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Cooperative Engineering to Develop Epistemic Practices: an English-Physics CLIL Sequence

A Case Study Illustrating Cooperative Engineering Design-Based Research

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Abstract

This paper describes how cooperative engineering design-based research was used to develop a Content and Language Integrated Learning (CLIL) didactic sequence. The sequence was designed by an English language teacher-researcher and a physics associate professor for the concurrent learning of English as a foreign language together with disciplinary knowledge of physics as a practice (Bloor, 2020; Bloor and Santini, 2022a). The article focusses on the cooperative action between the two teacher-researchers and presents detailed examples of classroom activity and resources, as well as extracts from the write-up of a lengthy telephone exchange to illustrate the cooperative action between the teachers and the evolving epistemic depth of the CLIL sequence. The Joint Action Theory in Didactics (JATD) notions of *jargon* and *thought style* are used to render visible the epistemic potential and evolution of the cooperative engineering work. The paper concludes with a number of insights into how knowledge was constructed and developed in an iterative process and how the epistemic quality of the sequence was improved as a result of the cooperative design-based research.

Key words

Cooperative engineering; Cooperative action; CLIL; Language learning; Uncertainty in measurement

INTRODUCTION

The question of how to fully engage students as social agents is of considerable interest in second or foreign language learning. There is untapped potential in science subjects for creating learning situations requiring a range of language functions such as forming and testing a hypothesis, giving a measurement or describing an object or a protocol. Such situations enable students to acquire language by being creatively and actively engaged in its use.

This was the origin of the motivation to develop a CLIL (Content and Language Integrated Learning) sequence in a cooperative engineering (Sensevy, Forest, Quilio & Morales, 2013). Such courses offer rich potential for the development of teaching–learning sequences designed to achieve the concurrent learning of disciplinary knowledge and a foreign or second language (Bloor, 2020).

In this paper we have described our use of cooperative engineering to develop the CLIL sequence. Cooperative engineering is a specific kind of research within the general paradigm of design-based research which involves an iterative, cooperative process. This was used to explore the scientific practice related to the question of uncertainty in measurement in physics and its potential for language learning. Our motivation to engage in the process of the cooperative engineering research was the expectation that in activating the social practice related to the question of uncertainty in measurement in physics, students would develop their English language proficiency as well as an appropriate conception of scientific measurement as a practice. As Sawyer states “Students learn deeper knowledge when they engage in activities that are similar to the everyday activities of professionals who work in a discipline” (2006, p.4).

The paper is organised in the following manner. First the epistemological notions underlying the work are presented, including the JATD notions of *jargon* and *thought style*. Following that, a general outline of the context of the study as well as the methodological tools employed are presented. Next, a number of salient examples of the cooperative work are then described: classroom practice, a teaching resource and an exchange between the teacher-researchers. The JATD notions of *jargon* and *thought style* are used to analyze the epistemic quality of the various examples of the practices presented. Finally, the paper concludes with some insights into how the epistemic potential of the sequence evolved and improved as a result of the cooperative engineering employed and how the notions of *jargon* and *thought style* serve to render visible this development.

1. Epistemological Underpinnings and Theoretical Notions

What constitutes a language is a complex question; depending on the field of research, language might be viewed as linguistic phenomena that can be studied as an abstract system (Bloomfield, 1933/1984; Chomsky, 1957), or as a semiotic system (Peirce, 1878), or as being inherently context sensitive (Foucault, 1969, Halliday, 1985). A principle underlying this study is that meaning is constructed in social spaces, and that language is not a uniquely individual phenomenon (Vygotsky, 1934; Mead, 1931; Dewey, 1938/1997; Halliday, 1978; Maniglier, 2016; Sensevy et al., 2019; Bloor, 2020; Bloor & Santini, 2022). Wittgenstein’s conception of the nature of language is the view of language adopted for the analytical aspect of this study. From Wittgenstein’s perspective words, gestures, expressions and so on, come alive within a language game, a culture or a “form of life”:

“For a large class of cases —though not for all— in which we employ the word ‘meaning’ it can be defined thus: the meaning of a word is its use in the language.” (Sect. 43 of Wittgenstein’s *Philosophical Investigations*, 1953).

In JATD and this paper, language is seen as being composed of language games within forms of life which produce certain *thought styles* (Fleck, 1935/2008; Bazerman, 1988; Sensevy, Gruson, Le Hénaff, 2019, Bloor, 2020, Bloor and Santini, 2022) together with an associated *jargon* (Sensevy et al. 2019, Bloor, 2020, Bloor and Santini, 2022). Based on this Wittgenstein conception of the nature of language, the notions of *jargon* and *thought style* are thus proposed as useful tools for modeling and analyzing didactic practice (Bloor, 2020, Bloor, 2022). These notions are described in detail below and will be used to analyze the exchanges between the two teacher-researchers working on the development of the cooperative engineering sequence, as well as the teaching-learning practice that resulted from their work.

