

# A Contribution to Disambiguation of Interdisciplinary Knowledge

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## BACKGROUND

Interdisciplinary research is recognised worldwide as a powerful strategy to increase fundamental knowledge, generate innovations and tackle real-world problems, such as global climate change. However, according to the Australian Council of Learned Academies, there is insufficient attention paid to interdisciplinary research in Australia. In extreme cases the isolated researchers waste resources by reinventing the wheel. Therefore, strategies are needed to facilitate interactions and collaborations between researchers working in different fields. One of the barriers to efficient interdisciplinary knowledge creation and sharing is a lack of unified nomenclature.

## PURPOSE

The intent is to contribute to disambiguation of fundamental scientific and engineering concepts needed in interdisciplinary communication, thus mitigating the obstacles such as homonymy and other ambiguities that hinder interdisciplinary sharing and creating of knowledge.

## DESIGN/METHOD

We hypothesise that the conflicts in interpretations of basic concepts significantly contribute to multiplication of ambiguities. Several cases of fundamental concepts are investigated by reviewing databases such as ScienceDirect (Elsevier) and SpringerLink. Questionnaires distributed at universities in and beyond Australia enabled collection of evidence about the ambiguity of selected fundamental engineering concepts.

## RESULTS

Examples ('technology', 'ontology' and 'definition') of inconsistent definitions and mismatching usage of three fundamental scientific concepts are investigated and analysed. The key aspects of a disambiguation strategy are proposed and options for transparent definition of these exemplary concepts are proposed for considerations.

## CONCLUSIONS

Interdisciplinary literature reviews and surveys conducted at several universities yield growing evidence about the ambiguities that penetrate the basic scientific concepts. However, there are quite straightforward solutions leading to promotion of generally transparent definitions that satisfy the whole spectrum of disciplines. Since English is common in science, education and engineering, it is proposed that an organised system of scientific nomenclature, free of unnecessary homonyms and other ambiguities should be adopted for fundamental concepts in the English language.

## KEYWORDS

Disambiguation, interdisciplinary, definition.

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## Introduction

The body of our knowledge continues to grow at an exponential rate. The development and maintenance of clear basic definitions is particularly important, since any inconsistency in fundamental notions may trigger an avalanche of misalignments. Basic concepts, and especially the terms that designate the overarching and generic notions, enable grasping in one word the depth and breadth of embraced ideas and theories. "It is impossible to reap the rewards of further studying, unless one can comprehend in simple terms all that can be expressed in great detail." (Laertius, 230).

Growing evidence indicates that reasoning modality is influenced by perceptions of similarity, which can be blunted by conceptual inconsistencies. Meaning can easily be lost due to the homonymy or synonymy. However, a trend in disseminating homonymous, synonymous, and otherwise ambiguous definitions of a whole range of scientific concepts, can be observed in publications distributed by maintainers of scientific databases, such as ScienceDirect (Elsevier) and SpringerLink. (Abhary et al., 2009, 2009a; Graham & Hallam, 2011).

Therefore it is important to continue research into the use of the fundamental engineering and scientific concepts and to propose possible improvements to this state of affairs.

## Methodology

We hypothesise that conflicts in interpretation of basic concepts significantly contribute to the multiplication of ambiguities, which hinder knowledge sharing.

The methodology used in this research is quite simple: questions (Survey forms, 2011) were distributed to the students at universities in Australia, Europe and China (anonymity for respondents/participants was granted). We received over 500 responses from which we have taken random samples of 300 answers. Then we used straightforward counting and calculation of the percentage of participants that agreed with various discussed points such as "there are, in fact, numerous... key (principal) terms and concepts that seriously hinder broadening, dissemination and use of our scientific and engineering knowledge" (Survey forms, 2011). Percentages quoted in this paper represent fraction of participants who agreed with the specific statement out of 300 participants.

The questionnaire responses provided only a first insight into the scope of the problem. However, the sheer count of those responses and the related evidence identified in scientific databases (ScienceDirect, Elsevier and SpringerLink) indicate strongly that the problem of ambiguity exists.

Exemplary concepts – 'technology', 'ontology' and 'definition' – are examined in more detail, since the above surveys confirmed that these concepts have differing interpretations and are thus associated with inevitable ambiguity. Moreover, the secondary reactions stirred by sheer questioning of the clarity of these concepts prompted the authors to reflect on the root beliefs and resulting intentions associated with these ambiguities.

