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Explaining Hooke's Law: Definitional Practices in a CLIL Physics Classroom

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This article examines how a teacher in a Content-and-Language-Integrated-Learning (CLIL) program engages in various definitional practices during a plenary episode in a physics class taught in English in Finland. The episode focuses on explaining Hooke's law, which involves defining its key concepts and their relations as instructable matters. Using multimodal conversation analysis, the article shows how the teacher accomplishes definitions and definition-related actions through talk and a range of embodied and material resources. The different configurations of resources are coordinated to elucidate the key concepts, to contextualize them in relation to the larger activity, and to situate them in the domain of physical laws. The teacher's actions occasion recipient responses from students that contingently shape the evolving lesson. The findings contribute to understanding how the installation of knowledge about a physical law is accomplished as the teacher's professional work in a CLIL setting. Thus, for CLIL science teacher education, the study indicates the indispensable need to attend to the artful coordination of multilingual and multimodal practices that teachers employ to define and contextualize physical phenomena.

1. INTRODUCTION

Social actions such as explaining, naming, defining, and classifying are central in the construction of everyday knowledge and knowledge associated with specialized domains, among them academic disciplines. In classroom instruction, such formulating actions are key methods by which the institutional purpose of formal education as knowledge installation (Macbeth 2000) is accomplished. In the context of learning academic content in a second language (L2) these actions are important means through which students are socialized into general academic and educational culture as well as in to subject cultures and their ways of constructing knowledge (Nikula 2015: 1–2; also Morton 2015). This article is concerned with the methods through which conceptual knowledge of a physical law (Hooke's law) is constructed through such formulating actions during a plenary teaching episode in a Content-and-Language-Integrated-Learning (CLIL) lesson. The plenary episode focuses on explaining the law, which involves defining the concepts related to it and their relations as instructable matters. Using multimodal conversation analysis, this article brings into view how the teacher accomplishes definitions and definition-related actions through talk and a wide range of embodied and material resources: inscriptions and drawings on the blackboard, position and movement in space, bodily visual illustrations, and demonstrations by means of material objects. It shows how different configurations of resources are coordinated to elucidate the propositions and concepts related to the law, to contextualize them in relation to the larger activity, and to situate them in the domain of physical laws. The teacher‘s actions and their design position the students as recipients of instructable subject matter and occasion recipient responses that show varied orientations to the teacher‘s actions.

While a number of earlier studies have described how teachers formulate explanations and definitions in different classroom settings, the detailed ways in which teachers (and students) coordinate verbal resources with resources of the body, space, and material objects are largely unexplored (but see Mortensen 2011; Morton 2015). This article generates new insights into definitions and related actions as locally situated, context-sensitive multimodal accomplishments and how these promote the larger activity of explaining a physical law (cf. e.g. Dalton-Puffer 2007; Koole 2010). More generally, the findings contribute to understanding how science education is achieved and the kinds of resources that CLIL physics teaching offers for defining and contextualizing physical phenomena (cf. Morton 2015).

2. SCIENCE TALK AS SITUATED ACTIVITY

Teaching and learning science is a situated activity anchored in the physical and material world of the classroom setting (e.g. Lemke 1990; Wellington and Osborne 2001; Roth 2005). This situated character of science education talk has been examined by Roth and collaborators in a series of studies that describe the use and role of gestures and visual and graphic inscriptions in explanations of scientific phenomena (e.g. Roth and Bowen 1999; Roth 2000; Roth and Lawless 2002a). Relevant for our focus are studies on teachers‘ gestures and spatial orientation during the explanations. Roth and Lawless (2002b) show how the teacher‘s spatial positioning, specifically their proximity and orientation to the audience or the blackboard/screen, influences the kind of talk produced. One key finding is that the way teachers employ iconic and deictic gestures in different spatial locations has an effect on how comprehensible the talk is to students. On the other hand, Pozzer-Ardenghi and Roth (2008) demonstrate how repeated ensembles of gesture and words represent the same idea within or across lectures and so make the science concept understandable for students. Since the core feature of the gesture remains stable throughout numerous repetitions, it enables students to recognize the concept even if the verbal component is changed. Hence the repeated gesture associates different terms with the same concept and provides an anchor for translating a term from the students‘ everyday language into the register of science. While these studies have shown how teachers utilize gestures to make L1 scientific discourse accessible to students, they have not paid attention to the sequential unfolding of the teacher's actions or the students' responses. In contrast, this article analyses how teacher's definitions and related actions unfold in multi-unit turns, how they position students and occasion displays of students' understanding in L2 science talk.

3. DEFINITIONS AND EXPLANATIONS

Definitions have been studied in different fields including semantics, rhetorics, discourse studies, philosophy, and education research. Accordingly, different types of definitions have been proposed, distinguished according to their forms, functions, and purpose (e.g. Manes 1980; Trimble 1985; Watson 1985; Flowerdew 1992; Markee 1994; Dalton-Puffer 2007; Temmerman 2009). But there is broad agreement that formal definitions have the format 'X is Y that Z', which is illustrated with the extract below from Dalton-Puffer's (2007) study of definitions in CLIL classrooms.

Adapted from Dalton-Puffer (2007: 133): Kidney

1	T:	a kidney isah an internal organ
2	S:	mhm
3	T:	ah that purifies the liquids inside you,

Here the teacher introduces 'a kidney' (line 1) as the term to be defined (X, the definiendum), identifies it as a member of the class (Y) 'an internal organ', and adds the distinguishing characteristic (Z) 'that purifies the liquids inside you' (l. 3) that makes X different from other members of its class. Together Y and Z make up the definiens. Without Z, the teacher would have classified the object but not defined the term. As the example highlights most previous studies have focused on the verbal form of definitions, while other modalities have received less attention. An exception is Flowerdew's (1992) study of L2 science lectures for undergraduates in Oman.

According to Flowerdew (1992), definitions have two tasks in the lecture discourse: they help signal how the lecture is structured and support students' understanding as the discourse progresses. He identifies four basic types of definition. A *formal definition* has the format X is Y that Z, as above. A *semi-formal definition* describes the distinguishing characteristics of the term without expressly identifying its class ('this is a fibrous root system/alright/where you have no one root being more important than the others ...'). A *substitution* replaces the new term with a more familiar expression ('fuse/by fuse I mean join together') or a paraphrase ('electropositive is likes to become positively charged'). In an *ostensive definition* the new term is associated with an object or a representation of it through a pointing gesture. (Flowerdew 1992: 209–212.) He also identifies three types of 'paralinguistic features' that lend salience to a definition in the lecture discourse: emphatic stress on the definiendum, graphic support (writing the term or the definition on a board or projector), and visual support such as objects, graphs, and other visual materials referenced in the definition (ibid.: 214–215). Although Flowerdew mentions the use of these features, the precise sequential and temporal organization of bodily actions in relation to the teacher‘s definition talk have not been investigated so far.

More pertinently, this article investigates how definitions are formulated and elaborated to forward the goal of explaining a physical law in a CLIL classroom (cf. Dalton-Puffer 2007). Previous studies of L2 science classes have shown that explanations are sequentially organized and involve multimodal practices (e.g. Kupetz 2011; Evnitskaya 2012; Morton 2015; for sequential patterns in L1 context, see Koole 2010). For instance, Evnitskaya‘s study (2012) on dialogic explanations during lab experiments and teacher-led whole-class activities highlights how gestures are used to support the teacher‘s verbal messages and to compensate for words that the teacher is searching (see also Evnitskaya and Morton 2011). In language learning research, several studies describe how unknown lexical items are made understandable to L2 speakers by deploying different types of gestures (e.g. Lazaraton 2004; Seo 2011) and mobilizing the material world (Mortensen 2011; Seo 2011). Waring *et al.* (2013) distinguish two approaches to vocabulary explanations: an animated approach embodies the use of various multimodal resources, whereas an analytic approach relies on verbal and textual means. In contrast, Morton‘s (2015) study of CLIL science classrooms found that most explanation sequences involved a combination of the two approaches.

