ON THE TRAIL OF THE VOCABULARY OF MATHEMATICAL SCIENCE IN EARLY MODERN ENGLISH

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ON THE TRAIL OF THE VOCABULARY OF MATHEMATICAL SCIENCE IN EARLY MODERN ENGLISH

di
Sonia PIOTTI
Ricercatore di Lingua inglese
Università Cattolica del Sacro Cuore
Sede di Brescia
Contents

1. Introduction ................................................................................................................. 1

2. The scientific sources of *The Whetstone of Witte* (1557): the interplay between Ancient, Medieval and Contemporary Authorities ................................................................. 3

   2.1 Ancient Authorities ................................................................................................. 3

   2.2 Medieval Authorities ............................................................................................... 3

   2.3 Contemporary Authorities ....................................................................................... 4

       2.3.1 Latin sources ........................................................................................................ 4

       2.3.2 Vernacular and Latin works of German mathematicians .......................... 5

       2.3.3 English vernacular sources ............................................................................... 8

3. The mechanisms of language change in *The Whetstone of Witte*: A taxonomy ......................... 8

   3.1 Onomasiological changes ....................................................................................... 9

       3.1.1 Borrowing ............................................................................................................ 10

       3.1.2 Loan translations ................................................................................................. 10

       3.1.3 Synonymy and renaming ................................................................................... 11

       3.1.4 Word formation processes: suffixation and ellipsis ................................ 13

   3.2 Semasiological changes ......................................................................................... 14

       3.2.1 Sense restriction ................................................................................................ 14

       3.2.2 Semantic loans ................................................................................................ 14

4. Recorde’s functional explanations for language change in *The Whetstone of Witte* ........................................ 14

5. A modern functional approach to language change in *The Whetstone of Witte* ........................................ 15

6. Conclusions .............................................................................................................. 19

References .................................................................................................................... 21
1. Introduction

This paper presents the preliminary findings of a study focusing on specific issues concerning the origins and development of the language of mathematical science, especially arithmetic and algebra, in Early Modern English. Special focus is given to Robert Recorde’s (1510ca. 1558) last work, the algebraic textbook entitled *The Whetstone of Witte* (1557) (fig. 1).

*Figure 1- Front-cover of The Whetstone of Witte (1557)*

```
The whetstone
of witte,
whiche is the seconde parte of
Arithmetike: containing the tra\%
ction of Roette: The Cofy  p\%
ate, with th\%
the rule of Equa\%
\%

Though many stone: doe beare greete priz,
The whetstone is for exercis,
As needfull, and in worke as strange:
Dulle blinde and harde it will so change,
And make them sharpe, to right good use:
All artemen knowe, that can not chafe,
But vs his helpe yet sometim sees,
Not sharpenesse smeth in it to bee.
The grounde of artes did brede this stone,
By vs is great, and more thon one,
Here if thou lift your witte to mende,
Macle sharpenesse therby flesh you gette,
Dulle wittes hereby doe greatly minde,
Sharpe wittes are fyned to ther fullc rude,
No b proue, and praffe, as you doe finde,
And to your self be not unkide.

These Bookes are to bee solde, at
the Whet boce of powles,
by John Kyngston.
```
Sonia Piotti

Recorde is unanimously regarded by historians of science as the author of the first competent introductions to arithmetic, algebra, astronomy and geometry in the vernacular language. Arithmetic apart, his treatises were the very first books totally devoted to the mathematical science to be printed in English. Recorde is regarded by historians of the English language as the most influential 16th century textbook writer in the vernacular language, and the scholar who largely contributed to the development of the language and vocabulary of mathematical science in England. The present study proposes a functional perspective of Recorde’s lexical innovation as regards the scientific vocabulary of arithmetic and algebra (in the light of the 16th century English question of ‘terms of art’).

