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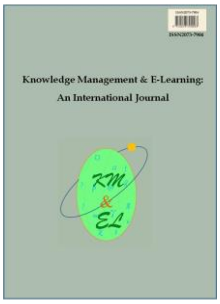

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Scientific language use and sensemaking in concept maps: Interaction between concept systems, scientific concepts and everyday concepts

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Abstract: The interaction between student language use and sensemaking is an area in science learning that needs further elucidation in order to meet government standards in science education. In this study, concept mapping was used to explore the relationship between scientific language use and sensemaking defined as the interaction between the scientific concept system and everyday concepts in order to make sense of a proposed phenomenon. Eighty-eight concept maps from five different school classes and two school systems were analyzed in terms of their language use and concept formation from a Vygotskian perspective. This work proposes an intimate relationship between student language use, concept system formation and sensemaking in science, indicating possible implications for the study of learning as well as formative assessment using concept maps.

Keywords: Sensemaking; Concept mapping; Science learning; Language use; Upper-secondary school; Chemistry

Biographical notes: Ylva Hamnell-Pamment is a doctoral candidate at the Department of Educational Sciences, Lund University. She has completed all the requirements for a doctoral degree and will defend her dissertation on October 27, 2023. Her research interests include sensemaking in science education, concept mapping, student language use, chemistry teaching and learning, and Vygotskian theory. In her thesis, she explores the role of language use in sensemaking in chemistry at upper-secondary school. The thesis will be published in October 2023.

1. Introduction

1.1. The role of scientific and everyday language in sensemaking in science

In the last decades, there has been an increased interest in science education in how students use language to make sense of scientific phenomena (Fang, 2016; Lemke, 1990, 2004; Norris & Phillips, 2003; Osborne, 2010; Taber, 2017b). This interest has been mirrored by changes in government policy, for instance in the United States, where standards have moved further toward students using language to make sense of phenomena as an essential part of classroom practices (Hakuta et al., 2013; Lee et al., 2018). An important aspect of meaningful learning is how students relate concepts within a concept system, forming a system of meanings that they then use for sensemaking (Kinchin, 2020; Kinchin et al., 2019; Novak, 2002). In science, such a concept system could be, for instance, the concepts that the students use to understand chemical equilibrium, photosynthesis, or gravity. However, students often struggle with sensemaking in science (Osborne, 2010; Taber, 2017b). It has been proposed that students need to use both their scientific language and their everyday language in the classroom to be able to translate between scientific systems of meaning and their everyday experience for sensemaking to take place (Blown & Bryce, 2017; Nygård Larsson & Jakobsson, 2020; Sherin, 2006; Taber, 2013).

The language of science is something that is developed through language use in the classroom (Adúriz-Bravo & Revel Chion, 2017; Fang, 2016; Lee et al., 2018; Lemke, 1990, 2005). As students master the scientific language, their expressions become more explicit and precise, increasing their ability to participate in the scientific discourse of the classroom (Lee et al., 2013, 2018). However, connecting the language of science to concrete experiences means that students need to connect back to a part of their language repertoire that has developed through everyday experience (Blown & Bryce, 2017; Brown & Spang, 2008; Clarà, 2017; Nygård Larsson & Jakobsson, 2020; Sherin, 2006; Vygotsky, 1934/1987). This means students move between concrete, everyday linguistic meanings and abstract, systematically connected scientific linguistic meanings as part of learning (Nygård Larsson, 2018). Hence, from a language learning perspective, students need to both participate in and learn the language of science as well as learn to navigate the relationship between scientific and everyday conceptual meanings. In this way, students can make sense of scientific phenomena and fill knowledge gaps by building explanations using their own words to connect their experience with theory (Odden & Russ, 2019; Taber, 2013). This process can also be referred to as the combined process of frame-shifting and conceptual blending in meaning construction (Coulson, 2001).

It has been pointed out by Hand et al. (2018) that, in order to fully understand the role of language in learning, much greater emphasis needs to be put on investigating how students' language use relates to their participation in science classroom practices. Even though studies of student concept maps indicate a disconnect between scientific and everyday concepts (Reiska et al., 2015) and low sensemaking while constructing the concept maps, the relationship between concept map structure and the use of scientific and everyday concepts has not been fully elucidated. In addition, in order to meet students' diverse needs, teachers who teach in classrooms diverse in terms of learner profiles and backgrounds need to be made aware of how students use language to make sense of different science topics (Maeng & Bell, 2015; Taber, 2017b). Hence, there is a need for further research that explores how student language use is related to sensemaking as part of concept formation in science education, which can be reflected in the concept map classroom product (Kinchin et al., 2000).