This article details how the teacher‘s definitional practices in a CLIL setting serve to make the discourse of physics accessible to the students via the sequential, temporal, and spatial organization of action. The analysis describes how the trajectory and practices of defining and elucidating elements of the law are fitted to the sequential unfolding of the larger activity of explaining the law and the material ecology of the classroom. Unlike word explanations in second language teaching, the definitional practices in the CLIL lesson also show an overall orientation to constructing conceptual knowledge rather than building L2 vocabulary.

4. DATA AND METHOD

The data are drawn from a corpus of classroom interaction (45 lessons in total) and originate from a 7th-grade physics lesson taught in English in Finland. The participants of the lesson are the teacher and six 13-year-old female students, all of whom have Finnish as their mother tongue. The students are taking part in a small-scale CLIL program (e.g. Llinares *et al.* 2012; Nikula 2015), where selected subjects in their school are taught in English. Participation in the program is voluntary, which explains the small number of participants on the course (see Supplementary Material for the layout of the classroom and the participant constellation).

Although the lesson is embedded in a particular social and educational environment, it is representative of an approach to physics pedagogy that is widely shared across educational settings. The topic of the lesson is ‘Hooke‘s law‘, which states that the extension of elastic material is proportional to the force that the material is being stretched with (e.g. Wikipedia: Hooke‘s law). As can be seen from the overall structural organization of the lesson, the teacher adopts the principles of active, experiential learning to his physics classes (also Kääntä and Piirainen-Marsh 2013; Nikula 2015). Specifically, the unit on Hooke‘s law evolves through three main ‘phases of activity‘ (Heritage and Clayman 2010:106): (1) a peer activity in which the students conduct the standard Hooke‘s law experiment; (2) the teacher‘s explanation of the law in plenary (‘teacher-fronted‘) talk; (3) textbook-based exercises in which the students apply the newly learned physics concepts.

For the experiment, the students work in pairs to test how a spring reacts to the application of force by using weights, measure the extension, and plot a graph of force against the extension. Through the practical peer work the students are introduced to the world of physics and gain first-hand experience of how the law operates. As the analysis will show, the experiment generates specific resources for constructing conceptual knowledge in subsequent instructional phases.

The analysis focuses on the second phase of the activity in which the law is explained by means of sequentially unfolding definitions and related actions. In the approach adopted by this teacher, the explanation phase is central for the construction of conceptual knowledge, since the peer activity is introduced in everyday language, with minimal reference to theory (see also Nikula 2015), before the physical phenomenon in focus is explained. The explanation activity is constructed through extended interactional sequences that serve to define and explicate the key conceptual elements of the law, including proportionality, extension, elasticity, bending, and compression. Each extended sequence involves the introduction, definition, and explanation of the concept in focus through such actions as naming, comparing, classifying, generalizing, and exemplifying. These different definitional practices by the teacher occasion various verbal and embodied recipient actions from students. They include the activity of writing, claims or demonstrations of understanding, and initiation of repair. The episode comes to a close when the teacher assigns the class the exercises to work on.

The analysis details the multimodal practices through which definitions are built and elaborated in the course of the explanation activity. To this end, we adopt the conversation analytic perspective on multimodality (see e.g. Goodwin 2000; Streeck *et al.* 2011; Deppermann 2013; Mondada 2014). In this approach, multimodality refers to the ‘various resources mobilized by participants for organizing their action‘ (Mondada 2014: 138). Different modalities—language, gestures, gaze, body position and movement, etc.—are seen as intertwined and constitutive of the actions performed. This position differs from various other approaches that deal with multimodality in terms of channels, media, and material representations of signs that provide various semiotic resources for action (e.g. Kress and van Leeuwen 2001). It also differs from approaches that deal with nonverbal phenomena in terms of paralinguistic and visual support for verbal activity (e.g. Flowerdew 1992; Lazaraton 2004). Instead, CA research investigates how the use of one or more types of embodied resources (e.g. gaze, a type of gesture) work together in their sequential environment to build action. In this study, the analysis seeks to show how diverse resources make sense together and are integrated in the definitional practices in a situated way, that is, how they are occasioned and assembled in various configurations within 'the activity, its ecology and its material and cultural constraints' (Mondada 2014: 139).

The participants' talk has been transcribed with standard conversation analytic conventions. The conventions for describing bodily actions have been adapted from Mondada (2014) to show the temporal and sequential organization of different resources with respect to the ongoing talk (see Supplementary Material). Students' names are pseudonyms.

5. TEACHER'S USE OF MULTIMODAL RESOURCES IN DEFINITIONAL PRACTICES

The analysis to follow details how the law is introduced (Extract 1) and then elaborated through interactional sequences that serve to define the concepts and explicate the proposition stated in the law (Extract 2), its key conceptual elements ('proportional', Extract 3), and its application to elastic materials and related phenomena ('elasticity', Extract 4a and 4b; 'bending', Extract 5a and 5b). After showing how the explanation activity begins, each section highlights how a specific type of resource is used, while concurrently demonstrating the ensemble of resources harnessed for 'doing definitions'.

5.1 Introducing the law

The plenary episode begins with the transition from the peer activity to the explanation of Hooke's law, at which point the law is established as the target of explanation. The first lines in Extract 1 mark the transition: while the students are still compiling the results of the experiment by plotting force-extension graphs into their notebooks, the teacher introduces the physical phenomenon related to the experiment.

Facing the board, the teacher produces an utterance that projects the naming of the law (l. 9).[1] However, when the name is due he puts the utterance in progress on hold, turns to face the class (l. 9), and redirects the talk to other laws that were previously on the instructional agenda ('Newton's laws', l. 10). In this way he explicitly situates the new topic in the domain of physical laws. The teacher's body shift and orientation toward the students through gaze highlight the importance of the new topic, whereas the reference to other laws in the side sequence invokes students' prior knowledge of similar physical categories. After this the teacher visibly resumes the main activity by turning towards the board again (l. 11), saying and writing first the name (l. 12–13) and then the formal statement of the law (l. 21, 23). Following the teacher's lead, most of the students write the statement into their notebooks.

Extract 1 Introduction to Hooke's law

```
9     T      ^so it's actually called* (0.7) uh (0.3)
             T WALKS CLOSE TO BB, GAZE AT IT*T GAZE AND BODY SHIFT TO CLASS
             ^T RAISES RH UP ON BB, WHERE IT STAYS-----------

10           we had these newton's laws an' stuff and,*
             ----------------------------------------------->*
             -----------------------------------------------

11           *(1.1) this also has a fancy*^ name (0.5)*^
             *T GAZE SHIFT TO BOOK------------->*T GAZE SHIFT TOWARD BB*
             -------------------------------->^T LOWERS AND RAISES RH^

12           *called ^hooke's ↓law
             *T GAZE AT BB-------------
                      ^T BEGINS TO WRITE

13           (0.6)  T WRITES ON BB
                    LIISA GAZE AT BB

14    Liisa  {↑WHAT?
             {LIISA STRAIGHTENS HERSELF

15           (0.7)  T WRITES ON BB
                    LIISA SHIFTS GAZE TOWARD JAANA'S NOTEBOOK

16    Liisa  hook's ↓law

17           (4.5)  T WRITES ON BB
                    LIISA GAZE AT JAANA'S NOTEBOOK
                         THEN AT HER OWN

18    Liisa  ^*tuo on tuo on* ^viivalla
              that is that is   on the line
             *T GAZE AT BB---->*T GAZE SHIFT TO BOOK ((ON T'S DESK))
             ^MOVES RH UNDER TEXT 'HOOKE'S LAW^T BODY SHIFT AT HIS BOOK

19           (1.1)  T GAZE AT HIS BOOK, LOWERS RH FURTHER DOWN
                     LIISA GAZE AT HER NOTEBOOK

20    T      ^so (0.9) ^this means that uhh ^(2.9)^ uhh ^(2.2)*^
             ------------------------------------------------------------>*
             ^T DRAWS RH NEAR HIS LH^          ^T STEP TO RIGHT^ ^T STEP TO LEFT^

21           *exten^sion [is .hh (.)^* [proporti^onal to the ^force.
             *T GAZE AND BODY SHIFT TOWARD BB*T GAZE AT BB-----------------------
                    ^T LIFTS RH UP ON BB^              ^T TOUCHES RH FIST ON BB^

22    Liisa                 [↑hoo↓ke's    [hooke's law,
                            LIISA GAZE AT BB

23           (23.0)  T WRITES THE LAW ON BB
                     4/6 STUDENTS WRITE IN THEIR NOTEBOOKS
```

