Euclid's *Elements* in Latin, 1482–1703: vocabulary and classification

Abstract

This paper attempts an improved classification of the Latin texts of the *Elements* printed between 1482 and 1703. It uses primarily a comparison of the 114 terms defined within the text, supplemented by a comparison of the number of definitions included in each book and spot-check comparison of portions of the text and diagrams. The result is a classification into fourteen families. The process of classification permits some reflections on the degree to which the Latin Euclidean vocabulary stabilized during this period, and on the practices of the editors of these versions of the text, which prove to have been in a high proportion of cases eclectic, with definitions, enunciations, proofs and diagrams frequently based on different sources or modified idiosyncratically, even in cases where a specific model was named in the paratext.

1 Introduction

The Latin tradition of the Euclidean *Elements* in the early modern period presents the appearance of a forbidding complexity, with more than a hundred different impressions whose interrelationships are seldom clear or explicit. Anyone who has worked with these texts will be familiar with the sense of eclecticism that many of them project, but it has not so far been possible to give more than an impressionistic account of the shape of the tradition. In some cases interrelationships are stated or suggested by the paratext, or within the main text, but more often it is at least partially unclear on what sources a particular verson of the text was based. There are certainly cases in which a paratext is misleading in these respects. Because the number of texts is large and the degree of variability is high, full collation is both infeasible and likely to be ineffective as a means of characterising the interrelationships of different texts or dividing them into families.

This paper presents a new classification of the Latin versions of the *Elements* from this period, based primarily on their vocabulary choices. It examines specifically the period 1482–1703, that is from the *editio princeps* of Ratdolt to the relatively scholarly edition by Gregory. It comments on the degree of stability of different parts of that vocabulary, as well as the rate at which it stabilised over the period, the degree to which different individual editors innovated or conformed with respect to their predecessors, and the degree of uptake which their innovations (if any) enjoyed. It combines this information with the variation in proposition lists from one edition to another, and with limited collation of portions of the texts themselves, in order to attempt a classification and stemma. It explicitly aims to improve on the classificatory work presented in (Wardhaugh *et al.* 2020), which was based only on the criterion of proposition counts. The data from that catalogue have also been imported into the *Medée* catalogue of Euclidean texts (Herreman and Vitrac), which provides a fine-grained, network-type presentation in which items are handled case-by-case, and with a relatively wide criterion for inclusion. Herreman and Vitrac also provide an important discussion of the typology of dependencies between Euclidean texts. What is attempted in the present paper is intended as complementary to the approach of the *Medée* project, using precise, replicable criteria to arrive at a relatively compact characterisation of the different families of texts, and is limited to a more uniform corpus, namely printed Latin texts which were in intention editions of some part of the Euclidean text. The ultimate aim of this work is to understand better the practices of early modern Euclidean editors, and by extension of mathematical editors in this period more generally.

2 Method

2.1 Texts

A list of Latin editions was compiled based on the catalogue (Wardhaugh *et al.* 2020); included were all Latin versions of the text which are not described there as re-impressions or re-issues of a specific predecessor. Most are texts in which a given editor is named for the first time, but second or subsequent editions by the same editor are included where there is reason to believe that substantial modifications were made, such as in the important second editions of Foix, Clavius and Dechales. A total of sixty texts were included; a complete list appears in Appendix 1. In two cases it was necessary to substitute a more accessible later reimpression of (what is believed to be) substantially the same version: namely (Tacquet 1665), substituting for the original impression of 1654, and (Dechales 1675), in place of the 1660 original. One version (Porpora 1702) was excluded

from the main cycle of comparison due to the author having no access to either a copy or a complete surrogate; in fact it appears to be a reimpression of a specific predecessor, as mentioned below (section 3.4/Commandino). Another (Maurolico 1575) was excluded from the comparison of vocabulary as containing none of the books in which the terms collated are defined; its definition counts and text were examined in the other ways described below.