1.1 Jargon

In general usage, the term jargon tends to have a somewhat negative connotation and can be associated with an obscure, even pretentious use of language. However, there is no negative connotation in the notion of *jargon* as used in this study. Its use is akin to a dictionary definition of the term, for example, that of the Cambridge Dictionary: “special words and phrases that are used by particular groups of people, especially in their work”. Our use of the term goes beyond this definition of specialized vocabulary to include an understanding of how the skills and crafts of a domain can literally be embedded in the *jargon* of its associated practice: it thus denotes more than vocabulary as it includes an understanding of the background to the practice which also gives it shape. The *jargon* of a cultural practice is thus its linguistic system: a network of terms, expressions and various discourses that might occur within the forms of life specific to that cultural practice. An example to illustrate this point, taken from this study, is how the uncertainty in a measurement might be described and discussed within a scientific community sharing that form of life. Such discussions would entail specific language games (Wittgenstein, 1953) associated with scientific practice. These would then be both the source and the result of the *jargon* related to the practice. This point will be illustrated with the specific examples of cooperative engineering practices in section 2.

1.2 Thought Style

A *thought style* refers to the intertwined perception and conception developed within a particular form of life. What one sees is not an action that is independent from the conception of the “object” of one’s gaze: there is an organic relationship between perception and conceptualization. A few common optical illusions to exemplify this disposition are the rabbit/duck and older/younger woman images: one sees a rabbit but in the next instant a duck; the wizened contours of an older woman’s face and in the following second the smooth profile of a young woman’s face and shoulders. These experiences of our own cognitive processes teach us how strongly our existing disposition to ‘see’ in a particular light will determine our take on reality: realities constructed not as individuals, but as communities in the meshwork of semiotic systems which make up the interpersonal spaces of the forms of life within which we exist (Vygotsky, 1934; Mead, 1931; Dewey, 1938/1997; Halliday, 1978; Sensevy, Gruson and Forest, 2015; Maniglier, 2016; Bloor, 2020). From this perspective, language is not separate from culture, nor an abstract tool to be used but rather an environment in which we live.

This moulded disposition of any given community to perceive/conceive in a particular light is denoted in this study by the term *thought style* (Sensevy et al., 2019, Bloor, 2022a). What might be considered to be the appropriate *thought style* of scientific practice in relation to measurement? This is a complex question. The view in this paper is one which is consistent with conceptions of scientific practice within what might be termed a *new empiricist* school of thought (Cartwright, 1989; Cartwright, 1999; Hacking, 1983; Sensevy et al., 2008): that is to say, an appropriate thought style for scientific practice is one that considers scientific practice as modelling a relationship between abstract, conceptual notions and more concrete, empirical realities. As regards scientific measurement and uncertainty in measurement, this entails recognizing that “the right measurement” is not something that exists independently of context; the context of any given measurement is necessarily part and parcel of its identification. This is what

Kuhn argues when he states, “The road from scientific law to scientific measurement can rarely be travelled in reverse direction” (Kuhn, 1977).

A common misrepresentation of scientific measurement is the idea that it is essentially a question of using sophisticated equipment and applying prescribed formulas with no personal involvement (Allie, Buffler, Campbell, & Lubben, 1998; Buffler, Lubben & Ibrahim, 2009; Bloor, 2020). In reality, scientists are very involved in the execution of their experiments: the viability of their results depends on an appropriate assimilated thought style. That is to say, the full recognition of the possible impact of every factor involved in a measurement, including their own involvement in the process. From this viewpoint, scientists are seen to use material and formulas as mastered tools linking theory to practice, or the abstract to the concrete, thanks to an appropriate, assimilated thought style acquired through socialization (Bazerman, 1988; Collins, 2011) in scientific communities of practice. It is thanks to this acquired precise understanding of the impact of each factor in a measurement, including their own practice, that scientists are able to measure effectively (Buffler et al., 2009; Caussarieu & Tiberghien 2017; Santini, 2021).

2. The Context of the Study and its Methodological Tools

A range of theoretical and methodological tools developed within the JATD framework was employed in this cooperative engineering. It is beyond the scope of this paper to describe in detail all the methodological aspects of this study (see Bloor, 2020 and Bloor & Santini, 2022a). However, to better contextualize the cooperative action and the iterative process of cooperative engineering which is the focus of this paper, a general outline of the conditions of the study and its various components will be presented.

2.1 The Context of the Study

The students investigated in this research are science undergraduates in a French university where courses of English as a foreign language are commonly included in degree and master programs. The teacher-researchers in the study are colleagues at the same university. The cooperative engineering presented in this paper began with a single lesson with the physics lecturer visiting the English teacher’s class so as to explore the possibility of including science subjects in English lessons for students at the university. Over a three-year period, this then developed into a complete teaching sequence on uncertainty in measurement which was integrated into a first-year science degree programme.