## Examples of Ambiguous Concepts

### Technology

Homonymous usage of the term 'technology' is notorious in interdisciplinary communication (Abhary et al., 2009). Strawn (1982) defines 'technology' as the science of techniques. However, the Massachusetts Institute of Technology (MIT) publishes that their mission "is to advance knowledge and educate students in science, technology, and other areas of scholarship" (MIT website, 2011). Therefore one can conclude that 'technology' is one of the scholarship areas that can be distinguished from sciences. Other sources embrace within the concept 'technology' actual 'techniques', including the pertinent materials, tools, equipment

and other means for achieving a certain aim. For example, The Economist Newspaper reports on a manufacturing advance that “squeezes the latest digital technology into a manageable package of 13kg.” (British National Corpus, 2011)

Numerous other sources use the term ‘technology’ to address an ‘application of techniques’, ‘system of techniques’ or ‘technical assets’. The Delft University of Technology commits to offering education and research within the technical sciences along with developing technologies for future generations (Abhary et al., 2009). Massachusetts Institute of Technology has published on the MIT website (2011) concerns such as “There is no settled definition of technology!”, while Engineers Australia on their website (2001) warns that “... the use of the term ‘technology’ is often misleading and confusing.” The responses to our surveys provided strong evidence that the concept of ‘technology’ is perceived as ambiguous by over 60 % of participants.

It is to be appreciated that there is a significant difference between offering new materialised resources (e.g. tools or equipment) along with the instructions for usage, compared to offering specific knowledge only (e.g. definitions, intelligence and instructions) without supplying any materialised tools, energy or other physico-chemical resources. (Abhary et al., 2009)

One of the obvious implications for engineering education is that the graduated students will carry on with a misconception about the meaning of technology in their engineering practice, thus complicating the professional communication.

## **Ontology**

Over 40 % of our survey respondents considered the concept of ‘ontology’ to be unclear. By original definition, coined in the 1600s, ontology is a philosophical discipline that includes questions such as ‘what is a hole?’. The way we answer these questions reflects the way we perceive and interact with the world. Hence, ‘ontology’ is the science that investigates which types of things there are in the universe (world) and what relations these things bear to one another. In other words, it studies being (existence) and the basic categories of being, to determine what entities and what types of entities exist (Welty & Guarino, 2001). An axiom of ontology states that the universe exists and that there are some things that can be compared within that universe. (Hofweber, 2004)

By the 1980s, researchers in Knowledge Engineering realised that ‘ontology’ was relevant to describing intelligent systems. This awareness spread to other disciplines and in the 1990s the term ‘ontology’ actually become a fashionable slogan in domains such as knowledge engineering, information sciences and engineering in general. This meaning of ‘ontology’ makes it synonymous with ‘conceptual model’, (Welty & Guarino, 2001). In information science, an ‘ontology’ is understood as a formal representation of a set of concepts within a domain and the relationships between those concepts. Ontological lexis is designed to enable knowledge defining, sharing and use; it implies definitions of terms and concepts for the purpose of constructing and understanding engineering systems. However, the notions of controlled vocabularies and ontologies, their formal notations, and how they should be implemented is controversial. (Abhary et al., 2009c; Gruber, 2005; Köhler, Philippi, Specht & and Rüegg, 2006)

Bearing in mind the above misalignment, it is obvious that the students in courses such as Knowledge Engineering would be at best deprived of the richness encompassed within the discipline of ontology and led to believe that this concept is limited to formal identification and codification of specific concepts of practical relevance to each particular system. More generally, by omitting the dissemination of true power of the ontology concept, we invite our students to into traps of narrowminded dilemmas. The authors have experienced in their classrooms too often the students' anxiety about the perceived limitations of their “existing” personal capability to understand and learn. In fact such thing (the locked existing ability of understanding complex theories) does not exist. What does exist is a process, ever changing

state of mind and noemas, that means a growth or a decline in the students intellectual capabilities, depending on how the student perceives it. Fundamentals such as 'ontology' and the following concept of 'definition' are intended to unlock this category of deadlocks.

## **Definition**

Extensive studies are devoted to notions of 'definition' within the disciplines of logic, informatics, philosophy and semantics (Fetzer, Shatz & Schlesinger, 1991; Robinson, 1963). Nevertheless, this fundamental concept remains to be affiliated with differing interpretations. Hurley (2002) provides an overview in the state of the art, pointing out that most logicians today agree that the 'definitions' are intended exclusively to explicate the meaning of the words. However, in many applications, 'definitions' are related to, or presented by, using figures, animations and nonverbal sounds.

