Learning and Instruction 92 (2024) 101932

Contents lists available at ScienceDirect

Learning and Instruction

journal homepage: www.elsevier.com/locate/learninstruc

Multimodal practices of unpacking and repacking subject-specific knowledge in CLIL physics and chemistry lessons☆

Tarja Nikula [a,*], Teppo Jakonen [b], Leila Kääntä [c]

[a] University of Jyväskylä, Centre for Applied Language Studies, P.O. Box 35, 40014, Jyväskylä, Finland
[b] University of Turku, School of Languages and Translation Studies, Arcanum Building, Vatselankatu 2, FI-20500, Turku, Finland
[c] University of Jyväskylä, Department of Language and Communication Studies, P.O. Box 35, 40014, Jyväskylä, Finland

ARTICLE INFO

Keywords:
Multimodal practices
Disciplinary knowledge
Semantic waves
CLIL Classroom interaction
Translanguaging

ABSTRACT

Background: Different school subjects have their specific meaning-making practices for building and conveying knowledge. Research drawing on the Semantics dimension of the Legitimation Code Theory has noted the importance of shifting between levels of abstraction and context-dependency in knowledge-building. There is a need to better understand how such shifting between different levels of abstraction is accomplished with multimodal resources in classroom interaction.
Aims: This study aims at exploring subject-specific knowledge construction as a form of translanguaging, i.e., as movement between different registers and multimodal resources of meaning-making.
Data: The data comes from a Finnish teacher development project aimed at supporting CLIL teachers' professional development. This exploratory study analyses teachers' knowledge-building practices in two STEM lessons video-recorded in the project, Physics and Chemistry.
Methods: The data is analysed using multimodal conversation analysis and analysis of semantic waves. Analysis focuses on how the teachers engage in unpacking and repacking subject-specific knowledge by talking, gesturing, as well as displaying, handling, and modifying various kinds of multimodal materials and artefacts.
Results: The teachers were found to use a versatile set of multimodal translanguaging practices for unpacking and repacking. The findings also indicate complexity in semantic waves due to multimodal resources accomplishing simultaneous shifts in semantic gravity and density, with either aligning or diverging functions.
Conclusions: The simultaneous use of different multimodal resources and their potential to serve different functions point to the need to acknowledge the multidimensionality of semantic waves. The multimodal translanguaging approach also has implications for conceptualising subject-specific knowledge-building as inherently multimodal.

1. Introduction

During the past decade, research and practice in multilingual education have been profoundly influenced by translanguaging approaches, which have foregrounded a view of multilingualism as the fluid use of different meaning-making resources. While the traditional emphasis of translanguaging studies has been on phenomena that transcend the boundaries between 'named' languages (García & Li, 2014), the scope of the term has more recently been considerably expanded. As for instance Li (2018), Lin (2019) and Tai (2023b) have argued, the kind of boundary-crossing covered by the term translanguaging is not limited to verbal phenomena (talk and writing) but also involves the use of diverse interactional resources such as gestures, body movements, facial expressions, and images. These new conceptual openings have moved the scope of translanguaging far beyond the phenomenon of code-switching and highlighted common ground between translanguaging and a multimodal understanding of social interaction (see e.g. Wagner, 2018) as well as the growing body of research in the paradigm of embodied learning (e.g., Airey & Linder, 2009; Atkinson, 2010; Horn & Wilburn, 2005).

☆ The authors share an interest in CLIL education, especially matters relating to content and language integration and its interactional accomplishment. They also have expertise in matters pertaining to L2 learning, multilingualism, bilingual education and disciplinary literacies.

* Corresponding author.
E-mail addresses: tarja.nikula@jyu.fi (T. Nikula), teppo.jakonen@utu.fi (T. Jakonen), leila.a.kaanta@jyu.fi (L. Kääntä).

https://doi.org/10.1016/j.learninstruc.2024.101932
Received 2 November 2023; Received in revised form 16 April 2024; Accepted 21 April 2024
Available online 12 May 2024

In this paper, we adopt such a multimodal translanguaging perspective to explore subject-specific knowledge-building in classroom interaction in content and language integrated lessons (CLIL) in Finland. As a form of dual-focused bilingual education, CLIL makes acutely visible the close connections between language and content in learning, drawing attention to their *integrated* nature as a key educational concern (Llinares et al., 2012; Nikula et al., 2016). One manifestation of such integration is the fact that different school subjects have specific ways of building and conveying knowledge through language, a perspective that is familiar from studies conducted within the frameworks of Systemic Functional Linguistics (SFL; e.g., Coffin, 2006; Schleppegrell, 2004), disciplinary literacies (e.g., Fang & Coatoam, 2013; Moje, 2008) and Legitimation Code Theory (LCT; e.g., Maton, 2013, 2014; Maton et al., 2016) conducted in non-CLIL contexts. LCT-based studies of semantic waves in particular have shown how classroom participants 'unpack' and 'repack' knowledge by constantly shifting between more and less abstract and more and less context-dependent forms of knowledge in ways that can promote learning (e.g., Cranwell & Whiteside, 2020; Macnaught et al., 2013). However, to date these knowledge construction processes have been largely examined by reference to spoken or written language rather than from a full-fledged translanguaging perspective that takes into account the use of the totality of human meaning-making resources. Consequently, less is known about how multimodality – i.e., resources offered by the body, the material environment, texts, images, etc. – shapes subject-specific knowledge-building in classroom interaction, despite a growing recognition that multimodality is an important part of discipline-specific knowledge (e.g., Doran, 2019a, b). The same applies to CLIL research where the focus on content and language integration in knowledge building needs to involve a view of 'language' that extends beyond speech and writing.

Combining the analytical perspectives of multimodal Conversation Analysis (e.g., Goodwin, 2018; Streeck et al., 2011) and Legitimation Code Theory, we explore how unpacking and repacking disciplinary knowledge is multimodally accomplished in CLIL Physics and Chemistry classroom interaction through teachers' talk, embodied actions, and by making relevant, displaying, and modifying various kinds of teaching materials and artefacts. Our aim is to expand the current LCT-based view of knowledge-building in (CLIL) classrooms by showing how the deployment of multimodal resources constitutes practices of unpacking and repacking subject-specific knowledge. Based on a multimodal CA analysis, we argue that unpacking and repacking occur simultaneously on multiple levels, sometimes so that different resources may pull in a uniform direction to either unpack *or* repack knowledge, whereas at other times they may be used to simultaneously unpack *and* repack knowledge in the same situation. Through a multimodal research lens, we seek to 1) explore semantic waves as extending beyond language to the totality of meaning-making resources, 2) offer new pathways for LCT-informed research to engage with the complex nature of semantic waves, and 3) contribute to translanguaging research by highlighting how shifts between and across different registers in classroom talk and other multimodal resources serve knowledge-building purposes.

2. Conceptual underpinnings and previous research

2.1. Legitimation code theory: semantics

Legitimation Code Theory (LCT, see e.g., Maton, 2013; 2014) is a sociological approach for analysing knowledge-building practices and their organising principles. In Maton's (2016: 3) words, LCT is a "practical theory of practice" that enables dialogue between theory and data. It consists of different dimensions of which the three of Specialisation, Semantics, and Autonomy have received most research attention, each focusing on different aspects of knowledge practices. Specialisation is concerned with knowledge and knower structures, depicting strengths in epistemic and social relations. Autonomy dimension helps outline how insulated or bounded knowledge objects and their uses are. This study focuses on the Semantics dimension because its orientation to varying strengths of complexity and abstraction is particularly useful for exploring knowledge-building practices in classroom contexts where a key task of teachers is to scaffold learners towards subject-specific knowledge. More specifically, the Semantics dimension views knowledge-building as an activity that results from the interplay of two organising principles: semantic gravity (SG) and semantic density (SD). Semantic gravity is about the extent to which verbal meaning relates to its context (i.e. context-embeddedness) and semantic density is about the level of complexity and condensation of meaning. Both gravity and density can be either stronger or weaker in force (expressed as SG + SG-; SD + SD-).

In the LCT framework, the dynamic ebb-and-flow of knowledge-building is often visualised as 'semantic waves' (Maton, 2013; Macnaught et al., 2013; see also section 6 of this paper). Such waves illustrate how semantic density and gravity undulate over time in discourse (such as over the course of a lesson or a written text) as participants move between, and weave together, higher and lower semantic scales through practices of 'unpacking' and 'repacking' knowledge (Macnaught et al., 2013; Maton, 2013). In the classroom, unpacking happens, for example, when teachers exemplify and concretise abstract subject-specific meanings with the help of less technical and more context-dependent everyday language. To give an example from our data, a chemistry teacher can be argued to engage in unpacking the meaning of the technical term 'equilibrium' when she instructs about chemical reaction equations by saying that "no atoms are lost or created in this reaction". In contrast, repacking involves moving back to more specialised and context-independent meanings and forms of expression, such as when teachers express or reformulate matters discussed in everyday language into more subject-specific and academic register. An example of this is the physics teacher rendering the less technical talk about laser beams passing through a surface into the subject-specific notion of the "angle of refraction".

Semantic wave analysis has increasingly been used to explore knowledge-building in different educational contexts such as STEM subjects and law (Clarence, 2017; Cranwell & Whiteside, 2020; Dankenbring et al., 2023). These studies have shed light on the dynamics of knowledge-building in a range of settings. For example, Walldén & Nygård Larsson, (2021) show in their interaction-based study how the explanation of disciplinary terms can sometimes happen through a semantic wave that resembles a "sandwich structure". In this kind of an explanation, an initial unpacking of an abstract term through everyday language use and checking of students' previous experiences is followed by an eventual repacking of the everyday into condensed subject-specific knowledge.

In CLIL research, LCT-informed analyses are an emerging focus of attention. For example, Lo et al. (2023) explore CLIL science teachers' practices of unpacking and repacking academic concepts, drawing attention both to their use of linguistic (academic, everyday and L1) and visual resources such as concretising pictures in this process. They argue that semantic waves offer a useful meta-language and serve as a pedagogical tool to engage CLIL teachers in the critical reflection of their classroom practices. In a similar manner, Llinares and Nashaat-Sobhy (2021) argue for the potential of semantic waves as a pedagogical tool to help trace learners' understanding of scientific concepts. They base their argument on the analysis of oral interviews between CLIL students and researcher-interviewers in which students were unpacking abstract terms such as 'ecosystem' when prompted by the interviewer or to open up other students' production of the term. Evnitskaya and Llinares (2022) also use the Semantics dimension of LCT as one of the tools to explore knowledge construction in two CLIL strands differentiated by high exposure (HE) and low exposure (LE) to CLIL provision, i.e., more subjects taught in English in the former. Based on coding classroom data according to different SG/SD constellations, they found that the proportion of classroom discourse involving high semantic density (SG + SD+ and SG-SD + codes) was clearly bigger in the HE than in the LE group (54% and 37%, respectively). This suggests that teachers may approach content in different ways in HE and LE groups. However, their study does not include attention to semantic waves, i.e., how knowledge is constructed in classroom interaction through shifts between decontextualised and abstract meanings to contextual and concrete ones.