2.2 From Description to Analysis

Filmed lessons played an essential role in documenting the main features of classroom activity in the evolving sequence (Sensevy, 2011). This was to provide an analogic representation of the actual activity in class, that is to say, a representation which included a maximum of detail without any additional commentary or interpretation. The films of classroom practice were then transcribed and carefully *described* (Ryle, 2009; Sensevy, 2011) before any attempt was made to analyse them. This was to provide an initial source of data which was as close as possible to the actual practice. Apart from a number of practical considerations such as sound quality, extracts from the many hours of filmed classroom activity were then chosen as emblematic examples (Kuhn, 1977) typical of the classroom activity in the study and therefore serving as useful examples to present a more general picture. The “Enhancing Fluency Extract” presented in 3.5 for example, was typical of many other student productions.

Analyses of classroom activity was undertaken using a clinical approach (Foucault, 1963; Sensevy, 2011; Santini et al., 2018). This entailed both pinpointing the exact knowledge at stake in each given

context and identifying how that knowledge related to the overall culturally constructed body of knowledge from which it emanated. The modelling of classroom activity with the notions of *jargon* and *thought style* (amongst other JATD model-notions) made it possible to apprehend the role of the various phenomena identified at a micro-level in relation to both the classroom activity as a whole and the epistemic stakes inherent in the classroom practice. In this way, phenomena were identified and contextualized at a micro-, meso-, and macro-level of analysis (Sensevy, 2011; Sensevy, 2012, Santini et al., 2018). The methodology used in this research thus relied on a multi-layered process of inquiry in order to piece together the traces of the classroom activity analysed.

3. Descriptions of the Cooperative Engineering Practices

This paper focuses on the nature of the cooperative work in this research which took several forms and spanned a period of more than three years. It included frequent meetings, email and telephone exchanges, the teachers visiting each other's lessons and the joint production of various teaching resources.

Below are salient examples of the nature of the cooperative engineering which will serve to lend insight into its general nature as well as illustrate how this cooperative engineering research worked. The first example is taken from the very beginning of the cooperative exercise: it is a description of an exploratory lesson in which the English teacher invited the physics lecturer into her lesson with a view to working conjointly on a video excerpt dealing with the subject of uncertainty in measurement. The second example is a teaching-learning activity developed after the exploratory lesson: here the epistemic quality of the sequence can be seen to evolve. The third example is a transcription of one of the many exchanges between the two teacher-researchers which were integral to the iterative process of the cooperative engineering. The fourth example is a description of a teaching resource conjointly designed by the two teacher-researchers. Finally, a description of a yet later lesson is presented where the *jargon* and *thought style* of the English teacher can be seen to have evolved thanks to the cooperative action between her and the physics lecturer.

3.1 The Exploratory Lesson

Walter Lewin is a former professor of physics at the Massachusetts Institute of Technology whose lectures are published via MIT's OpenCourseWare. An excerpt from one of Lewin's lectures was used in the first part of the English/Physics exploratory lesson described below. The second part of the lesson was based on a mini-group activity where students were asked to measure an object whilst exchanging amongst each other in English. The lesson teaching objectives were not clearly defined at this stage, but the general aim was to improve best practice in protocol, increase understanding of the importance of uncertainty in measurement and introduce students to English scientific vocabulary. The English teacher also sought to gain insight into how to develop Content and Language Integrated Learning. Hence, the main objective of the lesson, as with the initial stages of many cooperative engineering was (see Art de Faire Ensemble, 2024) to "see what happens", to learn from the experience and to consider the potential of this kind of cooperative action. A worksheet used to accompany the video extract in the first part of the lesson was prepared by the English teacher. An instruction sheet given to the mini groups in the second part of the lesson was prepared by the physics lecturer.

Part One of the Lesson: the MIT Excerpt

The group of twenty students in this exploratory lesson were studying a Maths and Physics course in preparation for entry into engineering schools. The main content of the MIT video extract concerned an experimental set-up devised by Walter Lewin, with a view to testing the validity of his grandmother's assertion that a person lying down was taller than a person standing up. To do this he asked for a student to volunteer to be measured standing up then lying down. Prior to this he assessed the accuracy of his

experimental set-ups by measuring an aluminium bar with first the vertical set-up then the horizontal set-up; from this he concluded he could measure with an accuracy of up to 1mm. Frames 1-3 below are some examples of class activity during this part of the lesson which are followed by a full transcription of the excerpt viewed.