As an example of specialised application, the concept 'definition' is used to denote the resolution of a TV screen. In computer science it is the concept for the number of pixels per square inch on a display. Publishers such as Elsevier Inc. distribute scientific works where the above concept is denoted by terms such as 'high-definition', 'standard definition', etc. This is misleading since it implies that the 'high-definition' screen automatically provides more knowledge than a 'standard definition' screen. Secondly, in many cases the resolution of knowledge record (sharpness of the font) does not affect the substance of the actual theory conveyed. Thus the concept of 'definition' is too high a category and it should not be used to denote the 'resolution' for a computer or TV screen. (Abhary et al., 2009c)

Hurley (2002) further acknowledges difficulties of providing a definition of 'definition', and instead, adopts a pragmatic approach by surveying the various kinds of 'definitions' that are used, and the functions that they actually serve. In some cases, such as in 'lexical', 'recursive' and 'genetic definitions', aspects such as the development method and history are emphasised, but the significance of the relation between definition intent and content is ignored. For 'stipulative definition' it is suggested that a corresponding term carries a meaning which a user wants it to convey for the purpose of her or his discourse. Thus, the term may be coined, or a 'stipulative definition' may allocate a new meaning to a term which is already in use (Hurley, 2002; Gupta 2008). We found, however, that prescribing new meaning to already existing terms is bad practice that leads to homonymy. It would be more appropriate to coin a new term for each new meaning.

According to an International Organisation for Standardization (ISO/DIS, 2011) "Definition is representation of a concept by a descriptive statement which serves to differentiate it from related concepts". The selection of "representation" as a superordinate concept introduces circularity which is further aggravated by introducing the explanatory concept of "descriptive statement". In addition, in the above standard, there is insufficient differentiation between the terms 'concept' and 'definition'. Furthermore, important "delimiting characteristics" are omitted, namely: definitions should serve as probability intensifiers for anticipated actualisations, they are infinitely shareable and they are terminable.

An all too common experience is illustrated by the following example when, using a high "technology" (an LCD projector), one of the authors has displayed the following incorrect piece of information to the students on a "high definition screen": "Weighing of your final grade is composed of (i) Quizzes - 30%, (ii) Assignments - 40%, and (iii) Exam - 50 %".

## **Some Aspects of a Disambiguation Strategy**

We propose analysing the key scientific definitions for a limited number of concepts based on the principles of science of knowledge, semantics, epistemology and ontology. The definitions of concepts that are already established in mathematics, chemistry, physics and other fundamental sciences should be given priority in a hierarchy in which further concepts can be designated by introducing newly coined terms to avoid homonymy, synonymy and other ambiguities. Since English is the lingua franca of science, new terms can be

conveniently coined by adopting foreign words. (Abhary et al., 2009b)

With regard to the concept 'technology', we suggest to follow an analogy with the nomenclature accepted in numerous other disciplines such as biology, geology, tribology, psychology, sociology, anthropology and toxicology. Each of these denotes a specific branch of relevant science. The English suffix '-logy' or '-ology' denotes a scientific field. Hence: 'technology' is the science of techniques, tools and other phenomena to which these techniques and tools are applied. 'Technique' is an organised human action that causes, directly or indirectly, a required change (alteration) of some phenomenon. Technique is a far-reaching term that includes both simple actions (such as picking the strawberries) and complex performance (such as ice-skating technique, bone transplanting technique, or a technique of landing a space-probe on the surface of Mars). Therefore, the term 'technique' includes modes of using a very wide range of tools, equipment, and other means. However, 'technique' implies actions designed by humans even when performed by quite remote means (e.g. robots, computers or artificial intelligence systems). These techniques are always planned, and intended to be controlled by humans. The hypernyms for 'technique' are 'manner', 'method' and 'ability'. The term 'technique' should not be used to denote an activity performed by any other creatures and living forms such as dolphins, ants, bees or amoebae. For such instances it is proposed to use more common nouns such as 'manner', 'ability', 'capacity', etc.

'Tool' is something which, when used in combination with corresponding techniques and definitions, significantly increases the probability of intended realisation (actualisation, objectivisation). A hypernym for 'tool' is 'means'.

A hypernym for 'technology' is 'science'. We propose avoiding the use of the term 'technology' to simply denote 'techniques' and 'tools'. In particular, 'information technology' stands for the branch of engineering science that deals with the use of computers and other equipment to process, store and transmit information. We do not recommend interpretation of 'information technology' as an engineering discipline that involves application, implementation, maintenance or management of computerised systems. By the same token, we do not recommend using this concept as a synonym for devices such as computers, computer networks, televisions or telephones, mobile phones, and portable media players.

The above discussion pointing at the terminological roots of the concept of 'technology' is relevant to the concept of 'ontology' as well. The concept of 'ontology' as a scientific discipline has a fundamental significance and should not be neglected in other disciplines. The question of how to decide whether some aspect of an engineering problem in fact does exist (or is just a subjective impression) can be addressed based on the principles of ontology in addition to scientific methods such as stochastic analysis. Homonymous applications in computer and information sciences can be avoided by using concepts such as 'taxonomy', 'metamodeling', 'terminology', 'specification of conceptualisation', or 'nomenclature'.

