Chemish in Chemistry Teaching and Learning

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Chemish, as defined by Markic & Childs as the scientific language of chemistry, is essential for communicating in and understanding chemistry. At the same time, Chemish is one of the major difficulties in teaching and learning chemistry in the school context.

Keywords: Pedagogical Scientific Language Knowledge ; Chemish ; Chemistry ; Disciplinary Literacy ; Scientific Language ; Teacher Knowledge

1. Introduction

The overarching goal of science education in general—and chemistry education in particular—is to promote scientific literacy and thus to enable students to engage as responsible citizens with science-related topics [1][2]. In the school context, language is the key to communicating knowledge. In science classes, understanding scientific language is a premise to become scientifically literate. Therefore, understanding scientific language as well as correct and addressee-oriented use of it are key competences for participating in chemistry class and essential for the acquisition of scientific literacy. Since understanding and using the scientific language of chemistry—the *Chemish* [3]—are competences to be acquired in chemistry class, chemistry teachers are responsible to support students in acquiring and using Chemish. To put it in the words of Laszlo [4] (p. 1682): “Chemistry teachers are linguistic guides, they are interpreters. They teach their students how to craft well-formed chemical sentences”. In conclusion, chemistry teachers must be adequately prepared to address their students’ difficulties in learning and using Chemish and to make scientific content accessible to all students. To do so, chemistry teachers must be confident in their use of Chemish. This requires first and foremost a fundamental knowledge of Chemish and concepts behind the language (content knowledge), as well as an awareness of Chemish and its characteristics. Furthermore, they need to possess knowledge on how to teach and learn Chemish.

2. Chemish in Chemistry Teaching and Learning

Language and literacy in general are the prerequisites for the acquisition of knowledge [5]. That becomes even more apparent when thinking of different classroom activities: every activity is essentially bound to at least one dimension of language—as they are reading, writing, listening, and talking [6]. Language serves concurrently as a goal of and a vehicle in education [7], even more so in science class as there is an additional language, the scientific language, which must be understood to participate in science class [6][8][9][10]. Postman and Weingartner [11] stated, that “almost all of what we customarily call ‘knowledge’ is language, which means that the key to understanding a subject is to understand its language” as cited in [9] (p. 3). Thus, knowing the scientific language enables students to think scientifically [12]. In more recent curricula, the role of scientific language in learning science has been taken into account to the extent that it has become an explicit goal of science education in several countries, e.g., [13][14][15][16][17].

Focusing on language, Yore and Treagust [10] describe the problems students may have in chemistry class as a three-language problem: students must switch between home language, instructional language, and scientific language. Thus, in chemistry classes, the usage of Chemish [3] is a special obstacle for learning [9]. Students’ challenges with Chemish itself can occur because, according to Lemke [18], the scientific language has its own semantics, supplemented by its grammar, rhetorical structures, and figures of speech. Additionally, one can examine the features of scientific language at three levels: the vocabulary, grammar, and genre level [19]. Finally, Chemish includes three different components: macroscopic (e.g., substances and phenomena), microscopic (e.g., molecules and atoms), and symbolic (e.g., formulas and equations) [20][21].

As described by Childs et al. [6] as well as by Quílez [22], this complexity of Chemish is very high and the language is multifaceted due to unfamiliar, sometimes polysyllabic technical terms which are often based on Greek or Latin; some technical terms are used only a few times in chemistry education in school over years; some technical terms have different meanings in different contexts; there are special verbs (e.g., explain, describe) and logical connectives;

additionally, there is the symbolic language as well as the use of diagrams, and it contains parts of mathematics. Besides the technical words, problems can occur since non-technical words are used in science in another way than in everyday language (e.g., the word ‘solution’) [23]. It is therefore important to incorporate students’ understanding of the term into the lesson and expand or modify the meaning in relation to Chemish. If this transition from understanding the term in everyday language to Chemish does not take place, teachers and students could use the same word but connote it with different meanings, which leads to misunderstandings and buildup of misconceptions on the side of the students.

