inclusive pedagogy. *Br. Edu. Res. J.* **2011**, 37, 813–828.
11. Schwab, S.; Sharma, U.; Hoffmann, L. How inclusive are the teaching practices of my German, Maths and English teachers? – psychometric properties of a newly developed scale to assess personalisation and differentiation in teaching practices. *Int. J. Incl.Edu.* **2019**, *22*, 1–16. doi:10.1080/13603116.2019.1629121
12. Heidinger, C.; Abels, S.; Plotz, T.; Koliander, B. Inclusion and Chemistry teaching – Deliberating Conflicting Demands. In *Electronic Proceedings of the ESERA 2017 Conference. Research, Practice and Collaboration in Science Education*; Finlayson, O. E., McLoughlin, E., Erduran, S., Childs, P., Eds.; Dublin City University: Dublin, Ireland, 2018; pp 1611–1619.
13. Abels, S. Scaffolding inquiry-based science and chemistry education in inclusive classrooms. In *New developments in science education research*; Yates, N. L., Ed.; Nova: New York City, USA, 2015; pp 77–96.
14. Mumba, F.; Banda, A.; Chabalengula, V. M. Chemistry Teachers' Perceived Benefits and Challenges of Inquiry-based Instruction in Inclusive Chemistry Classrooms. *Sci. Edu. Int.* **2015**, *26*, 180–194.
15. Tolsdorf, Y.; Kousa, P.; Markic, S.; Aksela, M. Learning to Teach at Heterogeneous and Diverse Chemistry Classes - Methods for University Chemistry Teacher Training Courses. *EURASIA J. Math., Sci Tech. Educ* **2018**, *14* . doi:10.29333/ejmste/93377
16. Abels, S. Science Teacher Professional Development for Inclusive Practice. *Int. J. Phys. Chem. Educ.* **2019**, *11*, 19–30.
17. Markic, S.; Abels, S. Heterogeneity and Diversity – A Growing Challenge or Enrichment for Science Education in German Schools? *EURASIA J. Math., Sci Tech. Educ* **2014,** *10*, 271–283. doi:10.12973/eurasia.2014.1082a
18. Walkowiak, M.; Rott, L.; Abels, S.; Nehring, A. Network and work for inclusive science education. In *Building bridges across disciplines*; Eilks, I., Markic, S., Ralle, B., Eds.; Shaker: Aachen, Germany, 2018; pp 269–274.
19. Abels, S.; Minnerop-Haeler, L. Lernwerkstatt: An Inclusive Approach in Science Education. In *Science Education towards Inclusion*; Markic, S., Abels, S., Eds.; Nova Science Publishers: New York City, USA, 2016; pp 137–156.

20. Klika, D.; Abels, S. Scaffolding guided inquiry-based chemistry education at an inclusive school. In *Electronic Proceedings of the ESERA 2015 Conference. Science education research: Engaging learners for a sustainable future*; Lavonen, J., Juuti, K., Lampiselkä, J., Uitto, A., & Hahl, K., Ed.; University of Helsinki: Helsinki, Finland, 2016; pp 1030–1037.
21. Abels, S.; Puddu, S. Inquiry-based Learning Environments to Welcome the Diversity of a Chemistry Class. In *E-Book Proceedings of the ESERA 2013 Conference: Science Education Research For Evidence-based Teaching and Coherence in Learning*; Constantinou, C. P., Papadouris, N., Hadjigeorgiou, A., Eds.; European Science Education Research Association: Nicosia, Cyprus, 2014; pp 122–130.
22. Therrien, W. J.; Taylor, J. C.; Hosp, J. L.; Kaldenberg, E. R.; Gorsh, J. Science Instruction for Students with Learning Disabilities: A Meta-Analysis. *Learn. Disabil. Res. Pract.* **2011**, *26*, 188–203.
23. Villanueva, M. G.; Taylor, J. A.; Therrien, W. J.; Hand, B. Science education for students with special needs. *Stud. Sci. Educ.* **2012,** *48*, 187–215.
24. Scruggs, T. E.; Mastropieri, M. A.; Okolo, C. M. Science and social studies for students with disabilities. *Focus Except. Child.* **2008,** *41*, 1–24.
