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# Translation as Method: Implications for History of Science*

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**Abstract**

The article deals with two significant problems in the history of science which are related to the transmission and circulation of knowledge across cultures. It focuses on the use of translation and the theoretical assumptions in translational activities inherent in any question that asks whether non-European cultures 'had' science. In the same matrix it also enquires into the relation between translation and transmission. The objective is to show that the framework of translation studies is extremely relevant to the discussion on transmission and circulation of knowledge. It tries and argues that it is yet another reason to consider the theoretical and practical aspects of translation as serious methodological issues in the history of science. The author proceeds with the supposition that the theoretical sciences are intrinsically dependent on mathematics, where mathematics should be understood broadly as a semiotic system with rules for manipulation of symbols.

**Key words:** Circulation, Knowledge, Methodology, Theory, Translation, Transmission.

## 1. Introduction

Two significant problems in the history of science are related to the transmission and circulation of ideas and knowledge across different cultures. The first one, as to whether civilizations such as China and India 'had' science, has a slightly longer history. The second question concerns the possibility of transmission of seminal scientific concepts from China and India to Europe before the origin of 'modern science'. The idea that modern science has multi-cultural origins is an argument related to the latter (Bala, 2006). The focus here is on the use of translation and the theoretical assumptions in such translational activities inherent in any question that asks whether non-European cultures 'had' science.

The author also uses the same matrix to enquire into the relation between translation and transmission. He hopes to show that the framework of translation studies is extremely relevant to the discussion on transmission and circulation of knowledge, thereby suggesting yet another reason to consider the theoretical and practical aspects of translation as serious methodological issues in the history of science.

Ideas travel across cultures that are both spatially and temporally distinct. When ideas move from one culture to another they are encountered primarily through translation. Let us first clarify what one means by translation. Here Jakobson's typology of three types of translation is followed: intra-lingual, inter-lingual and inter-semiotic (Jakobson, 1959, pp. 232-39). Intra-lingual translations are 'translations' of a word in one language into word(s) of the same language. Finding synonyms for a word is an act of intra-lingual translation. Inter-lingual translations correspond to translations from one language to another. Inter-semoitic translations are those

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translations in which words in natural language get 'replaced' by other semiotic expressions. Common examples include symbolization of a word such as replacing 'mass' with 'm' or using a graph to indicate a process. Both intra-lingual and inter-semiotic are very important modes of translation activities within the everyday practice of science (Sarukkai, 2001). In the global transmission of science, inter-lingual translation also becomes important since many seminal texts are translated from one language to another.

When ideas travel across cultures, there is, similarly, a process of inter-lingual translation when these ideas are translated from one language into another. When ideas travel across time in the 'same' culture, these ideas get modified (for example, they acquire new meanings) through the processes of intra-lingual translation.

Following a similar typology, we can characterize the movement of ideas and concepts into two types: intracultural and intercultural transmission and circulation. In the former, concepts move through the 'same' culture. A paradigmatic example of this could be scientific concepts where there is movement of concepts across different theories but this movement is within the same 'culture' which would involve some common theoretical and experimental structures. The development of the concepts of atoms, mass, space and motion, for example, illustrate how the 'same' concept changes over time within the scientific community. A similar example of a non-scientific term is the changing meaning of 'mistress', which in earlier times had positive value but over time begins to develop negative connotations.

Intercultural transmission and circulation correspond to movement of ideas, concepts and linguistic terms across cultures. It do not mean that ideas, concepts and linguistic terms are necessarily distinct but only want to specify these as separate categories in the discussion that follows. Typically they involve inter-lingual translation but are, often, more than that. The movement of mathematical ideas from India to Persia or the transmission of ideas from Europe into China are fundamentally concerned with translation from one language to another. In this sense, any global history of science has to – in principle – draw upon translation studies in order to understand the complexities of the translation process and how these influence the transmission and circulation of ideas across cultures. What happens to ideas when they are translated and placed within the linguistic and cultural space of another society? Do they get modified? Do they transmute? Do they acquire new connotations? If so, how?

