IPM Module 3

The difficulty of communication between people of different disciplines when they use the same or similar terminology

Introduction

Here we will look at the problem of

- communicating the technical meaning of scientific terms to people who are not scientists;
- different disciplines using the same terminology for different things, and how this can impact of the communication of ideas between them.

Such a problem impacts on how you write. Ultimately, when you write, you are not only writing for yourself but also for someone else. So you have to know who your audience is. Is your audience made up of experts from your own discipline? Is it made up of experts from another discipline? Or is it made up of lay people? The answer to these questions will influence how you write.

The truth is that scientific writing is loaded with very specific and precise meaning. Scientific text has what I call a "density of meaning". In other words, it has a degree of sophistication and depth of meaning, a specific way of being conceptualised, understood and put into practice. There is a kind of substance and richness to the meaning of scientific terms and discourse, whose aim is to communicate a scientific idea. And only an expert knows what this meaning is. People who are expert in other disciplines don't know the depth and subtlety of this meaning, and lay people cannot even conceive of this meaning. Your job is to pre-empt their lack of knowledge and/or their misunderstandings about the meaning of scientific terms and the text in general.

As an example of the problem consider the quote below with respect to the psychology of mathematics education, taken from "Psychological Theories in Mathematics Education: Introduction to the Special Issue", *Journal für Mathematik-Didaktik*, 2018, volume 39, p1–6.

> "Different research questions go hand in hand with different theoretical frameworks and terminology. As Nolte (2015) pointed out, researchers from psychology and mathematics education do not always speak the same language. As an illustration, Nolte considers the term "number magnitude", which is commonly used in the

psychological literature on numerical cognition. Mathematics educators—at least those in German speaking countries, where magnitude is often translated as "Größen"— may associate the term magnitude with the measurement aspect of numbers (e. g., 5 cm). Researchers in psychology, however, often use number magnitude to refer to the semantic meaning of numbers more general, including a variety of aspects such as the cardinality of collections of objects (e. g., Siegler 2016).

Another important difference between psychology and mathematics education concerns the research methods. Psychological research more often uses strictly controlled experiments to isolate potentially relevant factors. Mathematics education researchers, on the other hand, strive for understanding learning that occurs in more natural, realistic learning settings. When studying realistic settings, it is often not possible to use controlled designs, and doing so would threat external validity."

In these notes we will focus on the problematic issue of terminology and language/discourse (not on the different types of research questions or the different methods or theoretical frameworks used by the different disciplines).

Examples

Here are some example of words used in everyday situation which have different meanings to lay people compared to scientists:

- **Water**
  Everyday meaning: Liquid; H_2O; no smell, no colour; freezes at 0C, boils at 100C.
  Scientific meaning: Gas/liquid/solid; Water is acid, neutral, and base; Freezing temp depends on pressure, contaminants (salts, soft, …); Two atoms of hydrogen combined with one atom of oxygen; Contracts when heated: between 0C and 4C; pH neutral.

- **Atom**
  Everyday meaning: Something very small, too small to see;
  Scientific meaning: Smallest particle of an element that retains the properties of the element; Consists of a central nucleus made up of neutrons and protons, and has orbiting electrons to the same quantity of the number of proton; Protons have positive electric charge, neutron have no electric charge, and electrons have negative electric charge; The number of protons in an atom determines the element's physical properties;

- **Acid**

  Everyday meaning: Harmful, dangerous, corrosive, burn; Harmful (cannot be ingested); Acids are dangerous and therefore all strong!!

  Scientific meaning: Substance: a certain atomic configuration; pH: < 7 (can be easily tested by litmus paper); Not all acids are dangerous/harmful; Stomach contains hydrochloric acid; Classifications: strong, weak; Weak/Strong means the degree of chemical reactivity.

- **Force**

  Everyday meaning: Strength, ooomph, ... needed to push or pull something;

  Scientific meaning: Mass × acceleration (F = ma); Change in momentum (impulse: F = mv – mu); Only occurs if a mass is accelerating; Object moving at constant velocity have no force acting on them;

- **Thermometer**

  Everyday meaning: Mercury-in-glass instrument;

  Scientific meaning: Mercury-in-glass instrument (uses the displacement of a liquid as a way of measuring temperature); Thermocouples (electricity-based thermometers); Bi-metallic (uses distortion of metal as a way of measuring temperature); Pyrometer (radiation-based thermometer); Constant pressure gas thermometer; Platinum resistance thermometer;

<u>*Example from mathematics*</u>

Average		
Mean	**Median**	**Mode**
(1+1+1+1+2+4+5+5+10+20)/10 = 5	1+1+1+1+2+4+5+5+10+20: Middle number = (2+4)/2 = 3	1+1+1+1+2+4+5+5+10+20: Most repeated number = 1

Infinity	
General audience	**Mathematician**
1,000,000,000,000,000,000,000,000,000,000,000 or bigger.	1, 2, 3, 4, 5,… i.e. the sequence continues indefinitely.