2.2 Geometrical terms

Across these versions of the text, this study collated 114 vocabulary items introduced in books I–VII, X and XI. The list of terms follows that of (Wardhaugh 2024a): it includes all terms introduced in a portion of the text labelled a 'definition', as well as certain terms defined in the enunciations to propositions, namely those for classes of irrational line in book X. (It excludes structural terms such as 'proposition', 'theorem' and so on.) Duplicate appearances of the same term are generally avoided: 'even' and 'odd' (def. 7.6, 7.7) are included, for instance, but not 'evenly even' and 'evenly odd' (def. 7.8–7.10), definitions in which no new term is introduced. Terms defined more than once, such as 'centre' or 'cube' are included only once. Attention was paid, however, to the fact that in some cases the same Greek term is rendered differently in different contexts by some editors: πέρατα is the most important example, defined twice in book I and once in book XI (def. 1.3, 1.6, 11.2), sometimes translated using two or three different words (as in English: *ends*, *edges*, *faces*). All three appearances are included. A few additional terms are included, commonly defined in the early modern texts though not in the Greek text established by Heiberg (Heiberg/Stamatēs 1969–77): *ordinata proportio* in book V, ἀντιπεπονθώς [reciprocally related] and πελικότης ['size' of a ratio] in book VI, and τετράεδρον [tetrahedron] and στερεός παραλληλεπίπεδος [parallelepipedal solid] in book XI. A full list of the terms collated appears in Appendix 2. The numbering of definitions varies widely from one version of the text to others (and in some it is absent); in what follows, definition numbers are those of the Greek text of Heiberg.

The vocabulary items show superficially a complex pattern, with minor differences certainly the norm even between editions known to be closely related. It was evident, however, that a richer picture of relationships between editions could be derived from this set of data. After initial collation and checking, a normalized version of the vocabulary lists was prepared, with the intention of discarding (a) differences of spelling, punctuation, capitalization or abbreviation; (b) differences in the number and case of nouns and adjectives, or in the person, number, tense and voice of verbs resulting from changes of phrasing. The first of these criteria is easily applied; the second involves the exercise of some judgement. Zamberti's innovation *dimetiens*, for instance, was included as a distinct choice, not conflated

with *diameter*, despite being arguably no more than a different expression of the same verbal root. Similarly *ex aequalitate*, *ex aequo* and *ex aequali* were taken to be distinct renderings of δι᾽ ἴσου (def. 5.17); and *duplicata*, *dupla*, *duplo maiorem* and *duplex* of διπλάσιος (5.9).

Inevitably some information about the relationships between editions was lost during this process, since it is quite posible that an idiosyncratic choice of spelling or the decision to word a particular definition in the plural or the passive was in fact a mark of relationship between two versions of the text. The intention, however, was deliberately to achieve the highest possible degree of agreement between texts, so as to make salient those cases where editors differed as to the actual lexemes to be employed.

Once the terms had been normalized, innovative vocabulary choices were identified in each edition and distinct lexemes were counted for each Euclidean term. This made it possible to interrogate the data in a preliminary way, calculating the frequency with which each individual editor introduced novel vocabulary items, and the frequency with which each individual Greek term received a novel Latin rendering.

In pursuit of the main purpose of this paper – the classification of editions – for each pair of texts the degree of vocabulary agreement was calculated: specifically, the proportion of the later text's (normalized) terms that agreed with those of the earlier text. (This was carried out automatically using a custom VBA macro within Microsoft Excel.) To the resulting grid, listing the degrees of vocabulary agreement for 1,596 pairs of Euclidean texts, various forms of conditional colouring were successively applied in order to render salient the features of the data that were of interest.

This exercise made it clear that some editions elicited vocabulary agreement from their successors frequently, but others hardly at all; and similarly that some editions were in agreement with a high proportion of their predecessors, others with rather fewer. Both of these observations were quantified, by averaging the calculated degrees of agreement respectively across the successors and the predecessors of each edition.

Next, after some experimentation, a criterion of 95% agreement was chosen to distinguish the closely related from the less closely. For each edition, those successors matching this well or better were listed, and this information forms the basis of the discussion of edition families in Section 3 below. A new table of vocabulary items was prepared, with the texts arranged into these families. For each term, it was determined (again using a custom macro) whether or not it varied within each family; for each family the number of terms showing variation was determined. Terms diverging from the norm represented by the 'head' member of each family were highlighted.