As is visible, the introduction and naming of the law occasion different recipient actions from one student, Liisa. She first displays heightened attention and surprise both verbally and visually (l. 14). Her repetition of the name of the law while looking at her partner's notebook (l. 16) suggests that she does not recognize the new term.[2] When Liisa turns her gaze toward the board, she verbalizes her noticing of the written form of the name (l. 22). She first repeats it with an upward/downward prosodic contour and then says the whole name with an emphasis on *hooke's*, thereby displaying a new understanding of the teacher's reference.

Extract 1 demonstrates how different multimodal resources including verbal and embodied activity, the physical activity of writing, and the material world of the classroom feature in the turns where the law is introduced and named. It also shows how the teacher's talk positions the students as recipients of new instructable content. Students orient to this verbally (Liisa) and through their bodies: they shift their focus from the preceding activity toward the inscriptions on the board and begin to write in their notebooks.

5.2 Use of gestures

The following examples demonstrate how the teacher utilizes gestures, alongside other resources, in explaining the proposition of the law. Extract 2 involves the use of descriptive gestures that elucidate the meaning of the law, whereas Extract 3 shows how the teacher's gesturing toward the graph drawn on the board both directs students' attention to the graph and helps define the key concept (i.e. 'proportional').

Extract 2 continues from Extract 1: having written the law, the teacher puts the chalk away, turns, and begins to walk closer to the students (l. 24). The walking initiates a shift to elucidating the law (Mondada 2014; also Mikkola and Lehtinen 2014).

Extract 2 Proportional relationship

```
24    T       +an' (1.2) ^+this is one example uh +(1.6) of [these tha-]
              T WALKS TOWARD ST.^T STOPS, STANDS IN FRONT OF STUDENT DESKS------------
              +LIISA GAZE TO BB>+TO NOTEBOOK-------------->+TO BB---------------------

25    Liisa                                                   [IS THA-    ]

26            (0.3) T GAZE SHIFT TO LIISA, STANDS IN FRONT OF STUDENT DESKS
                    LIISA GAZE TO BB

27    Liisa   >I'm sorry.< +is that *pra (0.3) or pro=
                           +LIISA POINTS AT BB--------------
              T GAZE TO LIISA----------->*T GAZE TO BB---------

28    Neea?   =°PRA° ((whispered loudly))

29    T       ^pro<portional>=+
              ^T WALKS TO BB, GAZE AT BB
              LIISA-------------->+
```

```
30   Liisa   +=okay.^
             +LIISA GAZE AT NOTEBOOK
             T------>^

31           (2.0)   T ARRIVES AT BB, THEN CORRECTS LETTER O
                    STUDENTS WRITE IN THEIR NOTEBOOKS

32   T       *so (0.8) you will find that ma- ^in (.) in physics ^that
             *T GAZE TO BB-------------------------->^T TURNS TO CLASS------>^T WALKS

33           you have many things that are (.) one thing is
             TOWARD ST.----------------------------------------------

34           pro[portional to the other.
             ---------------------------------

35   Jaana     *[(onkse pro vai pra)
                 is it  pro  or  pra
               *JAANA LEANS TOWARD LIISA

36           (0.4)   T WALKS TOWARD STUDENTS
                     JAANA LOOKS AT LIISA'S NOTEBOOK
                     STUDENTS WRITE IN THEIR NOTEBOOKS

37   Liisa   proPO^
             -T WALKS>^

38           (0.5)   T STOPS, STANDS IN FRONT OF STUDENTS, GAZE AT THEM
                     LIISA GAZE TO BB
                     JAANA GAZE SHIFT TOWARD HER NOTEBOOK
                     STUDENTS WRITE IN THEIR NOTEBOOKS

39   Liisa   pro=

40   T       =which for instance means that if you double hhh the (0.6)
             T GAZE AT ST.----------------------------------------------------------

41           ªuhh *(0.6) *double the one quantity then the other will
             ---->*T GLANCE AT BB*T GAZE AT ST.------------------------------------
             ªLEENA STOPS WRITING, GAZE TOWARD T---------------------------------

42           be doubled as well.*ª
             T---------------------->*
             LEENA------------------>ª
```

While walking the teacher begins to elaborate on the topic (l. 24), but is interrupted by Liisa's other-initiation of repair to clarify the spelling of 'proportional' (l. 25, 27). In response, the teacher highlights the correct form of the word, emphasizing the first syllable *pro* (l. 29). He also walks back to the board and 'boldens' the letter 'o' to give it a stronger shape (l. 29–32). The problem dealt with, the teacher resumes the explanation activity and marks the shift by walking closer to the students (l. 32). Simultaneously, he begins to explain the proposition of the law with a general reference to a proportional relationship that applies to many things in physics (l. 32–34). The explanation is constructed by drawing on several multimodal resources, each advancing the ongoing activity in different ways. There is a noticeable micro-pause before the teacher produces the proposition, which is positioned at the end of the ongoing turn unit, where it is given as new information (Flowerdew 1992: 213).

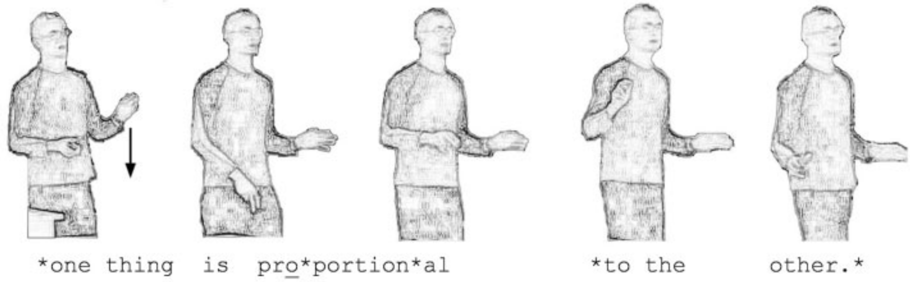


Figure 1: Teacher's gestures as he produces the proposition (l. 33-34)

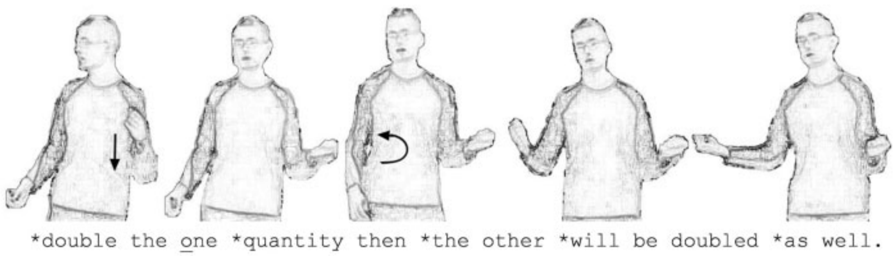


Figure 2: Teacher's repetition of the gestures (l. 41-42)

Prosodically, the emphasis on the first syllable of *proportional* (l. 34) echoes the earlier production of the term during the repair sequence (l. 29). The same rendering of the earlier performance exhibits the teacher's orientation toward students' potential unfamiliarity with the concept. The use of nonspecific referential terms ('many things') and the way the key concept is highlighted foreshadow further elaboration of the concept. Concurrently with the talk the teacher performs two successive gestures: first an up-down movement with the left hand and then a downward facing circling movement with his right hand (see Figure 1).