Table 1

Transcription of the MIT Video extract

Now all important in making measurements, which is always ignored in every college book, is the uncertainty in your measurement. Any measurement you make without any knowledge of the uncertainty is meaningless, I will repeat this, I want you to hear it tonight at 3 o'clock when you wake up, any measurement you make without a knowledge of its uncertainty is completely meaningless. My grandmother used to tell me that, at least she believed it, that someone who is lying in bed is longer than someone who stands up, and in honour of my grandmother today I'm going to bring this to a test. I have here a set-up where I can measure a person standing up and a person lying down, it's not the greatest bed, but lying down. I have to convince you about the uncertainty in my measurement because a measurement without knowledge of the uncertainty is meaningless and therefore what I will do is the following. I have here an aluminium bar and I make the reasonable, plausible assumption that when this aluminium bar is sleeping, when it is horizontal, that it is not longer than when it is standing up. If you accept that we can compare the length of this aluminium bar with this set-up and with this set-up. At least we have some kind of calibration to start with. I will measure it, you have to trust me, during these three months we have to trust each other, so I measure here 149.9 cm. However, I would think that - this is the aluminium bar, this is in vertical position, 149.9 - but I would think that the uncertainty of my position is probably 1 mm. I can't really guarantee you that I did it accurately any better - so that's the vertical one. Now we're going to measure the bar horizontally for which we have a set-up here. The scale is on the other side, so now I measure the length of this bar - 150.0 horizontally - 150.0 again plus or minus 0.1 centimetre, so you will agree with me that I am capable of measuring plus or minus one centimetre, that's the uncertainty of my measurement. Now if the difference in lengths between lying down and standing up, if that were one foot, we would all know it, wouldn't we? You get out of bed in the morning, you lie down and get up and you go clunk and you're one foot shorter, and we know that that's not the case. If the difference were only one millimetre we would never know. Therefore, I suspect that if my grandmother was right, that it's probably only a few centimetres, maybe an inch, and so I would argue that if I can measure the length of a student to one millimetre accuracy that should settle the issue. So I need a volunteer. You're the volunteer? Ok, what is your name? Zak. Ok Zak - nice day today Zak, yeah? You feel all right? Your first lecture at MIT. I don't. Ok man. Stand there - ok 183.2 stay there, don't move. Zak - this is vertical - what did I say 18? Only one person - three? Come on 183.2 and an uncertainty of about 0.1 centimetres. And now we are going to measure him horizontally. Zak I don't want you to break your bones so we have a little step for you here. Put your feet there - oh let me remove the aluminium bar - watch out for the scale that you don't break that because then it's all over. Ok I'll come on your side, I have to do that - yeah, yeah relax - think of this as a small sacrifice for the sake of science all right? Ok you good? You're comfortable? You're really comfortable right? Wonderful

You're ready? Ok 185.7 - stay where you are. 185.7 - I'm sure - we first make the subtraction right - 185.7 plus or minus 0.1 centimetres - oh that is 2.5 plus or minus 0.2 centimetres. You are about one inch taller when you sleep than when you stand up. My grandmother was right. She's always right. Can you get off here

Class Discussion Following the Video Excerpt Viewing

This episode occurs just after the students have listened to the excerpt from the MIT OpenCourseWare lecture. The lecturer in the video, Walter Lewin, is insisting on the importance of uncertainty in measurement. The physics lecturer in the class (henceforth PL) is explaining to the students and the English teacher (henceforth T) the validity of Walter Lewin's estimation of 1mm uncertainty for the aluminium bar (the relevant passage is in bold text in Table 1).

Table 2

Discussion of the MIT video

1. PL: ... measurement. It's two times 1mm in that case. So he should have taken 0.2 ... Centimetre. So two millimetres. And he didn't take that so ... for him,, his eye precision in the ruler when he looks at the length he's measuring the starting point and the end of the measurement, it is not 1mm. What is it?
2. T and students: ... (#4 silence)
3. T: So it should be 2mm?
4. PL: It should be 2mm
5. T: (inaudible)... only 1mm?
6. PL and T at the same time: inaudible
7. PL: The ruler accuracy is 1mm. So you have to put the beginning of the measurement like a starting point (frame 4) plus or minus 1mm and at the end it's plus or minus 1mm. So the whole thing is ...
8. Antoine: 3mm
9. PL: ... 2mm. And he takes one millimetre, why? It's obvious but he doesn't tell it. It's obvious for the students, they're not raising their finger ... their finger and saying oh you're wrong. It's his estimation.
10. T: He made a mistake? He made a mistake or .. it's a choice?
11. PL: No, no. It's a choice. He doesn't tell it.



Frame 4: 1mm at the start and the end of his measurement



Frame 5: A student tries to speak

The PL (1) discusses Walter Lewin's estimation of 1mm uncertainty for the measurement of the aluminium bar used to calibrate the vertical and horizontal measuring set-ups, suggesting 2mm would be possible too. The English teacher and the students struggle to understand why and respond either with silence (2), a question (3) or a suggestion of 3mm uncertainty (8). The PL says the reason for Walter Lewin's choice is obvious (9) but T does not find this choice obvious (10).

A Posteriori Analysis: *Jargon* and *Thought Style*

The English teacher does not fully understand the point the physics lecturer wishes to make regarding the choices involved in estimating uncertainty in measurement (speech turns 2, 3, 10). At this stage of their cooperative action she has a common misconception about the nature of science: that it is exact, with no room for doubt or personal choices. The idea that Walter Lewin could have decided on either 1mm or 2 mm for his uncertainty does not strike her as scientific (speech turn 10). In other words, she is not considering the situation within the *thought style* of experimental science. As we shall see, the multiple exchanges with the physics lecturer using the *jargon* of the practice such as “plus or minus” (speech turn 7) gradually enable her to gain insight into the *thought style* of experimental science.

Second Episode: the Decimal Point

Following the class work on the MIT video extract, the students form small groups to measure a dimension of one of a choice of objects using tools made available by the teachers.

