Scaffolding CLIL in the science classroom via visual thinking: a systemic functional multimodal approach

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Abstract

Content and Language Integrated Learning (CLIL) is a dual-focused pedagogical approach in which a foreign language is used for the learning and teaching of both content and language. CLIL specialists have recommended different types of scaffolding techniques, mainly in relation to language use. However, there is increasing interest in multimodal scaffolding techniques involving language in combination with visual resources. Within this context, visual thinking methodology is considered here as a potentially valuable tool for mediating CLIL. Using a Systemic Functional Multimodal Discourse Analysis (SF-MDA) approach, this study aims to identify several features of visual thinking that could help scaffold CLIL in the science classroom. The approach is explored in relation to students' understanding and communication of complex scientific knowledge in a foreign language in upper secondary education.

Keywords: Content and Language Integrated Learning (CLIL), scaffolding, visual thinking, multimodal discourse analysis, systemic functional theory, scientific language.

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1. Multimodal scaffolding and CLIL

The term 'scaffolding' operationalises the Vygotskyan notion of the Zone of Proximal Development (Wells 1999), according to which learning occurs within a zone marked by the distance between the learner's actual development level and the level achieved in collaboration with a more expert individual. In order to achieve scaffolding in a teaching and learning context, Gibbons (2003) advocates for provision of 'meaning abundance': an upsurge in various modes of learning in interaction with language. This provision of 'message abundance' could be done through 'mediational texts and artefacts', which structure or mediate the learning in a lesson (Hammond and Gibbons 2005, 17). Multimodality, which is concerned with the meanings arising from the integration of language with images and other resources in texts, interactions and events, is considered a valuable means for mediating teaching and learning processes, given that content is represented in various semiotic forms (Kress 2000; Kress, Tsatsarelis, Ogborn, and Jewitt 2001; Tang, Delgado, and Moje 2014; Author 2011). However, albeit the increase in the use of visual materials arising from the communicative approach to language teaching, the implications of a multimodal approach to L1 and L2 teaching in general, and to Content and Language Integrated Learning (CLIL) in particular, requires further exploration. Within this context, we propose a visual thinking (i.e. multimodal) methodology as a potentially valuable tool for mediating CLIL.

In the past two decades, CLIL has become a central issue in the field of foreign language teaching and learning, particularly in Europe. The term has been adopted to cover a wide diversity of practices for teaching and learning a content subject and/through a foreign language. In CLIL, the foreign language is frequently the means used to resolve the learners' difficulties that arise in that same language. This practice may hinder and, in some cases, prevent L2 learning and comprehension of disciplinary knowledge. These difficulties are aggravated in some discourses, such as science, in which complex linguistic patterns require a high level of command of L2.

Recent research has shown that CLIL teachers require discipline L2 awareness in order for their students to develop their own awareness of L2 academic features, and at the same time, to improve content learning (Nikula, 2015; Andrews and Lin 2017; He and Lin 2018). Scaffolding in this area begins with teacher language awareness. CLIL research has mainly focused on the use of linguistic scaffolding strategies, such as rephrasing, recasting, cue elicitation (e.g. Dafouz 2011; Llinares, Morton, and Whittaker 2012) or the process of translanguaging (Nikula and Moore 2016), 'by which students and teachers engage in complex discursive practices that include ALL the language practices of ALL students in a class in order to develop new language practices' (García and Kano 2014).

In addition, emerging research has identified the use of multimodal scaffolding resources, such as gestures, pointing, or visuals for mediating CLIL learning (Evnitskaya and Jakonen 2017; Forey and Polias 2017). Handbooks for CLIL implementation similarly point out the importance of visual resources as scaffolding tools, given that visual representations are integral components of most disciplines (e.g. timelines are used to organise events chronologically in history; and still images and animations are used to represent natural phenomena in science). These CLIL handbooks focus mostly on content learning by offering strategies for arranging content at the discourse level in graphic organisers (e.g. Ball, Kelly, and Clegg 2015; Coyle, Hood and Marsh, 2010; Dale, van der Es and Tanner 2011; Genesee and Hamayan, 2016). These manuals rarely address the use of visualisations to raise awareness about language features below the discourse level (i.e. the lexicogrammatical level), which is a potential source of difficulty for any speaker of a language.

While in L1 science, visualisations function to construct scientific knowledge, in CLIL they may also serve to scaffold learners' comprehension of the disciplinary content and language learning both at discourse level (genre) and below (e.g. clauses, noun phrases). As an example, CLIL can make use of distinct types of visual and multimodal representations to specifically address language issues which arise, for instance, from the extensive use of grammatical metaphor in scientific language, which leads to issues such as nominalisations, high lexical density, and syntactic ambiguity (see Halliday 1993a). Mastering these features of scientific writing is of paramount importance in language learning for constructing both appropriate scientific arguments and scientific knowledge itself (e.g. Järvinen 2010; Schleppegrell 2004). Recently, CLIL research has proved that multimodal practices could be well-coordinated with further linguistic practices to facilitate students' meaning-making in the CLIL classroom (Lin and Wu 2015; Yi Lo and Lin 2015). In this vein, based on Lin's (2015) concept of trans-semiotising, which covers the use of multimodalities to do the conceptualizing work of learning in CLIL, Lin and Wu (2015, 300) propose that

> successful CLIL depends on guidance through interaction in the context of shared experience, with the additional principle that (struggling) learners should be allowed to translanguage and trans-semiotise (…) by drawing on whatever familiar semiotic resources they have at their disposal: e.g. L1/L2 everyday wordings, L1/L2 academic wordings, as well as visuals, drawings, gestures, etc.

Therefore, this paper explores the use of visual thinking as a potentially valuable multimodal tool for scaffolding secondary education learners' acquisition of the conventions of the academic and scientific register, and their understanding of the scientific content in CLIL. In this analysis we adopt a Systemic Functional Multimodal Discourse Analysis (SF-MDA) approach. In the following sections we first provide a brief background to visual thinking, followed by an outline of the SF-MDA approach. We then outline some of the features of academic and scientific discourse that present challenges for L2 learners. Various options for mediating the complexities of CLIL language in science are offered, which are illustrated through a selection of sketchnotes based on scientific articles in physics. By selecting these scientific articles, this analysis serves to prove that visual thinking may contribute to make accessible highly complex and abstract linguistic expressions and, therefore, can be useful in lower levels of scientific and academic language, such as upper secondary education.

2. Visual thinking

Visual thinking is a multidisciplinary subject informed by work in different fields such as research on information design (Tufte 1983), spatial language and thinking (Tversky 2005), knowledge visualisation (Eppler 2013), visual perception and thinking (Arnheim 1969) or Peirce's idea of 'diagrammatic reasoning' (e.g. see Shin 2002). It encompasses a variety of semiotic resources, such as written language, basic visual shapes, and graphs, in order to meet goals such as mediating complex information, revealing a flow of ideas, or generating critical thinking. Among the results of visual thinking practices are well-known genres such as mind maps, concept maps, storyboards, maps, storymaps, infographics, sketchnotes or simply visual notes to accompany some explanation (Sibbet 2013). Recently, different practitioners have contributed to these resources and genres in the field of business (Roam 2008; Rohde 2013; Sibbet 2013), where visualisation constitutes a common practice in meetings, presentations and discussions.

Many of these visual thinking genres have already entered the classroom, and there has been some research on determining their effects on different aspects of learning (e.g. Nesbit and Adesope, 2006). For example, Bobek and Tversky (2016) have shown that learner-generated visual explanations (as opposed to verbal explanations) increase understanding and improve learning in STEM subjects. Yet, the effectiveness of visual thinking for CLIL remains relatively untested (e.g. Forey and Polias 2017).