In this paper, the author will argue that it is primarily through certain processes of translation that an original idea is appropriated into another culture and through this act the original idea might take on new characteristics. In general, it will be difficult to find an original idea in the same form after translation for the simple reason that ideas and concepts in a culture are supported by various metaphysical presuppositions and belief structures (Benjamin, 1989; Venuti, 1998). Very rarely does an idea get transmitted in this structural entirety. How then does one make sense of an idea from a culture without understanding the other concepts which support it? Very often, when ideas get transmitted, they are selectively transmitted. Consider, for example, the transmission of the ideas related to numbers, decimal system and zero from India to Arabia. At one level, there is a functional transmission of these concepts in the sense that the complete worldview of numbers and zero in Indian philosophical and mathematical systems was not borrowed in their entirety by the Arabs. In fact, these concepts get absorbed into the metaphysics and the larger supporting conceptual infrastructure of numbers in the other tradition. Another way to understand this is to say that ideas are often part

of a 'theory' and when ideas are transmitted it is not necessary that the whole supporting theory gets transmitted. In contemporary times, non-allopathic systems of medicine offer a good example of this process. For example, Ayurvedic medicines and concepts of health and healing get transmitted to different cultures but rarely (if ever!) do we see the whole theory of the body (that is so essential to Ayurveda) also getting transmitted in the new culture. Similarly, when concepts of mass and energy are translated into Indian languages, very often the complete theoretical presuppositions behind these concepts are often ignored.

This phenomenon leads to a methodological problem in the context of analysing transmission and circulation of ideas. If we remove an idea or concept and view it in isolation then it makes the comparative enterprise far more difficult. The author believes that the way out of this difficulty is to take the concerns of translation seriously. In fact, to make sense of an isolated concept from another culture it is best to use translation as a method (an idea which one borrow from the way science creates meanings for many of its concepts) which is not a search for equivalences but an active generation of new meaning for these concepts. This process leads one to argue that when we evaluate concepts across cultures we cannot be looking for equivalences but only for the potential to bear possible meanings, what author refers to in this paper as 'meaning-bearing capacity'. Translation as a particular method is the most optimum way towards generating these new possible meanings for concepts. In this sense, the author considers translation and its role in meaning-making as important methodological issues for history of science.

## 2. Translating scientific terms

Let us begin with translation of scientific terms from one culture to another. Almost every language has had a difficult history of translating science and scientific terms. Wright points out that Westerners, when confronted with the nature of Chinese language, doubted whether this language 'was even capable of dealing with science' (Wright, 1998). When eventual translation of scientific texts (from English to Chinese) had been accomplished, there were a number of techniques developed to deal with scientific terms. Wright isolates the following strategies: 1. Not translating the term at all; 2. Transliteration of the sounds into Chinese characters chosen for their phonetic values; 3. The use of existing terms (such as the attempt to retain alchemical terms); 4. The formation of a new term by juxtaposing two or more existing characters (descriptive translation such as oxygen = nourish + vapour/gas, hydrogen = light gas); 5. The resuscitation of an archaic character; 6. The creation of a new Chinese character; 7. The use of Japanese loanwords (Wright, 1998). We should note that these strategies were those followed in the early days of translating science and one can see similar strategies at work even in present day translations of scientific terms in different languages.

In the case of early Arab translation of scientific terms, the problem, in comparison to the Chinese case, was quite different primarily because of the presence of a contiguous tradition of science and philosophy in the Arabic world. The translation of Hellenistic science into Arabic was accomplished by several translators and with the help of many methods (Endress, 2002). According to Endress, there were several ways by which new terms in Arabic were created in early Islamic philosophy (al-Fārābī, Ibn Sinā). One was functional: a good example of this was the 'adoption of loan words', which were words taken from the original language and re-expressed in the translated language with little or no modification. Another method was 'loan-translation' where there is a literal translation of the semantic content of the original word. One example of an 'ad hoc transliteration' was the new *falsafa* (from the

Greek *philosophia*) instead of the Arabic *hikma* meaning 'wise saying'/wisdom'. Endress notes that loan-translations as well as loan-words, 'function as shells for the concepts they are appointed to represent.' Another method is what Endress calls 'Paradigmatical' where 'indigenous Arabic words were applied to technical concepts by analogy, extension' (Endress. 2002).