1.2. Concept maps as tools for assessment of scientific language in concept maps

Concept maps are classroom aids known for both promoting meaningful learning and assessing conceptual understanding in science classrooms (Kinchin, 2014; Kinchin et al., 2019; Machado & Carvalho, 2020; Novak, 2002, 2005). Concept maps can be versatile tools for formative assessment, either through comparative analysis of the precision of student language used to connect concepts or through visualizing both which concepts the students use to make meaning and how these concepts are used as part of a concept system to form meaning (Cañas et al., 2012; Novak, 2002; Novak & Gowin, 1984; Strautmane, 2012). For instance, concept maps can identify disconnected areas within a conceptual system or when concepts are less integrated as part of rote learning (Kinchin, 2020; Novak, 2002). From a qualitative perspective, knowledge growth can be seen in concept maps as increased use of relevant concepts and their internal relationships as well as an increase in the use of specific terminology (de Ries et al., 2022). Hence, qualitative analysis of concept maps is a suitable tool for the analysis of both scientific language use and the integration of scientific and everyday conceptual meanings. Indeed, concept mapping studies can reflect degrees of complexity and generality in concept maps (Kinchin et al., 2019), and can be used to analyze poorly developed conceptual meanings (Harrell, 2012). They can also be used to analyze the integration of practical and theoretical knowledge (Machado & Carvalho, 2020).

1.3. Study aim

The objective of the present study was to explore through the qualitative analysis of concept maps the relationship between student language use and the integration of scientific and everyday concepts in sensemaking in chemistry. Concept mapping was utilized for the qualitative analysis of how student language use relates to the integration of scientific and everyday concepts as part of concept formation in science learning. The analysis used current literature on language use in concept maps in combination with Vygotsky's (1934/1987) theory of concept development as a basis for analysis. The analysis focused on concept maps produced by 88 students in five different upper secondary school classes, as they studied the topic of the shift in chemical equilibrium.

2. Analytical framework

2.1. Analyzing concept formation from a Vygotskian perspective

The first aspect of the analytical framework focused on the aspect of sensemaking that relates to the connection between theory and personal experience. From the Vygotskian perspective, experienced meaning, or sense, is a changing entity that is culturally shaped through learning activities as the scientific and everyday word meanings approach one another (Vygotsky, 1934/1987). In essence, these learning activities need to be situations designed by the teacher to provide the student with an opportunity to relate to and reconstruct their meanings in a way that they would not have been able to do on their own (Miller, 2011). This cultural shaping involves the organization of the everyday word meaning into a scientific meaning system as well as the enrichment of the scientific word meaning by the life experience of the student embodied by the unstructured everyday word meaning (Vygotsky, 1934/1987). The connection between the scientific meaning and the everyday meaning allows for a connection between the abstract, organized meaning system and the concrete experience of the student, leading to conceptual growth (Clarà, 2017; Vygotsky, 1934/1987) (see Fig. 1).

When a concept is formed, this allows for abstract thinking in novel situations for the adolescent (Vygotsky, 1931/1994). The Zone of Proximal Development is a learning space for the student where, through the interaction with a teacher, the restructuring of the student's already learnt word meanings and their connected everyday meanings can produce a more enriched and differently structured meaning system (Clarà, 2017; Miller, 2011). For learning to take place within the Zone of Proximal Development, students need to have already available to them a certain set of word meanings, the meaning of which can change as they are restructured as part of the meaning system that is the focus of the teaching (Miller, 2011). Due to its focus on the *connection between concepts* and *systematization of concepts* (Novak, 2002), concept map construction as part of a classroom activity can be viewed as a socioculturally guided activity that can help mediate the reconstruction of word meaning (Aguilar-Tamayo & Aguilar-García, 2008).

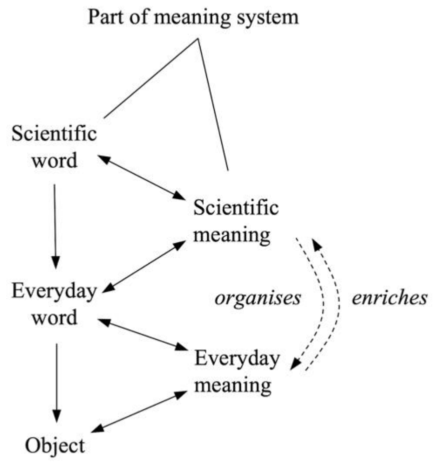

Fig. 1. The relationship between the scientific word meaning and the everyday word meaning in relation to the object of a students' experience. As a student uses a word in relation to an object (or a process), a word's meaning is formed (indicated by double arrows). According to the Vygotskian perspective (Vygotsky, 1934/1987), learning involves a mutual development of scientific and everyday meanings (indicated by single dotted arrows). The scientific word meaning has the benefit of being abstract and part of an organized system of word meanings, whereas the everyday word meaning has the benefit of being concrete and experiential and stands between the object (or process) and the scientific word meaning (indicated by single arrows), Adapted from Clarà (2017)

In terms of coding the connection between the scientific concept system and everyday language in the concept maps in the present study, particular attention was paid to Vygotskian terminology in terms of what could be defined as everyday language and what could be defined as language as part of a concept system and its constituent parts. In essence, the concept system studied was defined as the system describing *chemical equilibrium* (or shift in chemical equilibrium, which was the current topic studied). Concepts well-established for the students (such as "concentration") were considered formed or learnt (also known as spontaneous meanings or concepts; see Clarà, 2017) As more than one fairly new concept was used in connection with learning about chemical equilibrium (such as "reversibility" and "K" [the equilibrium constant]), these were considered not fully formed and regarded as separate from the learnt concepts. Words that could be tied to previous everyday experience (such as the given concept of "color change") were regarded as everyday concepts in the concept maps. Hence, the framework for coding had four aspects as a starting point: concept system connectedness, and the use of new concepts, learnt concepts, and everyday concepts as part of that system of meaning.