In addition to CLIL, a study by Argüelles-Álvarez and Morton (2023) in the context of university-level English-medium instruction (EMI) has explored the Semantics dimension of LCT. They analysed two computing lecturer's knowledge-building practices and showed that both included semantic waves, i.e. movements between higher and lower semantic density and stronger and weaker semantic gravity, but there were differences in these patterns and levels of complexity in the lecturers' talk that were found to depend on the nature of the course (introductory course for postgraduate students vs. a third-year course for prospective telecommunication engineers) and the level of expertise expected from the students. While CLIL and EMI tend to differ from each other in that language is usually not in an explicit focus in EMI (e.g. Schmidt-Unterberger, 2018), the findings by Argüelles-Álvarez and Morton show that teachers adapt subject-specific language use in ways that match the level of knowledge and understanding their students have.

Based on the above, a clear affordance of the LCT framework with its notions of unpacking and repacking and semantic waves is that it allows a systematic exploration of the processual nature of knowledge-building. Previous studies have convincingly shown that varying degrees of context-dependency and condensation of meaning are visible as register variation between more and less academic language in classroom talk (e.g., Argüelles-Álvarez & Morton, 2023; Clarence, 2017; Walldén & Nygård Larsson, 2021). However, as many of these studies are based on Systemic Functional Linguistics, the main focus has been on the linguistic features of teacher talk rather than on the interactional accomplishment of repacking and unpacking. In addition, research to date has paid relatively little attention to how unpacking and repacking can also be realised through embodied, material, and visual means such as leveraging gestures, pedagogical artefacts and images for instructional purposes in classroom interaction (although see Lo et al., 2023 for the use of mobile apps and Walldén & Nygård Larsson, 2021 for the use of visual images).

There is thus a need for LCT studies to expand the analytical focus beyond the verbal to interactional by considering how unpacking and repacking constitute a form of translanguaging between everyday/concrete and specialised/abstract meanings, achieved through a fluid and dynamic combination of diverse multimodal resources for interaction. This aligns with what Doran (2019b: 166) has argued about learning physics: "the key to doing physics is not just in being able to understand highly technical, abstract knowledge, but to vary the abstraction and technicality as required by the situation and to utilize **the particular semiotic resources that organize this**" (emphasis added). As our study seeks to show, embodied action and material artefacts provide a broad range of resources for teachers' translanguaging practices of constructing and conveying subject-specific meanings. Through such a research orientation, our study builds on existing research on multimodal CLIL classroom interaction, which we briefly review in the next section.

2.2. Knowledge-building as a multimodal phenomenon in CLIL

The conceptual expansion of educational translanguaging we referred to above aligns with the broader paradigm of embodied learning, which views learning as inherently multimodal and connected to the human body (e.g., Horn & Wilburn, 2005; Jusslin et al., 2022; Tang, 2013). With respect to the role of multimodality in knowledge-building, it is possible to distinguish at least two different perspectives. One of them is seeing multimodality as a key aspect of subject-specific knowledge itself. As Doran (2019b: 162) argues, knowledge in science subjects is organised multimodally and for this reason their "literacy demands involve not just language but also extend to the multiliteracies inherent in science schooling – where language, mathematics, images, specialised symbolic formulae, animations and demonstration apparatus all need to be 'read' as one." Aligning with similar thinking, Unsworth et al. (2022) propose a multimodal disciplinary literacy framework (MDF) to delineate how scientific reasoning integrates multiple semiotic modalities, including artefacts, embodied representation, symbols and a range of visuals means.

A second perspective is to approach multimodality and embodiment as an inherent part of what teachers and students do in classrooms, something which has been prominently investigated in conversation analytic (CA) studies of CLIL classroom interaction (for an overview, see Evnitskaya & Jakonen, 2017). For example, Evnitskaya and Morton (2011) show the importance of teachers' and students' use of multimodal resources such as body movement, gestures and material artefacts in building and maintaining the community of practice in CLIL science classrooms. Similarly, Escobar Urmeneta and Evnitskaya (2014) argue that multimodal resources are central to CLIL teachers' classroom interactional competence in ensuring comprehension and supporting learner-initiated participation patterns. Moving to matters of subject-specific knowledge-building, Kääntä et al. (2018) illustrate how definitions by a CLIL physics teacher are realised multimodally, both through talk and a range of embodied and material resources (see also Kääntä, 2021).

Particularly relevant for our study are recent research openings which have sought ways to combine the CA analytical lens with LCT to investigate multimodal knowledge-building practices in EMI settings. This includes (Bozbiyik and Morton, (2022; 2023) on chemistry lecturers' subject-specific knowledge-building practices in online university EMI instruction in Turkey. They show how lecturer practices of using talk and embodied resources position students with regard to the constructed knowledge, drawing on the Autonomy dimension of LCT. Their studies suggest that the combination of CA and LCT can offer a potentially fruitful interdisciplinary lens by bringing together CA's analytical power in illuminating the multimodal organisation of social interaction and LCT's principled account of how (subject-specific) knowledge is organised. The combination can push research forward in both fields, enabling us to see what LCT constructs look like at the micro level of CLIL classroom interaction and providing a way to view interactional practices uncovered by a CA analysis in terms of knowledge construction. However, more work is needed to explore classroom interaction also from the perspective of other LCT dimensions. This study contributes to the existing body of research by using multimodal CA to explore how two CLIL science teachers transcend between different semiotic resources to 'unpack' and 'repack' disciplinary knowledge in classroom interaction (the Semantics dimension of LCT). We will explore how the teachers regulate the degrees of context-dependency and condensation of meaning through multimodal translanguaging across linguistic choices, embodied actions and ways of making relevant, displaying, and modifying various material and visual artefacts. We aim to show what taking these multimodal phenomena into account suggests for the analysis of semantic waves in the analysed interactions.

3. CLIL in Finland

According to a well-known definition of Content and Language Integrated Learning, CLIL is a dual-focused approach where "content is taught through the medium of a foreign language, typically to students participating in some form of mainstream education" (Dalton-Puffer, 2011, p. 183). As elsewhere in Europe, CLIL started to gain momentum in Finland in the 1990s when changes in school legislation made it possible to use languages other than the national languages as the medium of instruction. In the early phases, CLIL often served as an umbrella term in Finland and many schools still label their programmes as CLIL. However, nowadays the term bilingual education is increasingly used in alignment with the Finnish National Core Curriculum for Basic Education (EDUFI, 2014). It draws a distinction between large-scale bilingual education when more than 25% of the curricular content is taught in the target language (including both CLIL/bilingual provision through foreign language and immersion programmes offered mainly in national languages), and small-scale bilingual education with less than 25% of teaching in the target language (EDUFI, 2014).

CLIL/bilingual programmes have become an established yet not a very extensive part of Finnish education. According to the latest national survey, 18% of all Finnish municipalities offer CLIL/bilingual programmes; they mainly represent urban rather than rural areas (Peltoniemi et al., 2018). Especially the large-scale programmes usually control the access to CLIL/bilingual provision through a selection process based on students' language and/or academic skills (Peltoniemi et al., 2018). Thus, CLIL teaching tends to be for select groups which may create tensions for maintaining equality between CLIL and non-CLIL groups but also for securing equity within CLIL groups as the conception of CLIL students as skilful and motivated may render invisible their diverse needs for support (Nikula et al., 2022).

English predominates as the language of instruction in CLIL, which reflects its status as the most studied foreign language (Statistics Finland, 2022) and a language present in different domains of Finnish society (Laitinen et al., 2023). Students in bilingual programmes are offered, in addition to English-as-a-foreign-language lessons, English-medium instruction in content subjects for the purpose of simultaneous language and content development. Yet, a challenge that has been identified is that due to the content-driven nature of CLIL/bilingual education, CLIL teachers' orientation to language tends to remain implicit or incidental (Nikula, 2015; Wever, 2020). At the same time, the Core Curriculum (EDUFI, 2014) highlights language awareness in schools and positions all teachers as teachers of the language typical of their subjects. Although both CLIL and non-CLIL subject teachers have been found to acknowledge such a role, they mainly do so from the perspective of special terminology (Skinnari & Nikula, 2017) without a clear articulation of content and language integration, an observation resonating with findings from other CLIL contexts (e.g., Morton, 2018). This points to the need for greater awareness among CLIL teachers about subject-specificity extending beyond vocabulary to the multiplicity of means involved in subject-specific knowledge building, a need identified both in Finland and in other CLIL contexts (e.g. He & Lin, 2018; Llinares & Nashaat-Sobhy, 2021). Paving way for greater awareness requires gaining a better understanding of how CLIL teachers engage in multimodal knowledge-building practices to support their learners. This study is one step towards that direction.

4. Data & method

The data for this exploratory study comes from a project conducted with a school offering a form of large-scale bilingual education (EDUFI, 2014) where most of the lessons in its CLIL strand are taught in English. The project aims at supporting CLIL teachers' professional development by raising their awareness of subject-specific knowledge-building practices as they are teaching their subject(s) through a second language (L2). To do this, we followed one 7th grade class (13–14-year-old students) and five of their teachers in different subjects in a secondary school during the academic year 2022–23. The subjects taught by the five teachers were arts, geography, physics, English, chemistry, and biology. In addition, not confining subject-specific knowledge to English-medium subjects only, we also followed Finnish as a mother tongue lessons taught in Finnish. The lessons were video recorded with three to four fixed cameras and audio recorded with five mp3-players, all devices placed so that they help capture as much as possible of all participants' multimodal actions. The total amount of lesson data is c. 12 h. All the teachers, students and the students' parents or guardians signed a consent form where they agreed the data (including teacher-generated instructional materials) can be used for research purposes and the students were given the choice of withdrawing from the study at any point if they so wanted.

For this study, we will focus on the knowledge-building practices of two STEM subjects of the project, the physics and chemistry lessons (90-min double lesson each). These lessons were chosen because in prior research STEM subjects have been found challenging for students due to their highly abstract nature and extensive use of images and equations (Blackie, 2014; Doran, 2019a). Since in CLIL these subjects are taught in an L2, it adds an additional layer of complexity that highlights they key role of teachers' practices in making subject-specific knowledge accessible to students. Therefore, we wanted to explore how the physics and chemistry teachers in our data unpack and repack subject-specific knowledge to students *in* and *through* L2-based classroom interaction in ways that help them understand and engage with disciplinary knowledge (also Kääntä et al., 2018).

As our method, we draw on multimodal conversation analysis that investigates human interaction as multimodal and co-operative (CA; e.g., Goodwin, 2018; Streeck et al., 2011) and LCT-informed analysis of semantic waves that draws attention to the levels of abstraction and complexity in knowledge-building (e.g., Argüelles-Álvarez & Morton, 2023; Maton, 2013). CA studies of multimodal interaction have shown that action and meaning are constructed through the simultaneous and layered deployment of diverse semiotic resources, such as language, gaze, gesture, and the material ecology of the setting (e.g., Goodwin, 2018; Mondada, 2018). Goodwin (2013) refers to this as the 'laminated' nature of social action. In this study, the metaphor of lamination allows us to examine the interplay of different multimodal resources in subject-specific knowledge-building that happens in teacher-led plenary interaction, while the analysis of semantic waves helps us focus attention to the variation in the semantic shifts between the dimensions of density and gravity, i.e., levels of abstraction, complexity and context-embeddedness conveyed through interactional resources.