Dimension	
General audience	**Mathematician**
1cm × 2cm 10m × 1.5m × 0.5m	$(x_1, x_2, x_3, \dots x_n)$ or 1-D, 2-D, 3-D, 4-D, …, n-D set of orthogonal axes.

<u>Exercise 1:</u> Fill in the table below where the first column refers to mathematical terminology.

Term	**General audience understanding (Lay meaning)**	**Expert audience understanding (mathematical meaning)**
Theory		
Solution		
Integer		
Differentiate		
Smooth		
Integrate		
Infinitesimal		
Arbitrarily small		

What these examples and exercises show is that we bring our own understanding to particular terms. If a lay person (or even someone from another discipline) uses the same term but in a different, or with a different perspective, then this can cause confusion between people, unless such terms, and their uses, are explained.

Even at the level of mathematical notation used in mathematics we need to be careful:

$\boldsymbol{\frac{dy}{dx}}$	The derivative: $\frac{d}{dx}(y)$	Dividing differential elements: $dy \div dx$
×	Standard multiplication symbol (at school)	Vector cross product (at university)
$\boldsymbol{4x}$ vs 4½	$4 \times x$	$4 + \frac{1}{2}$
$\boldsymbol{\sin^{-1}(x)}$ vs $\boldsymbol{\sin^2(x)}$	$\sin^{-1}(x)$ is $\arcsin(x)$	$\sin^2(x) = (\sin x) \times (\sin x)$
$\boldsymbol{i}$	Imaginary number: $i = \sqrt{-1}$	Unit vector in the *x* direction

And even at the level of mathematical notation used between discipline we need to be careful:

Symbol	Mathematics	Physics
$\boldsymbol{i}$	Imaginary number: $i = \sqrt{-1}$	Current (in Amperes)
$\boldsymbol{j}$	Unit vector in the *y* direction.	Imaginary number: $j = \sqrt{-1}$
c	Denotes any constant.	Denotes the speed of light only.
e	$e = 2.718281828 \ldots$	Denotes an electron
D	The differential operator $D(f) = \frac{df}{dx}$	Electric displacement or electric induction
k	Unit vector in the *z* direction	Boltzmann's constant
$\boldsymbol{\varepsilon}$	Arbitrarily small quantity	Permitivity (electromagnetism)

Exercise 2

Identify terms/terminology in your discipline, or in statistics, operational research, or mathematical modelling, which can have one meaning to experts and another meaning to lay people (non-experts). As an example, what does the word "significant" mean to a statistician and to a lay person? What does the word "solution" mean in mathematics and in chemistry?

Labelling and interpreting: Same word, different meaning

You, as expert, have ready-made ways of communicating the subject of your discipline. You use commonly accepted words/phrases, words/phrases already defined as part of your discourse, such as those above. But when talking to a general audience you have to be careful. Consider the case of talking about acids, or thermometers, or the average of some values, as highlighted above.

So the aim when writing for a general audience is to

- expand and simplify on the scientific meaning of terms, phrases and discourse, whilst trying to preserve the correct conceptual meaning of these;
- correct any assumptions and misconceptions of the scientific meaning of terms, phrases and discourse. Since our audience knows nothing about this, we have to predict or anticipate this issue.

So, what can we take for granted? What can we assume the reader will understand in terms of:

1. terminology, i.e. individual the words/phrases we take for granted, and use naturally as part of our discipline, but actually have very tight, narrow, specific and conceptually precise meanings?
2. the degree to which the discourse of "technical"? This depends on the audience we are writing for. To what extent will we have to
    a) write technical words in plain English?
    b) completely rewrite a whole text in plain English?
    c) use examples?
    d) use metaphors, make connections with other ideas, …?
    e) use pictures, diagrams, graphs, photos, etc.?
    f) ask (and answer) the questions the general audience wouldn't think of asking?
    g) go on explaining, expanding, developing an idea/concept?
    h) repeat all of the above as necessary?