2.2. Analyzing scientific language use

The second aspect of the analytical framework focused on the analysis of the scientific language used in concept maps. Many factors influence how student knowledge ends up being represented in concept maps, including overall structure, the freedom of the task (how much structure is provided for the students in terms of concepts given and overall structure indicated) and whether the students construct their own linking phrases between concepts or not (Cañas et al., 2012). Therefore, a valid comparison of knowledge representations in concept maps created under different conditions cannot be made (Cañas et al., 2012). However, in terms of assessing the quality of scientific language used in concept maps, it has been shown that the comparison of correctness and precision of propositions between students is an effective way of assessing differences in quality between concept maps (Burrows & Mooring, 2015; Lopez et al., 2011; Ruiz-Primo, Schultz, et al., 2001; Ruiz-Primo, Shavelson, et al., 2001; Yin et al., 2005). It has also been pointed out that the organization of the map, the comprehensiveness of the topic covered as well as the correctness of the propositions in the concept map all contribute to its overall quality (Besterfield-Sacre et al., 2004). In addition, it has been pointed out that concept choice and the use of relevant language in concept maps reflect developing expertise (de Ries et al., 2022). All these language aspects contribute to the explicitness and precision of language needed for science learning (Lee et al., 2013, 2018). To analyze the language used in the concept maps, the literature above was taken into account as a starting point for inductive coding of the language quality of the concept maps, whereas the analysis of the organization of the concept maps was represented by the Vygotskian analysis of concept connectedness.

2.3. Research question

The research question posed was: What can be elucidated about how student language use relates to the connectedness between scientific and everyday concepts, through the use of a Vygotskian perspective in the qualitative analysis of student concept maps on the topic of chemical equilibrium?

3. Research rationale and methods

3.1. Research rationale

To allow for a nuanced exploration of the patterns in the concept maps in the present study, a qualitative approach was taken to the collection and analysis of data. This approach included purposive sampling (Cohen et al., 2018) to enable maximum variation in the scientific language use and concept connectedness in the concept maps studied, as well as higher reliability in terms of interpretation (Cohen et al., 2018).

3.2. Sampling

Four schools were approached for the research study, where chemistry teachers were asked to provide access to their students. The schools were picked to represent a range of grade intake levels, settings (one small town school, one university town school, and two city schools) and two school systems (represented by three Swedish school classes and two

International Baccalaureate school classes – the latter were from the same school but had different chemistry teachers and were studied during different years). The topic of the shift in chemical equilibrium was chosen as the study of this topic includes a practical lesson (usually the study of the formation of iron thiocyanate) that requires a high degree of sensemaking on behalf of the students regarding the color changes observed. Hence, asking the students to prepare a concept map prior to this practical lesson ensured a fairly similar degree of preparedness among the students in terms of what had been taught (this was also confirmed through conversations with the responsible teachers). The timing of the concept map construction also provided certain representativeness in terms of the students' preparedness for sensemaking of a real-life phenomenon in a classroom situation.

3.3. Student participants

Eighty-eight students ages 16 to 17 volunteered to participate in the study. Their achievement levels (which were provided by the teachers) varied widely, with the higher grades slightly overrepresented in the sample (with slightly less than half of the students representing the two highest achievement levels and the rest evenly distributed over the mid-, low-, and failing levels). Most students had no previous concept mapping experience and 36% spoke a different language from the school language at home (this data was self-reported as part of the data collection).

3.4. Concept mapping rationale

To enable an analysis of the connection between scientific concepts and everyday concepts in relation to scientific language used in the concept maps produced in the study, a balance was struck between freedom of construction, the need for comparative analysis and the necessity for guidance for students new to concept mapping (Cañas et al., 2012). Hence, the students were given four core concepts of chemical equilibrium as a starting point and an everyday concept and were encouraged to add their own concepts as well. Also, particular attention was paid in the present study to recommendations in the literature on how to teach students how to construct concept maps in effective ways (Cañas et al., 2012; Novak & Gowin, 1984; Ruiz-Primo et al., 1997; Ruiz-Primo, Schultz, et al., 2001). In addition, taking into account the research literature showing the difficulties chemistry students have in constructing meaning in connecting experiences and theory through the use of language (Gilbert & Treagust, 2009; Taber, 2013, 2017a; Talanquer, 2015), reflective questions (adapted from the study by Thomas, 2017) and a scaffold was added as part of the concept maps to help students reflect around theory and experience in relation to the concept of chemical equilibrium.