The data extracts have been transcribed using CA conventions for talk (Jefferson, 2004). Participant's embodied conduct has been annotated in the transcripts by applying Mondada's (2018, 2022) system to make selected and relevant embodied conduct available to the reader in as accessible manner as possible. For key moments, we have also included pencilled line drawings to illustrate the use of the different semiotic resources.

5. Complex constellations of multimodal resources for unpacking and repacking subject-specific knowledge

To report the findings of our micro-level analysis, we have selected seven representative data extracts to illustrate the wide array of multimodal resources employed by both teachers to unpack and repack subject-specific knowledge. Apart from the range of multimodal resources, the findings also show that the ways in which talk and other resources are assembled for multimodal action can result in highly complex semantic waves through which teachers can simultaneously unpack and repack subject-specific knowledge. The analysis first describes how depictive gestures can be used to unpack subject-specific knowledge (section 5.1), after which it sheds light on the use of both everyday material objects and pedagogic artefacts for knowledge-building (5.2). It then considers how the annotation of visual presentations with embodied means can serve unpacking purposes while the visuals themselves maintain a high level of abstraction and complexity of subject-specific knowledge (5.3). In all extracts, the teachers' linguistic choices include shifts in register from everyday expressions to more subject-specific lexis and terms, such register shifts representing one aspect of translanguaging relevant for unpacking and repacking disciplinary knowledge.

5.1. Unpacking subject-specific knowledge with the use of depictive gestures

A key finding deriving from the data is that, throughout the lessons, multimodal resources offer the teachers multiple opportunities to reduce the complexity and abstraction of subject-specific knowledge, an observation noted also in earlier research (e.g. Lo et al., 2023; Walldén & Nygård Larsson, 2021). In this section, we analyse cases where teachers employ depictive gestures alongside talk to unpack the levels of abstraction and density of meaning frequently present in STEM subjects. The extracts demonstrate how the lamination of talk and gestural resources (Goodwin, 2013) works in tandem, i.e. they contribute towards a similar orientation to knowledge-building.

Extract 1 is an example of the physics teacher using the combination of talk and depictive gestures, i.e., movements of speaker's hands to convey a visual orientation to "what something *looks like* or *is like*" (Streeck, 2008, p. 289, emphasis in original). The extract comes from the beginning of a physics lesson when the class is checking students' homework on key concepts related to Snell's law, i.e. the principle of refraction. The extract illustrates how the teacher utilises both language and gestural resources to differentiate and explain the meanings of the terms 'convex' and 'concave'. The extract begins when the teacher first asks for an explanation of what 'convex' means (line 1, henceforth l.) after which he requests students to demonstrate its shape through embodied means (l. 2). The teacher thus orients to the possibility that CLIL students may not be able to explain the term verbally and provides them an alternative means to convey their understanding.

Extract 1. Physics_convex and concave

```
01   T      so what shape is convex,=
02          =could someone <show> that with their hands¿
03          (1.2)
04   T      convex?
05          (0.8)
06   T      because we are going to discuss these words today,
07          we have to know what they ↓mean.=
08          =.hh so what shape is convex? .hh
09          (0.9)
10   T      *is it #plump in the middle,*
            *bh gesture-----------------*
                    #Fig1
11          *or is it plump on# the top an' bottom?*
            *bh gesture-----------------------------*
                                #Fig2
12          (2.5)
13   T      like, could someone point at their notebook
14          .hh that [we-
15   Noora           [like,
16          it's ^like this (0.8)^
                 ^rh curved gesture^
17   T      [^yes.
18   Noora   [^the middle# is^ ^(here)^
             ^lh placed mid-air^
                               ^rh gesture^
                         #Fig3
19   T      yes.=the middle is wi*der. yes. .hh*#
                                 *draws on sb--*
                                               #Fig4
20          that is convex.
21          (0.6)
22   T      <well>, the opposite is <concave>.
23          so how does that shape go?
24          .hhh if *convex is thick in the middle. .hh
                    *bh gesture->
25          (0.5) what is concave? it- if it's the opposite.
26          (3.4)
27   T      everyone is half a*sleep.
                            ->*
28          so *( ) concave i:::s thinner*# in the middle.
               *draws on sb--------------*
                                          #Fig5
```

Figure 1

Figure 2

Figure 3

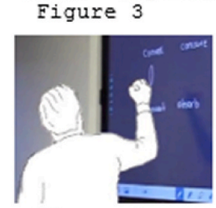

Figure 4

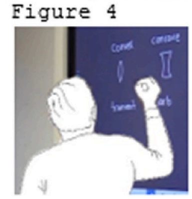

Figure 5

In terms of meaning condensation, the lines 1–8 orient to terminology and hence can be seen to represent a slightly heightened level of abstraction even if the call for students to display knowledge by embodied means also represents a movement towards greater concreteness. As none of the students bid for a turn or offer an embodied demonstration, the teacher reformulates the question by narrowing it down to two yes/no -questions (l. 10 & 11). These questions are multimodally designed and geared towards concretisation and reducing the level of abstraction in that the teacher both offers a verbal description using colloquial vocabulary, i.e., “plump”, alongside with which he performs corresponding depictive gestures Fig. 1 and 2. He thus multimodally unpacks the meaning of the terms ‘convex’ and ‘concave’ for the students, assembling language and gestural resources simultaneously and in an aligning manner to scaffold the content more concrete and less technical for students learning through L2 (l. 10 & 11). In response to the teacher’s question, Noora self-selects and produces an answer in the form of an embodied simile (l. 15–16, 18), where the verbal expression “it’s like this” is accompanied by a curved up-and-down gesture performed with the right hand that shows the ‘plumpness’ of the shape while she keeps the left hand stable in the air (l. 18, Fig. 3). Accepting the response by verbalising that the convex is wider in the middle (l. 17, 19), the teacher turns to the smartboard to draw the shape under the term, which he has written there at the beginning of the activity (l. 19, Fig. 4).

This phase marks a shift in orientation towards more subject-specific conventions in that the drawing together with the verbal explanation repacks the way the meaning of convex is represented. An important feature in the repacking is that the teacher replaces “plump” with “wider”, therefore modifying the register towards more formal one, yet without drawing explicit attention to the difference between these forms. As they move on to the next term, ‘concave’ (l. 22 onwards), he further modifies the register by describing the shape of convex being “thick in the middle” (l. 24) and that of concave as “thinner” (l. 28), emphasising the key words and accompanying the verbal description of convex with the corresponding depictive gesture (l. 24–27), while drawing the shape of concave on the smartboard (Fig. 5). In sum, Extract 1 shows the physics teacher employing talk and depictive gestures in tandem to unpack the meaning of the two key concepts, whereby he slowly begins to scaffold students’ understanding of subject-specific knowledge, i.e. that of the law of refraction.

Extract 2 from the chemistry lesson is another example of the teacher simultaneously using language and depictive gesture to lower the level of abstraction, depicted by Blackie (2014) as an inherent aspect of chemistry. The extract derives from a phase where the teacher provides a short whole-class instruction on the structure of molecules and the bonds between atoms during students’ task work. The teacher is going round the classroom, providing guidance and feedback to groups of students who are building ball-and-stick models of nitrogen molecules with the help of a molecular kit, i.e., a didactic teaching material package designed for chemistry to concretise the structure of chemical compounds. As the extract begins, the teacher is showing one group’s model to the whole classroom (l. 2, Fig. 6).

Extract 2. Chemistry_explosion

```
01   T   good. (0.7) excellent. (0.4)
02       so *this is what nitrogen looks like,#
            *shows model->               #Fig6
03       .hh an' since there is a triple bond,
04       >it's a< >it's a very< *tight bond,
                               *turns model around,
                                    lifts up again->
05       .hh but it reacts quite ea- easily.* (0.7)
```

Figure 6

```
                                  ->*gives model back to student
06       uhh (.) an' that *bond has a lot of ~energy in it.
                          *bh fingertips crunched, touching ->(l. 09)
                                            ~walks to front of classroom->
07       so >nitrogen< (1.1) <is used in ~many explosives>, (0.3)
                                        ->~
08       since when that *bond# breaks,*
                         *hands apart--*
                             #Fig7
```

Figure 7

Figure 8

```
09       it creates a lot of *energy#,
                           ->*hands apart->
                                  #Fig8
10       .hh an' then we get an explosion.* (1.6)
                                        ->*
11       okay?
```

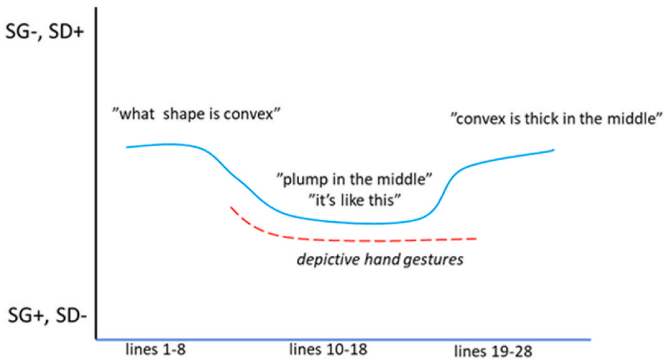

Fig. 1. The semantic wave of Extract 1 where teacher talk and gestures are aligning.

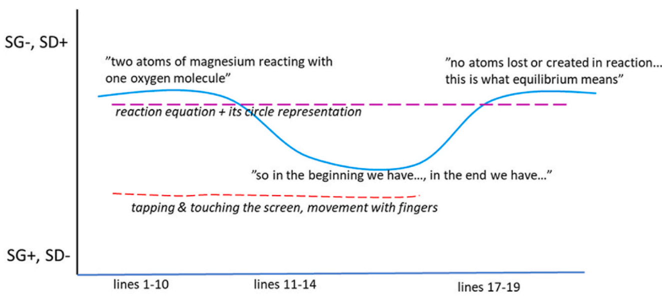

Fig. 2. Different multimodal resources with both aligning and diverging positions on semantic wave.

Direct, easy-to-understand reference to how the model looks combined with showing it to the class (l. 2) serve unpacking functions as they provide the students a concrete and observable representation of the type of bond between the nitrogen atoms, which is otherwise invisible to the naked eye. Lines 3–6 display some repacking in the form of register modification, shown in the more technical references to "triple bond" and "reacting". Together with the notion that bonds contain energy, this increases the abstraction level and represents quite complex subject-specific knowledge. The teacher is unpacking this complexity by both turning the model around in her hand (l. 4), which makes the model visually available to students from different angles, and simultaneously, using everyday language terms "very tight" and "a lot of energy" to describe the properties of the 'triple bond'.