Table 3

The decimal point

-
12. PL: you have to tell me two figures after the comma
13. Pierre: (...) comma?
14. T: do you mean the decimal point? After the decimal point.
15. PL: a dec?
16. T: a decimal point
17. PL: after the decimal point.



Frame 4: a decimal point

There is some confusion between the students and the PL (13) when PL uses “comma” to refer to the decimal point, the comma being the equivalent of the decimal point in French (12). The English teacher offers the correct term (16), a decimal point.

During the group-work, the physics lecturer communicates with one of the groups. The English teacher observes from behind the camera. At times she contributes some vocabulary as with this example of the decimal point. This kind of interaction between the physics lecturer and the English teacher enabled the research and development of an appropriate *jargon* in English for uncertainty in measurement and the production of resources such as a conjointly produced full laboratory report in English (see Bloor, 2020).

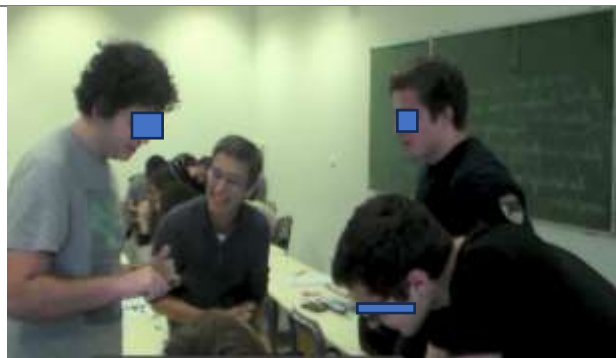
Third Episode: Measuring an Object in Small Groups

Pierre, a student working in a small group with the physics lecturer, begins measuring the side of a wooden rhombohedra so as to determine its height whilst at the same time attempting to describe his action in English to the physics lecturer and the other students in the group. The English teacher is an observer of the action behind the camera, occasionally intervening.

Table 4

Measuring an object in small groups

-
18. PL: What are you measuring?
19. Pierre: I mesure the first bord of the first face
20. T: Side
21. Pierre: - oh beuf
22. T: - no no, English is important in this lesson. English and science!
23. Pierre: The first side I mesure (heavy accent)
24. PL: Measure
25. Pierre: I measure 6.5 cm
26. PL: 6.50 is much more accurate than 6.5 as a physicist you should know that.



Frame 5: measuring an object

The PL generates an exchange around the activity by asking Pierre what he is measuring (18). Pierre manages to describe his action but lacks some vocabulary (19). T translates “face”, the word he lacks, with “side” but not “bord” (edge in English). Pierre’s “Oh beuf” suggests he does not consider the English vocabulary to be very important. T insists from behind the camera that the English is important (22). Pierre continues his description but pronounces “measure” incorrectly as if it were the French word “mésure” (23). The PL corrects his pronunciation (24). Pierre corrects his pronunciation of “measure” and specifies 6.5 cm as his measurement (25). The PL tells Pierre and the group that they should be aware of the fact that 6.50 (stated by PL as “six point fifty”) is far more accurate than 6.5 (26).

A Posteriori Analysis: Striving for Joint Action

The student Pierre does his best to carry out the instructions he has been given on a worksheet as well as respond to the various instructions of both the physics lecturer (18, 24, 26) and the English teacher (20, 22). He is handicapped by a limited vocabulary for the exercise (19) and is ill-prepared for the multiple requirements of the activity: he must use English (22), he must pronounce new words correctly (23), and he must be capable of best practice as a physicist (26). This somewhat confusing learning situation was later improved so as to be less stressful for students (see sections 2.4 and 2.5 below). Nevertheless, this exploratory lesson where the physics lecturer, English language teacher and students strived to achieve joint action in relation to the potential knowledge in the milieu was a useful stage in developing the more effective final sequence.

The apparent interest of the students and the inherent epistemic potential of combining learning English with physics, both in terms of the *jargon* (14, 19, 23,) and the scientific *thought style* (7, 11, 12, 26) encouraged both teachers to pursue the project. The exploratory lesson was subsequently re-worked and experimented further. The measuring task was simplified by exchanging the task of measuring one dimension of an object from a range of different objects to that of measuring the diameter of a tennis ball and the teaching-learning activities were spread over several lessons to become a teaching sequence. The enhancing-fluency exchange in the fourth episode below is a subsequent version of the mini-group activity in the exploratory lesson in which the condition of pre-arming students with the necessary *jargon* to complete the task required is respected.

As the cooperative engineering methodology progresses, the English teacher can be seen to gain insight into scientific practice (e.g. 2.2, 2.3, 2.4 and 2.5 below). The physics lecturer can be seen to strengthen her English (e.g. speech turn 12 and 17). She also stated that the exchanges with the English teacher helped her to gain insight into why students in general found the concept of uncertainty in measurement difficult to grasp.