2.3 Propositions

This study also recorded, for each text, the number of propositions included in each Euclidean book (including the spurious books XIV and XV, and the additional books XVI–XVIII published by Foix in 1566 and 1578). Certain cases described in their paratexts – or obviously intended – as abridgements, such as the selections from books XI and XII in (Grienberger 1629), were excluded. These data were added to the table of vocabulary items as arranged into families of editions, and handled in a similar way: for each book it was recorded whether its length showed any variation within each family; and divergences from the norm represented by the head of the family were noted.

2.4 Collation

Finally, spot-check comparison of pairs of texts was carried out. The leading member of each family was compared with the leading member of each earlier family (if any), to check for the possibility of a closer relationship than could be detected by comparing vocabulary and proposition counts. In fact no such relationship was found to exist. And within each family, each subsequent member was compared with the leading member, in order to detect cases where a version was either a close copy of a predecessor, or indeed more divergent than the comparison of vocabulary and proposition counts had suggested. Within the larger families it proved useful to compare certain other pairs of texts in order to establish relationships.

The collation consisted of the first five definitions and the first proposition (enunciation and proof) in which the pair of texts in question overlapped (if any). For texts with no proofs, the first five enunciations were collated. The letter labels in Proposition 1.1 (when present) were also collated. Variation in the form of diagrams is likely to be at least partially independent of variation in the text, but the two are of course linked through frequent reference to letter labels within the text. Variation in the labelling of diagrams proves in practice to be a useful tool for separating and relating texts within families and pointing up relationships between famiiles.

It is acknowledged – indeed, emphasised – that such a very limited collation is primarily of use for the negative results it provides: that certain texts are not close copies of one another. Conversely, this method carries the risk of generating false positive results, where two texts are reported as identical but in fact diverge outside the portion of the text collated. Nevertheless, the intention of this study was to balance feasibility with comprehensiveness in the pairwise comparison of this fairly large set of texts.

3 Results

The data produced during this study are available online at [***].

3.1 Vocabulary innovation and stabilization

Of the 58 texts collated, 23 (after Campanus) introduced one or more terms unknown to their predecessors. Those texts are listed in Table 1. That of Zamberti (1505) is unexpectedly the leader, with 48 new terms (44% of those he uses) in his fresh translation from the Greek: his text was deliberately, and rather sharply, different from the medieval Latin version of Campanus that had been printed in 1482 (in fact, there was heavy dependence on the *De expetendis* of Valla, a work which falls outside the scope of the present study). Second is the Rhäticus/Camerarius edition of 1549 with 32 (43%). No other editor introduced more than nine. The innovations range from later staples of Euclidean vocabulary such as *tetraedron* (Magnienus 1557) and *parallelepipedum* (Clavius 1574) to unsuccessful attempts such as *hexaedrum* for *cubus* (Richard 1645) or *certa* for *rationalis* (Foix 1566).

The willingness of editors to continue innovating well into the seventeenth century, together with the fact that some innovations were markedly more successful than others, makes it difficult to estimate from Table 1 whether the Euclidean vocabulary was in fact stabilizing during this period. Moreover, with so many editions (34) showing no innovation, it is not clear that a rank correlation between order of publication and number of innovations is meaningful. Better is a look at the number of Greek terms whose Latin translation was the subject of any difference of opinion during a given time frame. Breaking the texts down into groups of ten by publication date gives the results shown in Table 2 (the final two groups are allowed to overlap in order to achieve a constant size of group).

The number of disputed terms does not show a monotonic downward trend, but it is clear that it decreased over the period, and it shows a strong negative correlation with the date of publication: $\rho_s = -0.71$. That said, however, an important feature of these data is that nearly a third of the terms investigated were still subject to variation in the final three decades of the period.

It should be acknowledged, though, that these groups of ten are problematic units for analysis, since each contains some texts certainly related to one another as well as some likely to be at least partially independent. A better assessment will result, below, from grouping the texts into families of actually related editions.