After having given the model back to a student (l. 5), the teacher moves on to elaborate on the practical applications of nitrogen (l. 6–10). In doing so, she engages in unpacking as she reduces the abstraction level of her talk by using more concrete everyday verbal expressions such as the nitrogen "is used in many explosives", "that bond breaks", "a lot of energy" and "we get an explosion". The reduced abstraction level in these verbal resources is aligned with the teacher's three gestures that depict these processes in an embodied manner. Firstly, she visualises a 'bond' with the depictive gesture of putting her hands in front of her torso so that the fingertips touch each other (l. 6). In this kind of gesture, the closely scrunched fingertips depict the bond. Moving to the front of the classroom, she then first makes a smaller movement of hands away from each other as she utters "bond breaks" (l. 8, Fig. 7), and later a larger and quicker movement of hands apart as she refers to an explosion (l. 9–10, Fig. 8). Similar to Extract 1, these gestures are closely laminated with talk in a manner that enables the teacher to lower the level of abstraction in her explanation of subject-specific content, thus scaffolding CLIL students' learning opportunities.

5.2. *Using everyday material objects and pedagogical artefacts for knowledge-building*

While Extracts 1 and 2 showcased the deployment of depictive gestures, the lessons also include instances of teachers harnessing material objects and artefacts for the didactic purposes of unpacking and repacking subject-specific knowledge, including everyday objects and those specifically designed for teaching. Extract 3 illustrates how plastic cups and students' pens/pencils as the key objects in a practical experiment help the physics teacher to unpack the notion of transmission, while in Extract 4 the chemistry teacher mobilises the balls and sticks of the molecular kit to explain the composition of chemical molecules, thus lowering the level of abstraction with the help of the pedagogical artefacts (see also Lo et al., 2023 for the use of an animated mobile app).

Prior to Extract 3, the teacher has asked students to 'dip' a pen or a pencil into a cup of water placed on the two large tables around which the students sit. He has also asked them to discuss how this hands-on experiment is related to an image of a man in a swimming pool that the teacher is showing on the smartboard. At the beginning of the extract, we see that the class agrees that the man is alive, although he seems to be beheaded in the image (l. 32–34). The teacher then uses this shared knowledge to unpack the term 'transmission' that he has introduced to the class during the discussion.

Extract 3. Physics_transmission

```
32    T       he's alive.
33    Elina   I don't think he'd be smiling if he was dead.=
34    T       =I know, yeah. so he's (.) alive.
35            somehow that has to do with .hh the fact that
36            there is *a surface between *(0.2)#* <air>* *an'water.*#
                        *rh gesture----------------*       *bh gesture*
                                           *lh gesture---*
                                                 #Fig9              #Fig10
```

Figure 9

Figure 10

```
37            *.hh what is happening to the pen
              *rh pointing gesture->
38            when you* look from the ( ) *side?*
                    ->*                   *kneels*
39            (3.2)*(0.2)
                   *stands up->
40    T       so if you* l- look from the side,
                     ->*
41            *the thicker pen is ~actually *better this time. .hh
              *lh pointing gesture----------*
                                  ~walks to the other desk->
42            (1.2) what happens~ *to the (0.3)
                               ->~ *kneels->
43            oh #yeah, it does happen here.=
                 #Fig11
```

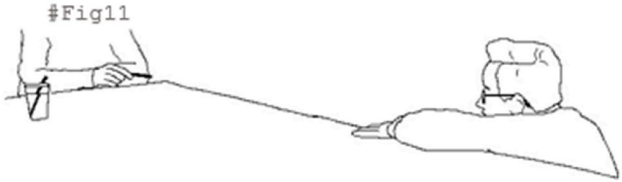

Figure 11

```
44            =what happens to the pen?
45            (2.6)
46    T       *it seeming*~ly in two halves. (0.3)
              *stands up-*~walks to front of class->
47            is it in two halves?
48            (0.6)
49    sts     no::.
50    T       no. it's still the pen.~
                                   ->~
51            the water doesn't break the pen. (0.5)
52            if the pen was sugar, it would dissolve. (0.5)
53            but it's still (0.3) the pen is still there.=
```

The unpacking is first accomplished through a lamination of talk and depictive gestures. The teacher starts by verbally explaining that the impression of the man being beheaded has to do with the surface between the air and the water (l. 35–36), thus alluding to the key factor behind the physical phenomenon of refraction. Simultaneously with this, he produces a left-handed horizontal gesture to establish a surface and a right-handed gesture to locate the air above it (l. 36, Fig. 9). This is followed by a both-handed gesture with which he motions water underneath the surface (Fig. 10). All these gestures can be seen as a way to concretise and re-iterate the importance of the boundary between two different substances to students. Tying the explanation to the hands-on experiment, the teacher then instructs the students to observe the pen from the side of the cup, asking them about the effect of the surface between the two elements on the pen (l. 37–38 & 40–44). The instruction is accompanied by the teacher kneeling, twice (l. 38 & 42–46), next to the two tables around which the students sit and on which the cups are placed (see Fig. 11 of the second kneel). The kneeling guides students to adopt a similar visual perspective, which all students do by crouching closer to the tabletop. In a similar fashion as with the image of the man in the pool, they are now able to inspect in very concrete terms the effect of the boundary between air and water on the pen. However, when no one responds to the teacher's question on the effect (l. 44), he explicitly scaffolds the students to observe it by asking if the pen has been cut in half by having been placed in water (l. 46–47). To this, the students respond negatively in unison (l. 49), whereby they display their understanding of the phenomenon.

While the use of the everyday material objects in the hands-on experiment together with the teacher's embodied explanation has rendered the theoretical notion of transmission as concrete to the students and helped the teacher to guide students to generalise on the notion by utilising both the image of the man without a head and the experiment, it remains unclear whether students are able to do so. Considering the fact that students are learning through L2, it may be that the upward semantic shift toward more decontextualised, abstract level would require several undulations of semantic waves (also Walldén & Nygård Larsson, 2021) and an explication of their relationship to the concept of 'refraction' that would eventually help the teacher to guide students to view the phenomenon, literally, with 'a scientific gaze' (Doran, 2019b).

Compared to Extract 3, where the use of the different modalities is aligned and serves unpacking purposes, in Extract 4 the chemistry teacher's use of multimodal resources is differentiated: while her talk maintains the high level of abstraction, the employed embodied and material resources help lower it. In the extract, the teacher begins to instruct a new group task the purpose of which is to make learners familiar with different molecule structures by introducing the ball-and-stick model. The extract shows that the teacher is not only concerned with outlining practical aspects of the next task, but also with establishing what kind of scientific phenomenon the "balls" and "sticks" relate to (l. 9–20). A key resource for accomplishing the instruction in addition to talk that involves the use of quite abstract notions of chemistry is the way the teacher simultaneously manipulates and shows the tangible and three-dimensional material artefacts to the class.

Extract 4. Chemistry_bond between atoms

```
01   T   so (0.9) uhm (0.8) what we are going to: (1.0)
02       erm build here (.) are ball an' stick models.
03       .hh so (0.5) these (0.9) *>kind of< joints that you have there,*
                                  *shows joints in both hands-----------*
04       (0.6) there's three different lengths, .hh
05       erm (0.2) *I wouldn't use these smallest ones,
                   *shows small joint->
06       since they are *<ve>ry tricky (.) to get off.*
                      ->*waves joint in air-----------*
07       .hh so (0.2) umm (0.8) *the- the middle size is the *best
                                *shows joint, turns wrist----*taps->
08       (0.2) .hh #*joint. *the best *stick.
                    *taps---*taps-----*taps
                   #Fig12
09       .hh an' what this stick describes,
10       is (1.4) uhh <*bond> between two atoms. (1.1)
                       *taps
11       'kay?
12       (0.3)
13   T   .hh so atoms bond in different way:s,
14       we will study that next year in chemistry¿
15       .hh but *this *stick is a *bond *between atoms. (0.3)
                 *taps *taps(lifts)*taps *taps
16       .hh okay? so I- I encourage you to *use this. (0.8) *uhh
                                            *shows joint-----*
17       (0.6) ^↑some↓^times (0.4) instead of having *just *one *bond,
               ^gaze to board^                        *shows*taps*taps
18       (0.4) *molecules can have a double bond.* (0.2)
               *taps                             *puts down joint
19       .hh an' that happens °es-° *(0.7) uhh (0.2)
                                    *picks up joint, attaches it to a
20       .mt .hhh for example,* in the oxygen atom? (0.6)
         ball-----------------*
21       so when you are doing-* >uhh sorry< (0.3) in oxygen *molecule=
                               *attaches another joint-------*shows model->
22       =so >when you are< building the oxygen molecule,
23       .hh use now the *lon#gest (1.0) joints?** (1.2)
                         *shows joint with thumb and index finger*
                                                               ->*
                             #Fig13
```

Figure 12

Figure 13

Figure 14

```
24       an' put: *two (1.3) joints there (.) in between (1.9)*
                  *attaches second ball to the model----------*
25       those (0.5) *atoms# of oxygen.*
                     *shows finished model*
                           #Fig14
```

The teacher performs different haptic actions as she instructs students in both the practical aspects related to the task (l. 1–8, 21–25) and the scientific relationship of representation between the parts of a chemical compound and the “sticks” in the ball-and-stick model (l. 9–20). For instance, the teacher holds up a mid-sized stick between her index finger and thumb and displays it to the class with precise wrist movements that make it visually accessible to all areas of the class (l. 7–8, Fig. 12). She also emphasises elements of her talk through her hand movements, such as when she waves the stick in her hand while telling that the small joints are “tricky to get off” (l. 6) and by rhythmically tapping with her hand and the stick in air as she explains that the stick represents “a bond between atoms” (l. 9–10, 15). While the showing of the stick and the tapping and touching actions serve to unpack the scientific aspect of the model, the teacher’s verbal explanation establishes an explicit semantic shift toward more abstract and subject-specific expression, including the elaboration of molecules having “a double bond” (l. 18).

Besides showing the elements, the teacher further concretises what she through talk has conveyed about the structure of molecules by concretely assembling the model of an Oxygen molecule (l. 19–25), which is one of the chemical structures that students need to complete in the task. As she instructs students to use the longest sticks (l. 23), she holds the half-finished Oxygen molecule in her left hand and holds her right-hand index finger and thumb at different ends of the stick (Fi g. 13), which can be seen as a form of pointing that highlights for the students an essential feature of the learning material. When the teacher has assembled the Oxygen molecule, she shows it to the class (l. 25, Fig. 14). In these ways, diverse embodied practices of displaying, manipulating and pointing at the learning material are central resources in not only instructing the students in the practical work of assembling the ball-and-stick model, but also repacking the practical aspects of the task into a scientific understanding of the phenomenon being scrutinised.