Given the importance of translation in making sense of science in the historical context, it is surprising that historians of science, as Elshakry also points out, have largely ignored the problem of translation (Elshakry, 2008). Even when engaging with translation, they have not, in general, taken into account the theoretical insights from the discipline of translation studies. A primary reason for this indifference is the commonly-held belief that translation is a passive activity. Philosophy and translation studies have for long disputed this belief since a translated text is a new text and the space of meanings created by a translated text is different from that of the original text (A. Benjamin, 1989; L. Venuti, 1998). Elshakry cites the example of Shumayyil's translation (from yet another translation) to indicate that the 'languages between which scientific translation takes place may themselves be shifting and, indeed, altered by the process of translation itself'(Elshakry,2008). In early Arabic translation of scientific terms, there was a process of 'domesticating' foreign terms. Transliteration of terms often indicates a difficulty in finding appropriate terms in a translated language. Such acts of transliteration, as Elshakry points out, was also politically sensitive since there was resistance to adding new foreign words to a language since, among other things, 'excessive borrowing' was seen 'as a sign of political subservience'(ibid). Thus, in the early period of the 20th century, there was a focussed attempt to discover or modify Arabic terms for scientific ones. Elshakry concludes by suggesting that the transliteration of scientific terms into Arabic 'was operating under the mistaken impression that the language of science was universal' and that later translation work overturned this belief. The belief about universality of scientific language was also open to criticism since there were political overtones in such claims.

In the case of India, almost all Indian languages encounter similar problems of translation of scientific terms. As an illustrative example, we will consider one language, Malayalam, a language spoken in the state of Kerala. Similar strategies of translation of scientific terms can be found in other Indian language science textbooks.

Here are some examples of scientific concepts in Malayalam used in the Department of Education school science textbooks (10th standard, 2004) for Malayalam medium in Kerala. For some concepts, new words in Malayalam are coined. For example, 'temperature' is translated as *thāpanila* (*thāpam* – heat; *nila* – 'level' which can be seen also as a measure); 'melting' as *dravikaranam* (karanam - process and *dravikaranam* as process of becoming liquid); 'latent heat' as *leenathāpam* (*leena* – latent); 'electric current' as *vaidyutha pravāha theevratha* (electric flow intensity). In these cases specific scientific terms are replaced with words from Malayalam. So temperature is translated as level of heat and electric current as the intensity of flow of electricity. The semantic ambiguity arises in using Malayalam words for heat which has its own connotations in its cultural uses.

Interestingly, there are various other terms which are not translated at all. 'Intrinsic semiconductor' is translated as *intrinsic ardhachālakam*; the word 'intrinsic' now becomes a 'part' of Malayalam. Similarly for extrinsic in 'extrinsic semiconductor'. The translation of n-type semiconductor retains 'n-type' in Malayalam. Other scientific terms that are retained as English words include the following: 'Loudspeaker',

'Mass defect', 'Binding energy', 'Radioactivity', 'Chain reaction', 'Nuclear fusion', 'Electron', 'Electrode', 'Ion', 'Electrolyte', 'Anode', 'Cathode', 'Electrolysis', 'Atomic', 'Mole', 'Nucleus', 'Electronegativity', 'Leaching', 'Calcination', 'Hardening', 'Annealing', 'Oxidation' (although for de-oxidation they use '*nir-oxi-karanam*' but they don't use *oxi-karanam* for oxi-dation where *karanam* is process). There are many more such examples.

Why do translators adopt such complex use of words and translation from other languages? This process is not new as illustrated in the extensive work done on loanwords, loan translation/calque, loan rendering and so on. But is there something special in these types of translation that becomes the mark of translation of scientific terms? Does it say anything about science as much as it says something about translation? (P. Dasgupta, 1993). Elshakry points to the politics of naming when growing Arab nationalism resisted the direct borrowing of non-Arabic words as part of the scientific lexicon. Here I want to point to the epistemological presuppositions hidden in such practices.

Transliteration is preferred in certain cases when the translators feel that there is no appropriate word in their language for the original word. But what is an appropriate word? While there are many dimensions to this question, for the purposes of my argument I want to highlight just one aspect, namely, the analogy between the transliteration of scientific terms and the translation of proper names. When a novel is translated into another language, the standard practice is to retain the names of the characters. So Hamlet will continue to be referred to as Hamlet in a translated version of that text. Proper names are not translated but only transliterated. Why are proper names not usually translated? In the case of proper names, one believes that there is an entity 'independent' of the name, one that functions perhaps as a 'rigid designator' of that name. Such a philosophical position is very influential in some traditions of philosophy of language. For instance, Russell's work on proper names as well as Kripke's use of rigid designators to describe proper names is well known in the literature. And since this entity is not defined by its meanings as much as by its existence, there is really no need to translate the proper name since the reference remains the same across linguistic utterances of different languages. So when scientific terms are transliterated they are essentially functioning as proper names: radioactivity and Hamlet are both transliterated and not translated.