Before moving on to that exercise, it is worth remarking on how the disputed terms are distributed among the different parts of the Euclidean text. Table 3 shows a breakdown by topic areas.

The overall average is that two thirds of terms are disputed. Ratio theory and solid geometry stand out with distinctly higher levels of dispute, number

Text	Number of new terms
Zamberti 1505	48
Rhäticus and Camerarius 1549	32
Magnienus and Gracilis 1557	9
Dasypodius 1564	8
Foix 1566	7
Tacquet 1654/1665	7
Rhodius 1609	5
Commandino 1572	4
Scheybl 1550	3
Dasypodius and Herlinus 1566	3
Briggs 1620	3
Herlinus 1537 (Zamberti section)	2
de Mondoré 1552	2
Peletier 1557	2
d'Étaples 1516 (Campanus section)	1
Ramus 1545	1
Nabod 1556	1
Dasypodius 1570	1
Clavius 1574	1
Montensis 1620	1
Grienberger 1629	1
Richard 1645	1
Gregory 1703	1

Table 1: Editors' introduction of new terms

theory as much lower. Plane geometry and – perhaps surprisingly – the theory of irrational magnitudes come out around the average. (The special case of Book II is discussed in depth by (Corry 2022), with attention to British versions of the text in particular.)

Disputed terms range from cases with just two choices (and one of those perhaps in a small minority) to some with six or seven. Thus ἑτερομήκης [oblong] (def. 1.22) was rendered into Latin in seven different ways, πέρας [extremity] (def. 1.3) in six, βαίνω [stand upon] (def. 3.9) and ἐναρμόζομαι [fit into] (def. 4.7) in five. The remaining terms with five or six different Latin translations are all ratio terms. The set of (normalized) Latin translations for each Greek term is given in Appendix 2.

Group	Disputed terms
1482–1537	52
1545–1566	57
1566–1609	57
1610–1643	31
1644–1674	34
1673–1703	31

Table 2: Stabilization of the vocabulary

3.2 Proposition counts

Certain books show no, or essentially no variation in their proposition count in the texts compared here (re-ordering or indeed substitution that does not affect the overall count is neglected in what follows). Book I always has 48 propositions. Book II always has 14, book IV 16 and book XIII 18.

Several books, by contrast, gained one, two or three propositions in the text of Zamberti as compared with that of Campanus. Specifically: book III (36/37 propositions), book VI (32/33), book VII (39/41), book VIII (25/27) and book XII (15/18). Certain books show the opposite situation, with extensions in Campanus not found in the Greek texts or in Zamberti's translation from them: book IX (39/36 propositions) and book XI (41/40). In each of these cases, Zamberti's lead was often followed by later editors, with the notable exception of Foix.

Two books present more complex situations. Book V has 34 propositions in Campanus, against just 25 in Zamberti. Later editors were evidently hesitant to exclude so much material that had previously appeared as part of the printed tradition of the *Elements*. Of 49 texts subsequent to Zamberti, 32 gave a longer – thus, broadly Campanine – version of the book, with 33, 34 or 35 propositions. Some marked the propositions after the twenty-fifth as an appendix.

Book X, conversely, takes a shorter form in Campanus (107 propositions) and a longer in Zamberti (118). Versions up to the mid-sixteenth century chose between those two options, but Mondoré's 1552 edition of book X alone contained 116 propositions; editors up to 1570 followed him, but Commandino (1572) gave 117 and all subsequent versions of the book followed his lead.

The spurious books – XIV and XV – existed in very different versions in the Campanine and Greek traditions, and the later editorial tradition tended to be influenced by the relatively generous versions of Foix, Clavius and Maurolicus (for the Greek tradition of these books see Vitrac and Djebbar 2011–12). Several editors explicitly stated that they had included propositions from more than one tradition. Thus, book XIV has 18 propositions in Campanus but just 4 in

Topic	Terms	Disputed	Disputed (%)
Plane geometry (I–V, V)	58	39	67
Ratio (V)	21	18	86
Number theory (VII)	8	1	13
Irrational lines (X)	11	7	64
Solid geometry (XI)	16	13	81
Total	114	78	68

Table 3: Disputed terms, by topic area

Zamberti. Foix restored 20, Clavius 32 and Maurolicus 39; there are subsequent texts with 7, 8, 27, and even (explicitly a conflation) 47. Similarly in book XV, Campanus has 13 propositions but Zamberti only 5. Foix and Clavius included 21 propositions, Maurolicus 13; later editors to the end of the seventeenth century followed either Zamberti or Foix/Clavius, but Gregory in 1703 reopened the question by including 7.