5.3. Unpacking abstract subject-specific visual representations with embodied means

As discussed in previous research (e.g., Blackie, 2014; Doran, 2019a, b), complex and context-independent specialised meanings in STEM subjects often reside in images, such as graphs and diagrams, and equations. In this section, we provide illustrative examples of cases where visuals have a repacking purpose in that they represent abstract, theoretical knowledge which is simultaneously unpacked by the teachers when they annotate their explanations of subject-specific terms and concepts both verbally and through embodied actions. The extracts demonstrate how this is done when subject-specific content is mediated by a Prezi (Ext. 5) or PowerPoint (Ext. 6) presentation or via the document camera (Ext. 7) on the smartboard screen. The embodied means harnessed for annotating actions include pointing and/or touching the smartboard screen (Ext. 5 and 6) and pointing, drawing and writing on a task sheet (Ext. 7).

Extract 5 comes from the plenary part of the physics lesson, where the content-to-be-learnt is the physical law related to refraction (i.e., Snell’s law) which the teacher explains with the help of a diagram that comprises the key elements of the law (see Fig. 18) and that he has designed on a Prezi-presentation. The extract demonstrates how the teacher unpacks the level of abstraction of the key concepts related to refraction and the information condensed in the diagram by using everyday register and by pointing at relevant places on the diagram. Prior to the extract the teacher has instructed the students to continue drawing a diagram into their notebooks by adding into a previously started drawing. At the beginning of the extract, he guides students to focus on the part below the surface (l. 10–14).

Extract 5. Physics_Angle of refraction

10 we're going to continue the dashed line .hh
11 through the surface.
12 (3.4)
13 an' we're going to let, (1.1) the (0.7)
14 laser beam, pass through (.) the surface. .hh
15 *(1.0)*
presses computer key:a diagonal line below horizontal appears
16 .hh an' this is <where> you have to pay
17 some attention to the angle. .hhh
18 (0.8)
19 the *angle has to be smaller on the bottom side.* (0.7)
rh pointing gesture-------------------------
20 *this angle# over here, has to be way smaller* than# eithe-
*rh pointing gesture--------------------------*rh back-and-
#Fig15 #Fig16

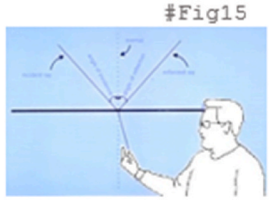
Figure 15

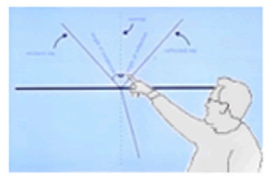
Figure 16

21 either one of these two angles on* top.
forth gesture---------------------*
22 (2.1)
23 smaller angles.
24 (2.3)
25 smaller angles.
26 (9.2)
27 an' this, (1.5) brings forth the fact that the PEN
28 (0.8) is as if it's bent,
29 an' this (0.5) gives (1.1) the idea of a man losing his head.
30 .hh because the angle on the water side is ↓smaller.
((lines omitted))
44 T *↓yes.*=angle# <of> refraction. (0.9) indeed.
presses computer key: name of angle appears
#Fig17

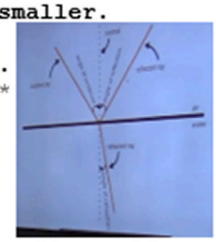
Figure 17

45 (2.0)
46 angle of refraction.
47 (3.6)
48 angle of refraction.
49 (9.0)
50 *an' there's* a law, (0.9) related to this
presses computer key: diagram is zoomed out
51 that explains why the man's head is detached from his body.
52 *.hh the* name of the law (0.4) is <Snell's law.#>
presses computer key: name of law appears #Fig.18

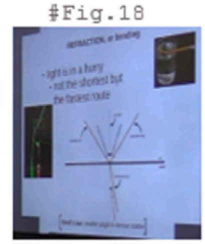
Figure 18

53 (1.6)
54 why is it called Snells?
55 because there was man (.) long time ago (1.1)
56 whose surname was Snell.
57 (1.3)
58 so, according to his law .hh
59 a smaller angle, *in this diagram,*
lh pointing gesture
60 appears in the denser, heavier matter.
61 (2.1)
62 <<smaller angle (0.8) in denser matter.>>
63 (4.2)
64 so, the denser th- uhh (.) substance is,
65 the smaller the angle in this diagram is.

Throughout the extract, the teacher reveals each new part of the diagram one by one to allow students time to draw (l. 15, 31, 38, 44, 50, & 52). This also provides him an opportunity to structure the explanation in a stepwise manner, using the affordances of the presentation to unpack the law. In line 15, the teacher reveals a diagonally drawn line into the diagram, after which he, using everyday register clearly bound to the context of the diagram ("this is where"), directs the students' attention to its angle, thus giving them a warning that it is of a specific kind before they draw it (l. 16–17). This heads-up is followed by a specification (l. 19–21) that establishes the difference between the angle of incidence and reflection to that of refraction. Noteworthy here is the teacher's use of everyday deictic expressions to locate the difference in the size of the angle, i.e., "smaller on the bottom side" and "than either one of these two angles on top". Accompanying the verbal specification, the teacher produces pointing gestures that identify the referents of the deictic expressions (l. 19, 20 and 21). The gesture in line 20 is produced so that the teacher's right-hand fingertip points upwards to the narrower angle below the water surface (l. 20, Fig. 15). When the teacher clarifies that the angles of incidence and reflection on the water surface are wider (l. 20–21), he traces the width of the angles with his right-hand fingertip in a back-and-forth gesture (Fig. 16). This way he both verbally and visually unpacks the condensation of meaning within the diagram by drawing students' attention to both the location and size of the refracted angle, i.e., to information needed to understand the law.

The teacher then relates the explanation of the angle to the practical experiment and the example the class discussed at the beginning of the lesson: how the pencil and the man's head seem to be "detached" when both are inspected through a plastic cup and a glass, respectively (l. 27–30), thereby connecting both to the law of refraction. The multimodal explanation phase is then followed by the teacher adopting a more theoretical stance, indicated by the three repetitions of the core concept, which may simultaneously serve as a CLIL strategy to ensure students' attention to the centrality of the concept (l. 44–48, Fig. 17). As a final step after this, the teacher both introduces and names the law (l. 50–56) and provides a formal explanation that he explicitly connects to the diagram by a pointing gesture and a deictic reference (l. 58–60). In line 62, he repeats its main idea in a shortened form that is also written on the presentation (see F ig. 18). To conclude, he again reformulates the idea by replacing "denser, heavier matter" (l. 60) with the slightly more technical "the denser the substance" (l. 64), such reiteration of the law showing a slight upward shift in the semantic density of the subject-specific lexis. The verbal reiterations of the law together with the visual diagram thus serve to repack its theoretical foundation by building on the practical experiment and the stepwise explanation of the visual diagram.

Extract 6 is another example of embodied annotation, showing how the chemistry teacher highlights semiotic resources on a displayed slide by touching and pointing at them with her fingers. Prior to the extract, the teacher has named and explained the law of the conservation of matter, and the extract illustrates how she unpacks it by reducing the complexity and density of subject-specific knowledge packed into chemistry formulas to show and explain to students how matter is conserved in an example chemical reaction equation.

Extract 6. Chemistry_equilibrium

```
01   T   .hh >we hav-< (.) >have to have the< ^same number of atoms
                                             ^walks to sb->
02       (0.5) >in the end< than we had in the beginning. (1.4)
03       so^ .hh when we are burning *magnesium, (0.4)
         ->^                         *points at '2 Mg' w/ index finger->
04       there always *↑two *atoms ↓of mag↑nesium, (1.0) are*
                    ->*taps 1st Mg atom
                            *taps 2nd Mg atom and holds index on it*
05        (0.5) uh reacting, with *<one> oxygen molecule. (2.5)
                                  *touches O atoms w/ index finger-
06       as a reac*tion the oxy*gen molecule *breaks apart# (1.4)
         ---------*            *touches oxygen atoms w/ two fingers
                                             *draws the fingers apart-
                                                          #Fig19
```

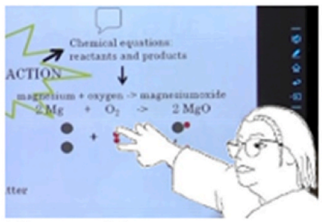

Figure 19

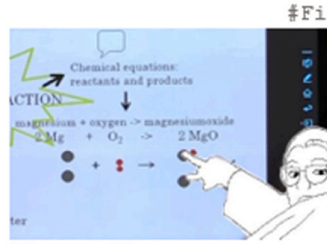

Figure 20

```
07   T   .hh an'* forms (0.4)
         -------*
08       uh *both of those of atoms*, >that are broken apart,<*
            *touches O atoms w/ index finger*keeps index on sb*
09       .hh they *form a bond (0.9) with# magnesium? (0.2)
                  *touches two Mg atoms w/ index and middle finger-
                                         #Fig20
10       an' two: (0.5) *uh pieces of mag*nesium oxide are formed. (1.1)
         ---------------*taps all four atoms one after the other*
11       so >in the beginning< we have *two magnesium* atoms,
                                       *taps Mg reactant atoms*
12       in *the end we have two magnesium °atoms°. (0.5)
            *taps product Mg atoms and holds index on top one-
13       in the beginn*ing, we have *<one (.) diatomic> oxygen molecule*
         -------------*             *touches reactant O atoms----------*
14       ↑in the end, we have (0.5) *uhh one* (0.4) oxygen (0.6)
                                    *taps product O atoms one by one*
15       atom bound *to both* of those (0.9) ↓magnesiums. (1.3)
                    *taps both product Mg atoms*
16   T   okay? (0.4)
17       so no atoms are lost, or created in this reaction.
18       (0.5).hh or any reaction. hh (2.2)
19       that is what equilibrium means, here.
```

Throughout the extract, the teacher performs haptic annotations to illustrate how the conservation of matter is visible in the reaction equation on the displayed slide. In line 3, she points (but does not observably touch) around the general direction of '2 Mg' and the green circles that represent the two magnesium atoms on the left-hand side of the equation as she introduces the first reactant in the equation. The verbal elements of the turn make a general (non-countable) reference to the burned substance ('magnesium', l. 3). In rest of the extract, the teacher visibly touches the circles that represent atoms on the slide, using either a brief tap or a sustained touch.

The sustained haptic annotations are performed in a recurring pattern of touching a circle in the slide, pausing talk and shifting gaze to students (such as in Fig. 20) and seem to serve scaffolding purposes. For instance, in line 6, the teacher depicts the bond breaking of the oxygen molecule by touching it with two fingers and then drawing her fingers slightly apart (l. 6–7, Fig. 19). This embellishes the two-dimensional static image shown on the slide by adding movement in it, thus concretising the chemical process. On the other hand, when the teacher refers to the products of the equation in lines 9–10, she places her index and middle finger on the green circles that represent magnesium atoms (Fig. 20) and keeps them in that position as a visual depiction of the more static 'bond' between atoms.