Many times transliteration is preferred by translators because of the perceived difficulty in finding a term in the translated language which matches the original term. Most often this difficulty reflects certain uneasiness in translating concepts. Sometimes transliteration becomes an easy way out when confronted with the problems of translating concepts. There are two problems with transliteration that are of relevance to the discussion in this paper. One, it doesn't let the concept take on new connotations in the translated language. Second, it masks the dynamics inherent in the processes of transmission and circulation. Transliteration keeps 'alien' concepts as alien and is often used to validate strict boundaries for concepts. The debate on the problems of translating concepts such as 'science', 'logic' or 'rationality', as well as the problems of translating some ancient concepts in terms of modern scientific ones, illustrate this constant tension between transliteration and translation. Moreover, the tendency to transliterate sometimes inhibits meaningful dialogue that is necessary to understand multicultural transmission of ideas since transliteration essentially suggests that the translated language does not have the resources to handle the original concept, whether they be larger concepts such as science, logic and rationality, or scientific concepts such as mass,

matter, and limit. For history of science, this tension is of some significance since it may be easier to claim that concepts such as science and rationality, or concepts related to calculus, were not available in other civilizations. Almost all seminal thinkers from Europe have shared the belief that Asiatic cultures in general did not 'possess' science, logic or reason. These thinkers range from Hegel to Gadamer and include Locke and others. These were also claims that were essential to the colonial discourse (Gadamer, 2001; Ganeri, 2001; Ada, 1989; Alvares, 1991; Halbfass, 1988). The point I wish to reiterate here is not that these concepts were available to different cultures but only that these issues of translation must become an integral part of a methodology of history of science.

No doubt, the questions as to whether Indians had science or technology or possessed concepts in calculus before its development in Europe or had developed the modified heliocentric model (Tycho Brahe model which postdates a similar model described earlier by the Kerala astronomers) go beyond the issue of transliteration and translation although they may be catalysed by the activity of translation. To illustrate the problems of translation in such claims, consider the recent debate on the contribution of the Kerala astronomy school and in particular the claims of their having anticipated calculus through the creation of ideas such as infinite series and limits.

As evidence one can see the sixteenth century (c. 1530) text in Malayalam called the *Gaṇita-Yukti-Bhāṣā* by Jyeṣṭhadeva (Ramasubrahmanian, Srinivas, and Sriram, 2008). This text introduces seminal ideas of calculus before the origin of similar ideas in Europe. There have been claims that conceptual ideas that led to modern calculus were first taken from this text and transmitted to Europe. There have been counter arguments to this theory of transmission but here I only want to look at the problems of translation of certain terms like limit and infinite series. If we translate a term in this text as limit or infinitesimal then the suggestion is that the idea of limit (in the context of infinite series and calculus) was first developed in the Indian schools before it developed in Europe. So how then do we decide to translate a term in this text as 'limit' or as 'infinitesimal'? Are such translations done with a view to claiming primacy of certain ideas?

In Chapter 6 of the *Gaṇita-Yukti-Bhāṣā*, there is a significant discussion on infinite series and error corrections in the context of calculating the circumference. Basically, this leads to an infinite series expansion for $\pi$. Now, if we look at the original text this expansion is written in natural language and not in a 'modern mathematical' form. In the English translation of the text alluded to above, the editors have also given a modern symbolic rewriting of the chapters. The symbolic rendering of the sixth chapter exhibits clearly – for those who are familiar with series in mathematics – what kind of a series is being discussed, what kind of conceptual ideas of calculus are possibly present in this text and so on. Without this rendering into the symbolic domain it is quite difficult to perceive links to calculus since the conceptual world in the natural language text is so different. For example, this text gives methods to calculate Rsine values. The Sanskrit term for these values is clearly translatable to Rsine. In Malayalam it is referred to as *jya* whereas in Sanskrit both *jya* and *jiva* are used.

The notion of limit is a little more complicated. Although there have been claims that this text describes the idea of limits the situation is perhaps a little more complex (C.K. Raju, 2001). If we ask whether there is a specific word standing for 'limit' which is used by the Kerala mathematicians, then the answer is probably no since the idea of limit is also linked to the ideas of infinity and the infinitesimal. Even in the history of calculus in Europe, the idea of limit comes much after the introduction of the infinitesimal.