3.5. Concept mapping procedure

Concept mapping was taught to the students in an 80-minute class according to the procedure of Ruiz-Primo et al. (2001), including giving instructions for concept mapping based on the recommendations of Novak and Gowin (1984). Following the procedure of Ruiz-Primo et al. (2001), students first constructed one whole-class concept map, followed by individual practice maps (scaffolded maps on the topic of thermodynamics with five starting concepts) where discussion was allowed, and questions were aired. During the last 20-25 minutes of the lesson, students constructed the scaffolded concept maps on the topic of the shift in chemical equilibrium analyzed in the present study, using the starting concepts of “concentration” (a concept considered learning for all students, as this concept is covered much earlier in both school systems), “reversible”, “K”, “⇌” (new concepts being studied by the students, i.e., concepts relating to chemical equilibrium), and, “color change” (an everyday concept). The students were encouraged to add as many of their own concepts as they liked and to revise their concept maps until satisfied. An evaluation of how well the students managed to construct concept maps showed that 91%used all the concepts provided, 99%used labelled arrows/lines and 99%provided at least one valid proposition (a statement connecting two or more concepts using linking words; see Novak, 2002), which was in line with previous research (Ruiz-Primo, Schultz, et al., 2001).

If students learn how to use concept maps, they can be a useful tool for both support and assessment of knowledge integration (Kinchin, 2020; Novak, 2002; Schwendimann, 2015). However, if students are not properly trained, this can result in a difference between how the students express their understanding in class and what they write in their concept maps (Jin & Wong, 2010). Therefore, to confirm the validity of the concept maps produced in the study, the teachers were shown three concept maps picked at random to represent low-, middle- and high-achieving students from each class. The teachers judged the concept maps representative of the students’ knowledge about chemical equilibrium in all cases.

3.6. Analysis

The concept maps produced by the students were computerized and subjected to content analysis, where Framework analysis (Ritchie et al., 2014) and a constant comparison approach were utilized to organize the data and maintain coding consistency. Framework analysis meant data was coded using NVivo and then charted into a coding matrix with coding labels, where each map could only be classified as one category within a theme. Constant comparison analysis meant the codes were checked for consistency repeatedly throughout the coding process. Both coding themes, i.e., language use and connection between Vygotskian-type concepts, used literature as a starting point for categorization (Besterfield-Sacre et al., 2004; Clarà, 2017; de Ries et al., 2022; Lopez et al., 2011; Ruiz-Primo et al., 1997; Ruiz-Primo, Schultz, et al., 2001; Vygotsky, 1934/1987; Yin et al., 2005). This meant a theoretical first wave of coding using previously defined categorizations found in this literature was used to inform the coding. The codes were then refined inductively in the second wave of coding. The language used in the concept maps was divided into categories based on the patterns in the language describing the concept of chemical equilibrium and shift in chemical equilibrium and ranked following previous examples in the literature. Following the example of Besterfield-Sacre et al. (2004), the four main categories of language use from the first wave of coding (0 – incorrect or irrelevant; 1 – vague and imprecise; 2 – correct but incomplete/partial; 3 – precise, correct, and complete) were divided into subcategories following the patterns of the data and then further refined. The connectedness between scientific concepts (learnt and new) and everyday concepts in the concept maps were divided into categories inductively based on the patterns in the data. The code definitions were refined iteratively as data was added (Miles et al., 2014), but did not change after the concept maps of the last two student groups were added, indicating data saturation (Cohen et al., 2018). A codebook of definitions was maintained throughout, and coding was accompanied by memoing. Finally, the codes were checked and verified by an associate professor of educational science with a PhD in Science, leading to some minor corrections of the code definitions. Translations of concept maps from Swedish to English were done by the author, who is a qualified chemistry teacher with teaching experience from both the Swedish education system and the International Baccalaureate education system. Relations between different codes discovered through NVivo queries were further explored using SPSS.

3.7. Considerations regarding the methodology

In the present study, a qualitative methodology was used to explore the relationship between scientific language use and sensemaking in science. Qualitative methodologies carry low generalizability (Cohen et al., 2018), but can on the other hand be used to explore context and nuance in data that cannot be covered by statistical analysis (Flyvbjerg, 2001). However, qualitative methodology is also reliant on its analytical framework. In the analysis, sensemaking was defined from an analytical perspective as students relating experience and theory for the purpose of making sense of phenomena, and Vygotsky's definition of the scientific and everyday concept (Vygotsky, 1934/1987) was used for the analysis. An objection to a Vygotskian categorization of concepts is that it is inherently difficult to decide whether a concept has been formed by a student or not if this concept is only integrated into the concept map without a proper definition. However, as Vygotsky points out, the functional use of a concept as part of a linguistic definition indicates a high degree of concept formation due to the demonstration of conscious awareness around its use (Vygotsky, 1931/1994). Hence the functional incorporation of concepts into concept maps can itself be evidence of their (full or partial) formation.

3.8. Ethical considerations

No sensitive data was collected during the study and the participants were not at risk of injury, which meant no ethical permit was required according to Swedish law (SFS 2003:460). However, the study followed the general ethical guidelines from the Swedish Research Council (2017), which include voluntary participation for all participants and full information about the study, its purpose and how the data was handled. Data handling followed GDPR, including the pseudonymization of concept maps and the safe storage of consent forms and code lists for pseudonymization. Before archiving upon the project's finalization, the data will be anonymized.

4. Results

4.1. Patterns of language use in the concept maps

The inductive coding showed that with increasing specificity of language, more relevant concepts were used in the concept maps as well, giving a more connected and complete definition of chemical equilibrium (see Table 1).