The teacher also shortly taps on the circles in the reaction equation in lines 10–15 as she recaps her explanation. Tapping serves to direct the students' attention to the circles and unpacks the principle of conservation of matter by showing visually that an equal number of circles is on both sides of the reaction equation. The images of green and red circles thus function as concrete representations of matter on the slide, which have different kinds of visual affordances for explaining the principle compared to the chemical symbols of atoms. Both the circles and the act of tapping, therefore, are unpacking the complexity of, and multiple processes packaged into, the reaction equation that represents the conventional subject-specific way of conveying knowledge in chemistry. Such versatile deployment of multimodal resources signals the teacher's awareness of the need to traverse different levels of abstraction and context-dependency to make the subject of chemistry that Blackie (2014: 462) describes as "profoundly abstract" more accessible to CLIL students who may face challenges deciphering the abstract content in L2.

Extract 7 is an example where the teacher's talk operates at rather abstract and complex levels of chemistry-specific knowledge, particularly in her use of chemical terminology, while other multimodal resources, such as the use of pen to point, underscore, draw symbols, and inscribe letters, serve unpacking functions by making such knowledge more accessible. They also, at times, help repack student contributions into subject-specific ways of building knowledge (cf. Walldén & Nygård Larsson, 2021). In the extract, the teacher and the students are collaboratively writing a reaction equation on a task sheet after an experiment involving a reaction between magnesium and hydrochloric acid. Prior to the extract, the teacher has already written 'Mg + 2HCl ->' on the task sheet. She has asked the students to come up with the product but has already rejected two suggestions by the students. As the extract begins, the third student responds.

Extract 7. Chemistry_reaction equation

```
01   S   (c two) (xx)
02   T   .hh ↑yes. ↑that was the closest one. so far.
03       .hh *so we ↑could ↓write* it, >kin' of< (0.4)
            *places pen on the answer line*
04       *two chlorines and magnesium*#,
         *writes 'CL2Mg'-------------*
                                      #Fig21
05       .hh but it's- it's just a habit that we
06       *write the magnesium*# first.
         *adds lines around the compound*
                             #Fig22
```

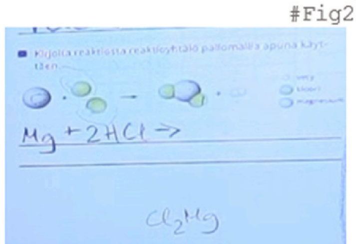

Figure 21

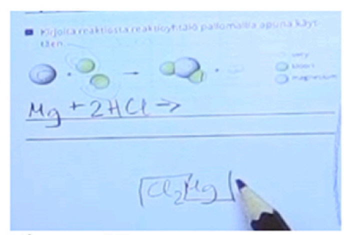

Figure 22

```
07       .hh *so we first* take this one *magnesium? >↑that is* there<
            *circles blue ball*         *writes 'Mg'---------*
08       .hh *an' then (.) *we put the two chlorine *atoms, (0.4)
            *touches green balls w/ pen*            *writes 'Cl2'->
09       e-* c l two. (0.5)
         ->*
10       .hh an' *this small two# here (.)
                 *traces '2'->
                            #Fig23
11       means* that they are *bound to this.* (1.4)
          ->*            *traces edges of blue ball*
```

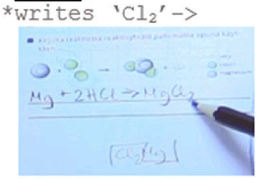

Figure 23

```
12       there's two chlorines bound to that one. (0.4)
13       .hhh an' then there's (0.3) *one ()hydro*gen molecule, (1.1)*
                                     *circles two balls*writes '+ H2'*
14       which we write as h two.
15       (3.4)
16   T   ↑okay?
17       (1.1)
18   T   ↑an' if you want (0.4) ↓you can write, (0.4)
19       *one (0.5) magnesium ↑atom (1.1) ↓plus two: (1.3)
         *writes->
20       hydrochloric acid (4.1) molecules, (2.9) *pro↑duces* (1.6)
                                                ->*draws arrow*
21       *↓>so in chemical equations# we< ha-
         *traces an arrow w/ pen->
                                   #Fig24
22       don't have .hh the (0.7) uhh equal* symbol
                                        ->*
23       but (.) m- *we use an arrow? (0.3)
                    *thickens the bigger arrow->
24       so (0.3) something is pro*duced,
                               ->*
```

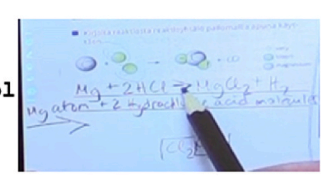

Figure 24

```
25       .hh an' as *products* we have (0.3)   *magnesium chloride? (1.2)
                    *points w/ pen to products* *writes->>
26       .hh magn- (.) ne(h)sium (2.2) chloride (1.9) plus (0.6) ↑two:
27       (0.6) ↓sorry (0.7) plus (0.8) hydrogen (1.5) .hh molecule.
```

The teacher responds to the student's answer by indicating verbally that it is partially correct (l. 2) and by visualising the correction by way of writing that is displayed to the class on the smartboard (l. 3–6). She writes the student's suggestion in an empty space on the task sheet, below the answer line (l. 4, Fig. 21). Together with the verbal description expressed in conditional form ("we could write it"), the place indicates that the student's proposition is incorrect. The teacher's correction evokes and makes explicit the subject-specific conventions, the language of chemistry, in the order of the compound ("a habit that we write magnesium first", l. 5–6). While talking, she draws a line as a depiction of reversing the order of the atoms (Fig. 22).

Moving to write down the correct answer above the line, the teacher first traces three times the inside contour of the blue ball that represents magnesium after which she writes the chemical symbol (l. 7). Then she quickly points at the two green, chlorine atoms before writing the chemical symbol (l. 8–9). She also unpacks what '2' in the resulting '$MgCl_2$' indicates about the structure of the molecule (l. 10–12), manifested both in the concrete and context-bound way of talking, including indexicals ("this", "that one"), and by tracing with her pencil the outline of the number and pointing at the blue ball (Fig. 23). These practices showcase the use of different semiotic resources for different purposes in that both the everyday, context-bound register "first we take this" and the concrete visualisation of an atom as a ball alongside tracing and pointing actions serve to unpack the complexity of chemistry-specific knowledge while writing the chemical equation repacks it by foregrounding the conventional knowledge representation in the discipline. Contextual dependency is also reduced in that the conventional equation demonstrates the general principle of the conservation of matter in the equation.

In addition to actions with the pencil, the teacher writes a verbal description of the reaction underneath the chemical equation in lines 18–27. She thus unpacks the symbol-based representation of chemistry knowledge not only as the names of the atoms and molecules but also in relation to students' possible other disciplinary knowledge by explaining and highlighting with the pen the difference to mathematical equations which use an "equal symbol" instead of an "arrow" (l. 21–22, Fig. 24). The teacher also explains why the arrow is used (l. 24). These explicit references to subject-specific conventions of representing knowledge – and their relation to other sets of conventions – can be seen as ways to support relevant disciplinary literacies. It is also noteworthy how the teacher's multimodal unpacking actions are simultaneously accompanied by repacking through talk that is rich in semantically dense subject-specific terminology (l. 19–20, 25–27) such as "magnesium atom", "hydrochloric acid molecules", "magnesium chloride". The other multimodal resources are thus serving the purpose of unpacking the complexities of such subject-specific language. All in all, these multimodal actions enable the teacher to draw students' attention to discipline-relevant writing practices and knowledge-building and to establish meaningful connections between the symbol-based expression in the reaction equation and the semiotic representations of atoms.

6. Discussion and conclusion

In this article, we have explored how different multimodal resources are used by a physics and a chemistry teacher to unpack and repack subject-specific knowledge in CLIL classroom interaction. Overall, the findings attest to the key role that multimodality has in CLIL classrooms in building and teaching disciplinary knowledge and the wide variety of resources used. Firstly, alongside the resources of spoken and written language, both teachers used depictive gestures and other embodied actions (Ext. 1, 2 and 6), material objects and artefacts (Ext. 3 and 4), different types of technology (computer, PowerPoint and Prezi presentations, smartboard; Ext. 5, 6 and 7) and inscriptions (Ext. 1 and 7) to build knowledge. Secondly, these resources were shown to serve important roles in knowledge-building and in supporting CLIL students' comprehension of the content. On the one hand, they were used to concretise and render observable theoretical abstraction typical for both physics and chemistry (e.g., the notions of refraction (Ext. 3) and molecular structure (Ext. 4)). In LCT terms, multimodal resources were used for unpacking purposes as they helped increase context-embeddedness and reduce complexity. Such unpacking is a key pedagogical strategy in CLIL classrooms as also attested by earlier classroom-based multimodal interaction analyses which have suggested that multimodal means have an important role in scaffolding learning (e.g. Escobar Urmeneta & Evnitskaya, 2014; Evnitskaya & Morton, 2011; Kääntä et al., 2018). However, in addition to scaffolding CLIL learners, multimodal resources were also shown to have a role in maintaining and building up the level of abstraction, as in the cases of the physics teacher using a diagram when explaining refraction (Ext. 5) or the chemistry teacher using the reaction equation to capture the conservation of matter (Ext. 6). In LCT terms, these constitute ways of repacking subject-specific knowledge to higher levels of abstraction and complexity.

By making visible the inherently multimodal nature of unpacking and repacking in CLIL classrooms, the present study complements the existing LCT-based research that has tended to explore knowledge-building practices from the perspective of spoken and written language (e.g., Clarence, 2017; Cranwell & Whiteside, 2020; Dankenbring et al., 2023). Its focus on multimodal resources also foregrounds the fluidity and flexibility of transcending between and across modalities as well as their simultaneous deployment. This can usefully be captured by the notion of translanguaging in its broader sense that sees it not only as a multilingual but also multimodal practice (e.g., Li, 2018; Tai, 2023b); multilingualism seen this way does not only concern named languages but also variation brought about by using different dialects, styles and registers, the latter particularly relevant in this study due to the frequency of shifts between technical/subject-specific and everyday registers. Such a view of translanguaging resonates with what Lin (2015; 2019) calls *trans*-semiotising, i.e. the fluid and dynamic interplay between language and other semiotic resources and the rich variety involved in the latter (visuals, human bodies, gestures, eye-gaze, etc.). The contribution of this study to translanguaging research derives from the insights it offers to the significant role that multimodal resources have in subject-specific knowledge-building practices (see also Tai, 2023a, b). More specifically, it shows the versatility both in the range of multimodal resources used and in their functions for repacking and unpacking subject-specific knowledge. It remains a task for future CLIL research to explore how best to make such multimodal resources a consciously planned part of CLIL pedagogy.

In addition to identifying processes of unpacking and repacking, the LCT-informed semantic wave analysis combined with CA yields information about the temporality of these processes. This means observing how the degrees of semantic density and gravity vary during the teaching episodes depicted in the extracts, i.e., what kind of semantic waves emerge. The detailed multimodal interaction analysis also helps discern the relationship between teacher talk and other multimodal resources in the process of unpacking and repacking. Argüelles-Álvarez and Morton , (2023: 7) conducted a semantic wave analysis of two lecturers' talk, tracing the strengths of semantic gravity and density separately. They noted that these dimensions occasionally draw towards opposite directions, i.e. the inverse relation between SD and SG often depicted in the literature does not necessarily always apply. The same can be observed in the relationship between teacher talk and other multimodal resources in our study: at times their unpacking and repacking functions align with each other, at others they diverge. In terms of semantic waves this means that instead of a clearly delineated undulation and progression of semantic waves smoothly following each other, our findings show the *simultaneity* in the use of different resources often pointing to different directions on the semantic scale.