However, we can discover the overlap with certain seminal themes in calculus even in texts before the *Gaṇita-Yukti-Bhāṣā* such as the notion of instantaneous velocity of the planets (as described by Bhāskarācārya, c. 1150) in contrast to the 'true daily motion'. The word used for 'instantaneous velocity' is *tātkālikagati*. The first seven chapters of the *Yukti-Bhāṣā* (comprising the *Gaṇita-Yukti-Bhāṣā* mentioned above) primarily deals with various topics in mathematics. Ramasubramanian and Srinivas describe some of the seminal ideas in these chapters which are related to calculus: "... detailed demonstrations of the results of Mādhava such as the infinite series for π, the arc-tangent, sine and the cosine functions, the estimation of correction terms and their use in the generation of faster convergent series. Demonstrations are also provided for the classical results of Āryabhaṭa (c. 499) on *kuṭṭākāra* (linear indeterminate equations), of Brahmagupta (c. 628) on the diagonals and the area of a cyclic quadrilateral, and of Bhāskara II (c. 1150) on the surface area and volume of a sphere" (K. Ramasubrahmanian and M.D. Srinivas, 2010). Moreover, this text also deals with the "estimation of the end-correction terms and the transformation of the π-series to achieve faster convergence and the derivation of the infinite series for Rsine and Rcosine due to Mādhava" (ibid). Later work on more elaborate calculation of the instantaneous velocity of planets only reinforces the conceptual world of calculus that is explicitly present in this tradition (and one might add, results that were obtained before similar ideas arose in Europe).

The mathematical texts were primarily in Sanskrit (most commonly in 'poetic' form) although the *Yukti-Bhāṣā* is was written in prose form in Malayalam. Translators and interpreters of these texts have to match concepts – for example, instantaneous velocity equated with *tātkālikagati* and *kuṭṭākāra* with linear indeterminate equations. The words used for summations, series and approximations are more literal and the matching seems clearer. Now, how do we show that the concept of instantaneous velocity and linear indeterminate equations were indeed part of these mathematicians' vocabulary? The best way to illustrate this equivalence is through translation. What Ramasubramanian and Srinivas or Raju do is rewrite the original Sanskrit or Malayalam prose text in symbolic form of contemporary mathematics and in this rewriting (translation) we can see the structure of their concepts. Thus, translation actually allows us to discover the structure of the concepts which were described in other languages.

Interestingly, such a method has been used in understanding some scientific implications of Newton's work. Chandrasekhar's monumental rewriting of Newton's *Principia* is a wonderful example of how this method of translation can be used for the purposes of history of science (Chandrasekhar, 1995). In this rewriting by Chandrasekhar, we can clearly note the significance of the concepts inherent, but not made explicit, in Newton's book. It is clear from this symbolic rewriting what the conceptual world of the *Principia* was. Symbolic rewriting of the text is nothing but a translation of the text from one language to another. Thus, an act of translation actually serves to exhibit the common conceptual world of two seemingly different discourses such as the *Principia* and modern classical physics.

My point is that to really understand what concepts and ideas were transmitted and circulated we have to first know what concepts and ideas were available in these cultures. Translation is perhaps the only way to do this, particularly when cultures have different languages. But to say that translation is the only way is to say little unless we specify what theoretical methods or practical strategies one uses in these translations. The debates on priority of concepts across different cultures (which is also one way of looking at the Needham question) are often not sensitive to the theoretical issues surrounding the activity of

translation. Therefore, this sometimes leads to rigid claims of the availability and priority of concepts.

Translations are actually ways to create new meanings for concepts. Questions of translation have often been caught up in the question of whether a given set of meanings of a term in a source language maps onto similar set of meanings in the translated or the target language. This is a static view of translation. The active view of translation begins by asking how meaning gets accrued to terms. How do terms get the set of meanings that they end up possessing at a given moment? How is it that we meaningfully grapple with concepts that seem to be so different when compared to the ones we are used to? The examples of *Yukti-Bhāṣā* and *Principia* suggest that translation is a *method* to generate and exhibit meanings for terms as well as a method to compare concepts from different cultures which may look 'alien' at the first instance but through acts of translation exhibit their interconnectedness. We can extend this to claim that meanings of concepts are also partly created through the activity of translation. This is particularly true of science and, in my view, is necessary for the creation of meaning of scientific concepts. The next section is a brief description of the mechanism of this process in science. My point in describing it here is to alert us to the role of complex methods of translation that are needed in any comparative work in the history and philosophy of science.