3.2 A CLIL activity to work on the *jargon* and *thought style* of scientific measurement

Following the exploratory lesson, the two teachers cooperated on developing an English-Physics CLIL sequence. Only the English teacher taught in all later versions of the sequence, whilst conferring regularly with the physics teacher for a better understanding of the scientific lesson content. The activity described below is a revised version of the mini group measuring activity in the exploratory lesson. Here, students are asked to devise a protocol to measure the diameter of a tennis ball and to estimate the level of uncertainty in their measurement.

Tennis balls were distributed to students who worked in twos or threes. The English teacher asked them to devise a protocol to measure its diameter using material readily available to hand.

Students could research vocabulary on search engines using the computers available in the classroom and the English teacher circulated to assist, encouraging students to use detailed descriptions and precise vocabulary, that is to say the *jargon* of the practice; the correct pronunciation could be checked by various means online. The teacher also challenged the students to justify the rigor of their protocol

though she did not mention directly the notion of uncertainty. The students were asked to note down their results and **not to share** them at this stage.

Once thus prepared, the students changed partners and described their protocol to a new partner who undertook the protocol following his or her instructions and using exactly the same instruments, again without giving their results. This organisation ensured that each student experienced both describing a protocol in detail and carrying out another student's protocol. When this activity was finished, each student wrote his or her result on the classroom black or whiteboard.

This exercise, invariably led to all the students obtaining **different** results, even when using the **same** ball, the **same** instruments and the **same** protocol. The students are then invited to reflect on the reasons for this fact which are numerous: material more or less adapted for the way it is used in the measurement set-up, lighting, eyesight, rigor in the measurement set-up etc.

This discussion is an effective way of guiding students to a more appropriate *thought style* for scientific measurement where the multiple factors involved in a result are recognised as well as a scientist's role in honestly estimating to what extent he or she can guarantee their result (see Bloor and Santini, 2022). It was designed to enable students to grasp why a measurement without mention of a degree of uncertainty is not correct scientific practice.

3.3 Uncertainty in measurement: the telephone exchange

A typical exchange between the two teacher-researchers is described in Table 5. Their conversation is in relation to the activity described in 2.2 and the discussion in class on why students obtain different measurement results even when using the same material and the same protocol to measure the diameter of the tennis ball. The exchange should help to illustrate the nature of the cooperative engineering and is an example of how knowledge was constructed in an iterative process: following experimentation in class, the teacher-researchers would confer so as to improve the sequence. The table shows transcribed excerpts from the English teacher's write up of a telephone exchange between her and the physics lecturer; the write-up of the conversation was subsequently commented on by the physics lecturer.

Table 5

Write-up of a telephone exchange (originally in French. Authors' translation)

Excerpt 1: A comment added to the write-up by PL

PL: Hi, I think you've understood - I've tried to explain even more because as I told you, estimating uncertainty is not simple at all. A mathematical calculation can be easy (or long and tedious), but it often gives uncertainties that are far too high because it adds everything together, whereas in reality some errors can cancel each other out.

As regards uncertainty, the students must understand the absolute necessity of estimating it if we want any measurement to make sense, that is to be able to write it correctly with the right number of significant figures. I need uncertainties to compare my experimental measurement with other measurements or with the result of a simulation, a theory etc.

Excerpt 2: T's write-up and PL response

T: (...) This episode is the transition between students working in pairs to measure the tennis ball and watching the video excerpt. The students propose ideas to explain their different results: I want to guide them towards a more refined understanding of the concept of uncertainty in measurement. When they suggest "materials" as the reason for their different results it seems to me pertinent but not quite the whole story.

P: Indeed, depending on the instrument, it can be more or less suitable; you can wrap a string around the ball more easily than with a flexible ruler (...) a tool like a string is more or less well-suited to the function you want to give it (wrapping the ball at its equator). The most suitable tool for measuring the circumference should be long, rather flat, flexible, and non-extensible (if it is graduated, that's even better, but it's not mandatory). The more suited the instrument is to its function, the more likely the measurement will be accurate.

Excerpt 3: T's write-up and PL response

T: So significant figures are important not because we can calculate or estimate the uncertainty by knowing how many significant figures are in a given number, but because it reveals how well the student has deeply understood tenths, hundredths, thousandths? If they make the mistake of putting three decimal places when their uncertainty corresponds to a few hundredths, it reveals a poor understanding of these concepts?

PL: that's it - it's the crux (or cornerstone, keystone) of experimental sciences. I will also ask the student to prove why they stop at two decimal places. Yes, without calculations or explanations, they cannot decide or choose that. An experienced experimenter will not add up all the errors because that would give an uncertainty that is too large: I estimate my uncertainty based on what I find most reasonable: if I estimate that the mouse cable adds at most one millimetre of uncertainty, I add it - but a good scientist will try to prove that this is indeed the case (or that it cannot be more than one millimetre).

