Searching lab on a chip literature: the need for a glossary of terms and concepts in a multidisciplinary environment†

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This paper investigates the problem of searching literature in a multidisciplinary environment. It is found that much relevant literature is not found because other disciplines use a different terminology, different units, or slightly different (but related) concepts. The paper suggests some approaches to enhance interdisciplinary understanding and improve exchange of ideas and literature.

Many readers will know the old testament story of the Tower of Babel (Old Testament, Genesis, ch. 11, verse 1–9[1]). This story tells how people from many different countries cooperated in the construction of an unprecedentedly large tower. When the work commenced they spoke one language and progress was so good that it seemed they would actually succeed in building the tower. Seeing this, God however confounded their languages so that their activities became a mess and they sadly never could finish their tower. In a mythological wrapping, this story tells about the advantage of a universal language for engineering and cooperation, and the detrimental fragmenting influence of language barriers.

Actually, the problem of the Tower of Babel (Fig. 1) is not only a problem of multicultural societies, but also a problem that characterizes areas of multidisciplinary research such as the lab on a chip field. The different disciplines that are supposed to cooperate are prevented from doing so effectively due to differences in scientific language and culture. The methodology used by physicists and biologists for example is quite different, sometimes presenting obstacles for cooperation that are hard to surmount. Differences in scientific language also exist but are more easy to overcome. This subject is actually related to a problem outlined by Andreas Manz in his 2007 New Year's message for the *Lab on a Chip* journal, where he wondered how to locate relevant literature and how to prevent endlessly repeating the same experiments in different groups of researchers.[3] Manz proposed that there should be a taxonomy for papers that allows for easy retrieval, much like it exists for insects. Papers would be classified on external characteristics such as similar figures or similar methods used. In this contribution, I will investigate another possible strategy for tackling this problem, namely by writing a multilingual glossary for the tower-builders: a list of synonyms and similar concepts across disciplines and time. To illustrate our approach I will give examples that are related to the lab on a chip (or microTAS!) literature, but the glossary method would surely hold more widely.

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Fig. 1 The confusion of tongues, an etch by Gustave Doré.[2] Scientists who are looking for literature in a multidisciplinary environment are rather in the position of the people in the foreground of this picture.

Expanding the knowledge universe

In the 20th century, science and technology have been growing at an ever increasing pace leading to an ever increasing amount of publications as well as an ever increasing growth of specialisms and sub-specialisms. The sheer size of the literature makes it virtually impossible for any individual to master an entire specialism, let alone an entire discipline like chemistry. Mastering the whole of science has, since the renaissance, eluded even the greatest minds. This expanding universe of words led to the coexistence of different island universes for the different disciplines with little cross-over and cross-fertilization. Quite similar concepts could as a result evolve in different disciplines, much like different organisms on evolutionary time scales have independently evolved similar traits in a process called convergent evolution, producing for example the very similar camera eyes of octopi and man.[4]

Crossing boundaries

Organizations like the AAAS (American Association for the Advancement of Sciences), the publisher of *Science*, have been expressly founded to enhance communication between scientists, engineers and the public. They do so mainly by publishing the interdisciplinary journal *Science*, aimed at a general public of scientists. The journal *Nature*, as well as more popularizing journals like *New Scientist* and *Scientific American*, also play an important role in making the research results from various disciplines accessible to a broader audience. In the last decades, the advent of the internet has opened up tremendous possibilities for crossing the boundaries between sciences, halting the ever increasing specialization and opening up multidisciplinary research. The internet, especially *via* tools like the Web of Science and Scopus, in combination with the rapid retrieval of electronic files, has caused a tremendous increase of the accessibility of literature. What used to take weeks or months to find in dusty libraries all over the country can now be accomplished in one afternoon behind the desk. Surely a less romantic undertaking, but so much more effective. Every literature researcher, however, will know that the problem of finding the right literature is not solved by easy retrieval alone, and that a major problem that remains is the existence of language and conceptual barriers between different disciplines. Little goldmines can stay hidden from us because we use the wrong keywords and search terms, or because investigators in other disciplines group their parameters differently or use different units. The remainder of this paper will address this issue. The similarity of the environment of the world wide web with that of the Tower of Babel has of course often been noted. It is, for example, expressed in the name of the language translator of search engine Alta Vista which is called Babel fish. The Babel fish itself is a fictional species that telepathically translates foreign languages for you when you stick it in your ear, and was created by Douglas Adams.[5]

Examples of the confusion of tongues

In the simplest case, confusion is caused when two different terms denote exactly the same thing in the same (sub)discipline, but at different moments in time. In the area of chemical analysis techniques, Jorgenson and Lukacs termed the separation method they were working on capillary zone electrophoresis (CZE), a name that nowadays is replaced by the shorter synonym capillary electrophoresis (CE).[6] In the same way MEKC (micellar electrokinetic chromatography) and MECC (micellar electrokinetic capillary chromatography) are used for the same analysis method but one can easily miss a part of the literature if not aware of this. There is even a third term for the same procedure, ironically introduced by John Knox to unify terminology, namely CMEC (capillary micellar electrochromatography).[7]

Confusion can also be created when a phenomenon has different names in different disciplines. Thus convection is mostly used in mechanics, thermodynamics, engineering and meteorology, while advection is more popular with oceanographers, computer scientists, physicists and mathematicians. To my knowledge both words mostly have the same meaning, but a part of the literature can certainly be missed if only one of the two is used.