### 3. Example of translation as method

Interestingly, it is in science that we see a fertile use of translation as a method for creating meaning of scientific concepts. Scientific concepts are very different from our ordinary concepts and in this sense can be called alien concepts (Dancy, 1983). In fact, there is one mark of alien-ness of scientific concepts and that is the creation of concepts that challenge commonsense. So how does science create a coherent discourse even though there is a constant creation of such alien concepts? One simple answer is this: through giving these alien concepts meaning without worrying in the first instance whether these meanings are correct or not. It is the generation of possible meanings of alien concepts that brings these concepts into a common discursive world. And this meaning-generation is largely catalyzed by translation. So translation becomes a method to find the boundaries of concepts and to discover the range of meanings that concepts can bear. So an essential aspect of scientific (particularly theoretical) activity is to explore the *meaning-bearing capacity* of new concepts, examples of which is discussed below. A similar approach to meaning of concepts, including concepts like 'science', might be useful in enriching the debates in history of science regarding transmission and circulation of knowledge across cultures.

Scientific concepts expand their semantic domain through the 'use' of strategies of translation. As we saw earlier, translation includes intra-lingual, inter-lingual and inter-semiotic translation. In what follows, I will restrict myself to pointing out how the activity of translation actually increases the semantic content of scientific concepts.

Symbolization is an act of translation and the effectiveness of this process to compare apparently different concepts was described in the last section. Here, we will briefly discuss one aspect of the act of symbolization in the sciences and its relation to the creation of meaning. First of all, symbolization is primarily an act of inter-semiotic translation. Replacing 'time' by 't' is firstly an act of translation where a word in one language is translated into a 'word' in another 'language'. The fundamental difference between inter-lingual translation (where, for example, 'time' is translated to '*kāla*' in Sanskrit) and inter-semiotic one is based on meaning. *Kāla* has a semantic domain associated with it whereas 't' is devoid of meaning. The power of symbolic

manipulation lies in this capacity to strip meaning from words and then, after subjecting the symbol to manipulations, put meaning back. This act is a classic description of the activity of translation whereby a word gets translated into another language and then the 'expressive capacities' of that language dictate the flow of ideas associated with the translated word. It is also indicative of a special strategy of retranslation in that there is a constant to and fro translation between the source language and the target language (Sarukkai, 2002).

Scientific discourse implicitly uses this strategy of translation through the process of symbolization. And there is a reason for this discourse to do this so effectively because this act of semiotic translation generates new meanings in ways not possible otherwise. That is, the shift into the symbolic mode is an important mode through which scientific concepts generate surplus of meaning. Consider a common example. When mass is translated into 'm' it is placed within a new language dealing with other symbols and operators. Once mass is put into the symbolic domain then one can *do* things with this 'word' in this new language. One can take the square root of 'm' although it doesn't make sense to take the square root of 'mass' as a word. If we look at the history of mass, one can see how every new theory of mass created new meanings of mass primarily based on interpretation of results of some symbolic manipulations (Jammer, 1961). So the translation into symbols allows us to do things to words which we cannot do otherwise. And the major reason for this efficacy is that symbols are not laden with meaning when these operations are performed. So scientific theorizing is a special act of translation where questions of meaning are constantly deferred. Translation is 'free' in the best sense of the word.

Now consider the problems of translating 'mass' into Indian languages. If we translate it into a word that is already available then what kind of mass is that referring to? It cannot be referring to the qualities of Newtonian and Einsteinian masses. But note that this is exactly the 'problem' when we translate mass to m. What is the meaning associated with 'm' – which kind of mass is it referring to? This question does not arise in this case since we have not decided the semantic space of 'm'. In the same way, translation of mass into a Malayalam word should be seen as a step in the formation of new meanings for mass in that language. However, the irony is that in almost all scientific contexts, including school science textbooks, mass is not translated into Malayalam but only transliterated. A counter argument to my position would be to point to the use of Sanskrit words in Malayalam. These words have often been transliterated and have become part of the vocabulary of Malayalam (and many other Indian languages also). But there are two important points of difference in absorbing Sanskrit words as against technical scientific words: one is that the languages themselves have high usage of Sanskrit words and significant portions of the languages are derived from Sanskrit. This is different from transliteration of words from English, Latin or other European languages. Second, the transliterated technical words have cultural currency too – for example, the word *dravyam* (from Sanskrit but now part of Malayalam, standing for 'matter') has many other connotations in the cultural space and is not restricted to the science textbooks alone. This makes transliterated words from a language like Sanskrit part of a larger process of meaning-making.