A Posteriori Analysis: *Jargon and Thought Style*

The exchanges in Table 5 offer some insight into the English teacher's evolving integration of an appropriate *jargon* and *thought style* with regard to the practice of measurement in experimental science. As the excerpts in Table 5 illustrate, this was a result of the cooperative action engaged in with the physics lecturer. For example, when the English teacher asks in excerpt 2 how to render more pertinent the suggestion of material to explain different results when measuring the diameter of a tennis ball, she indicates she is considering the situation with a more appropriate *thought style* than in the exchanges following the MIT video viewing (Table 2). In the former, she clearly understands the relevance of the material as a determining factor of the result, though still requires guidance on how exactly. This contrasts with the inappropriate *thought style* indicated by speech turns in 3 and 10 in the exploratory lesson where she expects some kind of exact unquestionable figure. Likewise, the reference to significant figures in excerpt 5 indicates her understanding of the *jargon* of the practice, in contrast to speech turn 10 where she is not familiar with the *jargon* "plus or minus" as she expects some kind of exact figure.

3.4 Cooperative engineering teaching resources: the protocol worksheet

As stated above, subsequent to the exploratory lesson, the two teachers cooperated on developing a complete English-Physics CLIL sequence (see Bloor, 2020). The English teacher taught in the later versions of the sequence whilst conferring with the physics lecturer on the scientific lesson content. The

episode described below is taken from an activity which was a revised version of the mini group measuring activity in the exploratory lesson. Here, students were asked to devise a protocol to measure the diameter of a tennis ball and to estimate the level of uncertainty in their measurement. To prepare this exercise they were given the conjointly elaborated worksheet presented in Table 6

Table 6

Teaching resource elaborated conjointly by the two teacher-researchers

Worksheet 1, 2, 3, 4, 5, 6:

The impact of protocols in experiments on uncertainties

Describe an experiment that you have decided to carry out to measure the diameter of a tennis ball. You must include in your description your protocol, the material you used and the problems you encountered and what you did to tackle them.

Specify the degree of uncertainty you expect to encounter measuring the diameter and give the result of your work with the correct written form: $D = (x \pm \Delta x)$ unit length (i.e. cm, mm etc.).

(NB: The number of significant figures written for x must correspond to the degree of estimated uncertainty.)

Explain in a detailed manner the basis of your estimation and what you did to reduce it to a minimum.

One-dimensional methods

Group 1) Hint: dough

Group 2) Hint: A photograph, a spirit level and ruler

Group 3) Hint: String or thread

Group 4) Hint: hard-backed books or square sets

Two-dimensional method

Group 5) Hint: ImageJ (free software)

Three-dimensional method

Group 6) Hint : transparent overflow vessel

In the episode described below, the first student had been given the hint “dough” and the second used his own method. Students were instructed to describe and justify their protocol to a partner in order to gain in fluency. This exercise was intended to develop an appropriate *thought style* for scientific measurement using the *jargon* of the practice.

3.5 The Enhancing-Fluency Exchange

In the episode below, Wassim first describes his protocol based on a method using dough to Pedro, who then in turn describes his protocol using a protractor and a ruler.

Table 7

The Enhancing-Fluency Exchange

27. Wassim: I begin with my process. My set-up is we make er ... we make a dow with a floor and water, in this er in this dow
28. T: dough
29. Wassim: dough, we will put the ball in.
30. Pedro: yes
31. Wassim: so when we er, when we, when the ball is in the dow
32. T: dough
33. Wassim: in the dough, it make a mark, and this mark, when we take off the ball, we have the mark of the ball.
34. Pedro: yes
35. Wassim: so we just, we just have to measure the diameter of the mark's ball... the ball's mark in the dough. What do you think about it?



Frame 6: describing the dough method



Frame 7: demonstrating a step in the protocol

Wassim begins describing his protocol to Pedro. He has assimilated some pertinent vocabulary, or *jargon*, such as “set-up” “flour” and “dough” but pronounces “flour” as “floor” and “dough” as “dow” (27,31). T corrects the pronunciation of dough twice (28,32). Wassim pronounces it correctly on his third use (33). Wassim speaks clearly without hesitation but with some grammatical inaccuracy such as “make” instead of “makes”(33), “will put” instead of “put” (29). T does not correct all the errors leaving him to develop fluency. Wassim self-corrects an error concerning the use of the possessive (35).

36. Pedro: It's er a good idea. Er, well for me, I have measured the ray of the ball with a rule.
37. T: ruler
38. Pedro: a ruler. We put er put a protractor in the end of the ball, we make it (...#3)
39. T: Steady?
40. Pedro: steady. We find er, three point two centimetres for the ray, then we multiplied by two and we get finally six point four centimetres, plus or mine two millimetres for the uncertitude.
41. T: What did you do with the protractor exactly? Did you use it to stabilize the ball?
42. Pedro: yes, to stabilize the ball. Then we measured the ray of the ball
43. T: the ray of the ball? What's the ray of the ball?
44. Pedro and Wassim: le rayon.
45. T: Ah the radius
46. Pedro: the radius yes, the radius of the ball and er we multiply it by two. Then we get finally the diameter of 6.4 cm plus or mine two millimetres.
47. T: Ok. You can ask him about how he determined his level of uncertainty.
48. Wassim: How did you ...(inaudible)



Frame 8: Pedro describes his protocol



Frame 9: Listening to Pedro Frame 7

After listening to Wassim's description Pedro makes a polite comment about Wassim's protocol (36) then begins to describe his own protocol. He makes a common pronunciation error: “rule” for “ruler” perhaps because in French it is the same word for both (*règle*). He is hesitant in expression so T suggests “steady” to keep the flow of dialogue going. T tries to understand Pedro's protocol by asking about the protractor (41). She does not understand the use of “ray” (43). The two students give the French word “rayon” (44) which T translates with “radius”(45). Pedro has partially assimilated the “plus or minus” when talking of uncertainty

in measurement, saying “mine” instead of “minus” (40,46). T tells Wassim to ask Pedro about his estimation of uncertainty (48) and leaves to film another group.

