Pontificia Universidad Católica de Valparaíso
Perspectiva Educacional. Formación de Profesores
Diciembre 2024, Vol 63(3), pp. 94-118

COOPERATIVE ENGINEERING TO DEVELOP EPISTEMIC PRACTICES: AN ENGLISH-PHYSICS CLIL SEQUENCE
A CASE STUDY ILLUSTRATING COOPERATIVE ENGINEERING DESIGN-BASED RESEARCH

INGENIERÍA COOPERATIVA PARA DESARROLLAR PRÁCTICAS EPISTÉMICAS: UNA SECUENCIA AICLE INGLÉS-FÍSICA
UN ESTUDIO DE CASO QUE ILUSTRA LA INVESTIGACIÓN COOPERATIVA BASADA EN EL DISEÑO DE INGENIERÍA

Tracy BLOOR
University of Franche-Comté,
Laboratory, CRIT – UA 3224, France

Gabrielle REGULA
University of Aix-Marseille, Université of Toulon,
CNRS, IM2NP, 13397, France

Resumen

Este artículo describe una secuencia didáctica cooperativa de enseñanza-aprendizaje desarrollada por un profesor-investigador de lengua inglesa y un profesor asociado de física, diseñada para el aprendizaje simultáneo del inglés como lengua extranjera junto con el conocimiento disciplinar de la física como práctica (Bloor, 2020; Bloor & Santini, 2022). Los estudiantes analizados en esta investigación son universitarios de ciencias en una universidad francesa, donde los cursos de inglés como lengua extranjera suelen formar parte de los programas de grado y máster. Estos cursos ofrecen un gran potencial para el desarrollo de secuencias didácticas que busquen lograr el aprendizaje concurrente de conocimientos disciplinares y una lengua extranjera o segunda lengua.

Describimos una secuencia didáctica diseñada mediante un proceso iterativo y cooperativo que exploró la práctica científica relacionada con la cuestión de la incertidumbre en la medición en física. Nuestra hipótesis era que, al activar la práctica social relacionada con esta cuestión, los estudiantes desarrollarían tanto su competencia en inglés como una concepción adecuada de la medición científica como práctica. Como señala Sawyer (2006): “los estudiantes adquieren un conocimiento más profundo cuando participan en actividades similares a las actividades cotidianas de los profesionales que trabajan en una disciplina” (p. 4).

A través de un análisis clínico, se examina de cerca la vida en el aula para identificar indicios de aprendizaje efectivo mediante prácticas epistémicas (Kelly & Licona, 2018; Santini et al., 2018), tanto en la competencia en lengua extranjera como en el aprendizaje disciplinar. La investigación sobre la actividad en el aula, en relación con el conocimiento potencial inherente a la secuencia, se fundamenta en el a priori de que el lenguaje y la práctica están orgánicamente vinculados (Wittgenstein, 1953/2009; Collins, 2011; Sensevy et al., 2019).

Las nociones de "estilo de pensamiento" y "jerga" de la Teoría de la Acción Conjunta en Didáctica (TACD) (Sensevy, 2011) se proponen como herramientas útiles para identificar el cuerpo de conocimiento culturalmente construido, relacionado con el potencial epistémico en juego, el potencial epistémico inherente a las situaciones diseñadas, así como el valor epistémico de las acciones de los actores en relación con el contexto. Dado que la práctica científica requiere atención al detalle y la necesidad de acordar una representación compartida de la realidad (Bazerman, 1988; Fleck, 1934/2008), el estudio concluye que el aprendizaje concurrente de una lengua extranjera junto con conocimientos científicos disciplinares ofrece un gran potencial para diseñar entornos de aprendizaje lingüístico enriquecidos basados en la exploración de sistemas semióticos en situaciones de aula. Esto se combina bien con el reto de cuestionar y explorar los aspectos más implícitos de la práctica científica, donde se puede motivar a los estudiantes a comprometerse epistémica y epistemológicamente.

(*) Autor para correspondencia:
Tracy Bloor
INSPE-Université de Franche-Comté
57, Avenue de Montjoux - BP 41665
25042 BESANCON Cedex
Correo de contacto: tracy.bloor@univ-fcomte.fr

RECIBIDO: 25.05.2024
ACEPTADO: 19.06.2024
DOI: 10.4151/07189729-Vol.63-Iss.3-Art.1600

Palabras clave: Ingeniería cooperativa; acción cooperativa; AICLE; aprendizaje de idiomas; incertidumbre en la medición.

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 & Santini, 2022). The article focusses on the cooperative action between the two teacher-researchers to illustrate how this led to 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 in the iterative process of the cooperative design-based research.

Keywords: Cooperative engineering; cooperative action; CLIL; language learning; uncertainty in measurement.