Scientific concepts cannot create the rich narratives about nature without the specific strategy of translation described above (Sarukkai, 2002). As much as science depends on theoretical structures (which are more than the use of symbols alone), it also needs a particular act of translation to create semantic plurality which is the most fundamental mark of scientific theorizing. In other words, translation and retranslation must be seen as part of scientific methodology and are

indispensable to it. Given this emphasis on symbolization it might seem that the author is primarily concerned with the mathematical and the theoretical sciences (Sarukkai, 2001). Galileo's influential claim, that mathematics is the 'language' of nature leads to the position that other natural languages *cannot* be equivalent to it. This places mathematics in a unique domain: as a language which cannot in principle be translated.

What about scientific theorizing that does not involve mathematics? First of all, there is a strong foundation of mathematics even in those areas of science which do not manifest it explicitly – for example, through dependence on prior fundamental theories. Secondly, the way language is used in these non-mathematical sciences (like some parts of biology or chemistry) illustrates a constant attempt of a move towards a 'technical' language. Nominalization is one well-known strategy that marks scientific writing even when symbolic systems are not used (Gerstberger, 2008; Halliday and Matthiesen, 1999).

So what is the consequence of understanding translation as an important method in the creation of scientific discourse? As mentioned earlier, there are contentious issues when we discover words in other cultures (both spatially and temporally displaced from the contemporary one) which we claim are translational equivalents of concepts used in contemporary discourse. Examples of terms in calculus, astronomy and indeed even larger concepts like 'science' and 'logic' have raised questions of priority when these terms have been matched with words already present in the translated language. The objection is primarily based on the claim that the meanings associated with these concepts today are not the same as terms used as translational equivalents from a different culture and different era (Narain, 1961). But this argument misses the fundamental point about how we make sense of very different concepts. The semantic domain of such concepts is actually discovered through translation. *Through translation the capacity of a concept to bear new meaning is tested*. It is an inclusive experimental strategy and not an exclusionist one. This experimental method of translation is a model that is recommended for dealing with translation of Indian science/mathematics texts. By allowing 'logic' to be translated as 'anumāna' or some words in Indian mathematics to be translated into modern mathematical concepts, we are only increasing the semantic space associated with these concepts. There are always choices made about which set of meanings is preferred but this judgement cannot occur before these acts of translation takes place.

## 4. Alien concepts and the ambiguity of translation

We shall use the phrase 'alien concepts' to indicate concepts that are very foreign to the conceptual structure that informs cognitive capacities of different communities. Dancy suggests that alien concepts are those that are 'essentially different' for a particular community (Dancy, 1983). When a modern mathematician encounters Indian mathematics, it is highly probable that even she might have trouble in making sense of the conceptual world of, say, the *Yukti-Bhāṣā*, just as much as these ancient mathematicians might have had with modern concepts in calculus. We are often confronted with completely different conceptual structures of some cultures and this leads to difficulties in understanding the behaviour of the members of these cultures. Interestingly, paradigm examples of alien concepts are mathematical and scientific concepts. We believe that scientific concepts are paradigmatically alien in that they challenge our normal cognitive capacities of sense-making. Nevertheless, we are able to negotiate with these concepts. It will be my contention that meanings are created in such concepts through the activity of translation and retranslation. Very good

examples of this process are endemic to translation of scientific terms and indeed the translation of the concept 'science' itself. In this section, a brief discussion will be made on the relationship between alien concepts and translation which then leads to the analysis of scientific terms as alien concepts.