In the enhancing-fluency example, both Wassim and Pedro are confronted with their language limitations (27, 31, 36, 38) and what they need to work on to progress towards the targeted knowledge, that is to say the fluent description of a protocol without grammatical or pronunciation errors; they do appear to gain in fluency by means of their efforts to describe their previously designed protocol.

The student Wassim describes his protocol with a sufficient degree of fluency and detail to be understood, despite some pronunciation and grammatical errors (27, 31, 33), including the incorrect pronunciation of “dough” which the teacher corrects persistently (28, 32). The protocol he describes is a credible method. Pedro is at times hesitant in expression (38) and lacks some essential vocabulary to describe his protocol (43, 44, 45). Furthermore, his description suggests his set-up lacked credibility; there is no clear reason why he would choose to measure the radius of the ball, nor of the role of the protractor in his set-up (38,40). However, he does give a credible result and does include an estimation of uncertainty so perhaps his set-up was credible, but he was not able to explain an essential part of his reasoning due to his language limitations.

Both Wassim and Pedro show some polite interest in each other’s protocol (30, 34, 36, 48) but their descriptions, are not sufficiently detailed and clear for them to be able to discuss their estimation of uncertainty in any meaningful way. This becomes possible at a later stage in the sequence (see Bloor, 2020; Bloor and Santini, 2022).

A Posteriori Analysis: *Jargon* and *Thought Style*

The exchanges in Table 7 again offer some insight into the English teacher’s evolving integration of an appropriate *jargon* and *thought style* with regard to the practice of measurement in experimental science. First by the very nature of the activity which she designed to develop language fluency and scientific rigor in the measurement set-up. In other words, the use of the *jargon* of scientific practice in the context of a practice. At this stage of the cooperative engineering, she knows the advantages and disadvantages of various protocols to measure the diameter of a tennis ball and can ask relevant probing questions about a student’s set-up using the appropriate *jargon* of the practice (see speech turns 39, 41 and 43). She has assimilated an understanding of the importance of uncertainty in measurement and can guide students to integrate this knowledge in the appropriate *thought style*. That is to say, she guides the students to recognise the full impact possible of every factor involved in a measurement, including their own involvement in the process (speech turn 47). The evolving epistemic quality of the sequence as a result of the cooperative engineering can be identified in the resources (table 6) and in the choice of teaching-learning situations: in activity 2.2 students are engaged in an inquiry-based activity (Dewey, 1935, CDpE, 2019) in an action-oriented approach (CEFL, 2001) to language learning using the *jargon* and *thought style* of measurement in physics practice.

4. Conclusions

To render visible the evolving epistemic quality of the CLIL sequence resulting from the cooperative engineering methodology, we have analysed descriptions of some of the cooperative engineering practices with the JATD notions of *jargon* and *thought style*. The focus in the analysis is on the progress of the English teacher and the jointly elaborated teaching resources.¹

This paper sought to present some insights into how knowledge was constructed with this example of cooperative engineering methodology and how the implementation and re-implementation of various teaching-learning situations in the sequence at the heart of its cooperative action led to the transformation of the educational practice. This can be seen by comparing didactic phenomena in the exploratory lesson in 2.1 to didactic phenomena in later versions of the sequence which were more epistemically dense. In 2.2, 2.4 and 2.5, the English teacher was seen to have assimilated the *jargon* to measure a tennis ball and to have gained insight into an appropriate *thought style* for experimental scientific practice. Consequently, she was able to guide students to a more appropriate *thought style* for scientific measurement where the multiple factors involved in a measurement result could be recognised as well as a scientist's role in honestly estimating to what extent he or she can guarantee their result. This led to the development of learning situations with more epistemic potential for students (2.2, 2.5) and teaching resources of better epistemic quality (2.4).

The paper concludes by positing the notions of *thought style* and *jargon* as efficient tools for the analyses of learning environments particularly where language can be seen to be organically linked to the practice in which it is embedded (Collins, 2011; Sensevy, G., Gruson, B., & Le Hénaff, 2019). It also recommends cooperative engineering as a fruitful methodology for developing or rendering visible epistemically dense educational practices (Bloor and Santini, 2022; Bloor and Greaves, 2022).

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¹ For a detailed description of the evolving epistemic potential of the sequence with regard to students' learning, see Bloor, 2020 ; Bloor and Santini, 2022a.

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