A proper investigation of the language change that an individual speaker introduces into a linguistic community involves some logically distinct steps, which aim at defining not only the mechanisms of language change but also the motivations for the language change. These motivations include the general motivations for language change, the general conditions for language change and the specific motivations that cause an individual to use one or more of those possibilities (Coseriu 1958). Drawing on the authoritative literature on lexical semantics (Ullmann 1951, 1962) and on more recent trends in theoretical semantics (Rosch 1977, 1978; Rosch & Mervis 1975) and historical semantics (Geeraerts 1983, 1986, 1997), the present study aims to blend the author’s functional explanations for the language changes he introduced with a functional perspective that a modern reader would look out for. Within both a synchronic and diachronic perspective the study integrates the semasiological and the onomasiological approach to lexical-semantic change into a more comprehensive theory of language change:

[the] structuralist position that true semantic change is a change in the semantically distinctive oppositions among the lexical items of a language (1964), discards from the domain of research the not uncommon type of change in which an item acquires a new meaning without involving another item or a change in distinctive feature oppositions. [...] this implies that not all changes in the expressive means of the language enter into semantic research – which can only lead to a distorted view of why language changes.

Further, it would be erroneous to restrict the study of semantic change to semasiological changes, not just because semasiological changes cannot be described properly without taking into account related onomasiological changes, but also because both notions indicate overlapping sets of phenomena rather than two clearly distinct types of phenomena. In fact, the most common type of
semantic change (a word acquiring a new meaning) is an example of semasiological change (involving the question “Why does a word acquire a new meaning?”) just as well as an example of onomasiological change (involving the question “How does a concept get expressed, i.e. how does it get attached to a particular lexical form?”). As such, the semasiological extension of existing words is itself an onomasiological mechanism.

If it is accepted that it would hence be wrong to impose a rigid separation between the onomasiological and the semasiological approach of lexical-semantic change, […]. (Geeraerts 1986: 68)

2. The scientific sources of *The Whetstone of Witte* (1557): the interplay between Ancient, Medieval and Contemporary Authorities

Reorde had several sources at hand. Several times he acknowledges other books and other scholars (Kaplan 1969; Piotti 2005). Though the names and titles of Recorde’s sources generally tend to remain unknown, some exceptions need to be made. These exceptions include the names of ancient authorities like Euclid, early medieval authorities like Boethius as well as contemporary authorities such as Cardano, Scheubel and Stifel. Any direct or indirect reference to scientific authority is relevant to the analysis of the origin of the terminology of mathematical science in *The Whetstone*.

2.1 Ancient Authorities

“Reorde constantly compares the classical authorities with respect to accuracy and adequacy of definitions and concepts” (Kaplan 1960: 137). Quite often Recorde cites Euclid’s *Elements* by book and proposition (Kaplan 1960: 138-140). Only once does he cite Euclid without specification of book or proposition. Recorde may have read Euclid either in Greek or in Latin, or both. There is evidence, however, that Recorde knew Greek, as he clearly demonstrates in his treatise on astronomy entitled *The Castle of Knowledge* (1556), where he criticizes Sacrobosco for an inadequate knowledge of Greek.

2.2 Medieval Authorities

Unlike Recorde’s earlier works, where several medieval scholars are clearly cited and acknowledged, in *The Whetstone* it is Boethius the only early medieval authority who is cited and acknowledged, although he is cited only once. The context is the classification of numbers according to their properties, where Boethius is cited along with Euclid and other writers whom Recorde does not name.
Boethius’ *De Institutione Arithmetica* was the Latin translation of the treatise on arithmetic of Nicomaco of Gerasa (1st century A.D.), which was a compendium of what had been known on arithmetic in Greece up to the 1st century A.D. Boethius’ terminology, widely diffused by Isidore of Seville, was the most influential on following Latin and vernacular treatises on arithmetic up to the 16th century. Recorde must have had Boethius in mind when he used the adjectives *absolute, abstracte, contracte, figuralle* and *relative* to classify numbers according to their properties:

**Master:** Nomber is diuided into diuerse kindes, for some are *whole nombers*, and thei onely of Euclide, Boetius, and other good writers are called nombers. […] But now in eche kinde of these, there are certaine nombers named Abstracte: and other called nombers Contracte. […] Then to procede, nombers abstracte are considered in .3. principall varieties: […] nombers absolute, […] nombers relatiue […] ,figuralle nombers. (*The Whetstone*, A.ii.-A.iii)

Recorde may have calqued the mathematical meaning of these adjectives either on Euclid or on Boethius (it is not clear); therefore, the terms the two authors used can be regarded as be the ‘spiritual’ etymology or matrix of Recorde’s terminology.