The teacher then defines the meaning of 'proportional' as the 'doubling'[3] of quantities (l. 40–42) and elaborates the relationship by repeating the two gestures, with his hands in an upward-facing fist (l. 41–42, Figure 2). On both occasions, the gestures are precisely timed to accompany the verbal elements of the turn and represent the proportional relationship between the elements.

Throughout the sequence, the students are writing in their notebooks. With their note taking they show that they orient to the law as a learning object (cf. Pekarek Doehler and Ziegler 2007), specifically as something they are expected to 'know' on such later occasions as the upcoming exam. A similar orientation is visible also in the side sequence, where Jaana verbally seeks clarification for the spelling of 'proportional' from Liisa (l. 35–39).

In this extract, the teacher first introduces Hooke's law by explaining it in a generic way (l. 32–34). The brief pause and prosodic packaging highlight the proposition, making it stand out from the rest of the turn (also Mortensen 2011), and thereby establish the concept of proportionality as the definiendum. The ensuing definition with its reference to quantity is abstract (l. 40–42). The referential expressions *one thing—the other, one quantity—the other* are elaborated by the co-occurring gestures that provide an analogous representation of the law's proposition (e.g. Roth and Lawless 2002b) and thus begin to open up the meaning of 'proportionality'. The recurrence of the gesture, although in slightly modified form, serves to elaborate the verbal definition through the visual representation. With the repetition the teacher may be addressing the students' lack of attention to his first embodied representation of the concept. Most of the students are occupied with note taking at this point, and only Leena visibly orients toward the teacher so that the gesture is in her visual field (l. 41).

Extract 3 Proportional

```
64    T       well, basically proportional *means the (.)[a]
              T GAZE AT ST.---------------------->*T GAZE AT BB----
              JAANA GAZE AT NOTEBOOK, WRITES-----------------------
              RONJA GAZE AT NOTEBOOK, WRITES---------------------->[a]
              LIISA GAZE AT NOTEBOOK/DOWN-------------------------

65            [a]^uh ~straight^ +line ^relationship.^*~ (.) ^so=
              ^T STEP CLOSER TO BB^     ^T STEP BACK----->^*T GAZE SHIFT AT ST.
                 ~T RH GESTURE PARALLEL TO LINE ON GRAPH ON BB~   ^T WALKS
              JAANA--------------------------------------------------
              [a]RONJA ERASES HER WRITING-------------------------------------
              LIISA------------->+LIISA GAZE TO T----------------------

66    Jaana   =°oka' °[x][a]
              JAANA-->[x]
              RONJA-->[a]
              LIISA--
              T WALKS TOWARD ST.

67    Ronja   [a][x]straight line.
              [a]RONJA GAZE AT NOTEBOOK
              [x]JAANA GAZE SHIFT AT BB
              LIISA-------------
              T-----------------

68            (1.8)  T WALKS TOWARD STUDENTS, GAZE AT THEM
                      LIISA GAZE AT BB, AT 0.7S GAZE DOWN
                      JAANA & LEENA GAZE AT BB
                      RONJA GAZE AT HER NOTEBOOK
                         AT 0.8S SHIFTS GAZE AT BB

69    T       y[eah^
              T---->^

70    Ronja    [in a straight [a]line.
               RONJA GAZE AT BB-->[a]RONJA GAZE AT NOTEBOOK
```

The teacher‘s movement closer to the students and the accompanying change of embodied orientation while producing the definition indexes a shift from presenting the new content visually on the blackboard to explaining it to the students (cf. Roth and Lawless 2002b). After a short side-sequence in which the teacher translates the word ‘proportional‘ into Finnish, he formulates a definition in English and elaborates it through a pointing gesture that draws the students‘ attention to a graph on the board (Extract 3).

At this point the teacher is positioned next to the board. He briefly glances at the Hooke‘s law inscription and the graph on the board before he turns toward the students. He then produces the definition of ‘proportional‘ in English in the basic ‘X means Y‘ format (l. 64–65). Similarly to Extract 2, he frames the definiendum of its key concept, that is, ‘straight line relationship‘, by first pausing slightly, then producing a vocalization (*uh*) followed by an emphatic production of the first word of the concept (*straight*), thereby highlighting its salience in the ongoing turn unit. When he states the definiendum, he mimics with his right arm the line he has drawn on the board within the graph of extension (l. 65). The line represents the relationship between the measured extensions and weights in the graph (see Supplementary Material). By providing this kind of ostensive definition of ‘straight line relationship‘ (Flowerdew 1992), the teacher invokes the students‘ experiential knowledge of the concept. Moreover, the gesturing invokes the relevance of prior talk and activity to the current situation. At this point most students are still engaged in writing, but some begin to show orientation to the teacher‘s talk. Liisa directs her gaze toward the teacher (l. 65) during the teacher‘s turn. When the teacher projects continuation of his turn, Jaana quickly claims understanding (l. 66) and Ronja repeats *straight line* (l. 67). Although both students produce their utterances while looking at their notebooks, their actions mark them as recipients of the teacher‘s definition. The teacher then walks toward the class, while several students, including Ronja, turn their gaze toward the board (l. 68). The teacher takes Ronja‘s repetition as an understanding check and confirms it (l. 69). In partial overlap, Ronja does a third-turn confirmation (l. 70), whereby she closes the confirmation sequence.

Extracts 2 and 3 illustrate how the teacher draws on verbal, prosodic, embodied, and spatial resources in constructing a definition of ‘proportionality‘ as the central concept in Hooke‘s law. Turn-constructional and prosodic features highlight proportionality as the definiendum and present the concept as new information to the students. In Extract 2 the verbal definition is elaborated by precision timed gestures that visually represent a proportional relationship between two physical phenomena. Extract 3 shows how the teacher contextualizes ‘proportionality‘ through another verbal definition, accompanied by gesturing, which ties the key concept to the practical activity that preceded the plenary episode and thereby invokes students‘ experiential knowledge related to the topic (cf. Morton 2015). The teacher‘s gesturing thus gains its shape and meaning within the activity in progress and its material ecology as well as the larger pedagogical context.

5.3 Use of material objects

Extracts 4a and 4b depict how the teacher introduces the concept of ‘elasticity‘ as another core element of Hooke‘s law. Roughly two minutes before the extract occurs, the teacher has told the students that the law applies to materials which ‘are called elastic‘. He has also written on the board the sentence ‘Materials with this property are called elastic‘,[4] which the students have copied into their notebooks. This is followed by a short side sequence, after which the teacher resumes the explanation activity by reiterating that the law applies only to elastic materials (see Extract 4a, l. 129–130).