The main patterns in the varied purposes for which the simultaneous multimodal resources are used can be depicted with the following figures of semantic waves. Fig. 1, based on Extract 1, roughly illustrates the unpacking and repacking processes revealed by our analysis, separated for teacher talk (blue line) and other multimodal resources (red line). It shows a case where the aligned use of all multimodal resources features especially strongly in the unpacking phase, i.e. at the hollow of the wave that involves increasing context-dependency (SG+) and reducing the level of complexity (SD-) simultaneously by means of teacher talk and other multimodal resources, i.e. the teacher's use of everyday register combined with depictive gestures. As we have seen, also other extracts (e.g. Extracts 2, 3) involve simultaneous unpacking by both teacher talk and use of other semiotic means. Such simultaneity may be a CLIL strategy, the use all possible resources helping to render the content more accessible to students learning through L2 but it may also reflect the abstract nature of the content studied. An interesting further avenue for future research would be to compare CLIL and non-CLIL classrooms to see how multimodal unpacking and repacking feature in each.

Our analyses above have also indicated that the simultaneity of various multimodal resources also means that they may be used for diverging purposes. This was noted, for example, in connection with Extracts 4, 5 and 7. Here we illustrate the simultaneous divergent functions with Fig. 2, based on Extract 6, which depicts how the chemistry teacher explained the meaning of equilibrium with the help of a chemical reaction displayed to the class. The figure shows, firstly, that the multimodal resources accompanying teacher talk cannot easily be represented as a coherent semantic wave. In this case, the teacher's tapping and touching actions and finger movements add context-boundness and concreteness (SG+, SD-) and are indicated by the red dashed line at the bottom, while the reaction equation and its visual representation with different-sized circles on the slide condense complex chemistry information (SG-, SD+) throughout the extract, indicated by the upper purple line. Secondly, the figure illustrates that there are both moments when talk and other multimodal means are aligned on the semantic wave and moments when they diverge. Alignment happens when teacher talk and embodied actions jointly serve unpacking purposes in lines 11–14 and when teacher talk and the condensed information on the slide jointly contribute towards repacking knowledge in lines 1–10 and 17–19. Divergence is visible when the different modalities draw to different directions as in lines 1–10 when the abstract and technical teacher talk and meaning-condensing visual (SG-, SD+) are accompanied by the teacher's embodied actions of tapping and touching the screen and depicting bong breakage with her fingers (SG+, SD-), or in lines 11–14 where the everyday register and tapping and touching the screen (SG+, SD-) are accompanied with an image that condenses information of a chemical reaction (SG-, SD+).

Fig. 2 thus demonstrates that taking into account the totality of multimodal resources for knowledge-building foregrounds the multilayered and complex nature of unpacking and repacking processes which does not neatly transfer into a unified wave formation. However, as we have shown above, all our data extracts involve teachers shifting between technical and everyday registers and different multimodal resources to both condense and open up subject-specific content knowledge. As Maton (2013: 19) argues, such upward and downward shifts are required for cumulative knowledge-building. Closer attention to the notion of semantic waves thus has pedagogical potential for all teaching but may be especially relevant for CLIL contexts where teaching subjects through L2 adds an extra challenge, leading teachers to often express the need for CLIL-specific pedagogical guidelines (see e.g. Lo, 2020). CLIL teachers might thus benefit from more conscious strategies of intertwining talk and other semiotic resources to unpack levels of abstraction and to scaffold the learning of subject-specific knowledge. Furthermore, they might also benefit from steering learners' attention to how, apart from scaffolding purposes, multimodal resources may constitute an important aspect of subject-specificity, forming a part of what has been referred to as different disciplines having their own "ways of knowing" (Moje, 2008, p. 99) or "ways of seeing the world" (Doran, 2019b, p. 181). There is room for future research to explore in more depth the role of multimodal means in condensing subject-specific knowledge and the kinds of pedagogical solutions that would be most beneficial in CLIL contexts for unpacking such condensed knowledge.

In addition to pointing towards the need for heightened awareness of the downward and upward semantic shifting as such, another important pedagogical implication raised by the findings relates to how explicitly these shifts are signposted and modelled by teachers to support learners. This is an important equity concern as there may be great variation among children in their ability to recognise and produce 'semantic ranges', i.e. variation between the more abstract and technicalised and the more concrete (Maton, 2014, p. 205). Education should guarantee similar opportunities for all learners to navigate and be cognisant of both the everyday/context-dependent and technical/complex forms of knowledge. We have seen that the teachers were constantly involved in variation and shifting between unpacking and repacking through multimodal means and register shifts. However, these shifts were rarely accompanied by explicit signposting by means of, for example, teachers drawing students' attention to differences between the more technical and everyday registers or to the relationship between different ways of representing knowledge. One of the rare examples where the discipline-specific conventions were explicitly evoked in our data was in the case of Extract 7 where the teacher directed students' attention to the specific conventions of conveying chemistry knowledge through equations. Otherwise, the teachers used but did not explicitly make students aware of the multiple means of conveying and constructing knowledge in their subjects. Therefore, it would be important to include such explicit signposting of subject-specific knowledge-building in CLIL teacher training, both in Finland and in other contexts, to support learning and learners' ability to display their knowledge in subject-specific ways in their L2.

In sum, given that CLIL teachers both in Finland and elsewhere may face the challenge of going beyond key terminology as an indication of subject-specificity, a key contribution of this study lies in highlighting how unpacking and repacking subject-specific knowledge is accomplished through the intricate use of teacher talk combined with other multimodal resources. Pedagogical implications concern, firstly, the need for teachers to introduce more explicitness when involved in shifts between abstraction levels. Such signposting provides scaffolding that can no doubt be beneficial for all learners but especially for those learning through L2. Secondly, while in CLIL methodology the key role of multimodal input to support learners' understanding has been acknowledged from the start (e.g., Dale et al., 2011), attention also needs to be paid to the role of multimodal resources in constituting a key component of subject-specific literacy, often condensing subject-relevant knowledge in highly abstract ways (Blackie, 2014; Doran, 2019a, 2019b). As we have seen in connection with graphs and equations, an important aspect of chemistry and physics teachers' skill set is the ability to unpack this highly condensed information to support learners' understanding of the content but also to guide the learners towards subject-specific conventions of knowledge building. Our analysis showed that there are occasions when high levels of abstraction in talk combine with high levels of abstraction in visuals. Therefore, it is important to develop strategies in CLIL teacher education for how best to tackle such moments of high semantic density.

We conclude by acknowledging the limitations of this exploratory study. Given its focus on two CLIL teachers and lessons in Finland, we are aware that the size of the data sample has limited generalisability and that due to diversity in CLIL implementation (for the situation in Europe, see Gülle & Nikula, 2024) classroom practices in other contexts might have different emphases. Therefore, further research is needed to gain a more comprehensive view of the role of multimodal resources and their interplay in knowledge-building in different subjects, across age and educational levels, and in different CLIL contexts. At the same time, we believe that a close microanalytic approach combined with semantic wave analysis, by enabling detailed attention to the accomplishment of social and epistemic actions, can offer valuable initial information on how transcending between different multimodal resources is employed in real-time interaction to accomplish practices of unpacking and repacking subject-specific knowledge and insights for CLIL research and pedagogy to be further developed in future studies.

Position in the aims and scope of learning & instruction

This submission is intended for a Special Issue “Multilingualism in CLIL” edited by Professor Kevin Tai, Professor Li Wei & Professor Elizabeth Loh and it is a contribution towards exploring the role of multilingual and multisemiotic resources in CLIL education.

CRediT authorship contribution statement

Tarja Nikula: Writing – original draft, Visualization, Investigation, Conceptualization. **Teppo Jakonen:** Writing – original draft, Visualization, Methodology, Investigation, Conceptualization. **Leila Kääntä:** Writing – original draft, Visualization, Methodology, Investigation, Conceptualization.

Declaration of competing interest

None.

Acknowledgements

This work was supported by the Academy of Finland [grant number 343480].

Appendix. transcription conventions

.	downward/stopping intonation
,	continuing intonation
?	rising intonation
¿	slightly rising intonation
↑	rise in pitch
↓	fall in pitch
what	word emphasis
>what<	compressed talk
<what>	slower talk
°what°	quiet/softer speech
WHAT	loud speech
wha:t	lengthening of a sound/syllable
(1.9)	duration of silence
(.)	micro pause
((laughs))	transcriber’s comments
(xx)	unrecognizable item(s)
(what)	dubious hearing
hhh	audible aspiration
.hh	audible inhalation
.yeah	word is said with an in breath
ye-	a cut-off word
[what]	overlapping talk
=	contiguous utterances or units of talk
£what£	smiley voice
wh(h)a(h)t	laughingly uttered word or phrase
* *	participant’s embodied actions are delimited between two identical symbols (one symbol per participant and per type of action) and are synchronized with correspondent stretches of talk or time indications.
*->	action described continues across subsequent lines
->*	until the same symbol is reached.
-≫	the described action continues beyond the extract
#	marks the temporal placement of figure in relation to talk
rh/lh/bh	right/left/both hand(s)
sb	smartboard

References

Airey, J., & Linder, C. (2009). A disciplinary discourse perspective on university science learning: Achieving fluency in a critical constellation of modes. *Journal of Research in Science Teaching, 46*(1), 27–49. https://doi.org/10.1002/tea.20265

Argüelles-Álvarez, I., & Morton, T. (2023). Using legitimation code theory to investigate English medium lecturers’ knowledge-building practices. *Journal of English for Academic Purposes, 65*(January). https://doi.org/10.1016/j.jeap.2023.101285

Atkinson, D. (2010). Extended, embodied cognition and second language acquisition. *Applied Linguistics, 31*(5), 599–622. https://doi.org/10.1093/applin/amq009

Blackie, M. A. L. (2014). Creating semantic waves: Using Legitimation Code Theory as a tool to aid the teaching of chemistry. *Chemistry Education: Research and Practice, 15*(4), 462–469. https://doi.org/10.1039/c4rp00147h

Bozbiyik, M., & Morton, T. (2022). Transitioning between ‘outside’ and ‘inside’ knowledge in an online university EMI chemistry course. *Applied Linguistics, 44*(2), 265–286. https://doi.org/10.1093/applin/amac068

Bozbıyık, M., & Morton, T. (2023). Lecturers’ use of examples in online university English-medium instruction: A micro-analytic classroom interaction and knowledge-building perspective. *Language and Education*, 1–20. https://doi.org/10.1080/09500782.2023.2173528

Clarence, S. (2017). Surfing the waves of learning: Enacting a semantics analysis of teaching in a first-year law course. *Higher Education Research and Development, 36*(5), 920–933. https://doi.org/10.1080/07294360.2016.1263831

Coffin, C. (2006). Historical discourse: the language of time, cause & evaluation. *Continuum*.