### 2.3 Contemporary Authorities

The contemporary sources in *The Whetstone* include both the Latin as well as the vernacular works of continental—mainly Italian and German— and also English mathematicians, some of whom are clearly cited and acknowledged by title and name.

#### 2.3.1 Latin sources

In the section of the extraction of square and cube roots Recorde cites the Italian mathematician Girolamo Cardano and we presume the works referred to are either his *Practica Arithmeticae* (1539) or his *Ars Magna* (1545). The discussion considers the steps to find cube roots. With respect to one step in the process the Master tells the Scholar that there are as many ways of going about it as there are writers. Then he quotes Cardano’s rule: «Multiply the roote squarely, and againe by .3. and that nomber shall be the diuisor vnto the remainder» (*The Whetstone*, O.iii). A few pages farther on he refers again to Cardan’s rule which fails to produce the correct answer. In his study on Recorde, Hughes (1993) also hypothesizes an indirect reference to Cardano’s *Ars Magna* in the Elizabethan author’s identification of the varieties of equations. After producing Scheubel’s varieties of equations,
Recorde adds parenthetically «As for the manyfolde varieties, that some other doe teache, I accoumpte it but an idle babyling, or (to speake more fauorably of them) an uncessary distinction» (The Whetstone, F.iii). Whereupon Hughes remarks:

Recorde may have had Cardano in mind because in his Artis Magnae, Ch. II, he lists many kinds of first and second degree equations. Further, Scheubel had a copy of this book, although it is not known when he obtained it. (Hughes 1993: 171)

2.3.2 Vernacular and Latin works of German mathematicians

In the section on the extraction of square and cube roots Recorde cites the German mathematician Michael Stifel (1487?-1567). This is the only clear reference to the German author. Yet, strong similarities between Recorde’s terminology and Stifel’s, both in his Latin treatises (Arithmetica Integra, 1544) and in his vernacular ones (Rechen Büchlein,1532; Deutsche Arithmetic, 1545; Rechenbuch von der Welschen und Deutschen Practick, 1546), have led us to presume that Recorde might have had in mind any of Stifel’s works. It is highly interesting that Stifel in his turn had studied the works of the Italian mathematician Luca Pacioli.

Johann Scheubel (1494-1580) is another contemporary ‘authority’ clearly cited in The Whetstone. The context is the definition of equation, which – in Recorde’s words - Scheubel made more complicated than it warrants. The second context of citation is a few pages further on; it is the identification of the varieties of equations, in which the reader «maie perceiue, how thei bee conteined in those .2. formes, named by me». (The Whetstone, F.iii)

Authoritative studies by historians of mathematics have proved that Stifel and Scheubel were Recorde’s main references. Yet, the issue of which of the two writers was his major source is still a subject of some controversy. Karpinski (1912-1913) claims it was Stifel; Hughes (1993: 171) disagrees with this position and holds that Scheubel’s Arithmeticae Compendiosa was the text closest to Recorde’s hand as he wrote The Whetstone on the basis of strong structural similarities between the two texts:

There are strong similarities between Recorde’s and Scheubel’s respective treatises on algebra. Both begin with the same presentation: the meaning of the symbols for what we call variables […], and they use the same symbols. Karpinski cites Stifel as the source of the symbols. Since Recorde uses so much of Scheubel’s text farther on, I prefer to think that he referred to this text while preparing these pages. The similarities between the two texts continue. Both authors discuss
how to add and subtract, multiply and divide algebraic statements [...].

Yet, the symbols used by Recorde (fig. 2) had been understood by continental mathematicians beginning a hundred years before, as Adam Riese himself remarked: «zeichen ader benennung Di in gemeinen brach teglich gehandelt werden» (fig. 3).

Figure 2- Examples of algebraic notation in The Whetstone of Witte (1557).
As for the examples and terminology, however, Hughes (193: 170) acknowledges some differences:

The examples, however, are not the same, and Recorde makes a better presentation. He continues to use the symbols he had explained, while Scheubel employs collateral terminology for the unknowns (e.g., $x$ is *prima*, $x'$ is *secunda* and so on).