4.2. Patterns of connectedness between scientific and everyday concepts in the concept maps

In the different categories of concept maps coded for scientific-everyday concept connectedness, four out of five categories showed a disconnect between the everyday word "color change" and the theory of chemical equilibrium (see Table 2).

Table 1
Description of the language used in the student sample concept maps, grouped by map category

Initial category	Further defined category	Description of language use and definition of the chemical equilibrium of the concept maps that belong to this category
3	3	Chemical equilibrium is defined in the clear and precise language in these maps. The essential concepts are connected. Most aspects of chemical equilibrium at this level are covered, and concepts are defined when relevant.
2	2+	Several relevant concepts are connected to a coherent definition of the equilibrium process. The concept maps may contain some vague parts but also relevant concept definitions.
	2-	Some relevant concepts are used to provide a clear but partial definition of chemical equilibrium in these maps. Occasionally, one of the propositions in a concept map may be incorrect but at least the language is explicit. Some concepts may be vaguely connected.
1	1+	Some concepts related to chemical equilibrium are described superficially in these maps. The concept maps are somewhat coherent in how the concepts are connected. Occasionally, concept definitions are given.
	1-	One or a few concepts related to chemical equilibrium are brought up in these maps, mostly in a vague manner. Less relevant concepts are also sometimes used, and the concepts can be connected in a somewhat incoherent way.
0	0	Non-existent or insufficient connections of concepts are given in these concept maps. Vague language is used. The concept maps can have irrelevant sections and/or incorrect/insufficient expressions.

Table 2
Description of different ways of connecting scientific concepts (new and learnt) with everyday concepts in the concept maps

Category	Description of the pattern of concept connectedness in the concept map belonging to the category
New-learnt-everyday	New, learnt, and everyday concepts are linked together in these concept maps. These concept maps are characterized by a high degree of interconnectedness and cross-links are common.
New-learnt	Theoretical (new and learnt) concepts are connected in these maps, which often show some cross-links between sections (vague or mathematical/symbolic). Some of the concept maps have more of a branched, linear-type construction and are not connected between sections. Typical of these concept maps is a very vague use of the everyday concept of "color change", which also shows up as disconnected from the other concepts.
New-learnt / learnt-everyday	Theoretical (new and learnt) concepts are connected in these maps, which typically show vague or no cross-links between map sections. Many of these concept maps have more of a branched, linear-type construction. Typical of these concept maps is that the concept "color change" is defined as an observational property of the reaction/experiment and thereby connected to scientific experimental concepts, but this is not in turn connected to the theory of chemical equilibrium.
Learnt-everyday	Only one concept map showed no knowledge of chemical equilibrium, but a connection between "concentration" and "color change".
No connection	No comprehensible connection is made between the concepts in these concept maps.

An example of the first category, where new, learnt and everyday concepts were connected within the concept map, is shown in Fig. 2. Thirty-nine students (44%) produced this type of concept map.

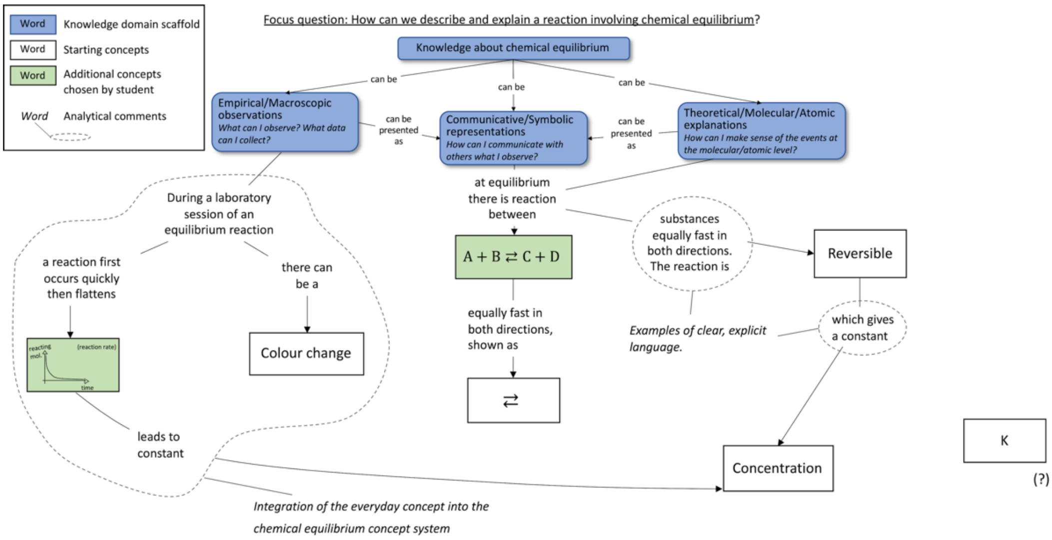

Fig. 2. Example of a student-produced concept map (computerized) where the everyday concept of "color change" has been connected to the concept system of chemical equilibrium (concept map category "Everyday-Learnt-New"). This concept map was coded 2+ in terms of language use in defining chemical equilibrium, which can be seen through the explicit language connecting the different concepts and the relevant own concepts chosen by the student (shown in green). Note that the given concept "K" was not used by the student. Translated from Swedish by the author

An example of a concept map of the "New-Learnt" category, showing the everyday concept disconnected from the scientific concept system, is shown in Fig. 3. Nineteen students (22%) produced this type of concept map.