We propose considering the definition of 'definition' as formulated by Abhary et al. (2009b, 2009c), Spuzic (2009), Spuzic and Nouwens (2004), and Spuzic, Abhary, Stevens and Uzunovic (2006). Clear definitions are knowledge probability intensifiers for expected actualisations. A valid definition is infinitely (and simultaneously) shareable, unalterable, terminable and it does not contradict any other definition. In other words: a definition (as well as a tool) increases a probability of anticipated realisation.

The difference between 'definition' and 'tool' is in that a definition can be used without a tool, while a tool cannot be used (in a sense in which its use was anticipated) without a definition. Furthermore, absolutely identical definitions can be used simultaneously at differing locations, while two arbitrary tools differ at least for some amount of tolerances.

## Root Causes of Ambiguities

There are quite a number of works (Spuzic, 2011) pointing to the importance of addressing the ambiguities in scientific, educational and engineering publications. Results from our surveys mentioned above confirm that the problem of ambiguities is significant not only with regard to the selected three concepts, but on a much broader scale. In spite of this, a number of educational institutions and editorial boards of scientific journals choose to treat this issue as insignificant or beyond the scope of their mission. Why is this matter not adequately addressed on a global scale, and why is there a lack of efficient motions calling for academically valid standardisation of fundamental concepts and relevant nomenclature? Do we really intend to share knowledge treasures? Do we actually believe that sharing knowledge on a global scale is of crucial importance for our survival?

Socio-economic systems can perform quite differently depending on how they communicate knowledge. Working towards a 'common goal' requires sharing perceptions, intentions, beliefs and knowledge. Looking at a local scale, there are known educational institutions and industrial organisations that have suffered financial losses due to the lack of dialogue between the antipode experts each protecting their area of knowledge. Such policies of intellectual protection and confidentiality safeguards have resulted in hindering learning and application, as well as in loss of expertise. Abhary et al. (2009)

Within the institutional fences, knowledge sharing is officially strongly promoted. Yet, we hypothesise that the declarative commitments are not sufficient and there is a need for addressing the core issues such as root beliefs and resulting intentions. For example, a belief that knowledge should be kept confidential and 'intellectually protected' instigates isolationism that blocks the exposure and verification of important concepts, theories and hypotheses. Abhary et al. (2009)

The above state of affairs provides fertile ground for multiplication of misconceptions. A diametrically different belief is that we depend on the processes on enormously wider scales. Numerous hypotheses predicting either the smallest particle, or the furthest galaxy, have been defeated. This trend attributes significant probability to an opposing hypothesis: the universe is infinitely large, and breaking into the depths of the "elemental" particles will bring in ever-smaller entities as our knowledge and instrumentation become more advanced. Are we hopelessly lost in an infinite and eternal space, or are we endlessly rich because of the limitless resources around us? This depends on our capacity for studying our environment, a capacity that is cardinally affected by the way we share knowledge. This realisation prompts recognition of constructive motives, which in turn can dramatically change our beliefs about the local significances.

Another progressive belief is that the efficiency, growth and validity of knowledge increase with the quantity of the informed participants. The importance of knowledge disambiguation extends beyond the scope of any discipline, and limitations of any single culture. Once the importance of sharing and application of knowledge is recognised on a more global scale, the obstacles such as ambiguous definitions will become obvious thus triggering the energy needed for activation of the mitigating processes. Information systems are omnipresent in knowledge dissemination and today human-computer interaction lies at the crossroads of many disciplines. In this new environment the mission of academe should include promoting knowledge transparency, shared beliefs and constructive intentions, which will all lead to a decrease in the information entropy.

## Conclusions

- Interdisciplinary literature reviews and surveys conducted at several universities have yielded growing evidence about the ambiguities that penetrate basic scientific and engineering concepts.
- Since English is the universally used language in science, education and engineering, it is proposed that an organised system of fundamental scientific nomenclature, free of

unnecessary homonyms and other ambiguities, should be adopted at least for fundamental concepts in the English language.

- The significance of establishing and maintaining unambiguous concepts and non-homonymic nomenclature is in defining knowledge in terms of its sharing and application.
- If learning is the process of weaving new knowledge into something the students already understand, then the misaligned use of already learned concepts could not only obstruct the progress – it could disrupt already established intellectual constructs.
- Engineering by definition is application of knowledge, and engineering education should not contribute to any distortion of knowledge; on the contrary, by means of promoting the transparency of its disciplines (including knowledge engineering) engineering education should contribute to knowledge dissemination, utilisation, validation and extension.
- The significance of concept disambiguation extends beyond any single discipline, regional language and local culture. This significance stems from appreciation of the actual size and depth of our environment (the universe and below the nano-cosmical strata) and the global implications on scales beyond and above the short-ranged interdependences.

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