Quílez [22] stated that the barriers for students learning Chemish are diverse: (i) they lie in teaching tools and materials (e.g., the way chemistry texts are written, the language of chemistry exam questions, and how problems are expressed), (ii) they are influenced by chemistry teachers’ preparation for teaching scientific language and their awareness of the barriers [22], and (iii) they lie within the above-named characteristics of Chemish. Thus, Chemish can be an issue that hinders students’ enculturation in the discipline of chemistry [24], and consequently hinders them from becoming scientifically literate.

Since students are not innately familiar with Chemish and need to first acquire it, learning Chemish is very often compared to learning an additional language [9][25][26][27][28][29]. However, this does not mean that learning Chemish is equal to second language acquisition. In second language acquisition, the native language serves as a reference; in contrast, in the acquisition of scientific concepts and, therefore, the scientific language, the concept and the language must be acquired simultaneously [30]. Rincke [31] confirms this way of scientific language acquisition for physics education. This way of acquiring Chemish results in a double challenge of “increased cognitive demands embedded in meaningfully engaging in the STEM practices [that] are accompanied by increased linguistic demands associated with expressing one’s ideas about these practices” [32] (p. 363). Following this double challenge and keeping in mind the named characteristics of Chemish, chemistry teachers need to be aware of (i) characteristics of Chemish, (ii) students’ knowledge about certain words and concepts, and (iii) the methods and tools to teach Chemish. Keeping this in mind, chemistry teachers need to consider the high degree of accuracy in using Chemish in their classes.

Summing up the named requirements, chemistry teachers need to act as linguistic guides [4] for their students to enable them access to the scientific language and thereby participation in the chemistry class. Hence, chemistry classes become language classes focusing on Chemish [22]. According to Kulgemeyer [33], thematizing the differences of everyday and scientific language and considering students’ alternative conceptions and preconceptions according to the scientific language are important when teaching science. However, approaches that focus on the “hidden conventions” of scientific language, and thus on metalanguage, “that govern the way language is used to produce and communicate scientific knowledge” are missing [19] (p. 1312). Metalanguage in the context of science therefore “refers to the technical terms for talking about scientific language” [19] (p. 1312).

To categorize different types of teacher knowledge, Shulman [34][35] distinguishes between content knowledge (CK), pedagogical knowledge (PK), and pedagogical content knowledge (PCK), which is “a special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding” [35] (p. 8).

Galguera [36] specified the PCK in terms of academic language and first proposed the need for teachers to develop *Pedagogical Language Knowledge* (PLK) as PCK for academic language development rather than to prepare teachers to teach English Language Learners (ELLs). This knowledge includes creating opportunities purposefully for the development of language and therefore literacy in and through teaching content. Crucial components of PLK are *language awareness* [37] and *metalinguistic awareness* [38], as well as *critical language awareness* [7][39][40]. *Language awareness* defines explicit knowledge about language and perceiving and using language consciously. *Metalinguistic awareness* is defined “as conscious knowledge of the formal aspects of the target language (e.g., grammar)” [38] (p. 248). *Critical language awareness*, on the other hand, refers to the social, political, and ideological aspects of language, while language practices are seen to sustain and reproduce power relations. In this sense, language proficiency can be seen as empowerment for participation [40]. Finally, a crucial point for developing PLK are opportunities to practice for the teacher to pay active attention to (critical) language and metalinguistic awareness, as well as language usage.

According to Galguera [36], Bunch [41] defined PLK “as knowledge of language directly related to disciplinary teaching and learning and situated in the particular (and multiple) contexts in which teaching and learning take place” [41] (p. 307) with a special focus on ELLs. This knowledge is different from the PCK of second language teachers and that of mainstream teachers on their subject area(s). Developing PLK in the sense of Bunch [41] means focusing primarily on developing critical language awareness. Additional attention should be paid to “linguistics, SLA [Second Language Acquisition], bilingualism, and other language-related knowledge bases” [41] (p. 307). Besides these rather theoretical knowledge bases, putting the knowledge into practice is essential, as the notion of language as action serves as an overarching principle [41].