Even between experts, technical terms may have different meanings. For example,

- Smooth:
  - Maths: an infinitely differentiable function.
  - Physics: theoretical property of the surface of an object: coefficient of friction = 0.
- Digit:
  - Medicine: Anatomy – finger or toe.
  - Maths: number between 0 and 9.
- Critical point:
  - Chemistry: when three phases of matter are in equilibrium.
  - Maths: the point where the denominator of an algebraic fraction is zero.
- Power:
  - Maths: The exponent of a number. The number of times a number should be multiplied by itself.
  - Physics/mechanics: rate of work.
  - Stats: the ability to correctly reject a false hypothesis.
- Differentiation
  - Medicine: "Cell differentiation is how generic cells become specialized cells. This occurs through a process called gene expression."
  - Maths: related to gradients, slopes and rates of changes of functions.
- Integration
  - Maths: the opposite of differentiation; finding areas and volumes bounded by functions;
  - CS: Joining different subsystems or components of software into one larger system so that this larger system now works as a whole.
- Calculus
  - Maths: the study of continuous/instantaneous change.
  - Medicine: a solid mass, usually inorganic material, that forms in a cavity or tissue of the body. Such a calculus is often found in the gall bladder, kidney or urinary bladder—otherwise known as a stone.

- Matrix:
    - Maths: a rectangular array of number or expressions;
    - Biology: the material or tissue between cells in which more specialized structures are embedded;
    - Chemistry: the non-analyte components of a sample;
    - Geology: the fine-grained material in which larger objects are embedded;
- Solution:
    - Maths: the complete, step-by-step process of finding the answer to a problem;
    - Chemistry: a combination of substances fully and homogeneously mixed together;

How do we bridge the gap between the way a non-scientific audience understands the meaning of these terms and the way experts understand these terms? Consider 2., a) – h) on page 6.

"A familiar word such as 'scientist', 'experiment', 'research', 'apparatus', 'scientific paper', etc. can carry a whole raft of formal meanings. It may well be defined quite differently in different contexts. But in each context it is understood to refer to the same discernible element, or feature of the world. Such words thus act as mental bridges re-uniting the various aspects or dimensions into which a natural entity may have been analysed." John Ziman (p9), *Real Science*.

Exercise 3

From your own discipline, or from statistics, operational research, or mathematical modelling, find individual terms or phrases that could be interpreted one way by a general audience and another way by an expert audience. For each term

- write down what you think a lay person would understand these terms or phrases to mean;
- write down the actually meaning of these terms.

Large-scale language: discourse

Things become more difficult when it comes to discourse, the large-scale writing and style of language used by a discipline. Can you guess which discipline the following text might relate to?

1. "Most of the members of [set] E will be obvious, such as D, G and M, but some remarks may nonetheless be helpful. For example, the two coordinates C and S indicate …"

   Maths?

2. "Most of the members of [set] E will be obvious, such as D, G and M, but some remarks may nonetheless be helpful. For example, the two coordinates C and S indicate that cognition and knowledge are not self-existing, …"

   Psychology?

3. "Most of the members of [set] E will be obvious, such as D, G and M, but some remarks may nonetheless be helpful. For example, the two coordinates C and S indicate that cognition and knowledge are not self-existing, but activities of real people in a particular social environment."

   Social science? Anthropology?

Real answer: Philosophy of science. "Demarcating science from nonscience", Martin Mahner in *General Philosophy of Science* (2007), p 515-575.

Scientific communication

Scientific communication is declarative: everything is written as fact. All words, phrases, and sentences have precise meanings. If properly written the statement is clear and unambiguous. There is no possibility of debate about what the statement means since everybody skilled in the discipline will understand it to mean the same thing.

<u>*Examples*</u>

Mathematics

If a function has a limit then this limit is unique. If this were not the case then we would have two limits L and L'. The Cauchy sequences $\{a_n\}$ which arbitrarily approaches L could not also arbitrarily approach L' since L and L' are at a fixed distance from each other. In other words, L and L' are two different values.

Statistics

"The sample mean $\bar{x}$ is called the point estimate for the population mean μ. […] The *null hypothesis* is a statement asserting no change, or no difference, or no effect. The *alternate hypothesis* is a statement that might be true instead of the null hypothesis. A *test statistic* is a quantity that is used to make a decision in a test of hypotheses. The *critical region* consists of those values of the test statistic that provide strong evidence in favour of the alternative hypothesis. Hence a value in the critical region leads to rejection of the null hypothesis"

(*General Statistics* (3rd Edition), Chase and Bown)

Mathematics: "A Treatise of Algebra", Colin Maclaurin, 1748

§4. In Algebra, the Root of an Equation, when it is an impoſſible Quantity, has its Expreſſion; but in Geometry, it has none. In Algebra you obtain a general Solution, and there is an Expreſſion, in all Caſes, of the thing required; only, within certain Bounds, that Expreſſion repreſents an *imaginary* Quantity, or rather, "*is the Symbol of an Operation which, in that Caſe cannot be performed*;" and ſerves only

300 *A* TREATISE *of* Part III.

only to ſhew the *Geneſis* of the Quantity, and the *Limits* within which it is poſſible.