Finally, the additional books provided by Foix in 1566 and 1578 have a slightly more complex history than might be expected (see further Wardhaugh 2024b). Books XVII and XVIII have respectively 28 and 45 propositions in all of their appearances (namely in 1578, 1626 and 1644). Book XVI, however, was first published in 1566 with 37 propositions, extended in Foix's own second edition of 1578 to 46 (followed at that length by Mersenne's texts of 1626 and 1644); but Clavius had meanwhile (in 1574) shortened it to 31, and there were subsequent appearances at that length in 1589 and 1645. Beyond the scope of this paper, book XVI makes appearances at various lengths in several vernacular languages down to the middle of the eighteenth century.

The upshot is that exact matches with respect to proposition count are in the minority (just under 25% of all pairs of texts), and such agreement can be taken as at least confirmatory evidence for a relationship between two texts. It will be clear from what has been said that the prominent innovators with respect to proposition counts were editors whose names are well known to scholars of early modern Euclideanism: Zamberti (new proposition counts in 11 books), Foix (5, setting aside his own additional books), Commandino (3) and Maurolicus (2). Beyond these four, innovation with respect to just one book is found in Mondoré (1552), Clavius (1574), Rhodius (1609), Mersenne (1626), Hérigone (1634) and Dechales (1660/1675).

Campanus 1482	Triangulum equilaterum supra datam lineam rectam collocare.
Zamberti 1505	Super data recta linea terminata: triangulum aequilaterum constituere.
Rhäticus and Camerarius 1549	Super data recta finita, triangulum aequalium laterum contituendum est.
Scheybl 1550	Super data recta linea terminata, triangulum aequilaterum constituere.
Peletier 1557	Super data recta linea, Triangulum aequilaterum constituere.
Magnienus and Gracilis 1557	Super data recta linea terminata, triangulum aequilaterum constituere.
Dasypodius 1564	Super data linea recta finita, triangulum aequilaterum constituere.
Foix 1566	Super data recta linea terminata, triangulum aequilaterum constituere.
Commandino 1572	In data recta linea terminata, triangulum aequilaterum constituere.
Briggs 1620	Super data rectam finitam, triangulum aequilaterum constituere.
Montensis 1620	Super data recta linea terminata triangulum aequilaterum constituere.
Tacquet 1654/1665	Super data recta (AB) triangulum aequilaterum constituere.
Oxford 1703	Super datam rectam terminatam, triangulum aequilaterum constituere.

Table 4: Proposition 1.1 in various versions.

3.3 Text collation and diagram labels

It might have been expected that the collation of even a small portion of the texts would enable a still more fine-grained assessment of the degree of relationship between them. In fact it does not, but instead reveals rather starkly how ineffective collation is likely to be for understanding the complex tangle of relationships which unite these texts. Table 4 gives the Latin versions of Prop. 1.1 (enunciation) in the thirteen 'family-leading' texts which possess it: four of which prove to have effectively identical wording to Zamberti's. The norm, as illustrated here, is that any pair of non-Campanine texts run parallel for a few words or even a whole sentence, then diverge, then run parallel again, in a pattern which makes the assessment of similarity and difference a hopeless task. It seems quite obvious that evidence of this kind cannot distinguish re-translation of the Greek from paraphrase of a Latin predecessor or predecessors, still less that it can identify with confidence which Latin predecessors might have been used.