Several scholars have also recognized the importance of teaching language in content areas and therefore a need for a special kind of teacher knowledge as well. Only to mention a few approaches: Lucas and Villegas [42] claim a need for *linguistically responsive teachers* to help ELLs learn the content. Turkan et al. [43] present a theoretical framework in *Disciplinary Linguistic Knowledge* (DLK) to teach the content of a specific discipline to ELLs. Fulmer et al. [44] describe a need for *teachers' knowledge of language as an epistemic tool* in science classes. All the approaches [36][41][42][43][44] have in common that teachers need to know the linguistic features spoken in their content area(s), be aware of these features, and actively and purposefully incorporate that discipline-specific language into classroom activities. The crucial component and overarching principle are, however, to put the knowledge and attitudes into practice. As the scholars of the approaches on teaching language in content areas already stated, only in this way the full knowledge will develop over time. However, except the approaches of Galguera [36] and Fulmer et al. [44], all approaches focus solely on teacher knowledge for teaching ELLs. However, because Chemish is challenging not only for second language learners but for all learners, a special type of chemistry teacher knowledge on teaching Chemish is needed.

Starting from the concept of PLK, it can be concluded that chemistry teachers need more than PCK and CK (and also PK) for teaching Chemish—and not separately, as it is mostly taught at German universities. In line with Ollerhead [45], chemistry teachers must develop professional knowledge with the focus on Chemish: *Pedagogical Scientific Language Knowledge* (PSLK). PSLK was defined by Markic [46] (p. 181) as "teachers' Pedagogical Language Knowledge (PLK) with the focus on the scientific language of chemistry". Developing PSLK means acquiring the knowledge and competences mentioned below in theory, but the crucial point here as well as at the other approaches is to put the knowledge into practice. To be able to put the knowledge into practice, however, (critical) language awareness as well as metalinguistic awareness are necessary regarding Chemish.

Since CK and PCK are essential for the teachers to meet students' needs when learning Chemish, PSLK can be seen as —speaking in the words of Shulman—an amalgamation of CK and PCK regarding Chemish. Besides the CK on different chemistry topics and concepts the teachers must also have CK on Chemish, more precisely at two levels: (i) on the vocabulary level to understand the meaning of the words and the concepts behind the words, and the connections to other related topics; and (ii) on the meta-level in terms of the special semantics, grammar, rhetorical structures, rules of nomenclature, and different representational forms, as well as to identify differences in the meaning of words used in everyday language and scientific language. Therefore, science teachers in general and chemistry teachers in particular must have a clear understanding of the meanings of terms used and different speech genres [47]. In part, PSLK is tied to the scientific vocabulary and therefore specific content areas, but in part, PSLK focuses on the characteristics of Chemish and therefore is also universally applicable to different content areas regarding, e.g., the different components, and can therefore be seen more as a cross-topic principle for chemistry education. Since the PSLK includes the knowledge to put the CK into practice, it can be in part equated with the PCK regarding Chemish. Therefore, along Shulman's [34] definition of PCK, the PSLK also includes knowledge on (i) the most comprehensible representations of content taking into account the Chemish and (ii) students' preconceptions and misconceptions of different scientific terms and associated problems in learning Chemish at both beforementioned levels. The connection of different teacher knowledge domains for teaching and learning Chemish is to be found in **Figure 1**.