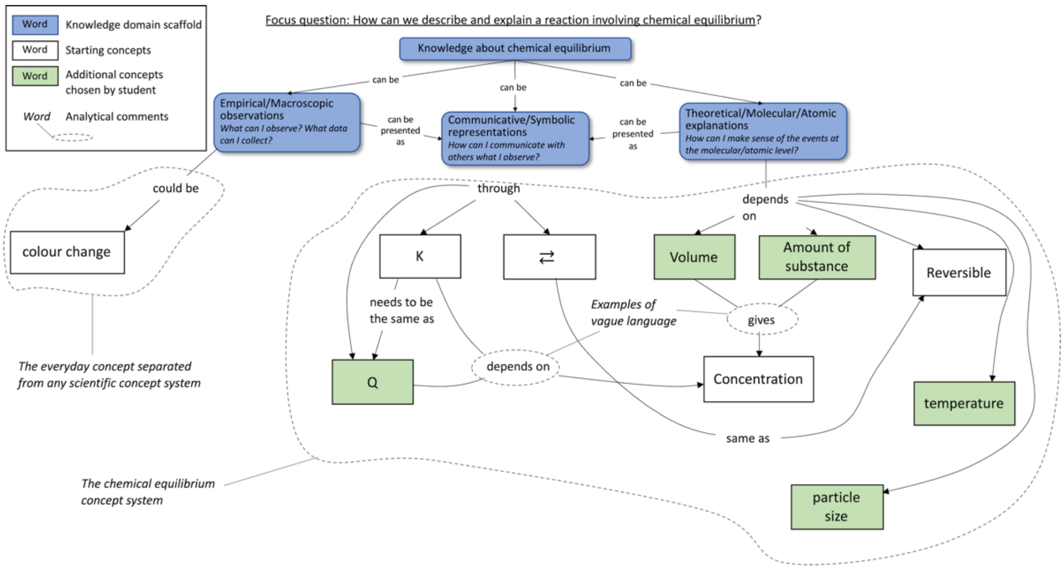

Fig. 3. Example of a student-produced concept map (computerized) where the everyday concept of "color change" has *not* been connected to the concept system of chemical equilibrium (concept map category "New-Learnt"). This concept map was coded 1- in terms of language use in defining

chemical equilibrium, which can be seen through the vague language connecting the different concepts, but also in the purely mathematical definitions given for chemical equilibrium (“K needs to be the same as Q”, and “Volume and amount of substance gives concentration”). Translated from Swedish by the author

Fig. 4 shows an example of the type of concept map in the category “New-Learnt/Learnt-Everyday”, where the everyday concept is defined as an experimental property. Twenty-four students (27%) produced this type of map.

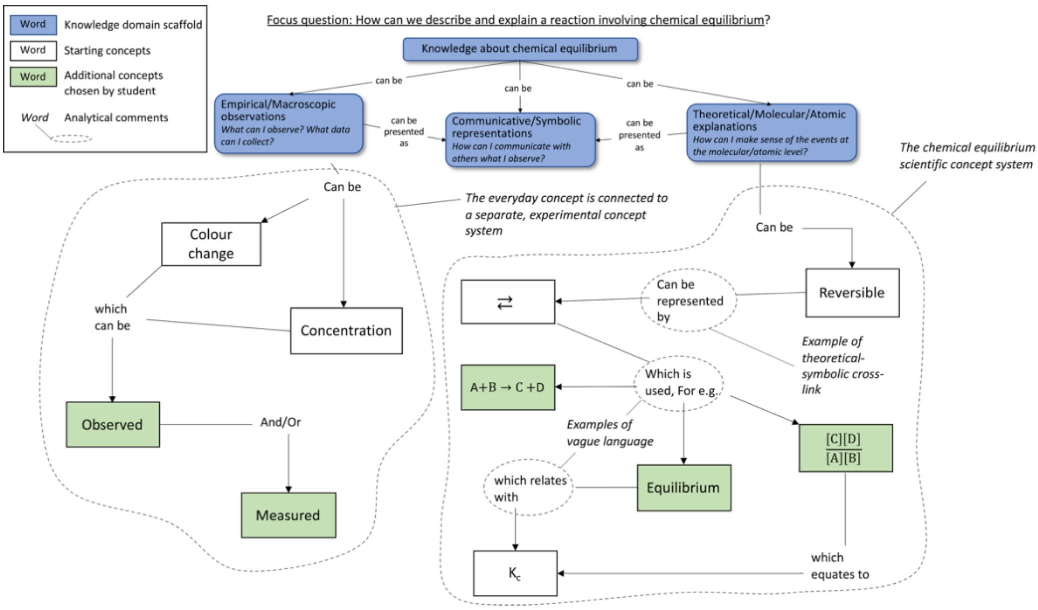

Fig. 4. Example of a student-produced concept map (computerized) where the everyday concept of “color change” has *not* been connected to the concept system of chemical equilibrium and is instead included in a separate, experimental concept system (concept map category “New-Learnt/Learnt-Everyday”). This concept map was coded 1- in terms of language use in defining chemical equilibrium, which can be seen through the vague language connecting the different concepts, but also through the mathematical expression associated with chemical equilibrium (the concentration quotient is equated to K_c, which is related to equilibrium)

Fig. 5 shows an example of the type of concept map in the category “No connection”, which included concept maps with no comprehensible connections between the different types of concepts. Five students (6%) produced this type of map.