The teacher resumes the explanation activity by referring to the law as a previously mentioned topic and pointing toward the statement of Hooke‘s law on the board (l. 128). By pointing and also verbally referencing and emphasizing the generic class (i.e. *certain materials*, l. 129), he explicitly orients the students‘ attention to a specific part of the law to be elaborated next. He then names the definiendum (i.e. ‘elastic‘, l. 130) in turn final position where it is given as new information. Moreover, just before naming it, the teacher pauses, steps away from the board, and shifts his embodied orientation toward the students, thereby also visually framing the definiendum.

Having named the class of material, the teacher moves on to locate a member of the class (steel) as a method to further explicate the concept of ‘elasticity‘ (l. 131–132). He does this by referring to the springs the class used in the experiment (l. 132), whereby he invokes the relevance of the object and the students‘ experiential knowledge of the experiment for his current project. Moreover, by emphasizing the class (*steel*) in turn final position, he projects talk specifically aimed at explicating elasticity in relation to steel. Next, he walks to the other side of the room where the spring is located (l. 134) and thereby projects an action involving the use of the spring (Mondada 2014). Having arrived at the other side of the room, he takes the spring from the table (l. 136) and formulates an explanation of how materials made of steel are understood as elastic (l. 136–137). The explanation highlights that while elasticity as a property of steel is ‘usually‘ not visible in our lifeworld, the perspective of physics makes that property known. Concurrently with referring to ‘extension‘, he demonstrates it by stretching the spring (l. 137–138, Figure 3) and thus gives students a more tangible idea of what the elastic property of steel means. The property that is highlighted in the explanation is then generalized to other materials (‘any kind of steel‘, l. 138–139). As further illustration, the teacher evokes the physical space and material ecology of the classroom: he visibly scans the room with his gaze (l. 139–140) and simultaneously classifies the frames of the desks and chairs as elastic (l. 140–141).

During the sequence, Liisa is the only student who actively looks at and follows the teacher with her gaze (l. 136). When the teacher classifies the desks and tables as elastic, Liisa glances at the spring he is holding (l. 141). After a short silence (l. 142) she reacts to the teacher‘s classification by visibly straightening herself and producing a vocal response that displays surprise (l.

Extract 4a Elastic_steel

```
128  T      ^uh but^ ^this *topic about hooke's law.^
            T GAZE AT BB------>*T GAZE SHIFT TO HIS LEFT------
            ^T STEPS CLOSE TO BB^
                    ^T RH HOVERS NEAR PROPOSITION OF LAW ON BB>^

129         =so this *only applies to ^certain materials
            T GAZE TO HIS LEFT>*T GAZE AT BB----------------------
                                        ^T POINTS AT BB--------

130         an' these are called*^ ^(0.9) elas↑tic
            ----------------------->*T GAZE SHIFT TO CLASS
            ----------------------->^T WITHDRAWS HAND^T TAKES 3 STEPS

131         an' the same thing applies to^ *(0.9)
            ------------------------------------->*T GAZE TO HIS SIDE
            TOWARD ST.------------------------->^T STOPS

132         well, the springs we had they uhm ^are*made of steel.*
            --------------------------------------------->*T GLANCE AT CLASS>*
                                                  ^T TAKES STEPS TOWARD ST.

133         (1.2) T TAKES STEPS TOWARD STUDENTS, GAZE TO HIS SIDE
                  LEENA, RONJA & NEEA WRITE IN THEIR NOTEBOOKS
                  LIISA GAZE TO BB
                  ILONA PLAYS WITH HER PHONE

134  T      ^so ^(1.0) it's kind of interes^ting uh^ (1.2)
            ^T TURNS AROUND^T WALKS BEHIND T'S TABLE TO OTHER END----
                                              ^T PUTS CHALK ON TABLE^
            LIISA GAZE IN FRONT OF HER (RIGHT)----------------------

135         that usually (2.3)^+
            T------------------->^
            LIISA--------------->+

136         +^well steel has been bent in such a way that you
            ^T TAKES SPRING FROM TABLE, GAZE AT IT----------------------
            +LIISA GAZE TO T--------------------------------------------

137         can barely see the ^extension. (0.2)
            T---------------------------------------
                                 ^T STRETCHES SPRING-
            LIISA-----------------------------------
```

FIGURE 3

```
138         but the same thing #app^lies^ to (1.1)
            T---------------------#FIG.3----------------
            --------------------------->^T LETS SPRING LOOSE^
            LIISA---------------------------------------

139         *to any kind of steel really. +(1.0)+
            *T GAZE SHIFT TO CLASS, SWEEPS SLOWLY FROM RIGHT SIDE
            LIISA------------------------------->+LIISA GAZE DOWN+

140         like (1.1) the (0.8) frames of these desks *an' chairs+
            TO LEFT SIDE TO T'S DESK AND BACK TO CLASS----------->*T GAZE AT ST.
            LIISA GAZE DOWN, THEN IN FRONT OF HER, YAWNS--------------------->+

141         +(.) are also +elastic.
            T-------------------------
            +LIISA GAZE TO T>+LIISA GLANCES AT SPRING IN T'S HAND

142         (0.8)  T GAZE AT STUDENTS
                   LEENA, ILONA, & NEEA GAZE AT T
                   LIISA GAZE AT T
                   RONJA & JAANA GAZE ELSEWHERE

143  Liisa  {+↑hm=
            +LIISA GAZE DOWN AT DESK
            {LIISA STRAIGHTENS HERSELF ((slightly))

144  T      =but (.) +you don't really notice it (0.2)
            T GAZE AT ST.--------------------------------------
            LIISA GAZE DOWN AT DESK----------------------------
                      +LIISA TOUCHES HER DESK, FEELING IT------

145         #because *(.) uh
            ---------->*T GAZE TO BB
            #FIG. 4 LIISA GAZES AND TOUCHES HER DESK->
```

FIGURE 4

Extract 4b Elastic_table

```
164  T      so I think you- *(1.1) I think we: (0.4)
            T NOT VISIBLE IN CAMERA*T STANDS IN FRONT, GAZE AT ST.

165         I mentioned something about this ^elastic thing uh
            ------------------------------------------------------
                                               ^T POINTS TOWARD BB W/ RH

166         when we ^(1.0) talked about this *uh (1.8)^*(1.2)
            ---------------------------------------->*T GAZE DOWN*T GAZE
            --------->^T RH OPEN PALM, UPWARDS---------------->^T WITHDRAWS

167         this ^balancing forces.=when I said that uh^*
            AT ST.---------------------------------------------->*
                ^T SPREADS HANDS APART------------------------->^

168         (0.9) uh when I'm standing on *table ^an' the force-
            T GAZE DOWN------------------------>*T GAZE NOT IN CAMERA-------
              ^0.3S T GETS ON TABLE-------------------^T STANDS ON TABLE---

169         table will be actually: ^bent down #a little bit.^
            -----------------------------------------------------
                                       ^T GESTURE----#FIG.5---------->^
```

FIGURE 5

```
170         (0.4) T STANDS ON TABLE, GAZE NOT IN CAMERA
                  LIISA, NEEA & ILONA GAZE AT T
                  JAANA, RONJA & LEENA GAZE ELSEWHERE

171  Liisa  yeah.=
            LIISA GAZE TO T
            T GAZE NOT IN CAMERA>

172  T      *=the table is elastic.
            *T GAZE AT ST.-------------

173         (0.7) T STANDS ON TABLE, GAZE AT STUDENTS
                   ALL STUDENTS GAZE AT T

174  Liisa  ↓oh [↑yeah +that's- ]
            ------------->+LIISA GAZE DOWN

175  T          [so [that where] the force comes [from.]
                T GAZE-----------------------------------------

176  Ronja          [elastic?  ]
                    RONJA GAZE AT T

177  Neea                                            [°↓oh ]
                                                    NEEA GAZE AT T

178          [yeah°, oh *↑yeah (that one) yeah (x)  ]
              ------------>*NEEA GAZE TO RONJA---------------

179  Ronja  *[>oh yeah, so it ^goes *like< @poing po]ing poing@*^#
            RONJA GAZE AT T-------------->*RONJA GAZE IN FRONT------------*
            *T GAZE DOWN----------^T GETS DOWN FROM TABLE----------------->^
                                                                     FIG.6#
```