Indeed, our analysis of Recorde’s and Stifel’s respective treatises on algebra has brought to light some similarities as far as terminology is concerned. Hence, we prefer to think that both Scheubel and Stifel equally contributed to *The Whetstone* (Piotti 2005): Scheubel influenced the structure, Stifel influenced the terminology: beside Boethius, Recorde borrowed some of his terminology from Stifel too. Besides the two German authors, however, there may have been other sources which are not cited; as already mentioned, our comparison of texts has also pointed to some contribution from Rudolf’s *Die Coss*. It is indeed highly interesting that Stifel devoted himself to the 1553 edition of Rudolf’s *Die Coss.*
2.3.3 English vernacular sources

In several passages Recorde argues the need to write on science in English, both for the widespread dissemination of learning and also on the grounds that some of his contemporaries have used English in their works. Yet, the titles and names of these books and scholars remain unknown. As regards arithmetic, he acknowledges he was not the first to write a treatise in English: he may have been referring either to the first Arithmetic printed in English in 1537 or to other sources.

3. The mechanisms of language change in The Whetstone of Witte: A taxonomy

Recorde’s several linguistic comments throughout The Whetstone reveal that he was well aware of the difficulties involved in writing on science in a language that had no vernacular tradition in the field, in particular as regards technical terms. This is clearly reflected in the author’s exploitation of the whole range of mechanisms of language change commonly used in Early Modern English, ranging from borrowing to word-formation processes on foreign and native bases, to synonymy, sense restrictions and semantic loans (Piotti 2005). All the items discussed in the present study first appeared in the English language in The Whetstone of Witte. Some have survived, others have disappeared.

In this section, the mechanisms exploited in The Whetstone of Witte will be identified and classified according to the traditional classification of lexical change, which is often restricted to the semasiology-onomasiology divide (Table 1).
Table 1 - Mechanisms of lexical change according to the strict distinction between the semasiological and onomasiological approaches.
(Adapted from Geeraerts 1997: 94)

<table>
<thead>
<tr>
<th>Onomasiological changes</th>
<th>Semasiological changes of denotational meaning</th>
<th>Semasiological changes of non-denotational meaning (any type of non-referential meaning)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Word-formation</td>
<td>Independent changes</td>
<td>Inter alia</td>
</tr>
<tr>
<td>Deformation (i.e. ellipsis, blending, etc.)</td>
<td>Specialization</td>
<td>Pejorative change</td>
</tr>
<tr>
<td>Borrowing</td>
<td>Generalization</td>
<td>Ameliorative change</td>
</tr>
<tr>
<td>Word creation (i.e. onomatopoeia, brand names, etc.)</td>
<td>Metonymy</td>
<td></td>
</tr>
<tr>
<td>Semasiological extension of existing expressions</td>
<td>Metaphor</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Analogue changes</td>
<td></td>
</tr>
</tbody>
</table>

3.1 Onomasiological changes

The mechanisms of onomasiological change in The Whetstone, which include borrowing, loan translations, synonymy, word-formation, and ‘renaming’, are summarized in Table 2.

Table 2 - An overview of the mechanisms of lexical change in The Whetstone of Witte according to the strict distinction between the semasiological and onomasiological approaches

<table>
<thead>
<tr>
<th>Perspective</th>
<th>Mechanism of linguistic innovation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Onomasiological changes</td>
<td>Borrowing</td>
</tr>
<tr>
<td></td>
<td>Word-formation</td>
</tr>
<tr>
<td></td>
<td>Loan translations</td>
</tr>
<tr>
<td></td>
<td>Synonymy</td>
</tr>
<tr>
<td>Semasiological changes</td>
<td>Sense restrictions</td>
</tr>
<tr>
<td></td>
<td>Semantic loans</td>
</tr>
</tbody>
</table>
3.1.1 Borrowing

The borrowing process is the mechanism of language change most extensively used in *The Whetstone*. Almost all the loanwords are from Latin (*MULTIPLEX*, *SUPERPARTICULAR*, *SUPERPARTIENS*, *SURDE*, etc.), whose influence is also evident in the etymologising alterations of some modern terms (*BINOMIALLE*, *RESIDUALLE*). Some Latin loanwords show the influence of French morphology on the derivational endings (*INCOMMENSURABLE*, *COMMUNICANTE*, *ABSOLUTE*, *ABSTRACTE*, *CONTRACTE*, *RELATIVE*). A few loanwords are from German (*ZENIKE*, *CUBIKE*, *COSSIKE*, etc.), only one item, *COSE*, is from Italian.