Several studies have explored the effects of the combination of verbal and pictorial information for language learning. The dual-coding theory (Clark and Paivio 1991; Sadoski and Paivio 2001) has inspired much of this research. This theory assumes that cognition takes place in two independent but connected codes: the verbal code for language and the nonverbal code for mental imagery. In terms of vocabulary learning, for example, findings point to a positive effect of dual coding on vocabulary recall (Mayer and Anderson 1991; Paivio and Csapo 1973). When the processing of concrete and abstract language is addressed, various studies suggest that the dual-code approach should be supplemented with a context-availability method, which argues that faster recognition of concrete versus abstract nouns results from a larger contextual support of concrete words and not from a distinct nonverbal system (Aslandağ and Yanpar 2014; Jessen, Heun, Erb, Granath, Klose, Papassotiropoulos and Grodd 2000). Visual thinking makes use of both techniques: it uses word-image equivalence (dual-coding) and also it contextualises language (context-availability method).

In what follows, we explain the systemic functional multimodal approach which underpins the visual thinking methodology developed in this study. Following this, the difficulties of scientific writing are discussed in relation to 'grammatical metaphor' which accounts (in part) for the complexity and abstractness of scientific language. From there, visual thinking as a resemiotisation strategy in the science classroom is introduced and possible pedagogical interventions are presented. Lastly, some concluding comments are made in relation to the visual thinking approach for CLIL.

3. Methodology: Systemic Functional Multimodal Discourse Analysis (SF-MDA)

Multimodal Discourse Analysis (MDA) is a branch of discourse analysis in which language is studied together with other modes of communication, such as images, gestures, sounds, and icons. In this paper, we make use of Systemic Functional Multimodal Discourse Analysis (SF-MDA) as the framework of analysis because it is concerned with the functions and systems through which language, images and other resources create meaning.

Among the prominent approaches in MDA, SF-MDA draws on Halliday's Systemic Functional Linguistics and extends the underlying theoretical principles to the study of multimodal semiotic resources (e.g. Kress and van Leeuwen 2001; Author 2008; Author, Author and Author 2016). The three most relevant principles here are: (a) constituency and stratification, (b) the metafunctional hypothesis, and (c) resemiotisation.

3.1 Constituency and stratification

There are two structuring principles in systemic functional linguistics (SFL): constituency and stratification. Constituency addresses the syntagmatic dimension of the language, which accounts for compositional layers or ranks in texts. These ranks are discourse (text extending beyond the sentence), clause complex, clause, phrase/group, word, and morpheme, where each rank is composed of elements from a lower rank (Halliday and Matthiessen 2014, 21-22). SFL is also concerned with three strata, or levels of abstraction, where a higher stratum is realised through choices in the next lower stratum, as follows: the discourse semantics stratum (text and discourse) is realised through choices in the lexicogrammar stratum (clause), which in turn is realised in phonology (for spoken language) and graphology (for written language).

3.2 Metafunctions

Language and other semiotic resources are structured (differently) to make meanings which are conceptualised in terms of metafunctions: namely, (a) *ideational* metafunction for making sense of and construing events and things in the world (i.e. *experiential* meaning) and making logical connections between events (i.e. *logical* meaning), (b) *interpersonal* metafunction for enacting social relations, and (c) *textual* metafunction for arranging meanings coherently (Halliday 1978; Halliday and Matthiessen 2014).

In language, experiential meaning construes events as being organised around a process, (something happening), the participants engaging in the process and the circumstances in which the process is taking place. Processes are categorised according to what type of action is taking place. For example, Material processes typically encode concrete actions, such as doing or giving; and Relational processes encode states of being. In science, Relational processes are favoured. These are typically used to define terms (e.g. x = y), assign attributes to entities (e.g. x has y), and construct arguments (e.g. x causes y). In typical spoken language, logical meaning is realised through conjunctions which encode logical connections between and among clauses. Interpersonal meaning is realised (1) in the clause through the Mood system (e.g. declarative, interrogative, and imperative), which is turn realises choices in speech function from the rank of discourse (e.g. statements, questions, commands and offers) and mood choices and (2) in the Modality system, which encodes degrees of likelihood, obligation, usuality, obligation and inclination. Finally, textual meaning is realised in the way information is organised in text. Although there are also metafunctionally-based systems which function across larger passages of text (see Martin and Rose 2007), this study is largely concerned with Halliday's clause grammar (e.g. Halliday and Matthiessen 2014) as the basis for the construction of meaning through language and other multimodal resources, such as images.

3.3 Resemiotisation

This concept resonates well with Lin's (2015) concept of trans-semiotising in CLIL. Resemiotisation entails the transformation of ideas from a source text, interaction or event into another meaning-making form (Iedema 2003) using linguistic, visual and other resources. Resemiotisation can be conceptualised as intersemiotic translation, which is 'the basis of cultural communication through which ideas are circulated, translated and explained using language, images and other semiotic resources' (Author, Author and

Author 2016). In conclusion, resemiotisation becomes a basic concept for visual thinking as in visual thinking abstract meanings are made accessible through the process of resemiotisation, whereby complex linguistic constructions in scientific texts are reconstrued more accessibly using images and other multimodal resources.

4. Grammatical metaphor

Academic scientific texts are typically written in language which is both highly abstract and highly technical. These are critical features of academic and scientific discourse which present challenges in CLIL as well as other learning contexts. Behind the abstraction and technicality is what Halliday (1993a, 1993b) refers to as grammatical metaphor. Halliday (1993a) points to grammatical metaphor as a central component of the evolution of scientific English. As Halliday (1993b: 80) explains, the traditional wordings in English for realising processes, participants, circumstance and logical reasoning are:

- Verbs realise processes (actions, events, mental processes, relations).
- Nouns realise participants (people, animals, concrete and abstract objects which take part in various processes).
- Adverbs and prepositional phrases realise circumstances (time, place, manner, cause and condition).
- Conjunctions realise logical relations between one process and another.

Based on these ideas, Halliday (1993b: 80) gives the following example of the traditional (or congruent) way of writing:

(1) **The cast** [noun] **acted** [verb] **brilliantly** [adverb] **so** [conjunction] **the audience** [noun] **applauded** [verb] **for a long time** [prepositional phrase].

Halliday (1993) shows how this can be reworded metaphorically using grammatical metaphor:

(2) The cast's brilliant acting [noun] drew [verb] lengthy applause [noun] from the audience [prepositional phrase].

In the metaphorical version, the processes **acted** and **applauded** have become nouns **acting** and **applause**; the participant **the cast** has become a possessive; **the audience** has become part of a prepositional phrase; the circumstances **brilliantly** and **for a long time** have become adjectives in the noun group; and the logical relation **so** has become a process **drew**. As Halliday (1993b) explains, the effect is that acting and applauding appear as things, and the only event which takes place is the causal relation between these two things.

Similarly, grammatical metaphor configures scientific and academic concepts through objectification of the various processes and entities. This results in several related complexities in written CLIL scientific language such as nominalisation, lexical density, and syntactic ambiguity (e.g. see Halliday 1993b).

5. Scaffolding CLIL in the science classroom: visual thinking as a resemiotisation strategy

Using a Systemic Functional Multimodal Discourse Analysis (SF-MDA) approach, this study aims to identify several features of visual thinking that could help scaffold learners' development of CLIL in scientific English, mainly concerning grammatical metaphor and issues at lexicogrammar level. In the examples provided below, we apply the principles of constituency and stratification, metafunctions and resemiotisation.