FIGURE 6

```
180  T      *[so      ]
            *T GAZE SHIFT TO ST., STANDING ON THE FLOOR

181  Neea    [@↑poing] poing poing@*
             --------------------------->*

182         (1.1)  T LOOKING DOWN AT TABLE/SPRING IN HIS HAND
                   STUDENTS GAZE AT DIFFERENT PLACES

183  T      but uh (1.1) *but it ^doesn't uhm work out*^
            T GAZE DOWN---->*T GAZE UP TO HIS RIGHT------------->*
                                       ^T RH TOWARD TABLE-------->^

184         ^indefinitely. (0.4) ^if you stretch it too
            T GAZE TO ST.----------------------------------------
            ^T TAPS DESK TWICE------->^T WITHDRAWS HAND

185         much, then things will break.
            ---------------------------------
```

143). Immediately after, she begins to feel the frame of her desk, looking at it (l. 144–145, Figure 4). Both of her actions manifest the newsworthiness of the teacher's classification. This is further corroborated by Liisa's touching the frame of the desk as a way of inspecting whether the classification is tenable.[5] In a latched turn, the teacher adds that the extension is unnoticeable (l. 144) and begins to give an account for it (l. 145). However, once more, he aborts the turn and walks toward the board. This occasions a side sequence during which Leena initiates repair on the text on the board (data not shown). When the problem has been solved, the teacher resumes his talk to further clarify the notion of 'elasticity' as shown in Extract 4b.

When the teacher resumes the topic, he does not continue where he left off but restarts from another perspective. After self-repairing (l. 164) and restarting the turn by mentioning an earlier topic (l. 165–167), he moves to demonstrate the notion of elasticity by stepping on one of the student desks and standing on it. Concurrently, he both explains what happens when he stands on the table (l. 167–169) and produces an iconic gesture with a curved back-and-forth downward movement of his right hand (Figure 5). He then classifies the table as elastic (l. 172).

Similarly to Waring *et al.*'s (2013) observation of scene enactments in vocabulary explanations, the teacher's demonstration attracts the attention of the entire class (all students now gaze at him; l. 173) and generates understanding displays from several students. Liisa and Neea both claim new understanding with oh-prefaced responses (l. 174, 177–178; e.g. Heritage 1984; Koole 2010), while Ronja produces a demonstration of understanding through an ensemble of linguistic and multimodal resources (l. 179): her verbal turn is completed with a rhythmic onomatopoeic utterance 'poing poing poing' and a bouncing gesture (Figure 6). The gesture invokes the action of the spring the students witnessed in the Hooke's law experiment. Neea repeats Ronja's vocalization, also with a smiling voice though without the accompanying gesture (l. 181). Through their claiming and showing understanding the students clearly orient to the teacher's stepping on the desk as an instructional demonstration rather than as mere entertainment. The teacher treats the students' collective understanding claims and performances as a sufficient foundation to move on to the next topic, the limits of elasticity (l. 183–185).

Extract 4 demonstrates how the teacher employs both material objects and the affordances of his body alongside with talk to explicate the notion of 'elasticity' and its role in understanding Hooke's law. The teacher's walking to get the spring, and thus his positioning closer to the students, projects the explication of the concept in relation to steel. By verbally referencing and stretching the spring, the teacher invokes students' prior experience and gives a tangible, visual demonstration of the elastic character of steel. An even more elaborate demonstration is offered when the teacher stands on a desk and uses his body weight and an iconic gesture to illustrate the elasticity of materials. This multimodal performance engages the students' attention and occasions multiple collaborative understanding displays.

Extract 5a Bending_stretching and compression

233 T *I'd like to mention one thing *about this uh ^(1.6)*
*T GAZE FROM DOWN TO ST.-------------->*T GAZE TO HIS RIGHT------*
^T TAKES 3

234 *bending. because bending is^ actually *uh (1.0)
*T GAZE AT ST.---------------------------------->*T GAZE DOWN TO
STEPS TO HIS RIGHT--------------->^

235 in bending you (0.3)
TABLE-------------------

236 have a- stretching *an' compression #together.
--------------------->*T GAZE AT ST.------------------
#FIG.7

237 (1.0) T GAZE AT STUDENTS
NEEA GAZE TOWARD BB/TEACHER

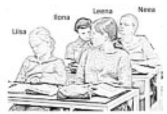


FIGURE 7

238 T *when ^you're bending something uh (0.3) like
*T GAZE TOWARD BB-------------------------------------
^T WALKS TO BB------------------------------------

239 (3.0) T ARRIVES AT BB AT 0.5s AND
STARTS TO DRAW A RECTANGULAR SHAPE
LEENA & NEEA GAZE TOWARD BB
LIISA GAZE AT HER NOTEBOOK
AT 1.7S SHIFTS GAZE TOWARD BB

240 T some ^piece of material.

DRAWS->^

241 =when you're ^bending it and^ ^(0.5)
----
^T DRAWS AN ARROW->^ ^T RH HOVERS

242 making it like ^this

OVER BB---------->^T BEGINS TO DRAW

243 (5.8) T DRAWS A BENT SHAPE
NEEA GAZE TOWARD BB
LIISA DRAWS IN HER NOTEBOOK
LEENA TAKES HER NOTEBOOK AND BEGINS TO DRAW

Extract 5b Bending_stretched and compressed

248 T then you might notice that (0.8)^* (3.8)
T GAZE AT OBJECTS---------------------->*T GAZE AT BB
T PLACES OBJECTS ON THE FLOOR---------->^T WALKS TO BB

249 the ^top side (.)*has actually^ gotten* (.) ^longer. (.)
------------------->*T GAZE AT ST.------------>*T GAZE AT BB--------
---->^T POINTS ON BB----------------->^T MOVES HAND-->^T POINTS ON BB

250 an' the ^bot^tom side* (.) has ^got*ten shor^ter.*^
------------------------>*T GAZE AT ST.--->*T GAZE AT BB--->*
--------->^T MOVES RH^T POINTS----->^T MOVES RH--->^T POINTS ON BB^

251 (1.2) T ADJUSTS CHALK IN RH, GAZE AT IT
JAANA, LIISA, LEENA & NEEA GAZE TOWARD BB
RONJA & ILONA GAZE ELSEWHERE

252 T so ^(1.4)^ ^so this is ben↑ding
T GAZE AT BB-------------------------
^T TAKES 3 STEPS TO BB^ ^T BEGINS TO WRITE

253 (3.1) T WRITES UNTIL END OF SILENCE
LIISA GAZE AT BB
JAANA, LEENA & NEEA WRITE
IN THEIR NOTEBOOKS
RONJA & ILONA DO OTHER THINGS

254 T but the (.) ^top side is^ actually ^(0.8)^ uh
T GAZE AT BB--
^T DRAWS AN ARROW^ ^T WRITES A LETTER AFTER ARROW^

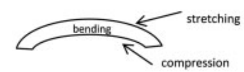
255 ^(1.4)^ [being] stretched.
----
^T WIPES THE LETTER AWAY^

256 Liisa [tension]

257 (4.5) T WRITES 'STRETCHING' ON BB
LIISA GAZE AT BB
JAANA, LEENA, ILONA & NEEA WRITE
IN THEIR NOTEBOOKS
RONJA DOING OTHER THINGS

258 T an' this ^bottom side is being^ compressed.
----
^T DRAWS AN ARROW---------^

259 (8.7) T WRITES 'COMPRESSION' ON BB
THEN BACKS AWAY FROM BB
STUDENTS WRITE IN THEIR NOTEBOOKS
RONJA DOING OTHER THINGS



5.4 Drawing and writing on the board

Extracts 5a and 5b illustrate how the teacher introduces the concept of ‘bending‘ by way of drawing visual illustrations of the transformation on the board and explicating the concept through both everyday and scientific terms with the help of the drawings. Pointing gestures tied to the sequential unfolding of the teacher‘s talk, writing, and drawing on the board serve as coordinated methods of explicating the target concepts. Extract 5a opens with the teacher‘s announcement of the concept that is defined next (l. 233–234).