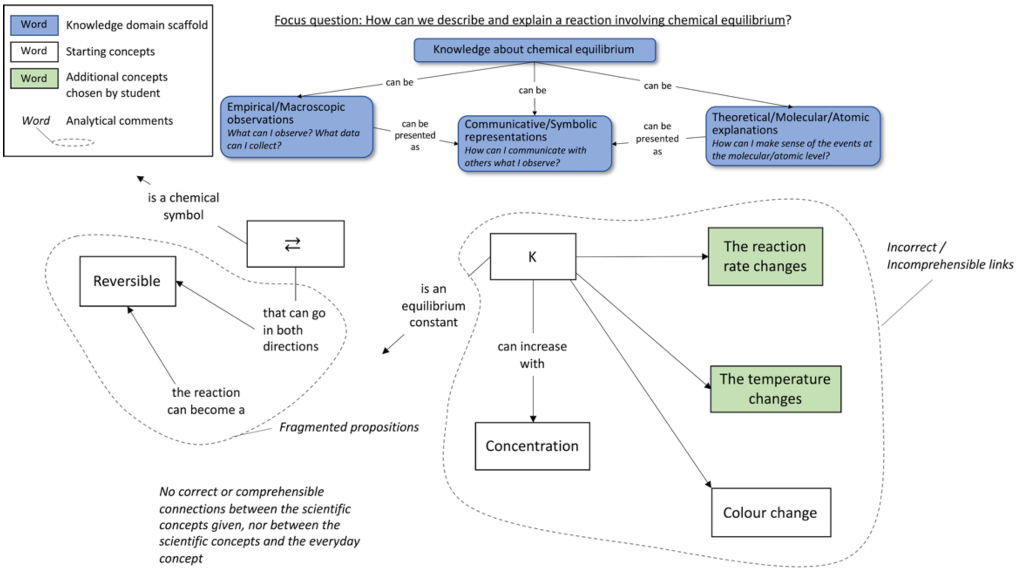

Fig. 5. Example of a student-produced concept map (computerized) where no connection is noted between the different types of concepts (new, learnt or everyday concepts). This concept map was coded 0 in terms of language use in defining chemical equilibrium, which can be seen through the incorrect or incomprehensible links between the concepts, but also in the fragmented statements produced by the student. Translated from Swedish by the author

4.3. The relationship between language use and concept connectedness in the concept maps

When the distribution of the different categories of language use was explored with regard to the incorporation of the everyday concept into the chemical equilibrium concept system using the chi-square statistic, a statistically significant difference was found in the data between students using specific language (categories 2–, 2+ and 3) and students using either vague language or not sufficient language to connect the concepts (categories 0, 1– and 1+) ($\chi^2 = 10.193$, $\rho = 0.01$). As can be seen in Fig. 6, students using a more specific language significantly more often integrated the everyday concept compared to students using a vague language.

Looking more closely at the data, based on the interaction between scientific language use and scientific/everyday concept connectedness, the concept maps could be divided into three overall groups:

1. One small group (*N* = 6) where little or insufficient connections were made between the concepts.
2. In one larger group (*N* = 39) where vague or superficial language was used (coded as categories 1– and 1+), some concepts of chemical equilibrium were connected and a connection between the theory of chemical equilibrium and the everyday concept of "color change" was made in 20-30% of the concept maps.
3. In another large group (*N* = 43) where the specific language was used (coded as categories 2–, 2+ and 3), some or all relevant concepts were used to define

chemical equilibrium, and 60-65% of the concept maps contained a connection between the scientific concept system and the everyday concept of “color change”.

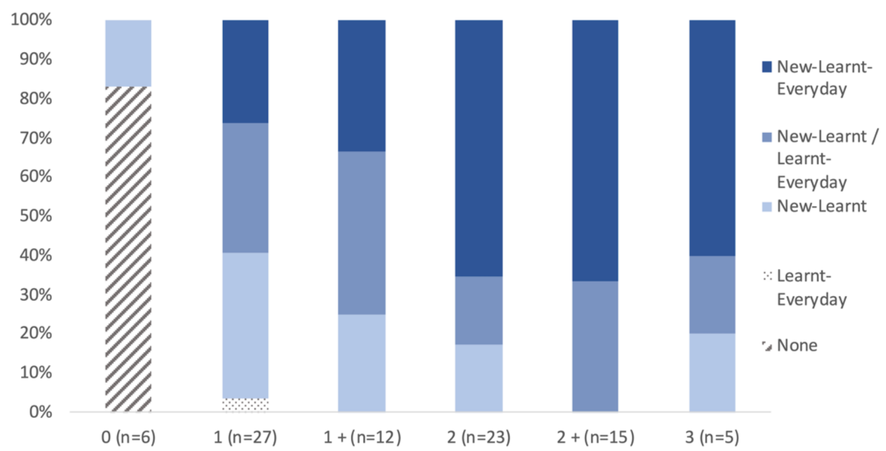

Fig. 6. The distribution of type of concept connectedness in the concept maps (between the different types of scientific concepts – i.e., new and learnt – and everyday concepts), with percentage for each category of concept connectedness shown for each type of language use. The types of language use ranged from 0 (incorrect, irrelevant, or not contributing to sensemaking about chemical equilibrium) to 3 (complete and correct in terms of explicitness and precision in relation to what has been taught)