3.1.2 Loan translations

Loan translations can be grouped into two main categories: noun phrases whose head is *MORE*, which are calqued on the Latin *sesqui-* ‘a half more’ series (*A QUARTER MORE* calqued on Lat. *sesquiquarta*, *A TWELVEETH MORE* calqued on Lat. *sesquiduodecima*, etc.) (fig. 4); derivatives in –*FOLDE*, which are calqued on the Latin *–plus* (–*a*, –*um*) series (*OWERFOLDE*, calqued on Latin *quadrupla* or French *quadruple*; *TINNEFOLDE*, calqued on Latin *decupla*, etc.). (fig. 5).

*Figure 4* - «Kinds of proportion of the greater inequality» (The Whetstone of Witte B.iii.).
3.1.3 Synonymy and renaming

Recorde often adapts well-known concepts of arithmetic to geometry and algebra and renames them by means of new lexical items (mainly of German origin), on the grounds that only these new names can explain either the geometric or algebraic nature of such concepts. This process generates several pairs of synonyms, where names commonly used at the time in the works of continental and English mathematicians are used alongside the author’s new ones. Here follow some examples, which refer to the geometric nature of numbers: **BODILY** ‘(said of) numbers which give
birth to a solid in their geometric projection’ (The Whetstone) :: SOLIDE (The Art of Nombrayng 1430); SQUARE ‘pertaining to numbers that generate a square in their geometric projection’ (The Whetstone) :: QUADRAT (The Art of Nombrayng 1430); FLATTE ‘(said of) numbers corresponding to plane surfaces’ (The Whetstone) :: SUPERFICIALLE (John of Trevisa 1398). Some of those new names denote «rooted numbers»: they refer to the algebraic nature of numbers and consist in recursive combinations of SQUARES and CUBES often preceded by LONGE, to refer to rooted numbers: LONGE CUBES (The Whetstone) :: SQUARES OF SQUARES; SQUARES OF CUBES (The Whetstone) :: SURSOLIDES; LONGE CUBIKE CUBES (The Whetstone) :: SECONDE SURSOLIDES; etc. (fig. 6).

Figure 6 - «The table of rooted numbers» (The Whetstone of Witte D.i).
3.1.4 Word formation processes: suffixation and ellipsis

Word-formation is second only to loanwords as a mechanism of linguistic innovation in *The Whetstone*. This process mainly generates derivatives by means of suffixation and ellipsis.

Suffixation accounts for a small number of new words, which are all coined on loans, either from Latin or from vernacular languages, by means of native suffixes. These words include the adverbs *squa-re-ly, co-si-ke-ly, cu-bi-ke-ly*, the adjective *see-angel-ic*, and the two abstract nouns *commensurable-ness* and *incommensurable-ness*.

Unlike suffixation, ellipsis makes a substantial contribution to language change and accounts for deadjectival nouns from several noun phrases whose head is *nombers* (*binomiales < binomialle nombers; residualles < residualle nombers; squares < square nombers; zenzikes < zenzike nombers*, etc.) (Piotti 2005: 138-141):

- Binomialle number(s) ⇒ binomialle(s)
- residualle number(s) ⇒ residualle(s)
- square number(s) ⇒ square(s)
- surde number(s) ⇒ surde(s)
- sursolides number(s) ⇒ sursolide(s)
- zenzike number(s) ⇒ zenzike(s)
- zenzizenzike number(s) ⇒ zenzike(s)
- zenzicubike number(s) ⇒ zenzicubike(s)
- zenzizenzicubike number(s) ⇒ zenzizenzicubike(s).

Apart from *binomialle* and *residualle*, all the adjectives that qualify *nombers* also specify the head noun *roote*. Yet, no elliptical uses have been found for adjectival phrases whose head is the word *roote*:

- square roote(s) ⇒ *square(s)
- surde roote(s) ⇒ *surde(s)
- sursolides roote(s) ⇒ *sursolide(s)
- zenzike roote(s) ⇒ *zenzike(s)
- zenzizenzike roote(s) ⇒ *zenzike(s)
- zenzicubike roote(s) ⇒ *zenzicubike(s)
- zenzizenzicubike roote(s) ⇒ *zenzizenzicubike(s).