Another source of confusion is the fact that functional structures can have widely differing names across disciplines. Just consider the words (with the disciplines in brackets) capillary (biology, geology), pore (biology, membrane science, chromatography, soil science), channel (biology, geology), (nano)tube ((chemical) physics, chromatography), (nano)tubule (membrane science) and (nano)channel (micro- and nanofluidics). When we are looking for phenomena occurring in channels, we will probably miss the same phenomena described when it takes place in pores. Fig. 2 gives an example of the possible pitfalls. In the Web of Science, we looked for different combinations of the above synonyms of "capillary" with "permselectivity", and then grouped the papers found into different sets. Clear sets can be distinguished of papers that use only one of the synonyms of "capillary" together with "permselectivity", while some of the papers form the intersection of both sets mentioning both terms and "permselectivity". Almost all literature on the subject would in fact be missed if a search had been undertaken for "microchannel and permselectivity". The figure also shows in brackets the disciplines where the papers on "x" and "permselectivity" were written. Clearly different disciplines have their own favorite word for "capillary". Of course, "permselectivity" can have different names in different disciplines as well. . .

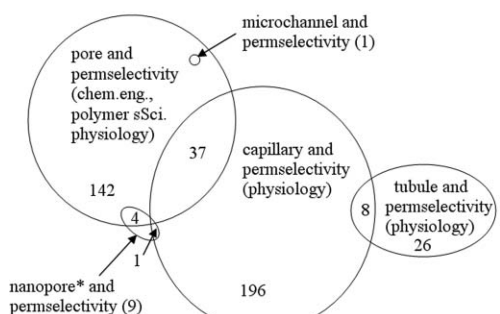

Fig. 2 Number of papers found by Web of Science for the search terms mentioned with in between brackets the main disciplines where the papers were produced.

Then we have quantities that in different disciplines are quantified in different units, receive a different name and therefore are hard to find. Chemists generally prefer to express quantities per mole, while physicists prefer to express the same quantities per molecule. Thus the chemical potential of water (which will determine the direction of water flow by osmosis, pervaporation or evaporation) is expressed in J mol^{-1} by chemists, in J m^{-3} or Pa by biologists (the so-called water potential) and in J kg^{-1} (also confusingly termed water potential) by soil scientists.[8] Furthermore physicists like to describe the average energy of a molecule with Boltzmann's constant k (J), while chemists like to describe the average energy of a whole mole of molecules by the gas constant R (J mol^{-1}). Exactly the same holds for the unit charge q (1.6×10^{-19} C) and the Faraday unit F (96 485 C mol^{-1}), employed respectively by physicists and chemists.

Similar concepts can also develop independently in different disciplines and lead to slightly different theoretical descriptions that can be mutually enriching to study. This situation looks much like the parallel and independent evolution of the eye of the octopus and mammals mentioned above. As an example we mention the concept of the Stern layer in electrochemistry (the layer closest to a charged object where we find tightly bound counterions), which is much similar to the concept of ion condensation in polyelectrolyte theory. Actually the founding fathers of polyelectrolyte theory (Oosawa, Manning) were unaware of the much older Stern model.[9–11]

Probably even more important and also more easy to miss are relationships between different parameters or material properties since they enable us to connect different disciplines. The so-called Einstein equation for example, relates the mobility of an analyte to its diffusion coefficient, giving us the insight that both parameters basically express the friction of the analyte with its medium.[12] As another example, it is very insightful to express the interfacial tension between water and a solid material as the sum of the van der Waals interaction, electrical double layer repulsions and short-range polar interactions.[13]

When a broader range of literature can be unlocked, ideas and solutions from the past or from other disciplines can enrich our present research by providing new viewpoints or opening up new horizons. Certainly cross disciplinary input will always provide useful analogues for explanatory purposes. But it can also deepen our theoretical insight or suggest new types of applications.

Strategies to cross boundaries between disciplines in literature search

The first strategy is the common one now followed by most, which is just doing it all yourself. This is a process of exploration, in which you for example follow the citation track and see where it takes you. If by chance an author of one of the papers you read has already performed a multidisciplinary research this will allow you to cross disciplinary boundaries. Another approach is to think up synonyms, where you can look for help or inspiration in the titles or abstracts of papers mentioned in the references of your starting papers (*e.g.* the use of the word capillary in one of the references of a paper that is about pores). This process of exploration certainly contains some elements of chance and creativity (who hasn't chanced into a really interesting paper that suddenly created new insights) that should remain and can't be replaced by automated methods. However, the efforts of many scientists compiling their own mental sets of synonyms and related phenomena can much better be combined, and a journal like *Lab on a Chip* or the Royal Society of Chemistry could provide the means and framework for such an activity. It would be very worthwhile to compile a list of synonyms, relationships and references, much like a glossary or handbook. This compilation could be done in an open-access Wikipedia-like manner, by the contributions of investigators with backgrounds in all relevant disciplines. This list could then, in a later stage, be implemented in a search machine, such as the Web of Science or Scopus. People interested in such an undertaking are certainly free to contact me. I'm sure the field of lab on a chip can benefit much from facilitated communication with all the disciplines that feed it, to prevent unnecessary repetition but most importantly to provide new insights and inspiration.

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