The high incidence of grammatical metaphor in scientific writing results in the objectification of meanings as participants, process and circumstances become abstract entities which in turn are related to other abstract entities. One effect of this is that grammatical metaphor increases the lexical density of scientific writing as information is packaged into abstract entities in relational clauses, which in turn are connected to other similar configurations. In this way, scientific language reorders the physical world, with the assistance of mathematical symbolism, scientific diagrams and graphs. In visual thinking, however, processes, participants and circumstances can be represented by combining very simple shapes. To these basic shapes, other visual thinking elements that represent both quantitative and qualitative data such as graphs can be added. By accessing the meaning potential of this array of semiotic resources, the ideational meaning of scientific content, densely packed through grammatical metaphor in the scientific register, can be made more accessible through resemiotisation in visual thinking texts. Author, Author, Author and Author (2018) identify five types of resemiotisation in skechnotes (see Table 1). Type 2, for instance, addresses the translation from language in the original text (scientific paper) into a visual representation in the sketchnote.

RESEMIOTISATION TYPE	IN THE PAPER	IN THE SKETCHNOTE	MEANINGS/METAFUNCTIONS

Type 1	Incongruent linguistic system	→	Congruent linguistic system.	- IDEATIONAL: participants, processes and circumstances are kept in resemiotisation. - INTERPERSONAL: increases through unpacking of grammatical metaphor and more accessible message. - TEXTUAL: information is conveniently organised for understanding.
Type 2	Congruent or incongruent linguistic system	→	Visual system (image)	- IDEATIONAL: participants, processes and circumstances are kept in resemiotisation. - INTERPERSONAL: increases through mechanisms such as visual metaphor and humour. - TEXTUAL: language and image system are connected through convenient organisation and position of the parts. Cohesion.
Type 3			Congruent or incongruent linguistic system → Visual system (image)	
Type 4	Mathematics image system (graph, diagram)	→	Mathematics image system (graph, diagram).	- IDEATIONAL: participants, processes and circumstances are kept in resemiotisation. - INTERPERSONAL: increases due to the resulting uncluttered version of the original. Decrease of intricacy of display. Comments and labels included. - TEXTUAL: Essential information for understanding is selected and prioritised through visual marking devices. Cohesion (graph/diagram parts are linked to comments).
Type 5	Mathematics symbolism system	→	Linguistic system	- IDEATIONAL: ideation, participants, processes, circumstances, and relations are kept in resemiotisation. - INTERPERSONAL: increases through the use of simple language. - TEXTUAL: information is conveniently organised and positioned for understanding.

Table 1. Resemiotisation types identified in sketchnotes (Adapted from Author, Author, Author and Author 2018).

Due to the nature of the phenomena described in science, science textbooks are rich in visual devices that depict the processes that characterise the content subject, similar to the example shown in Figure 1, where several content-based visuals are used. For example, in the first multimodal complex, i.e. structures that combine language, images, graphs, and various other semiotic resources into cohesive units of meaning[1],

[1] Textual meaning can be identified in the distribution of visual thinking resources in the arrangement of these multimodal complexes within the visual thinking genre at the discourse level. In addition, it can be also identified within the multimodal complex itself. In this case, the proximity of elements, compositional vectors and frames around multimodal complexes help mark them as units of meaning.

(‘Definition of skyrmion lattice’), a visual depicts the skyrmion as a ‘magnetic spin texture’. The words ‘magnetic spin texture’ and the information concerning the shape of the skyrmion contained in the paper are resemiotised and represented visually. This visual creates an anchor point that helps the reader of the scientific article understand the language that addresses the shape of the skyrmion. Similarly, in multimodal complex 2 in Figure 1, resemiotisation is identified in the sketch of a multilayer structure, which is not found in the original article (see Figure 2). Through resemiotisation this sketch makes reference to the following sentence: ‘In step one, PMA thin films with a nominal structure of [Co (0.5 nm)/Pd (1 nm)]10 were grown on naturally oxidized Si substrates with a Pd seed layer by DC magnetron sputtering in a 0.67-Pa Ar atmosphere (base pressure ~ 1.2×10^{-6}Pa)’.

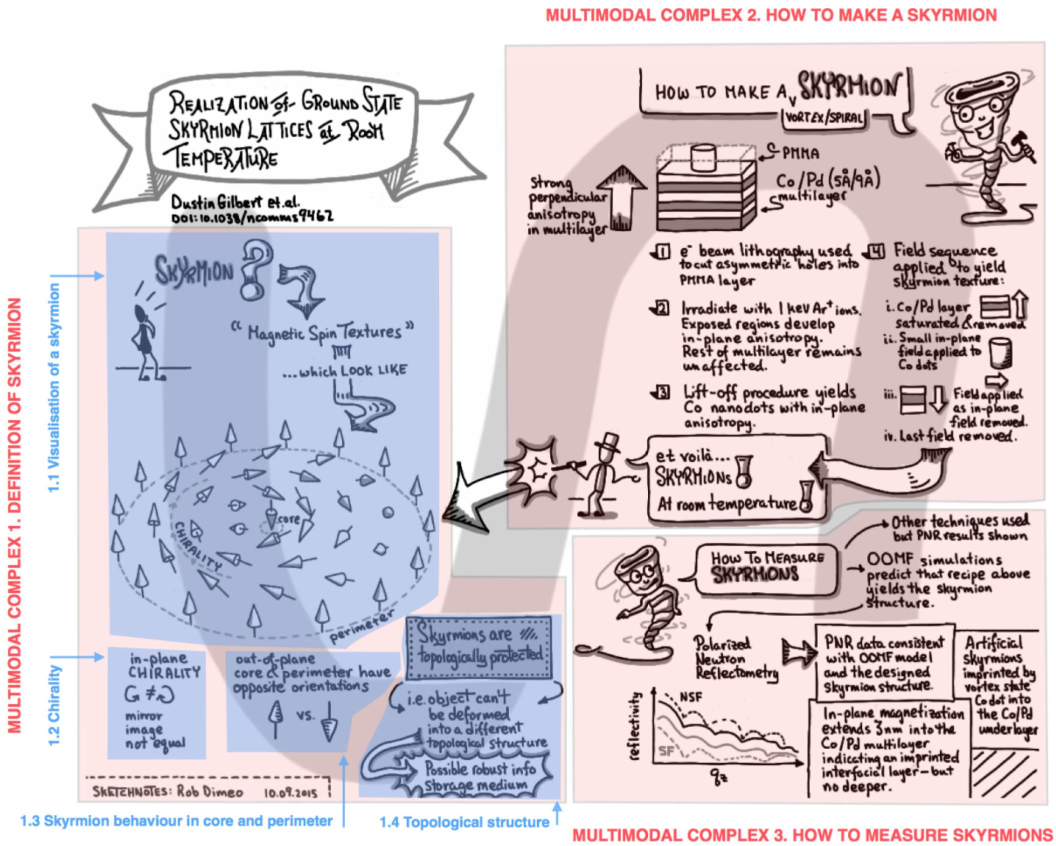

Figure 1. Sketchnote ‘Realization of ground state skyrmion lattices at room temperature’ by Robert Dimeo, based on Gilbert, Maranville, Balk, Kirbi, Fischer, Pierce, Ungury, Borchers and Liu (2015).