The fact that in *Reorde* ellipsis only occurs in noun phrases whose head is *nomber(s)* may suggest an attitude of familiarity to the referent (Piotti 2005). Therefore, the omitted sign could be easily recovered because the reader could easily associate it with its source due to linguistic and
pragmatic contexts. Hence, in *The Whetstone* ellipsis is a regular word-
formation process which is semantically and lexically conditioned.

### 3.2 Semasiological changes

The mechanisms of semasiological change in *The Whetstone* include
sense restriction alongside semantic loans. Such changes consist in new
concepts through the intermediary of existing ones, new concepts seen as
variations on either known or more general ones, that do not call for overall
changes in the conceptual organization of a language (Piotti 2005).

#### 3.2.1 Sense restriction

Under this category the adjectives *COMPOUNDE* and *UNCOMPOUNDED*
can be included. These adjectives had been in use in arithmetic since the early
XV century to refer to either ‘prime numbers’ or ‘numbers compounded of a
multiple of ten and a digit’ (*The Crafte of Nombrynge* XV century);
Recorde uses these adjectives to refer to ‘numbers obtained by
multiplication of two numbers’ (*The Whetstone* 1557).

#### 3.2.2 Semantic loans

Under this category several adjectives of both Latin/French, Anglo-
Saxon and German origin can be included (*ABSTRACTE*, *SOUNDE*, *FLATTE*,
*RELATIVE*, *BODILY*, etc.). One example is represented by the adjective
*ABSTRACTE*: since the 14th c. it had been used in logic with the meaning of
‘separated from material embodiment’; Recorde (*The Whetstone*) used it to
refer to numbers ‘which are free from any denomination’ on Latin
*abstractus* (the arithmetical meaning being calqued on Boethius).

### 4. Recorde’s functional explanations for language change in *The
Whetstone of Witte*

Absence of adequate means of expression is universally acknowledged as
the most common cause of linguistic innovation in Early Modern English,
especially as regards ‘terms of art’ (Larkey 1937; Jones 1953; Barber 1976).
In this respect, *The Whetstone* is no exception: several times Recorde openly
acknowledges that the English language lacks adequate means of expression
in the subjects he deals with in *The Whetstone*. At a concrete level, this
motivation generates two different strategies, as can be inferred from the
explicatory devices Recode uses in term-presentation. These strategies can
be referred to as ‘scholarly nicety’ and ‘didactic utility’ (Piotti 2008).
In the present study, ‘scholarly nicety’ is referred to whenever Recorde, openly recognizing his sources and acknowledging ancient and medieval authorities on the subject, feels obliged to retain their terminology to avoid criticism (Piotti 2008). This is the case of almost all Latin borrowings, which are used in the discussion and classification of numbers according to their properties; this is the area of arithmetic where the burden of scientific tradition, as the author acknowledges, is much heavier than elsewhere. ‘Didactic utility’ is referred to whenever linguistic issues emerge in *The Whetstone* in response to the Scholar’s questions about Latin terms (*The Whetstone* is a dialogue between Master and Scholar). The Master, voicing Recorde’s opinion, reformulates these terms in a variety of ways thus making them accessible (Piotti 2008).

Recorde’s overt functional explanations of linguistic innovation are summarized in the table below (Table 3). These are integrated with the interpretations that have been inferred from the author’s attitudes to term-presentation.

Table 3 - Motivations and mechanisms of linguistic innovation in *The Whetstone of Witte* according to the author’s functional explanations.

<table>
<thead>
<tr>
<th>Motivation behind linguistic innovation</th>
<th>Strategy adopted</th>
<th>Mechanism of linguistic innovation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absence of adequate means of expression</td>
<td>Scholarly nicety</td>
<td>Borrowing</td>
</tr>
</tbody>
</table>
| Absence of adequate means of expression | Didactic utility           | Loan translations
                |                           | Word-formation
                |                           | Renaming
                |                           | Semasiological change      |

5. A modern functional approach to language change in *The Whetstone of Witte*

Recorde’s explanations of linguistic innovation can be brought together into a functional cognitive perspective, which can offer a new insight into the explanation and classification of lexical-semantic change in *The Whetstone of Witte*. Central to this perspective are two different types of strategies or principles, which appear to embody «in a particularly clear fashion the principle of conceptual economy and cognitive efficiency» (Geeraerts 1983: 227): these strategies include ‘principles of efficiency’ (typically speaker-oriented) and ‘expressive mechanisms’ (typically hearer-
oriented). Both strategies contribute, on a concrete level, to the ‘efficiency of communication’, which is the general purpose of communication and one of the major principles guiding language change and corresponds to the speaker’s communicative and expressive need (Blank 1997, 1999; Geeraerts 1983, 1986, 1997).