In the Geometrical Reſolution of a Queſtion, the Thing required is exhibited only in thoſe Caſes when the Queſtion admits of a *real* Solution; and, beyond thoſe Limits, no Solution appears. So in finding the Interſections of a given Circle and a ſtrait Line, if you determine them by an Equation, you will find two general Expreſſions for the Diſtances of the Points of Interſection from the Perpendicular drawn from the Center on the given Line. But, Geometrically, thoſe Interſections will be exhibited only when the Diſtance of the ſtrait Line from the Center is leſs than the Radius of the given Circle.

Simplifying discourse

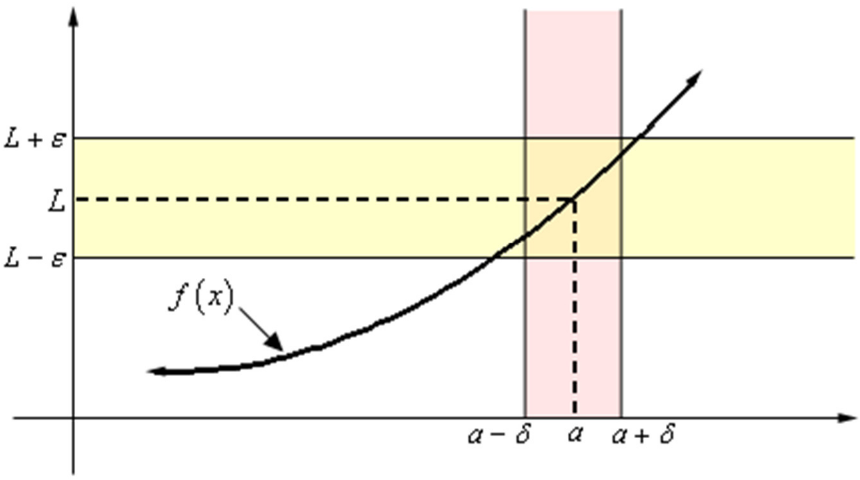
But what about people who are not skilled in the discourse of a discipline? This does not just mean the average person on the street, but also the highly educated social scientist of historian. What then do we do to communicate science to these non-mathematically oriented people?

To answer this, consider the following mathematical definition of a limit and continuity:

> Let $f(x)$ be defined for all x on some open interval containing $x = a$. We write
>
> $$\lim_{x \to a} f(x) = L.$$
>
> If for any given number $\epsilon > 0$ there exists a number $\delta > 0$ such that
>
> $$|f(x) - L| < \varepsilon \text{ if } |x - a| < \delta.$$
>
> If $f(a) = \lim_{x \to a} f(x)$ then the function is said to be continuous.

In order to help a general audience understand this we could describe the above as follows:

> To try and understand the meaning behind this abstract definition, see diagram below. We first need to choose a number ϵ which lies just above or just below L. We then have a band around L with which we can work. All values of our function must then lie within the band around L. in order to show continuity we are going to want to choose ϵ to be arbitrarily small. This will force all function values to be as close to L as is possible.
>
> We then need to determine if there is a band around a on the x-axis so that for all values of x (excluding $x = a$) inside the δ band, the corresponding y-values lie inside the ε band. In other words, we first pick a prescribed closeness (ε) to L. Then we get close enough, by an amount δ, to $x = a$ so that all the corresponding y-values fall inside the ε band. If a δ can be found for each value of ϵ, then we have proven that L is the correct limit. If we cannot find any δ which makes this work then the limit L does not exist.



(Image taken from http://tutorial.math.lamar.edu/classes/calcI/defnoflimit.aspx, text adapted from https://www.math.ucdavis.edu/~kouba/CalcOneDIRECTORY/preciselimdirectory/PreciseLimit.html

Quote

"Is simplification of language desirable in science education? My view is that 'the language problem' of the science classroom is not adequately solved by adjusting 'readability levels' downwards, or by trying to avoid technical terms. It is more to do with an absence of encouragement for flexibility of expression, for putting the same idea in more than one way. [...] a word like 'elastic' means more when 'squashable', 'stretchable', 'resilient', and 'compressible', are used alongside it, rather than as a replacement for it, and of course they show that there is something about the material which we are trying to *interpret*, not just to label." (emphasis added)

Clive Sutton, *Words, science and learning*, chap 9, p80, note 2.

Exercise 4

Choose a text from your own discipline, and rewrite it for a general audience. How far do you think you need to go in simplifying technical terms, phrases, sentences or the discourse in general? How much detail will you need to include? Will you need to include examples, metaphors, diagrams in order to help you communicate the technical concepts to that audience? Consider 2., a) – h) on page 6.