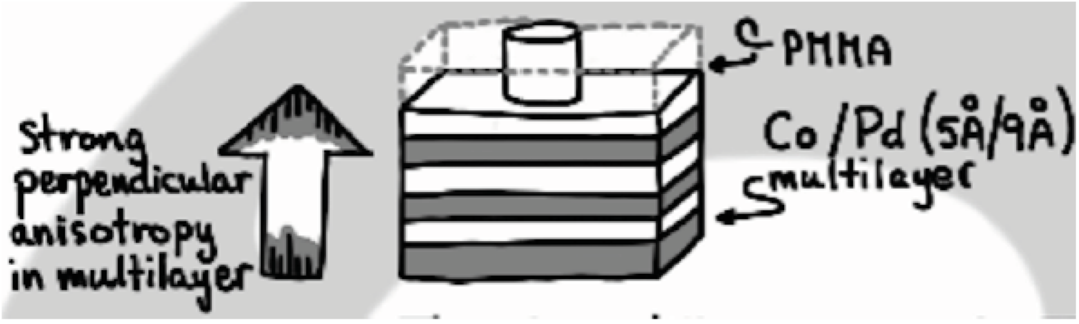

Figure 2. Multilayer picture and repacking instance in linguistic mode.

Multimodal resources should not prevent the learner from accessing the original content through resemiotisation but they should provide ‘message abundance’ (Gibbons 2003) by bridging the gap between the original content and the learners’ L2 proficiency. In this way, CLIL science materials could benefit from multimodal resources that relate directly to the complexities of the scientific discourse and lexicogrammatical strategies which are employed, while maintaining the conceptual density of the scientific content and its defining linguistic features. Figure 3 shows an instance of two further forms of resemiotisation that provide direct support to language understanding. Type 1 refers to change from metaphorical language in the original paper to congruent language in the sketchnote. Another type takes place within the sketchnote itself and transforms either congruent or metaphorical language into a visual representation. The sketchnote (see Figure 3) to which this multimodal complex belongs describes a quantum physics paper on a Wheeler’s delayed-choice thought experiment, which involves a moving object which has been given the choice to act like a particle or a wave. Wheeler’s experiment asks at which point a decision is made. In this instance, ‘Wheeler’s delayed-choice of a single atom’, a shorter version of the original title ‘Wheeler’s delayed-choice gedanken experiment with a single atom’, is resemiotised in the congruent interrogative clause ‘Which way does the particle go?’ and this is further resemiotised in the visual that whimsically portrays an ‘atom’ deciding its way, expressed by two opposing arrows and question marks. The double resemiotisation in this example assumes the complexity imposed by the original text and uses congruent language and a visual image to re-represent the meanings which are made. In Figure 3 the noun ‘choice’ is converted into ‘which way’ and the verbal group ‘does go’.

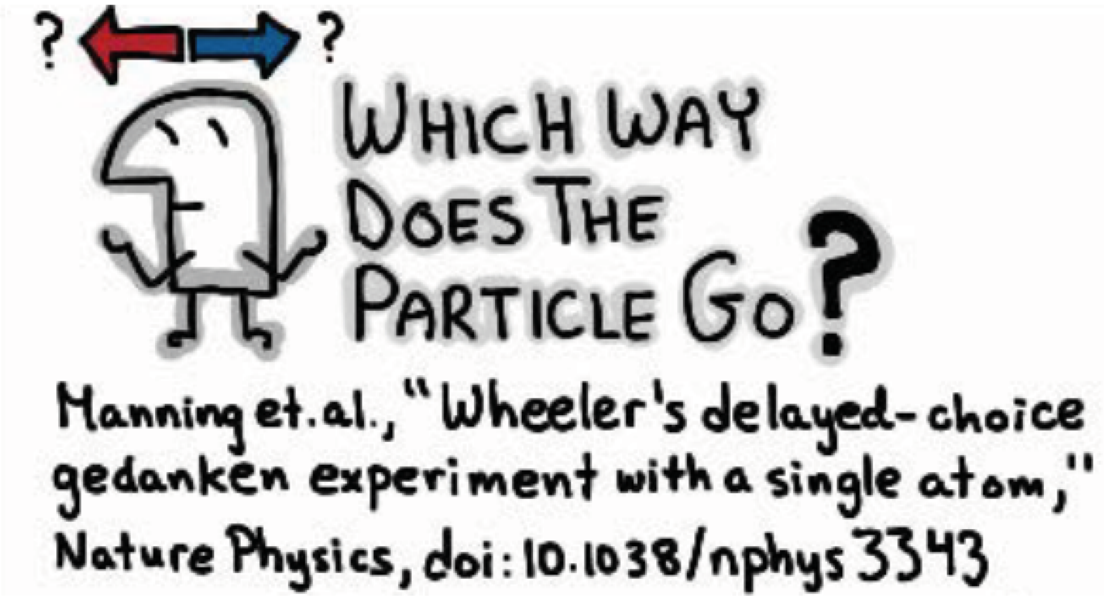

Figure 3. Sketchnote 'Wheeler's delayed-choice gedanken experiment with a single atom' by Robert Dimeo, based on Manning, Khakimov, Dall and Truscott (2015).

At the lexical level, scientific language also presents difficulties for the CLIL learner in the long abstract and technical nominalisations that result from grammatical metaphor. In Figure 1, for instance, the terms 'skyrmion', 'lattice', 'texture', 'core', 'perimeter', and 'chirality' can be learned through the language-to-visual resemiotisation of a skyrmion into the image of a magnetic spin texture with core, perimeter and chirality linguistic labels, and into a vortex cartoon-like figure.

6. Some suggestions for pedagogical interventions

Students start working with generalisations, abstraction, and other features of scientific language in secondary education (Christie 2002, 46). Based on the examples above, we offer some potential ideas for dealing with typical difficulties at lexicogrammatical level in CLIL scientific English via visual thinking, with the dual aim of enabling development of academic literacy along with content understanding.

Our proposal is grounded on a series of pedagogical ideas and frameworks from discourse analysis, second language learning and CLIL. For instance, we follow Lemke's (1990, ix) notion of 'talking science', understood as doing science through language by a number of functions, such as 'observing, describing, comparing, classifying, analyzing, (…) and teaching in and through the language of science'. We also draw on Lin's (2012) idea of doing science by allowing teachers and students to dialogue and shift freely and fluently between the communicative resources available, by means of translanguaging (i.e. moving from/to L1 to/from L2) in oral, written, colloquial or academic registers, as well as by using trans-semiotising or resemiotisation between multimodalities.

Furthermore, in line with recent research in CLIL following the SF tradition, we advocate the use of genres (Llinares and Morton 2010, Lorenzo 2013), through which ample scientific register input could be provided. The introduction of scientific genres constitutes proper ground for working with linguistic devices that express the discourse semantics and lexicogrammatical levels. As Llinares and Morton (2010, 98) note, a genre approach can be compatible with Lyster's (2007, 135) recommendations for an approach that integrates content-based and form-focused instruction, 'in that raising CLIL learners' awareness of the organisational and particularly the lexicogrammatical features of the genres they use can be seen as enhancing input through noticing and awareness activity'. In this context, Focus on Form (FonF) could promote noticing conflicting structures of the scientific language by means of the scaffolding potential of visual thinking. According to Järvinen (2010, 165), 'linguistic devices that are used to express core content in the discipline are prime candidates for focused learning'. Dealing with the complexities of these linguistic devices attempts to contribute to talking science in Lemke's terms, it should be an opportunity for doing science through meaning making and development of scientific knowledge. For that purpose, the integration of FonF should be contextualised in the functions that happen in the scientific genres most used at each educational level (Christie and Derewianka 2010).