The distribution of the incorporation of the everyday concept into the scientific concept system was also explored in the data using the chi-square statistic with regard to whether the student spoke the school language at home or not, and a statistically significant difference was found in the data between students who spoke the school language at home and those who did not ($\chi^2 = 4.523$, $\rho = 0.033$). As can be seen in Table 3, students who spoke the school language at home significantly more often incorporated the everyday concept as part of the chemical equilibrium concept system, compared to students who did not speak the school language at home. Out of the 88 students participating in the study, 6 declined to give information on whether they spoke the school language at home.

Table 3
Crosstabulation of whether the student spoke the school language at home versus whether the everyday concept was integrated into the chemical equilibrium concept system in the concept map produced by the student

	Students not speaking the school language at home	Students speaking the school language at home	Total
Everyday concept integrated	16	21	37
Everyday concepts not integrated	30	15	45
Total	46	36	82

5. Discussion and conclusion

This study aimed to, from a qualitative perspective, examine the relationship between students' scientific language use and the aspect of sensemaking that is represented by the connectedness between scientific and everyday concepts, here studied on the topic of the shift in chemical equilibrium.

The coding of scientific language used in the concept maps showed that increased use of specific language also meant more relevant concepts were used to explain the shift in chemical equilibrium, confirming previous research (de Ries et al., 2022). The connection between expertise and concept interconnectedness in concept maps has also been shown by others (Kinchin, 2020; Kinchin & Cabot, 2010; Koponen & Pehkonen, 2008). This result also connects the scientific language use of students with their ability to construct a coherent definition of chemical equilibrium through a concept system and indicates that the language use of students is intimately connected with their ability to define a scientific concept. This result agrees with studies showing the beneficial effects of concept mapping on literacy and language development (Isabelle, 2015; Wang & Chen, 2018), possibly indicating a dialectical relationship between language use and the development of the conceptual structure.

The coding of scientific and everyday concepts in the concept maps showed that a large part of the student sample had difficulties in sensemaking, i.e., connecting the scientific theory of chemical equilibrium with the everyday concept of "color change" (a proposed observation using a word meaning steeped in everyday experience). This agrees with previous research showing chemistry students having difficulties connecting observations (including qualitative observations such as changes in color etc.) with theory in chemistry (Gilbert & Treagust, 2009; Taber, 2013, 2017a; Talanquer, 2015), and also with previous research in concept mapping showing low connectedness between scientific concepts and everyday life concepts in concept maps at the upper secondary level (Reiska et al., 2015). Interestingly, only the most highly interconnected concept maps in the present study incorporated the everyday concept as part of the scientific concept system.

In the study sample, there was a significant difference between students using vague language and specific language in the concept maps in terms of sensemaking. That is, there was a connection in the student sample between using a specific scientific language, organizing a scientific concept system and connecting this scientific concept system to the everyday concept given. This data supports Vygotsky's theory of conceptual development as the building of a conceptual system and a journey from the abstract to the concrete (Rowlands, 2000). However, the data also underlines the importance of students having access to a well-developed scientific language to access learning as meaning formation within the Zone of Proximal Development, defined as the restructuring of the everyday concept in relation to the scientific concept system (Clarà, 2017). As shown by the poorer sensemaking produced by students not speaking the school language at home, students learning science in their second language may need extra support for sensemaking in the classroom. In other words, the study indicated a relationship between language competency and sensemaking in science.

As this was a qualitative study, the results cannot be generalized to larger student populations. However, the study results highlight the importance of the further study of language use and sensemaking in science using concept maps, with possible implications both for the study of learning processes and formative assessment practices using concept mapping in science education. For instance, structural analysis of concept maps (Anohina-

Naumeca, 2015; Kinchin, 2020) could potentially be used to formatively assess student sensemaking through an investigation of their incorporation of everyday concepts into scientific concept systems, and further research could explore how student language use is related to sensemaking during concept map construction. The results of this study also indicate a possible role for concept maps as a tool for teachers to encourage both individual and collaborative sensemaking through the integration of everyday concepts into scientific concept systems as part of science classroom learning. Using concept mapping as a tool for sensemaking might be especially beneficial if students can construct and then revise their maps several times over a longer period of time (Campbell, 2022). However, support for second-language learners may be needed during such practices. Such support could be explaining concepts to students in words that are known to them (Gieske et al., 2022), shifting between student home languages and the language of instruction as part of a translanguaging practice (Slotte & Ahlholm, 2017), or using small-group discussions to support students sharing their scientific language use with, and learning from, each other (Jakobsson & Kouns, 2023)

Author Statement

The author declares that there is no conflict of interest.

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