1. 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 et al., 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 (2006) states, "students learn deeper knowledge when they engage in activities that are similar to the everyday activities of professionals who work in a discipline" (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.

2. . 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 (Bloor, 2020; Bloor & Santini, 2022; Dewey, 1938/1997; Halliday, 1978; Maniglier, 2016; Mead, 1931; Sensevy et al., 2019; Vygotsky, 1934). 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 (1953/2009), 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).

In JATD and this paper, language is seen as being composed of language games within forms of life which produce certain *thought styles* (Bazerman, 1988; Bloor, 2020; Bloor & Santini, 2022; Fleck, 1935/2008; Sensevy et al., 2019) together with an associated *jargon* (Bloor, 2020; Bloor & Santini, 2022; Sensevy et al. 2019). 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 & Greaves 2022; Bloor & Santini, 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.

2.1. 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, 1953/2009) 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 4.

2.2. 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 (Bloor, 2020; Dewey, 1938/1997; Halliday, 2004; Maniglier, 2018; Mead, 1931; Sensevy et al., 2015; Vygotsky, 1962). 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* (Bloor, 2022; Sensevy et al., 2019). 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,1999; Hacking, 1983; Sensevy et al., 2008, 2021): 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 (1996) argues when he states, "Far more clearly than the immediate experience from which they in part derive, operations and measurements are paradigm-determined"" (p. 126).

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 et al., 1998; Bloor, 2020; Buffler et al., 2009; Sensevy, 2021). 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).

3. 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, 2022). 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.

3.1. 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.

3.2. 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 analogical 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, 1996 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 4.5 for example, was typical of many other student productions.

Analyses of classroom activity were undertaken using a clinical approach (Foucault, 1963; Santini et al., 2018; Sensevy, 2011). 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 (Santini et al., 2018; Sensevy, 2011). The methodology used in this research thus relied on a multi-layered process of inquiry to piece together the traces of the classroom activity analysed.

4. Descriptions of the Cooperative Engineering Practices

As stated earlier, 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.

4.1. 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. A clip 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 engineerings (see Collectif Didactique pour Enseigner [CDpE], 2024), was 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.

4.1.1. 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 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 (Figure 1) are some examples of class activity during this part of the lesson which are followed by a partial transcription of the clip viewed.

Figure 1

The MIT video excerpt

		
Frame 1: Walter Lewin	*Frame 2: discussing the MIT extract*	*Frame 3: finding the words*

Table 1

Transcription of the MIT Video excerpt

Now all important in making measurements, which is always ignored in every college book, is the uncertainty in your measurement. My grandmother used to tell me that someone who is lying in bed is longer than someone who stands up, and (…) 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. 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, so I measure here 149.9 cm. (…) this is in vertical position, 149.9 - but I would think that the uncertainty of my position is probably 1 mm. (…) - so that's the vertical one. Now we're going to measure the bar horizontally for which we have a set-up here (…) 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.

4.1.2. 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 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.

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

Frame 5: A student tries to speak

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.

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). PL says the reason for Walter Lewin's choice is obvious (9) but T does not find this choice obvious (10).

4.1.3. 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.

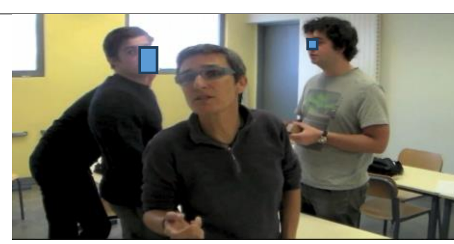
4.1.4. Second Episode: the Decimal Point

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

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



Frame 6: 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).

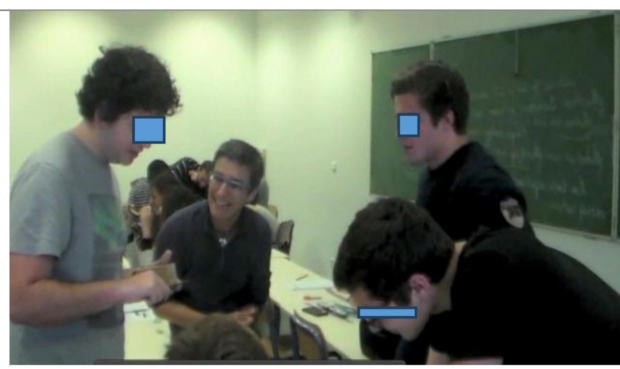
4.1.5. Third Episode: Measuring an Object in Small Groups

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

1. PL: What are you measuring?
2. Pierre: I mésure the first bord of the first face
3. T: Side
4. Pierre: – oh beuf
5. T: – no no, English is important in this lesson. English and science!
6. Pierre: The first side I mésure (heavy accent)
7. PL: Measure
8. Pierre: I measure 6.5 cm



Frame 7: measuring an object

9. PL: 6.50 is much more accurate than 6.5 as a physicist you should know that.

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

4.1.6. 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 4.5 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 complete 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 research progresses, the English teacher can be seen to gain insight into scientific practice (e.g. 4.3 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.