Form-focused instruction consists of two main types: proactive and reactive. Proactive FonF instruction is a kind of designed-in scaffolding process (Hammond and Gibbons 2005) for enabling 'students to notice and to use target language features that might otherwise not be used or even noticed in classroom discourse' (Lyster 2007, 44). Some of the following language awareness pedagogical strategies of proactive FonF involving visuals could be incorporated in teachers' interventions, instructional materials or in task design. Precisely, within a task-based approach, following Lorenzo (2007) and Nikula (2015), these practices could be located in pre-task phases, so as to connect new CLIL knowledge with students' prior knowledge on the topic, or post-task phases, where problematic linguistic issues could be discussed.

Reactive FonF corresponds to a type of spontaneous teacher-student interactive scaffolding (Hammond and Gibbons 2005) through which students' 'Corrective feedback as well as other attempts to draw learners' attention to language features in relatively unplanned and spontaneous ways' is provided (Lyster 2007, 47). In reactive FonF, some forms of teacher's corrective feedback displayed to sort out the difficulties imposed by grammatical metaphor can be complemented by the use of visual thinking strategies, such as the ones displayed in Figures 4 and 5 (see examples below).

In any case, as Lyster (2007, 61) notes, a balanced use of visuals, gestures and non-linguistic support in language instruction should be made in order to prevent possible negative effects on the development of learners' L2. In this vein, visual thinking strategies should never be a replacement for the L2 but should work in conjunction with natural and metaphorical L2 and L1 structures.

Before presenting some examples of FonF CLIL scaffolding strategies, it should be made clear that proactive and reactive FonF is developed by the teacher, and, in that sense, visual thinking would be mostly used as a comprehension tool. However, on some other occasions, the students may be required to work with their own visualisations to prove they understand the target structure. In this case, visual thinking would be a retrieval tool.

6.1 FonF through visual thinking scaffolding strategies for the CLIL science classroom: the case of grammatical metaphor

Various resemiotisation strategies could be articulated to facilitate access to meaning or to reinforce the learning of certain problematic target features in science at lexicogrammatical level, such as grammatical metaphor. According to Järvinen (2010, 165-166), in teaching grammatical metaphor, noticing should involve, among others, the comparison of incongruent and congruent expressions, and the 'unpacking' of congruent forms turning nominalisations to clauses and vice versa. In our proposal, we extend beyond these ideas by incorporating visualisations as both contributing and scaffolding FonF in CLIL. We suggest several types of FonF strategies that may serve as the basis for activities aimed at raising explicit awareness towards grammatical metaphors in the scientific register.

The following example is taken from a report on Down Syndrome written by a girl aged 15/16 (adapted from Christie and Derewianka's (2010, 190-195) analysis of a collection of texts produced by high school students of science). Although it has been produced by a student, the sentence is typical of the kind of language a CLIL learner can come across in the input of a secondary-school science classroom:

(3) L2 incongruent form: ‘Down Syndrome is a **chromosomal disorder**, its **cause** is directly related to a **mutation** or **abnormality** of chromosome 21’.

Christie and Derewianka (2010, 193) provide the following congruent alternative for the abstraction expressed through the words in bold:

(4) L2 congruent form: ‘Chromosome 21 mutates so that it becomes abnormal and (so that) this produces a person with Down Syndrome’.

In this case, the participants and processes in the incongruent form are naturally expressed in the L2 congruent form as follows: the adjective ‘chromosomal’ is expressed through the noun ‘Chromosome 21’, the noun ‘mutation’ becomes the verb ‘mutates’, and ‘abnormality’ turns into the adjective ‘abnormal’. Both ‘mutates’ and ‘abnormality’ serve to conceptualise a disorder. In addition, the causal relationships between the different parts (clauses of result) can be revealed through the L2 congruent form by means of conjunctions such as ‘so that’ instead of nouns such as ‘cause’. Translanguaging, i.e. moving among the languages in the learners’ repertoire, could accompany this scaffolding work. For instance, let us use Spanish L1 sentences (5) and (6) below:

(5) L1 incongruent form: ‘*El síndrome de Down es un* ***trastorno cromosómico****, su causa está directamente relacionada con una* ***mutación*** *o* ***anomalía*** *del cromosoma 21*’.

(6) L1 congruent form: ‘*El cromosoma 21 muta así que se convierte en anormal y así produce una persona con síndrome de Down*’.

In sentence (5), the L1 incongruent form may facilitate the understanding of the L2 incongruent form to the Spanish L1 learner. However, it preserves the grammatical metaphors of the L2 incongruent form and, in that sense, keeps some of the complexities of the original L2 form, e.g. ‘chromosomal’ is translated with the adjective ‘*cromosómico’*, and ’disorder’ with the nominalisation ‘*trastorno’*. Sentence (6), as sentence (4), goes one step further in facilitating understanding by unpacking the elements in the original sentence.

Along with this translanguaging, in some cases, the complexity of the clause or sentence could benefit from a more or less explicit visualisation of the participants, processes and circumstances as well as their relationships in incongruent and congruent forms. The visualisation of the semantic elements of a clause would permit the learner to reach the reality conceptualised by the L2 and L1 structures and, at the same time, it would be a means for raising awareness towards the linguistic forms. Figure 4 offers a possible visual resemiotisation of sentence (3), which illustrates the pedagogical approach we describe to resolve these lexicogrammatical issues.

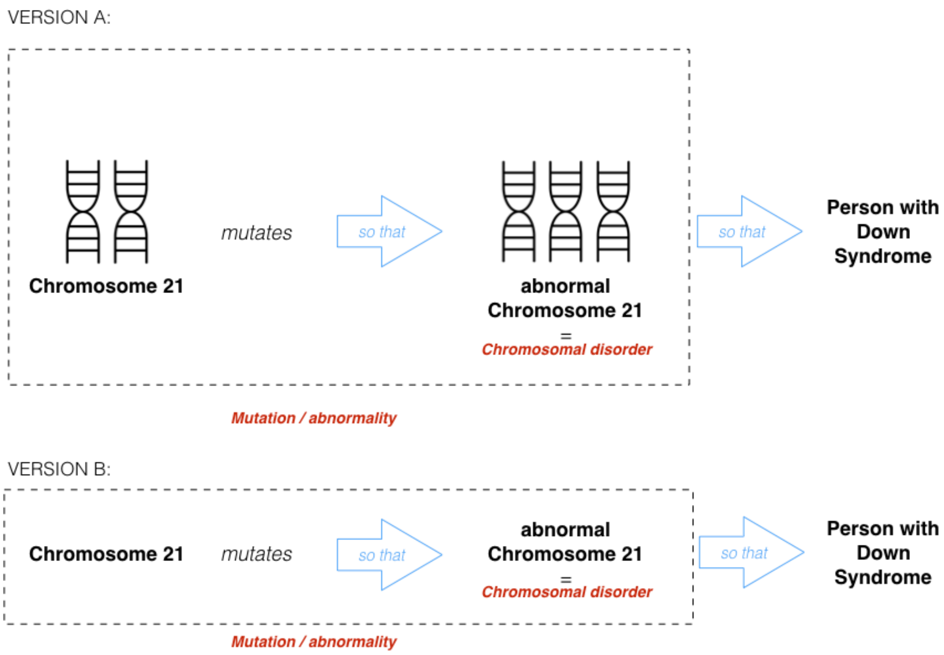

Figure 4. Proposal of visual resemiotisation at lexicogrammatical level. (Chromosome icon adapted from 'chromosome' by Jaohuarye from the Noun Project).