The teacher‘s formulation of the announcement (l. 233–234) references an earlier, but brief, mention of the concept ‘bending‘, and thus connects the new topic to what has preceded in the plenary. As before, the teacher highlights the target concept by first producing a preliminary metacomment, then pausing for 1.6 s during which he waits for two students to return to their seats, after which he produces the target word emphasizing the first syllable. All these production features mark the concept as the definiendum. He then begins to define the concept using the structure definiendum + copula verb (*bending is*) but self-repairs and formulates the definition in general terms using the possessive verb (*in bending you have*, l. 235–236). The self-repair replaces ‘bending‘ as the grammatical subject with a locative and so foregrounds the definiens, that is, the two processes of stretching and compression that constitute ‘bending‘. The teacher‘s talk is accompanied by iconic gestures (l. 236, Figure 8) that provide a visual display of the actions that the nouns denote. The gestures are a recurrence of another gesture ensemble performed earlier in the plenary when the two processes were defined for the first time. On this occasion, the teacher again visually shows the processes to the students (cf. Pozzer-Ardenghi and Roth 2008). However, at this point only one student is visibly attending to the teacher‘s actions (Neea, Figure 7).

Once the teacher has defined ‘bending‘ in terms of the general processes it involves, he moves on to explain how the processes are visible in bending. He marks the shift in the activity by gazing at and walking to the board, thus visibly preparing for producing an inscription (l. 238; Mondada 2014; Mikkola and Lehtinen 2014). The explanation opens with a general verbal description (‘something like‘) which projects a noun phrase complement, followed by the action of drawing a rectangular shape on the board (see visual representation, l. 239). The act of drawing is thus sequentially intertwined with turn construction and elaborates the explanation by producing a visual representation of some material to be bent. After completing the turn (‘some piece of material‘, l. 240), the teacher repeats the turn initial description, replacing the object with the anaphoric ‘it‘, and describes in general terms what happens in bending (l. 241–242). Again, the turn unfolds so that after the description (*like this*) the teacher draws a shape on the board, thereby completing the turn (l. 243). The prospective indexical (Goodwin 1996) highlights the relevance of the emerging drawing, the shape of which is unknown until it is drawn.

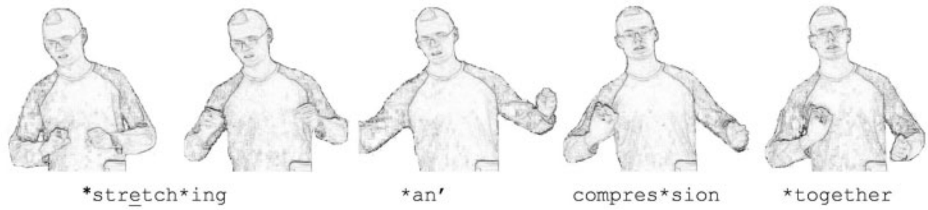


Figure 8: Teacher's iconic gestures of 'stretching' and 'compression' (line 236)

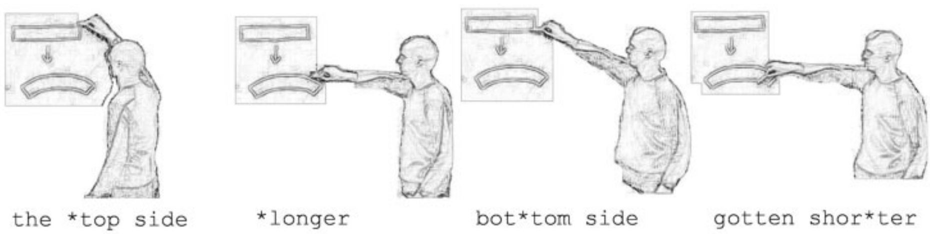


Figure 9: Teacher's pointing gestures (l. 249–250)

The teacher's explanation continues in Extract 5b after a short break during which the teacher removes some of the objects used in the peer activity from the table. It shows how he uses the illustrations to explicate how stretching and compression are both concurrently present in bending, and particularly, to highlight what bending does to the material.

Having returned to the board (l. 248), the teacher draws the students' attention to the transformations the bent piece has endured by formulating them in everyday language ('top side', 'longer', l. 248–250). In each turn, the part in focus is referred to in turn-initial position and the action it endures is provided in turn-final position. There is thus a rhythmical pattern in the turn design. It is further emphasized by the accompanying pointing gestures that highlight the elastic transformation the material has undergone (Figure 9). At this juncture, the meaning of 'bending' is elucidated through indexical expressions tied to visual referents in the sequential unfolding of talking and pointing.

The explication is then followed by an ostensive definition (Flowerdew 1992) where the teacher points at the bent shape and formulates the process that produces such a shape as bending (l. 252). The anaphoric 'this' not only references the shape, but the entire explanation sequence that has served to explicate the transformation process. To further highlight this, the teacher writes the term inside the bent shape (see visual representation, l. 253). In continuation, he ties the visible transformations to the two concepts—stretching and compression—thereby providing their scientific names (l. 254–255, 258). Again, each is rhythmically produced at the end of the ongoing turn, where they are placed as new information (Flowerdew 1992). Both are also written on the board where they are linked with arrows to the appropriate transformations (l. 257 and 259, respectively). The teacher‘s talk and the writing unfold sequentially so that the transformations are first named and then written on the board (in their nominal forms).

As with Extracts 1 and 2, during this sequence, the students mainly focus on the action of writing and taking notes of the teacher‘s explanation. They are thus treating the topic as object of instruction. The teacher‘s actions, and particularly his extended gaze and bodily orientation toward the board, further attest to this: he focuses on delivering the explanation rather than on inviting students‘ participation.

In this extract, the teacher methodically draws connections between the different concepts related to Hooke‘s law, thus far mainly introduced through individual classifications (e.g. stretching, compression). This is accomplished at the board, which the teacher uses to develop a visual definition and explication of ‘bending‘ (also Flowerdew 1992). The explication depicts bending as a complex concept that cannot be defined without understanding the two fundamental transformations of compression and stretching. These are visually demonstrated through environmentally coupled gestures (Goodwin 2007) that are tightly coordinated with the respective transformation-specific labels in the verbal turn. The ensemble of talk and iconic gestures provides a visual and concrete example of the transformations. The definition is then elaborated with the help of two drawn illustrations sequentially intertwined with talk. Together with the teacher‘s talk, the drawings explicate the transformation that a piece of material undergoes when it is bent. The sequential development of talking, drawing, and writing as well as the embodied and spatial resources mobilized for these actions position the students as recipients of instructables and serve to make all three concepts accessible and understandable to the students, particularly when the teacher explicates the transformation process first in everyday words and then in the language of physics.