4.2. 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 & 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.

4.3. 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 3.2 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.
Excerpt 2: T's write-up and PL response
T: (…) 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, flat, flexible, and non-extensible (…). 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. (…)
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.

4.3.1. 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.

4.4. 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: 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 ± Δx) unit length (i.e. cm, mm etc.). (<u>NB: The number of significant figures written for x must correspond to the degree of estimated uncertainty</u>.) 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.

4.5. 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. 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.

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

Pedro 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).

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 & Santini, 2022).

4.5.1. 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 4.5 students are engaged in an inquiry-based activity (CDpE, 2019; Dewey, 1935) in an action-oriented approach (CEFL, 2000) to language learning using the *jargon* and *thought style* of measurement in physics practice.

5. Conclusions

To render visible the evolving epistemic quality of the CLIL sequence resulting from the cooperative engineering design-based research, 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 design-based research 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 4.1 to didactic phenomena in later versions of the sequence which were more epistemically dense. In 4.4 and 4.5 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 (4.5) and teaching resources of better epistemic quality (4.4).

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 et al., 2019). It also recommends cooperative engineering as a fruitful form of design-based research for developing and rendering visible epistemically dense educational practices (Bloor & Santini, 2022; Bloor & Greaves, 2022).

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

6. References

Bazerman, C. (1988). Shaping written knowledge: the genre and activity of the experimental article in science. Rhetoric of the human sciences. University of Wisconsin Press.

Bloor, T. (2020). Travail Coopératif Entre Une Enseignante-Chercheuse de Physique et Une Professeure d'anglais Dans Le Secteur LANSAD (LANgues Poru Les Specialistes d'Autres Disciplines): Une Étude Clinique En TACD Menée Dans Le Cadre d'un Projet CLIL (Content and Language Integrated Learning) [Doctoral thesis, University of Western Brittany, Rennes]. Portail HAL theses. https://theses.hal.science/tel-03366555

Bloor, T., & Greaves, S. (2022). Creative writing teaching-learning practice in second language learning: A didactic study. E-rea, 20.1. https://doi.org/10.4000/erea.15504

Bloor, T., & Santini, J. (2022). Modeling the Epistemic Value of Classroom Practice in the Investigation of Effective Learning. Science & Education 32, 169-197. https://doi.org/10.1007/s11191-021-00298-9

Bloomfield, L. (1933). Language. University of Chicago Press. http://hdl.handle.net/1959.9-/524847

Cartwright, N. (1999). The dappled world: A study of the boundaries of science. Cambridge University Press.

Chevallard, Y. (1989, August 3-7). On Didactic Transposition Theory: Some Introductory Notes [Keynote]. International Symposium on Selected Domains of Research and Development in Mathematics Education, Bratislava.

Chomsky, N. (1957). Logical structures in language. American Documentation, 8(4), 284–291. https://doi.org/10.1002/asi.5090080406

Collectif Didactique pour Enseigner. (2019). Didactique pour enseigner. Presses Universitaires de Rennes.

Collectif Didactique pour Enseigner. (2024). Un art de faire ensemble. Les ingénieries coopératives. Presses Universitaires de Rennes.

Collins, H. (2011). Language and practice. Social Studies of Science, 41(2), 271-300. https://doi.org/10.1177/0306312711399665

Conseil de l'Europe. (2000). Cadre européen de référence pour les langues : apprendre, enseigner, évaluer. https://www.coe.int/fr/web/common-european-framework-reference-languages

Dewey, J. (1997). Experience and education (1. ed). Simon & Schuster.

Fleck, L., Trenn, T. J., Merton, R. K., & Bradley, F. (1934/2008). Genesis and development of a scientific fact (Repr. 11. Aufl). Univ. of Chicago Press.

Foucault, M. (1969/2005). L'archéologie du savoir. Gallimard.

Hacking, I. (1983). Representing and intervening: Introductory topics in the philosophy of natural science. Cambridge University Press.

Halliday, M. A. K., & Matthiessen, C. M. I. M. (2004). An introduction to functional grammar (3rd ed). Oxford University Press.

Kuhn, T. S. (1996a). The structure of scientific revolutions (3rd ed). University of Chicago Press.

Kuhn, T. S. (1996b). The structure of scientific revolutions (3rd ed). University of Chicago Press.