In Figure 4, Version A is more visually explicit than Version B, and the teacher can choose any other variation or mix depending on the difficulty of the construction. Some elements of the clause can be expressed visually (e.g. 'Chromosome 21' and its 'mutation'). Others, such as qualities, are expressed through language (e.g. 'abnormal'). The relationships of result are expressed by means of arrows in both cases, and in Version A the conjunction is displayed along with this visual connector. In both cases, the non-congruent expressions (in red colour) can be incorporated in the teacher's explanation of the resemiotisation process.

Alternatively, the teacher can plan FonF activities in which students work from the visualisation of the clause elements to the production of congruent L2 (and/or L1) and finally to incongruent L2 (and/or L1) forms. The visualisation of the elements could be used as the basis from which learners generate metaphorical linguistic forms by following the reification patterns of the grammatical metaphor. Congruent and corresponding incongruent forms, e.g. ‘chromosome’ – ‘chromosomal’ or ‘to mutate’ – ‘mutation’ (from the examples above), could act as clues to scaffold this process.

In all cases, a side by side comparison of metaphorical and congruent instances could be used as a guide to support the process towards noticing and learning further examples of abstract instances appearing in the CLIL science classroom.

Moreover, by making ideational meanings accessible, visual thinking can assist in managing highly complex issues brought about by grammatical metaphor, such as lexical density and syntactic ambiguity. For example, the clause ‘lung cancer death rates are clearly associated with increased smoking’ (Halliday 1993b, 67-68), taken from a Year 6 science textbook but with a typical structure of superior levels, is lexically dense and syntactically ambiguous. Gee (2011, 51-55) reaches 112 different possible meanings, based on the possible interpretations for each grammatical metaphor in it.

For example, the nominalisation ‘lung cancer death rates’ could be understood as:

(7) [lung cancer] [death rates] = rates (number) of people dying from lung cancer = how many people die from lung cancer

(8) [lung cancer] [death rates] = rates (speed) of people dying from lung cancer = how quickly people die from lung cancer

In addition, the relational predicate ‘are associated with’ could mean:

(9) caused by

(10) correlated with

And the interpretations for the nominalisation ‘increased smoking’ could be:

(11) increased smoking = people smoke more

(12) increased smoking = more people smoke

While a competent speaker of English can access the most relevant meanings of the above clause (i.e. more people die from lung cancer because more people smoke/people smoke more) without evaluating all the possible meanings, the sentence can be problematic for a learner of English as a foreign language. For clauses like this, the structure underlying the relationship between the processes and participants could be accessed via resemiotisation into a visual and/or congruent linguistic representation, as shown in Figure 5.

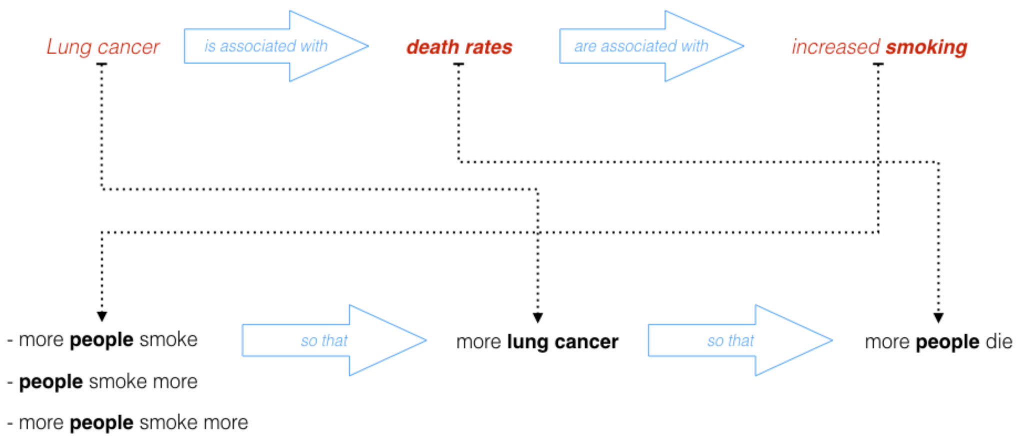

Figure 5. Proposal of visual resemiotisation for dealing with lexical density and syntactic ambiguity.

In coping with the difficulties of the sentence ‘lung cancer death rates are associated with increased smoking’, the teacher could use visual thinking as follows: first, to reveal the participants behind the metaphorical realisations and establish comparisons between congruent and incongruent forms, e.g. ‘people smoke’ instead of ‘smoking’; and, second, to show the relational processes in the congruent form, e.g. there is more lung cancer because more people smoke/people smoke more/more people smoke more, or more people are dying because there is more lung cancer (note that this second association is hidden in the incongruent long noun phrase ‘lung cancer death rates’). Comparisons are established through shifts between relational processes in the congruent form and in the incongruent form. Again, comparing L2 and L1 structures through translanguaging could be helpful in these tasks.

All the techniques above could also extend to the realm of discourse by showing learners how objectifications in phrases relate to clauses, clause complexes and discourse. Indeed, at discourse and text level, CLIL learners can also generate their own visual thinking genres, such as sketchnotes or infographics, in order to make visible and foreground the structure of scientific genres and summarise or explain complex scientific processes. When learners make use of linguistic and visual resources to produce these types of coherent visual thinking products, they provide valuable evidence of their learning, misunderstandings or gaps in conceptual knowledge (Bobek and Tversky 2016).

7. Conclusion

This paper has shown that visual thinking techniques which involve the use of multimodal resources have potential for dealing with recurring problems in CLIL instruction. A Systemic Functional Multimodal Discourse Approach (SF-MDA) has been used to describe those visual thinking features that could help scaffold CLIL in the science classroom, especially grammatical metaphor.

Based on the intensification of interpersonal meaning, visual thinking can be considered a semiotic mediational process that can deal with difficulties at different levels of the language. The above examples have illustrated that the display of logical structure is possible by means of visual strategies. At the lexicogrammatical level, visual thinking offers various options for facilitating the learner's access to the linguistic constructions typical of scientific discourse. For example, it succeeds in unpacking grammatical metaphors by resemiotising them into more congruent and accessible representations. This practice could mediate the understanding of semantic and grammatical relationships of the components of complex nominal groups by providing message abundance through the elaboration of the input. In this sense, visual thinking attempts to assist with the scaffolding of knowledge while maintaining links to the ideational meaning of the original content. In any case, the strategies explained here are by no means exhaustive and many others involving visual thinking and mediating practices such as translanguaging could be developed to address the issues emerging in the CLIL science classroom.

This study is designed to contribute to the field of multimodal scaffolding techniques for Content and Language Integrated Learning. Further research is needed that explores the effect on learning in different CLIL subjects of visual thinking resources. Implications of this research should be particularly taken into consideration in the design of printed and e-learning teaching materials.