25. Brigham, F.; Scruggs, T. E.; Mastropieri, M. A. Science Education and Students with Learning Disabilities. *Learn. Disabi.l Res. Pract.***2011**, *26*, 223–232.
26. Lee, O.; Deaktor, R.; Hart, J.; Cuevas, P.; Enders, C. An Instructional Intervention's Impact on the Science and Literacy Achievement of Culturally and Linguistically Diverse Elementary Students. *J. Res. Sci. Teach.* **2005,** 42 , 857–887.
27. Wang, J.-R.; Wang, Y.-C.; Tai, H.-J.; Chen, W.-J. Investigating the effectiveness of inquiry-based instruction on students with different prior knowledge and reading abilities. *Int. J. Sci. Math. Educ* **2010,** *8*, 801–820. doi:10.1007/s10763-009-9186-7
28. McGrath, A. L.; Hughes, M. T. Students With Learning Disabilities in Inquiry-Based Science Classrooms: A Cross-Case Analysis. *Learn. Disabil. Q.* **2018**, *41*, 131–143. doi:10.1177/0731948717736007
29. Ødegaard, M.; Klette, K. Teaching Activities and Language use in Science Classrooms. In Science Education Research and Practice in Europe; Jorde, D., Dillon, J., Eds.; Sense Publishers: Rotterdam, Boston, Taipei, 2012; pp 181–202.
30. Abels, S. Inklusiver naturwissenschaftlicher Unterricht in der Lernwerkstatt Donaustadt. In *Grundlagen inklusiver Bildung. Teil 1. Inklusive Unterrichtspraxis und -entwicklung*; Siedenbiedel, C., Theurer, C., Eds. 28; Prolog: Immenhausen bei Kassel, Germany, 2015; pp 125–134.
31. Kuckartz, U.; Dresing, T.; Rädiker, S.; Stefer, C. Qualitative Evaluation. DerEinstieg in die Praxis; VS Verlag für Sozialwissenschaften: Wiesbaden, Germany, 2008.
32. Bonnet, A. Die Dokumentarische Methode in der Unterrichtsforschung: ein integratives Forschungsinstrument für Strukturrekonstruktion und Kompetenzanalyse. Zeitschrift für Qualitative Forschung **2009**, 10 , 219–240.
33. Ruhrig, J.; Höttecke, D. Components of science teachers' professional competence and their orientational frameworks when dealing with uncertain evidence in science teaching. *Int. J. Sci. Math. Educ*. **2015,** *13* , 447–465.
34. Pfaff, N.; Bohnsack, R.; Weller, W. Brazilian and German educational science: an introduction. In R. Bohnsack, N. Pfaff & W. In *Qualitative analysis and documentary method in international educational research*; Bohnsack, R., Pfaff, N., Weller, W., Eds.; B. Budrich: Opladen, Germany, 2010; pp 7–38.
35. Bohnsack, R. Documentary Method and group discussions. In *Qualitative analysis and documentary method in international educational research;* Bohnsack, R., Pfaff, N., Weller, W., Eds.; B. Budrich: Opladen, 2010; pp 99–124.
36. Bohnsack, R. Dokumentarische Methode und die Logik der Praxis. In Pierre Bourdieus Konzeption des Habitus. Grundlagen, Zugänge, Forschungsperspektiven; Lenger, A., Schneickert, C., Schumacher, F., Eds.; Springer: Heidelberg, Germany 2013; pp 175–200.
37. Erickson, F. Classroom Discourse as Improvisation: Relationships between Academic Task Structure and Social Participation Structure in Lessons. In Communicating in the classroom; Wilkinson, L. C., Ed.; Language, thought, and culture; Academic Press: New York, NY, USA 1982; pp 153–181.
38. Johnstone, A. H. Why is science difficult to learn? Things are seldom what they seem. *J. Comput. Assist. Lear.* **1991**, *7*, 75–83.

39. Mortimer, E. F.; Scott, P. Meaning making in secondary science classrooms; Open University Press: Maidenhead, UK, 2003.
40. Taber, K. S. Revisiting the chemistry triplet: drawing upon the nature of chemical knowledge and the psychology of learning to inform chemistry education. *Chem. Educ. Res. Pract.* **2013**, *14*, 156–168.