Dancy makes an interesting point about alien concepts in the context of ostension (Dancy, 1983). The problems in understanding concepts across theories have been much discussed as the problem of incommensurability. The charge of incommensurability does not necessarily need inter-lingual translation as concepts in succeeding theories (in the same 'language') are sometimes seen to be incommensurable. The larger question here is whether one can make any sense of concepts that are very different from the ones we hold? Dancy points out that many, including Davidson, answer in the negative (ibid). How then can we make 'sense' of concepts from ancient Indian and Chinese societies or even contemporary scientific ones? The claim that I am making here is that specific modes of re-translations are ways to make the alien more familiar. In terms of meaning, this claim implies that meanings of concepts are actually created through engaging with the alien in *ambiguous* ways.

In the context of translating concepts across diverse cultures, my suggestion is that translation showed function like ostension. Merely from a translated word we cannot know what element this word is referring to in the original concept. When a translator translates logic as *anumāna*, she is doing the following. She is 'pointing' to the concept 'logic' and uttering the word '*anumāna'* just as a native utters 'Gavagai' on seeing a rabbit. The word '*anumāna'* points to 'logic' just as, following Quine's example, Gavagai points to the rabbit. The ambiguity present in ostension is present in translation also and it is exactly of the same kind: *we cannot be sure what it is in the semantic space of 'anumāna' that points to what of 'logic'*. The richer task of translation comes from the way science engages in re-translations in order to increase the semantic content of concepts. It is the ambiguity of translation that is necessary for the expansion of semantic space.

One can extend this analogy between translation and ostension to understand what happens in symbolization, which is often the first step to developing theory in physics. When a symbol comes to stand for a term, say 'm' for 'mass', this is an act of translation. Like ostension, one can point to 'm' and utter 'mass'. A person might not understand what in 'm' really refers to 'mass'. Symbolization is an extension of the ostension problem except that in this case it is *maximally ambiguous*. There is really little that constrains what 'm' could be and this allows its use in symbolic manipulations that are allowed under that particular theory. At various points, the expressions based on 'm' are then retranslated back into the language associated with 'mass' and new meanings are thus added to 'mass'. This process is so well exemplified in the long history of mass from Newtonian to the quantum formulation of mass (Jammer, 1997). Even fundamental principles like energy-mass equivalence follow a similar process. Re-translation really functions as a scientific method which allows the creation of rich semantic spaces associated with scientific concepts. In fact, scientific texts use multiple semiotic systems like figures, diagrams, graphs, pictures and symbols primarily to create a rich surplus of meaning (Lemke, 1988).

It is through translation and retranslation that concepts get new meaning. Boundaries of concepts are expanded through retranslations like in the case of mass. Alien concepts cannot be grasped in full and ambiguity characterises the relation between matching terms standing for a concept. This ambiguity is not a problem; on the contrary, this is the mode by which the boundaries

of concepts get redefined. In the case of concepts of calculus discussed by the Kerala mathematicians one would have to say that in principle it is not a question of exact matching of concepts of calculus in their tradition with the European ones but it is more a question of how retranslations add new possible meaning to these concepts in *both* these traditions.

Similarly, the meaning of 'logic' gets expanded once there is the engagement with its translated counterpart, '*anumāna'*. Claiming that *anumāna* is not strictly like logic, as understood by the Greeks, is not a useful strategy. Instead, once logic is translated as *anumāna*, the next step is to explore how the meaning of logic changes in negotiation with the meanings of *anumāna* (Matilal, 1985; Mohanty, 1992; Sarukkai, 2005).

## 5. Concluding Remarks

This observation also leads us to conclude that translation of concepts as if they were proper names (using the foreign words like names) is antithetical to this process of meaning making of concepts. It would be profussed if Malayalam words for 'mass', 'intrinsic', 'extrinsic', 'nuclear fission' etc., are used in science textbooks for they will suggest new meanings of these terms which will further catalyse the growth of these ideas within the community of Malayalam speakers leading to creative work in science. To the argument that transliterated words have often become part of another language and hence there is really no problem in these transliterations, I would only suggest that transliteration of scientific terms show far more obduracy in becoming part of the semantic world of a verbal language. They retain their exclusivity by various discursive means. The argument in this paper about the creative uses of translation in matters of interest to history of science is not against the presumed hegemony and universality of science nor is it to primarily support local language writing in science. It is purely a matter of following a practice that has had a great success in scientific theorizing. Needless argument about whether the Kerala mathematicians 'really' had knowledge of 'calculus' misses the point about the relation between translation and meaning. A dynamic and open view of translation and re-translation should inform our understanding of the circulation of knowledge across cultures.

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