Cranwell, P. B., & Whiteside, K. L. (2020). Investigation into the semantic density and semantic gravity wave profile of teachers when discussing electrophilic aromatic substitution (SEAr). *Journal of Chemical Education, 97*(10), 3540–3550. https://doi.org/10.1021/acs.jchemed.0c00571

Dale, L., van der Es, W., & Tanner, R. (2011). *CLIL skills: A practical book on content and language integrated learning*. European Platform.

Dalton-Puffer, C. (2011). Content-and-language integrated learning: From practice to principles? *Annual Review of Applied Linguistics, 31*, 182–204.

Dankenbring, C. A., Guzey, S. S., & Bryan, L. A. (2023). Legitimation Code Theory as an analytical framework for integrated STEM curriculum and its enactment. *Research in Science Education*, (123456789)https://doi.org/10.1007/s11165-023-10103-y

Doran, Y. J. (2019a). Building knowledge through images in physics. *Visual Communication, 18*(2), 251–277.

Doran, Y. J. (2019b). Multimodal knowledge. Using language, mathematics and images in physics. In K. Maton, J. R. Martin, & Y. J. Doran (Eds.), *Teaching science: Knowledge, language, pedagogy* (pp. 162–184). Taylor & Francis.

EDUFI. (2014). *[Finnish National Agency for Education] Perusopetuksen opetussuunnitelman perusteet 2014 ['National core Curriculum for basic education 2014']*. Finnish National Agency for Education.

Escobar Urmeneta, C., & Evnitskaya, N. (2014). 'Do you know actimel?' The adaptive nature of dialogic teacher-led discussions in the CLIL science classroom: A case study. *Language Learning Journal, 42*(2), 165–180. https://doi.org/10.1080/09571736.2014.889507

Evnitskaya, N., & Jakonen, T. (2017). Multimodal conversation analysis and CLIL classroom practices. In A. Llinares, & T. Morton (Eds.), *Applied linguistics perspectives on CLIL* (pp. 201–220). John Benjamins.

Evnitskaya, N., & Llinares, A. (2022). (In)equity in CLIL programs? Classroom interaction and the development of higher order thinking skills across bilingual strands. *AILA Review, 35*(2), 227–249. https://doi.org/10.1075/aila.22026.evn

Evnitskaya, N., & Morton, T. (2011). Knowledge construction, meaning-making and interaction in CLIL science classroom communities of practice. *Language and Education, 25*(2), 109–127. https://doi.org/10.1080/09500782.2010.547199

Fang, Z., & Coatoam, S. (2013). Disciplinary literacy and what you want to know about it. *Journal of Adolescent & Adult Literacy, 56*(8), Article 627e632.

García, O., & Li, W. (2014). *Translanguaging: Language, bilingualism and education*. Palgrave.

Goodwin, C. (2013). The co-operative, transformative organization of human action and knowledge. *Journal of Pragmatics, 46*(1), 8–23. https://doi.org/10.1016/j.pragma.2012.09.003

Goodwin, C. (2018). *Co-operative action*. Cambridge University Press.

Gülle, T., & Nikula, T. (2024). *Overview of CLIL provision in Europe and country-specific insights: A report by CLILNetLE working group 1*. https://phaidra.univie.ac.at/detail/o:2050619.

He, P., & Lin, A. M. Y. (2018). Becoming a 'language-aware' content teacher: Content and language integrated learning (CLIL) teacher professional development as a collaborative, dynamic, dialogic process. *Journal of Immersion and Content-Based Education, 6*(2), 162–188.

Horn, J., & Wilburn, D. (2005). The embodiment of learning. *Educational Philosophy and Theory, 37*(5), 745–760. https://doi.org/10.1111/j.1469-5812.2005.00154.x

Jusslin, S., Korpinen, K., Lilja, N., Martin, R., Lehtinen-Schnabel, J., & Anttila, E. (2022). Embodied learning and teaching approaches in language education: A mixed studies review. *Educational Research Review, 100480*. https://doi.org/10.1016/j.edurev.2022.100480

Kääntä, L. (2021). Multimodal perspective into teachers' definitional practices: Comparing subject-specific language in physics and history lessons. In S. Kunitz, N. Markee, & O. Sert (Eds.), *Classroom-based conversation analytic research: Theoretical and applied perspectives on pedagogy* (pp. 197–223). Springer.

Kääntä, L., Kasper, G., & Piirainen-Marsh, A. (2018). Explaining Hooke's law: Definitional practices in a CLIL physics classroom. *Applied Linguistics, 39*(5), 694–717. https://doi.org/10.1093/applin/amw025

Laitinen, M., Leppänen, S., Rautionaho, P., & Backman, S. (2023). *Englanti Suomen kansalliskielten rinnalla. Kohti joustavaa monikielisyyttä* [English alongside Finnish national languages. Towards flexible multilingualism]. *Publications of the Government's analysis, assessment and research activities 2023:59*. https://julkaisut.valtioneuvosto.fi/handle/10024/165230.

Li, W. (2018). Translanguaging as a practical theory of language. *Applied Linguistics, 39*(1), 9–30. https://doi.org/10.1093/applin/amx039

Lin, A. M. Y. (2019). Theories of trans/languaging and trans-semiotizing: Implications for content-based education classrooms. *International Journal of Bilingual Education and Bilingualism, 22*(1), 5–16. https://doi.org/10.1080/13670050.2018.1515175

Llinares, A., Morton, T., & Whittaker, R. (2012). *The roles of language in CLIL*. Cambridge University Press.

Llinares, A., & Nashaat-Sobhy, N. (2021). What is an ecosystem? Defining science in primary school CLIL contexts. *Language Teaching for Young Learners, 3*(2), 337–362.

Lo, Y. Y. (2020). *Professional development of CLIL teachers*. Springer.

Lo, Y. Y., Lin, A. M. Y., & Liu, Y. (2023). Exploring content and language co-construction in CLIL with semantic waves. *International Journal of Bilingual Education and Bilingualism, 26*(3), 289–310.

Macnaught, L., Maton, K., Martin, J. R., & Matruglio, E. (2013). Jointly constructing semantic waves: Implications for teacher training. *Linguistics and Education, 24*(1), 50–63.

Maton, K. (2013). Making semantic waves: A key to cumulative knowledge-building. *Linguistics and Education, 24*(1), 8–22.

Maton, K. (2014). *Knowledge and knowers. Towards a realist sociology of education*. Routledge.

Maton, K., Hood, S., & Shay, S. (2016). *Knowledge-building: Educational studies in legitimation code theory*. Taylor and Francis.

Moje, E. B. (2008). Foregrounding the disciplines in secondary literacy teaching and learning: A call for change. *Journal of Adolescent & Adult Literacy, 52*(2), 96–107. http://www.jstor.org/stable/20111747.

Mondada, L. (2018). Multiple temporalities of language and body in interaction: Challenges for transcribing multimodality. *Research on Language and Social Interaction, 51*(1), 85–106. https://doi.org/10.1080/08351813.2018.1413878

Mondada, L. (2022). Conventions for multimodal transcription. https://www.lorenzamondada.net/multimodal-transcription.

Morton, T. (2018). Reconceptualizing and describing teachers' knowledge of language for content and language integrated learning (CLIL). *International Journal of Bilingual Education and Bilingualism, 21*(3), 275–286. https://doi.org/10.1080/13670050.2017.1383352

Morton, T., & Nashaat-Sobhy, N. (2023). Exploring bases of achievement in content and language integrated assessment in a bilingual education program. *TESOL Quarterly*. https://doi.org/10.1002/tesq.3207. early view at.

Nikula, T. (2015). Hands-on tasks in CLIL science classrooms as sites for subject-specific language use and learning. *System, 54*, 14–27. https://doi.org/10.1016/j.system.2015.04.003

Nikula, T., Skinnari, K., & Mård-Miettinen, K. (2022). Diversity in CLIL as experienced by Finnish CLIL teachers and students: Matters of equality and equity. *International Journal of Bilingual Education and Bilingualism*. https://doi.org/10.1080/13670050.2022.2028125

Conceptualising integration in CLIL and multilingual education. In Nikula, T., Dafouz, E., Moore, P., & Smit, U. (Eds.), *Multilingual matters*, (2016).

Peltoniemi, A., Skinnari, K., Sjöberg, S., & Mård-Miettinen, K. (2018). *Monella kielellä suomen kunnissa 2017. Selvitys muun laajamittaisen ja suppeamman kaksikielisen varhaiskasvatuksen, esiopetuksen ja perusopetuksen tilanteesta*. University of Jyväskylä. http://urn.fi/URN:ISBN:978-951-39-7391-9.

Schleppegrell, M. J. (2004). *The language of schooling: A functional linguistics approach*. Lawrence Erlbaum.

Schmidt-Unterberger, B. (2018). The English-medium paradigm: A conceptualisation of English-medium teaching in higher education. *International Journal of Bilingual Education and Bilingualism, 21*(5), 527–539.

Skinnari, K., & Nikula, T. (2017). Teachers' perceptions on the changing role of language in the curriculum. *European Journal of Applied Linguistics, 5*(2), 223–244. https://doi.org/10.1515/eujal-2017-0005

Statistics Finland. (2022). *Subject choices of students* [online publication]. Reference period: 2022. https://stat.fi/en/publication/cl8lc7zv7m5z90duk0uxu8s7y.

Streeck, J. (2008). Depicting by gesture. *Gesture, 8*(3), 285–301. https://doi.org/10.1075/gest.8.3.02str

Streeck, J., Goodwin, C., & LeBaron, C. (2011). *Embodied interaction: Language and body in the material world*. Cambridge University Press.

Tai, K. W. (2023a). Creating translanguaging spaces in a Hong Kong English medium instruction mathematics classroom: A comparative analysis of classroom interactions with and without the use of iPad. *Linguistics and Education, 78*, Article 101227.

Tai, K. W. H. (2023b). Shaping student responses into academic expressions: Analysing an English medium instruction history classroom from a translanguaging perspective. *International Journal of Bilingual Education and Bilingualism*. https://doi.org/10.1080/13670050.2023.2232089

Tang, K.-S. (2013). Instantiation of multimodal semiotic systems in science classroom discourse. *Language Sciences, 37*, 22–35.

Unsworth, L., Tytler, R., Fenwick, L., Humphrey, S., Chandler, P., Herrington, M., & Pham, L. (2022). Multimodal literacy in school science. *Transdisciplinary perspectives on theory, research and pedagogy*. Routledge.

Walldén, R., & Nygård Larsson, P. (2021). Can you take a wild guess?" Using images and expanding knowledge through interaction in the teaching and learning of history. *Linguistics and Education, 65*. https://doi.org/10.1016/j.linged.2021.100960

Wever, T. (2020). Assessment of young learners' English language proficiency in bilingual content instruction (CLIL) in Finland: Practices, challenges and points for development. In M. deBoer, & D. Leontjev (Eds.), *Assessment and learning in content and language integrated learning (CLIL) classrooms* (pp. 137–166). Springer.