6. CONCLUDING DISCUSSION

This article set out to explore a teacher‘s definitional practices as part of his larger project of explaining Hooke‘s law in a plenary episode within a physics lesson. It shows how the teacher introduces the law, defines its key concepts, and elaborates the concepts and their relations via a bundle of definition-related actions, including naming, classifying, and exemplifying. As methods to elucidate the explanandum, these actions are sequentially organized over multiple turns, oriented to the larger pedagogical activity in which they are embedded, and configured through a multiplicity of coordinated situated practices, including verbal formulations, writing and drawing, embodied and ambulatory practices, object manipulation, and recruiting the material ecology of the classroom. The multimodal practices reflexively constitute Hooke‘s law as an instructable matter whose delivery is recipient designed at every moment for the students in the room.

Multimodal practices are tightly coordinated with the verbal formulations through which definitions are accomplished. In turns that introduce a concept to be defined, multimodal production features serve to frame it as the definiendum: features of prosody and shifts of embodied orientation highlight the definiendum and invite students to attend to the emerging definition. Actions that elucidate the meaning of the definiendum are performed through ensembles of verbal and bodily visual action that provides visual displays of the phenomena. The sequential unfolding of definitions is also sensitive to the spatial organization and material environment. The teacher's movement closer toward the students can signal a transition from a formal definition to elaboration of the concept (cf. Roth and Lawless's, 2002b, narration space) and also occasion student displays of recipiency. Movement in space (e.g. walking) can also project further actions (e.g. demonstration by using material objects) that serve to explicate the definiendum. The use of material objects (e.g. Extract 4a and 4b) provides tangible resources for explicating physical phenomena with reference to earlier phases of the instructional activity. Sequentially intertwined physical actions of drawing and writing on the board provide visual representations that are referenced in talk to explicate the phenomena in focus (Extract 5a and 5b).

Although the analytical focus in this study is on the teacher's instructional work, it also shows that the plenary episode is jointly accomplished by teacher and students. In a number of ways the students treat the law and its concepts as learning objects (Pekarek Doehler and Ziegler 2007) or learnables (Zemel and Koschmann 2014), most conspicuously by copying inscriptions from the blackboard in their notebooks. The teacher's turns occasion recipient actions ranging from verbal initiation of repair (e.g. Extract 2) to verbal and embodied claims and demonstrations of understanding (e.g. Extract 4b). We observed that the use of material objects engenders more elaborate recipient displays than elaboration of new concepts through gesturing coupled with talk or inscriptions accomplished at the board (also Waring *et al.* 2013). A salient example is Extract 4b, where the teacher stands on the table to explicate the elasticity of materials. The action, intertwined with talk and iconic gesturing, involves the use of the whole body and is performed in close physical proximity to the students (cf. Mondada 2014). This configuration occasions immediate and engaged displays of attention and understanding from the students, which in turn prompt the teacher to close the sequence (also Kasper and Kääntä 2016, manuscript in preparation).

Previous research shows that CLIL classrooms are predominantly concerned with subject content (Dalton-Puffer 2007; Kääntä and Piirainen-Marsh 2013; Nikula 2015). The plenary episode observed in this study is no exception. We noted initially that the episode is an activity phase in the overall organization of an instructional unit on Hooke's law, situated after a peer experiment and before written assignments. The structure embodies a curricular orientation to active, experiential learning in physics education: through practical collective work on an experiment and recording of measurements, students gain experiential, pre-analytical knowledge that serves as a resource for the teacher's formal explanation of the abstract physical law in the plenary episode. Both teacher and students repeatedly reference the experiment, the springs as the focal physical objects, and the force-extension plot to accomplish definitions and explanations during the teacher-led activity in an effort to build the students' conceptual knowledge about the physical law. In the teacher's talk verbal references and depictive and environmentally coupled gestures (Goodwin 2007) mutually elaborate each other and contextualize the definitions within the larger activity. In Extract 3, for example, the teacher's deictic gesturing ties the definition to the practical experiment and invokes the students' experiential knowledge of what 'proportional relationship' means (cf. Morton 2015). The analysis also provides evidence of an overarching goal of science education, which is to translate science concepts from everyday language into the register of the particular science (e.g. Pozzer-Ardenghi and Roth 2008; Evnitskaya 2012). In that sense the study shows how 'doing science' and 'doing language' in an L2 physics lesson are intrinsically connected (Pekarek Doehler and Ziegler 2007). But does the accomplishment of physics education *in* a CLIL classroom imply that students and teacher conduct their work *as* CLIL?

Earlier work has pointed to several practices through which teachers and students orient to the CLIL setting. For instance, Evnitskaya (2012, also Evnitskaya and Morton 2011) observed that teachers use gestures to compensate for unavailable L2 words. In our study, the teacher uses embodied action as a key representational resource (see Extracts 2, 3, and 5a) rather than in compensatory function. In the CLIL setting examined by Morton (2015), the teacher repeatedly shifts from a focus on the content matter to a focus on L2 lexical items, some of which ('blessing', 'harmful') are clearly part of the everyday lexicon. The physics teacher in our data, in contrast, maintains his orientation to the agenda of the physics lesson. First, the selection of words that he treats as instructables comes from their role as concepts in the target law. Second, his explanation of 'proportional' (Extract 2) formulates and visually performs proportionality as a physics concept (the relationship of two quantities with a constant ratio) rather as an everyday term. The only focus on linguistic form in the extracts is initiated by Liisa's clarification request of how the first syllable of 'proportional' is spelled on the board. The repair sequence with its focus on spelling and pronunciation does focus on language form, but language-related problems of this kind can occur in L1 content classes as well.

For the most part, the use of English is not problematic for teacher and students, and they treat English as the normative language of instruction during the plenary episode. At other moments during the teacher-led talk, not shown in this study, the students occasionally codeswitch to Finnish to clarify a vocabulary item (Kasper and Kääntä 2016, manuscript in preparation), a practice also known from other CLIL contexts (e.g. Dalton-Puffer 2007). In the data above, codeswitching to Finnish is limited to indexing students' talk as side sequences (Auer 1984) that are not intended to contribute to the official classroom business (Liisa's noticing in Extract 1, l. 18; Jaana's clarification request addressed to Liisa in Extract 2, l. 35; also Nikula 2007). The codeswitching orients to the classroom as a bilingual setting but not as an L2 learning environment.

In sum, the article contributes to the limited literature on physics education in a CLIL classroom, specifically to research on how the installation of knowledge about a physical law is accomplished as the teacher's professional work. Although the study focused on the teacher, it shows how the students play a constitutive role in the plenary episode: the teacher's actions are designed so as to be understandable for *these* students, and the students show their understanding and non-understanding as the instruction unfolds and so contingently shape the evolving lesson. For science teacher education in CLIL contexts, the study indicates the indispensable need to attend to the artful coordination of multilingual and multimodal practices. With its analytical interest in the local situated accomplishment of physics teaching as a socially constituted activity, the study also shows how the students contingently orient to instructional matters as learning objects, but it did not, and indeed would not have been able to, address the question of learning outcomes. Finally, students' and teacher's unproblematic way of using English contrasts with CLIL research in other settings, suggesting that the wider sociocultural and educational context affords teachers and students varying expertise in the second language as medium of instruction.

SUPPLEMENTARY DATA

Supplementary material is available at *Applied Linguistics* online.

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NOTES

1 The 'it' in his turn is an anaphoric reference to Hooke's law being a new topic that the teacher mentioned moments before.

2 In the transcript, her turn in line 16 is an attempt to represent her hearing of the name of the law rather than its written form.

3 'Doubling' can be seen as a recipient-designed version of 'changing by a constant factor'. The teacher's gesture represents that general relationship.

4 'This property' in the proposition refers to the theoretical statement of Hooke's law.

5 She in fact tries to stretch the frame with her hands but, naturally, is unable to do so.

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