It is true, of course, that avoiding paraphrases or complex words and creating metaphors, metonymies or ellipses instead is efficient […], in this case, the efficiency operates on a more concrete level, and it is indeed a linguistic strategy speakers adopt more or less willingly. On the same level, expressivity is also a strategy that speakers can adopt for optimizing their communicative success when they want to impress their interlocutors, treat him or her gently, manifest emotions, show things under a different light, etc; in short, when they want to come out on top. Both strategies then contribute in their specific manner to the general efficiency of communication and of language change. (Blank 1999: 65)

These strategies contribute to maximize success in communication by either reducing or increasing linguistic effort from the part of either interlocutor (Langacker 1977; Kemmer 1992, Blank 1997; Blank-Koch 1999). These strategies are to be understood as the speaker’s specific motivations and sufficient conditions for language change, which trigger specific mechanisms of innovation. These mechanisms, in turn, derive either from the speaker’s perception of the world and his or her way of structuring concepts or from the structure and form of the speaker’s language lexicon. Each strategy can relate both to the conceptual aspects of language and to its stylistic and formal aspects at the same time, thus allowing for overlapping sets of onomasiological and semasiological mechanisms rather than two clearly distinct types of phenomena (Table 4).
With regard to *The Whetstone of Witte*, the mechanisms of lexical change exploited by the author are the result of the interplay between the principle of conceptual economy and the principle of cognitive efficiency as the primary functional factor of innovation. Among the primary functional factors of language innovation in *The Whetstone* are expressive factors on the level of cognitive content (or conceptual expressivity) embodied by borrowing, semantic changes, loan words and regular processes of word-formation. What distinguishes semantic changes from loan words and regular processes of word-formation is what we now call the principle of «conceptual efficiency» principle (Geeraerts 1986) as a secondary or subsidiary factor of linguistic innovation (Table 4). This principle refers to the meanings that can be easily reached by starting from the original meaning of the word in question either through associative mechanisms or through restrictions or generalisations on the new meaning.

Yet, not all semantic and lexical changes in the *Whetstone* are due to conceptual expressivity as the primary factor. Formal expressivity seems to be the primary cause of semantic change for the adjectives *bodily*, *sound*, *square* and *flatte*. They do not introduce new concepts: apart from *square*, they all represent native variants to established terms derived from Latin, which had already been used in the English language for mathematical

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**Table 4 - A modern functional explanation of lexical change**
(Adapted from Geeraerts 1983: 234)

<table>
<thead>
<tr>
<th>Expressive factors</th>
<th>Principles of efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>On the level of (cognitive or emotive) content</strong></td>
<td></td>
</tr>
<tr>
<td>Introducing new concepts expressing</td>
<td>Prototypical transfers, more particularly</td>
</tr>
<tr>
<td>– objective changes in the world (cognitive content)</td>
<td>– metaphor (similarity relations)</td>
</tr>
<tr>
<td>– subjective changes in one’s knowledge of/attitude towards the world (emotive content)</td>
<td>– metonymy (contiguity relations)</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>On the formal level</strong></td>
<td>a. “One form, one meaning” (avoiding homonymic clashes)</td>
</tr>
<tr>
<td>Introducing new word forms with social or stylistical (<em>sic</em>) expressive value</td>
<td>b. Economy of expression (ellipsis)</td>
</tr>
<tr>
<td></td>
<td>c. Transparency (popular etymology)</td>
</tr>
</tbody>
</table>
purposes before Recorde. Accordingly, they give birth to the following synonyms: bodily :: solide; cube :: cubike; sounde :: solide; square :: quadrate; flatte :: superficiale. Conceptual efficiency is once again the secondary cause of lexical-semantic change.

Recorde’s motivations, mechanisms and strategies of language change are summarized in the table below.