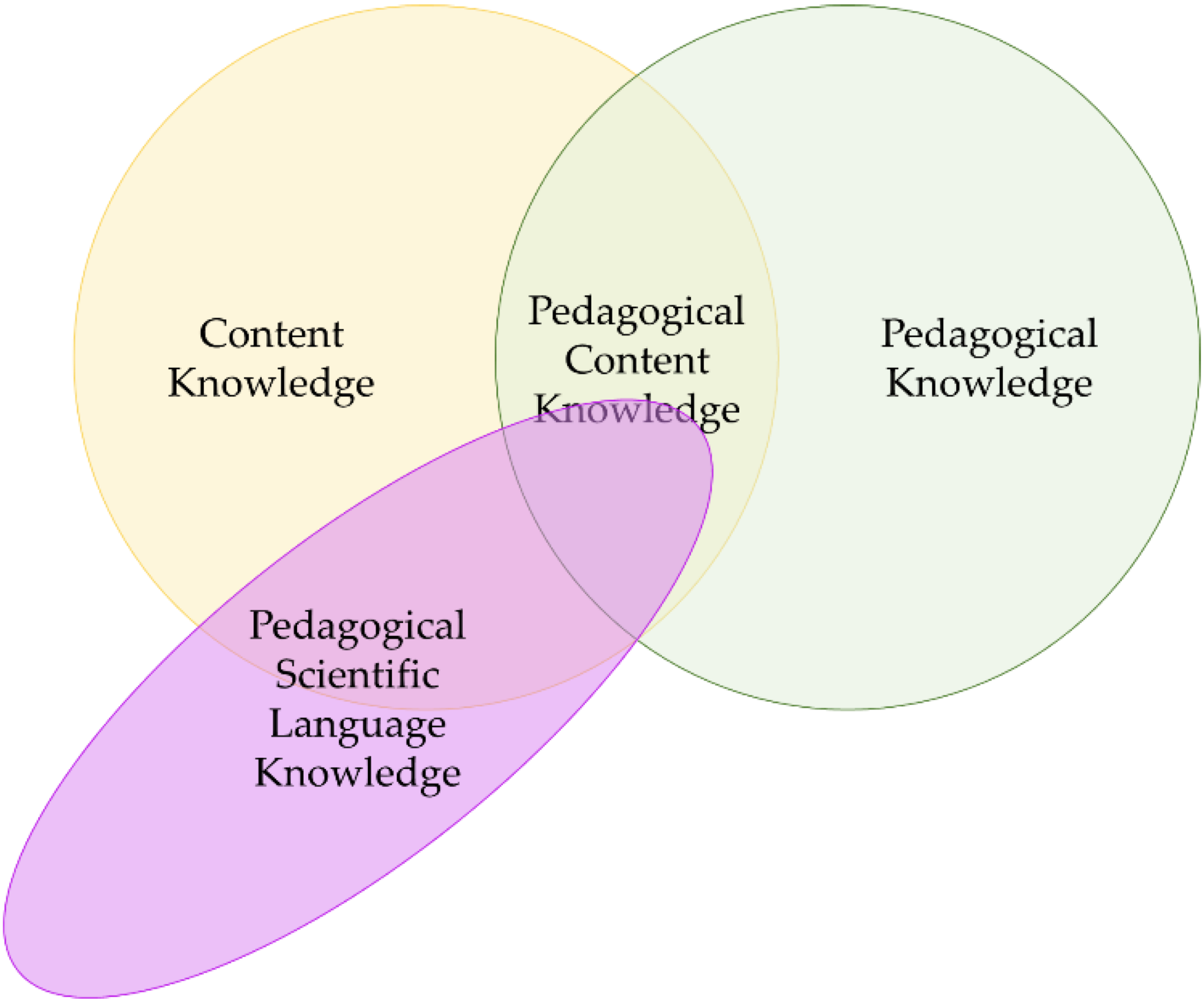

Figure 1. Connection of the different teacher knowledge bases with PSLK.

A premise to being able to develop PSLK is to develop language awareness, metalinguistic awareness, as well as critical language awareness in general and additionally with the focus on Chemish. This enables one to pay explicit attention to the usage of Chemish when teaching. Therefore, metalinguistic awareness and metalanguage (as parts of PSLK) are needed to identify the special linguistic features of scientific language and to be aware of and be able to disclose linguistic choices made to communicate meaning. Another aspect of science and therefore chemistry teachers must be aware of is the importance of knowing (about) the scientific language which includes “(a) knowledge about the distinctive grammatical and structural features of scientific language as compared to other disciplines and (b) the functions of these language features in constructing and arguing scientific propositions and knowledge claims” [48] (p. 1072).

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