8. Acknowledgements

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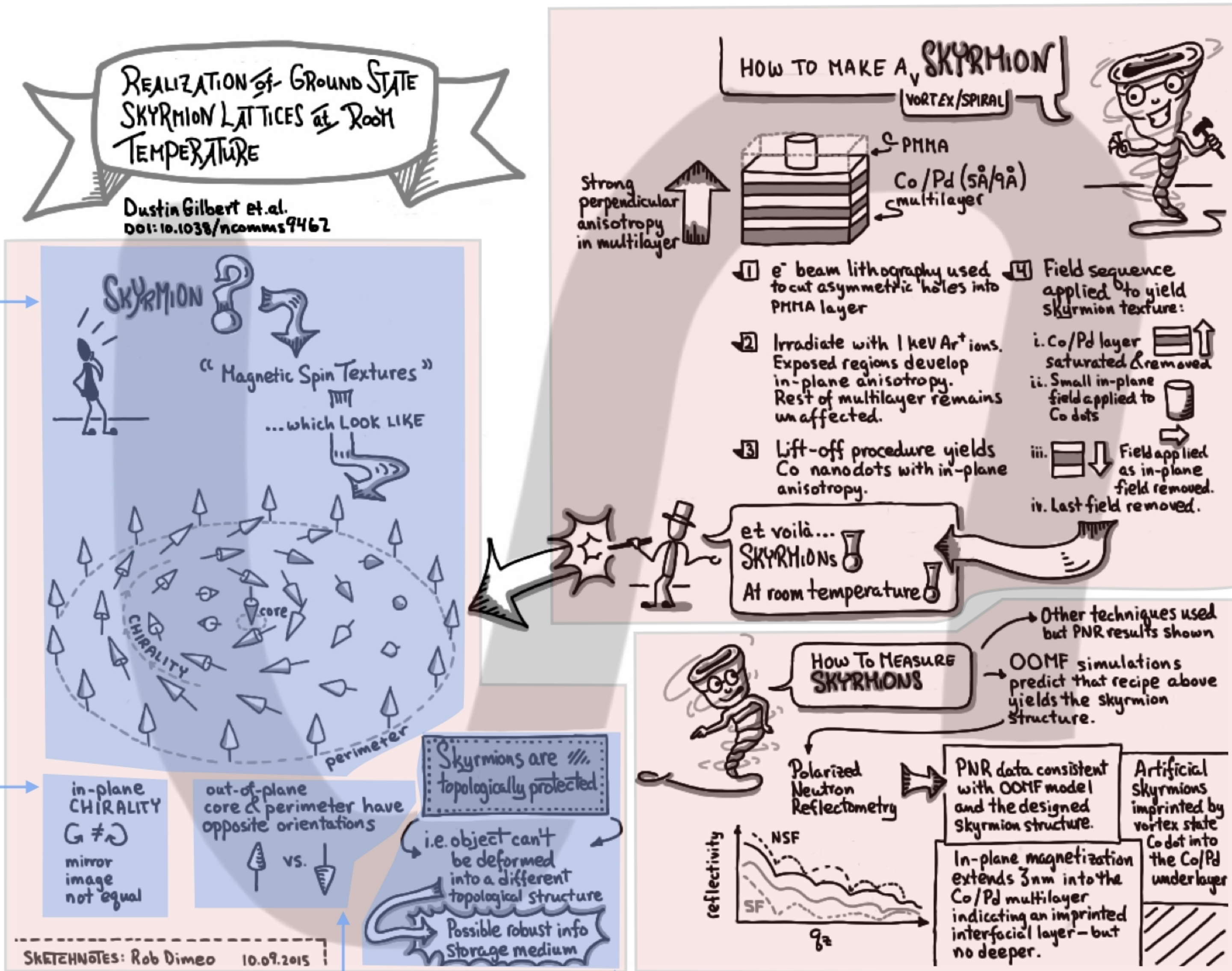
MULTIMODAL COMPLEX 2. HOW TO MAKE A SKYRMION