Table 5 - Motivations, strategies and mechanisms of language innovation in The Whetstone in a cognitive perspective

<table>
<thead>
<tr>
<th>General motivation behind linguistic innovation</th>
<th>Specific motivation for concrete innovation</th>
<th>Mechanism of linguistic innovation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency of communication</td>
<td>Expressivity (hearer-oriented: optimization of perception)</td>
<td>Borrowing (MULTIPLEX, SUPERPARTICULAR, SUPERPARTIENS, SURD; INCOMMENSURABLE, COMMUNICANTE; ZENZIKE, CUBIKE, COSSIKE; COSE)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Suffixation (COMMENSURABLENESS; INCOMMENSURABLENESS; SISEANGLED, SQUAREDLY, COSSIKELY, CUBIKELY,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Loan translations (A QUARTER MORE, A TWELUETH MORE, etc.; FOWERFOLDE, TINNEFOLDE, etc.)</td>
</tr>
<tr>
<td>Efficiency of communication</td>
<td>Efficiency (speaker-oriented: optimization of production)</td>
<td>Ellipsis (BINOMIALLES; RESIDUALLES; SQUARES; ZENZIKES)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sense restrictions (COMPOUNDE; UNCOMPONDE)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Semantic loans (ABSTRACTE; SOUNDE; FLATTE; RELATIVE; BODILY)</td>
</tr>
</tbody>
</table>

The specific motivations and sufficient conditions for language change in The Whetstone of Witte range from the author’s need for a new name to verbalize new concepts (borrowing, suffixation, loan translations), to the need for a new name to verbalize old concepts (renaming), to the author’s need to verbalize new and old concepts at the lowest possible costs both
from the formal and conceptual point of view (lexical ellipsis, sense restrictions, semantic loans).

6. Conclusions

The aim of this study was twofold: to offer an overview of Recorde’s contribution to the creation of the scientific vocabulary of arithmetic and algebra in the light of the 16th century English dilemma of the vocabulary of mathematical science and the setting of learning in the vernacular and to integrate this investigation into a functional perspective on the motivations and mechanisms for language change that a modern reader needs to look out for.

As regards the former, Robert Recorde may be regarded as a paradigm of a period and country –Tudor England- which were fundamental for the formation of scientific language. Long before the Royal Society and the high debate of seventeenth-century English philosophers and pedagogues about the epistemological and methodological features of science, a real ‘debate on the language of science’ is well documented in the prefaces to scientific works and the works themselves in the vernacular of sixteenth century English men of science. Their debate followed and reflected ‘old’ issues which had been raised and documented in scientific works - particularly in Italy- beginning nearly a hundred years before. Recorde’s works were not original masterpieces from the pen of an original thinker; yet,

standing appreciatively and critically on the shoulders of the earlier natural philosophers, and approaching his contemporaries in the same way, this worldly scholar was able to bridge the gap between the university and the craftsman through his skillful (sic) use of the vernacular [...]. This not inconsiderable achievement is one of Recorde’s most important contributions to the historical development of science (Kaplan 1960: 179-180).

As for the mechanisms and motivations for language change, the preliminary findings of the analysis carried out in the present study seem to confirm the need to integrate the descriptive approach of traditional historical linguistics into the pragmatic assumptions of cognitive semantics. The fourfold division of language change advanced by recent functional cognitive approaches (Table 4) is not a classification of language change as such; it is a classification of the factors at work in language change at any time.
It is a functional classification, first because it is based on principles connected with the communicative purpose of language and the way it tries to achieve this goal, and second because it goes beyond a mere taxonomical approach and analyses how language change comes about. In this genetic, factorial analysis of language changes not all of the four principles have the same value: primary and secondary causes have to be distinguished. (Geeraerts 1983: 237)

The assumptions of cognitive semantics, in turn, confirm the tripartite typology of motivations of language change elaborated by Coseriu (1958), whereby:

There is, on one side, a particular situative motivation for an individual to risk a semantic innovation; on the other side, innovation is generally motivated by the wish to communicate as efficiently as possible, i.e. to influence the interlocutor in the desired manner and to do this at the least possible expense. Finally, one finds that the individual motivations can be grouped into [...] types of general motivations or sufficient conditions for semantic innovation [...] These conditions derive either from our perception of the world and our way of structuring our concepts or from the structure and form of one's language lexicon. The several subtypes are to be understood as more specific frameworks that trigger specific mechanisms of semantic change. (Blank 1999: 83)
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