Kelly, G. J., & Licona, P. (2018). Epistemic Practices and Science Education. In M. R. Matthews (Éd.), History, Philosophy and Science Teaching (pp. 139-165). Springer International Publishing. https://doi.org/10.1007/978-3-319-62616-1_5

Maniglier, Patrice. « La vérité des autres : discours de la méthode comparée » : MétaphysiqueS, Presses Universitaires de France, 2018, pp. 463-78. https://doi.org/10.3917/-puf.alloa.2018.01.0463.

Mead, G. H., & Morris, C. W. (1934/1974). Works of George Herbert Mead. Vol. 1: Mind, self, and society: from the standpoint of a social behaviorist (19. impr). Univ. of Chicago Press.

Morales, G. (2014). L'enseignement et l'apprentissage de la représentation : une étude de cas en maternelle: le "Jeu des Trésors" [Doctoral thesis, University of Western Brittany, Rennes]. Portail HAL theses. https://theses.hal.science/tel-01366889

Morellato, M. (2019). Ingénierie didactique coopérative : Quelle pratique de collaboration entre professeurs et chercheurs?: Conditions pour la constitution d'une expérience collective. Questions vives recherches en éducation, [online], (32). https://doi.org/10.4000/questionsvives.4438

Neves Dias, S. W., Becker, M., Ouaddah, H., Périchaud, I., Reinhart, G., Mangelinck-Noël, N., & Regula, G. (2022). Dislocation Dynamics in Monocrystalline Si near the Melting Point Studied in Situ by X-Ray Bragg Diffraction Imaging. Physica Status Solidi (b), 259(6), 2100594. https://doi.org/10.1002/pssb.202100594

Peirce, C. S., & Welby, V. (1977a). Semiotic and significs: The correspondence between Charles S. Peirce and Lady Victoria Welby. Indiana University Press.Ryle, G. (2009). Teaching and Training. In Collected Essays 1929–1968: Collected Papers (volume 2, pp. 464-478). Routledge. https://doi.org/10.4324/9780203875308

Santini, J., Bloor, T., & Sensevy, G. (2018). Modeling Conceptualization and Investigating Teaching Efectiveness: A Comparative Case Study of Earthquakes Studied in Classroom Practice and in Science. Science & Education, 27(9-10), 921-961. https://doi.org/10.1007/s11191-018-0016-6

Sawyer, R. K. (2006). Analyzing Collaborative Discourse. In The Cambridge handbook of the learning sciences (pp. 187-204). Cambridge University Press. https://doi.org/10.1017/CBO9780511816833.013

Sensevy, G., Tiberghien, A., Santini, J., Laubé, S., & Griggs, P. (2008). An epistemological approach to modeling: Cases studies and implications for science teaching. Science Education, 92(3), 424–446.

https://doi.org/10.1002/sce.20268

Sensevy, G. (2011). Le sens du savoir: Éléments pour une théorie de l'action conjointe en didactique. De Boeck. https://doi.org/10.3917/dbu.sense.2011.01

Sensevy, G. (2021). Des sciences interventionnelles ancrées sur des alliances entre recherche et terrain ? Le cas des ingénieries coopératives. Raisons éducatives, 25(1), 163-194. https://doi.org/10.3917/raised.025.0163.

Sensevy, G., & Bloor, T. (2019). Cooperative Didactic Engineering. In S. Lerman (Ed.), Encyclopedia of Mathematics Education (pp. 1-5). Springer International Publishing. https://doi.org/10.1007/978-3-319-77487-9_100037-1

Sensevy, G., Forest, D., Quilio, S., & Morales, G. (2013). Coopérative engineering as a specific design-based Research. ZDM The International Journal on Mathematics Education, 45(7), 1031-1043. https://doi.org/10.1007/s11858-013-0532-4

Sensevy, G., Gruson, B., & Forest, D. (2015). On the Nature of the Semiotic Structure of the Didactic Action: The Joint Action Theory in Didactics Within a Comparative Approach. Interchange, 46(4), 387-412. https://doi.org/10.1007/s10780-015-9266-2

Sensevy, G., Gruson, B., & Le Hénaff, C. (2019). Sur la notion de jargon. Quelques réflexions sur le langage et les langues. In C. Chaplier, & A.-M. O'Connel (Éd.), Épistémologie à usage didactique. Langue de spécialité (pp. 35-52). L'Harmattan.

Vygotsky, L.S., (1962). Thought and Language. The M.I.T. Press

Wittgenstein, L. (1953/2009). Philosophical investigations (G. E. M. Anscombe, P. M. S. Hacker, & J. Schulte, Trans., 3rd ed.). Wiley-Blackwell.