MULTIMODAL COMPLEX 1. DEFINITION OF SKYRMION

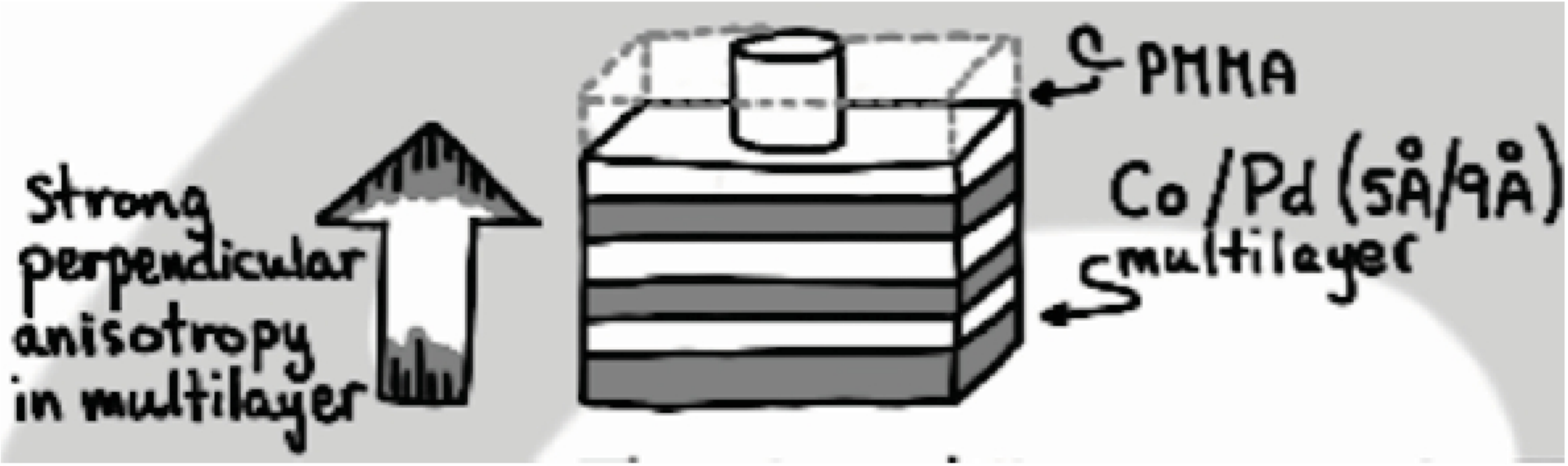
1.1 Visualisation of a skyrmion

1.2 Chirality

1.3 Skyrmion behaviour in core and perimeter

1.4 Topological structure

MULTIMODAL COMPLEX 3. HOW TO MEASURE SKYRMIONS

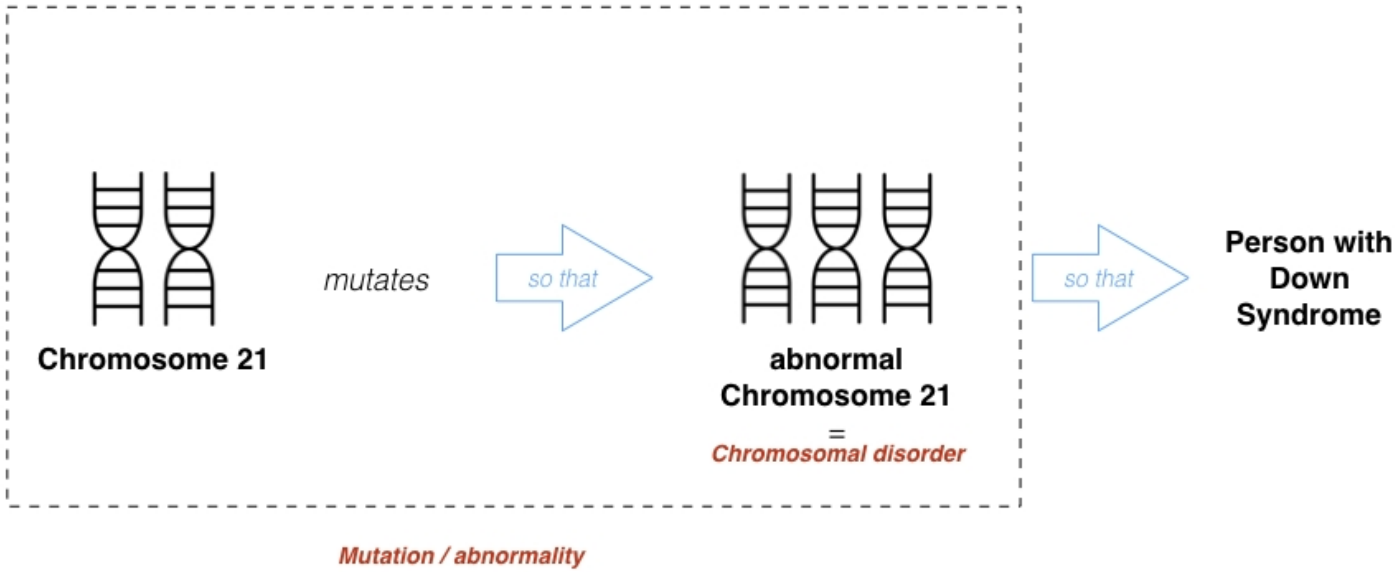


PMMA
Co/Pd (5Å/9Å)
multilayer
Strong
perpendicular
anisotropy
in multilayer

WHICH WAY DOES THE PARTICLE GO?

Manning et. al., "Wheeler's delayed-choice gedanken experiment with a single atom," Nature Physics, doi: 10.1038/nphys3343

VERSION A:



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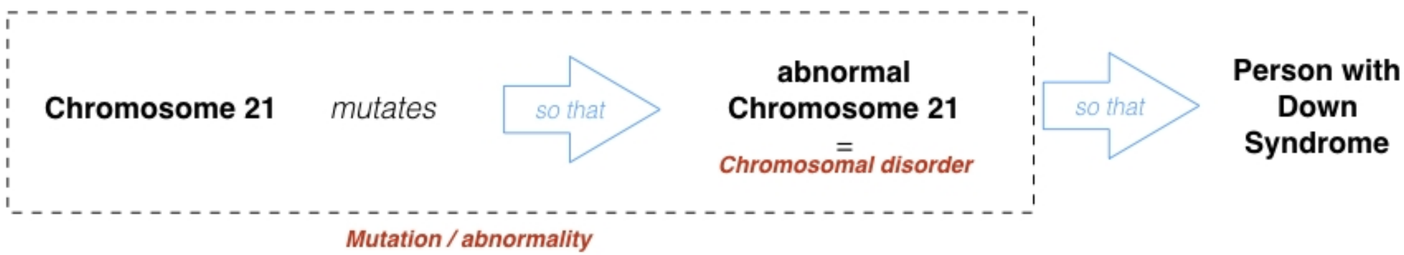

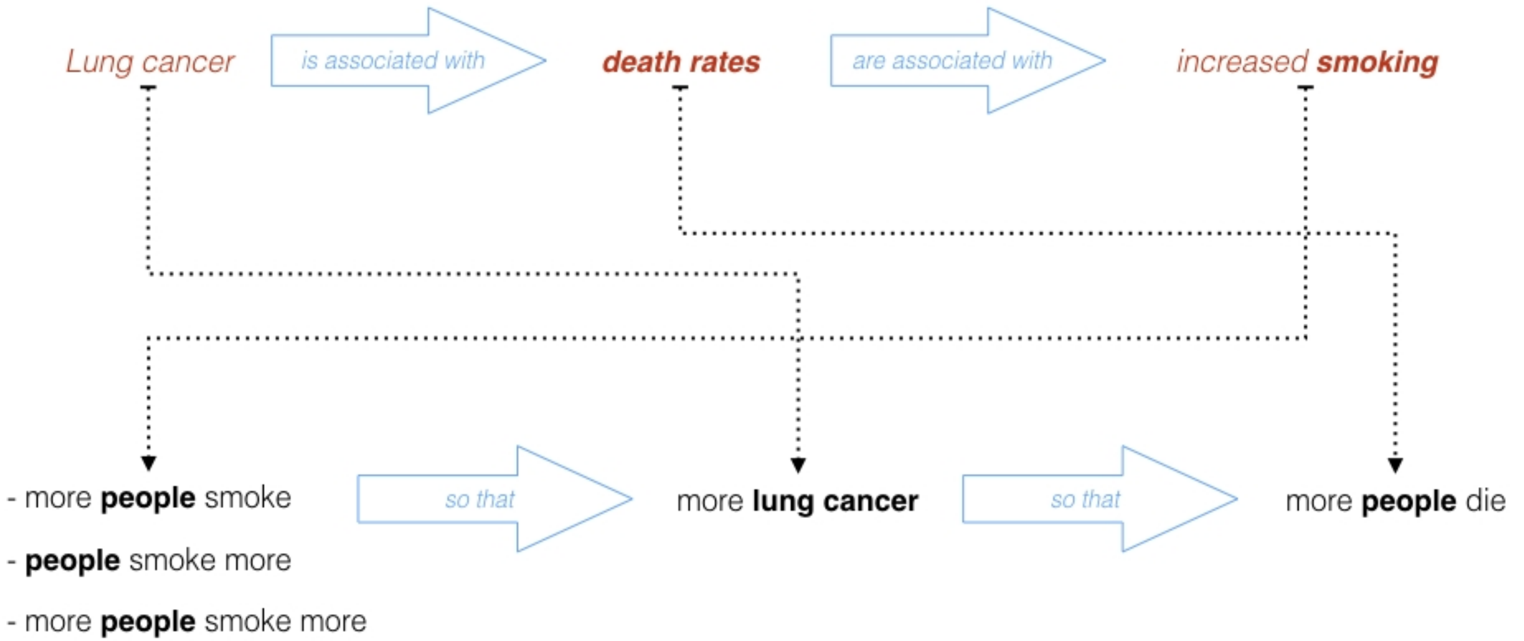
Lung cancer
is associated with
death rates
are associated with
increased smoking
- more people smoke
- people smoke more
- more people smoke more
so that
more lung cancer
so that
more people die

RESEMIOTISATION TYPE	IN THE PAPER		IN THE SKETCHNOTE	MEANINGS/METAFUNCTIONS
Type 1	Incongruent linguistic system	→	Congruent linguistic system.	- IDEATIONAL: participants, processes and circumstances are kept in resemiotisation. - INTERPERSONAL: increases through unpacking of grammatical metaphor and more accessible message. - TEXTUAL: information is conveniently organised for understanding.
Type 2	Congruent or incongruent linguistic system	→	Visual system (image)	- IDEATIONAL: participants, processes and circumstances are kept in resemiotisation. - INTERPERSONAL: increases through mechanisms such as visual metaphor and humour. - TEXTUAL: language and image system are connected through convenient organisation and position of the parts. Cohesion.
Type 3			Congruent or incongruent linguistic system → Visual system (image)	
Type 4	Mathematics image system (graph, diagram)	→	Mathematics image system (graph, diagram).	- IDEATIONAL: participants, processes and circumstances are kept in resemiotisation. - INTERPERSONAL: increases due to the resulting uncluttered version of the original. Decrease of intricacy of display. Comments and labels included. - TEXTUAL: Essential information for understanding is selected and prioritised through visual marking devices. Cohesion (graph/diagram parts are linked to comments).
Type 5	Mathematics symbolism system	→	Linguistic system	- IDEATIONAL: ideation, participants, processes, circumstances, and relations are kept in resemiotisation. - INTERPERSONAL: increases through the use of simple language. - TEXTUAL: information is conveniently organised and positioned for understanding.

Table 1. Resemiotisation types identified in sketchnotes (Adapted from Author, Author, Author and Author [2018]).