On the other hand, collation of texts within the same family does prove to be a helpful tool for identifying cases in which the texts are identical or very nearly so. These are not always clearly flagged as reimpressions in their paratext, and a close similarity is not always visually obvious if the pagination is very different or if commentary (or proofs) have been added or removed. Cases of match or near-match in this sense are noted below, and constitute a small but significant addition to the picture of interrelationship between the texts studied. Conversely, quite a high proportion of texts identified as using the same vocabulary as a given predecessor turn out not to be reimpressions of the same text, because some combination of definitions, enunciations and proofs have been rewritten. Such cases, for the reasons just mentioned, can only be reported as non-matches; it seems impossible to distinguish paraphrase from re-translation, or to identify sources with any specificity. Table 5 shows, as an illustration, the first sentence of the proof of proposition 1.1 in the 11 distinct texts of the Clavian tradition (excluding the

Clavius 1574/1589/Anon. 1684	Sit igitur proposita recta linea terminata AB, super quam constituere iubemur triangulum æquilaterum. Centro A, & interuallo rectæ AB, describatur circulus CBD:
Dybvad 1603	Data sit BD è cuius puncto B, interuallo BD circulus desribatur *per 3. post.*
Rhodius 1609	Intervallo *ab* ex *a* & *b* describantur duo circuli
Doino 1628/Anon. 1644	Sit data recta linea terminata AB, super quam construere iubemur triangulum aequilaterum. facto centro in A, ad interuallum AB, describatur circulus CBD,
Grienberger 1629	Centro A, interuallo AB, describatur per 3. postul. circulus CBD
Fournier 1643/Melder 1673	Ex centris A. & B. spatio AB, describe duos circulos
Richard 1645	Data sit recta AB terminata, super qua describendum sit triangulum æquilaterum, vel isosceles vel scalenum. ... Centro A, extremo rectæ AB datæ, & interuallo ipsious rectæ AB describatur circumferentia circuli:
Barrow 1655	Centris A & B, eodem intervallo AB, vel BA describe duos circulos
Schott 1661	Sit data recta linea terminata AB, super qua oporteat constituere triangulum æquilaterum, cujus unum latus sit linea data. Centro A, intervallo AB, describatur circulus CBD, *per 3. Pet.*
Coetsius 1691	Centro A radio AB, describe circulum BCE.
Astorinus 1691	Ex A per B, & ex B per A ducantur *3. Post.* duo circuli

Table 5: Proposition 1.1 in the Clavian versions.

symbolic presentation of Hérigone).

The collation of letter labels, finally, proves to be a useful tool for confirming similarity and difference between the different families of texts. Nine different combinations of labels were used in proposition 1.1: the editions introducing a new set were Campanus 1482, Zamberti 1505, Herlinus 1537, Tacquet 1654, Peletier 1557, Foix 1566, Clavius 1574, Dybvad 1603, Rhodius 1609 and Coetsius 1691. These include most of the editions identified as the heads of families on the basis of vocabulary comparison, as will be seen below: not all, however, and certain editions not innovative in respect of vocabulary or proposition count nevertheless turn out to have modified at least this diagram, sometimes drastically (as in the case of Dybvad). The important cases are discussed below.

3.4 Families of editions

Campanus. Far the easiest group to recognize both from its vocabulary and its proposition counts is that consisting of the Campanine text (15 books) printed by Ratdolt in 1482 and its descendants (on the antecedents of the Campanine text itself see Busard 2005; on variation within Ratdolt's impression Baldasso 2009 and 2013). The impression at Vicenza in 1491 by de Basilea and de Papia is a page-for-page reimpression of the text of 1482; the only change detected by this study is the substitution of *superficies equidistantibus contenta lateribus* for *superficies equidistantium laterum* in proposition 1.34. Lacher's 1506 edition (books I–IV) appears to print the same text, as does Pacioli's (1509: books I–XV); the latter adds a commentary. The 1516 edition of d'Étaples (books I–XV) prints what is

described as the text of Campanus, though there are small changes. Within the section compared, d'Étaples changes a sentence break and adds a word within the first proof (on the wider mathematical agenda of d'Étaples and his circle see Oosterhoff 2018). The 1537 edition appears to be an exact reimpression of the 1516 edition as far as the Campanine text is concerned (see below on changes introduced elsewhere). There are no differences of vocabulary or proposition count within this group, whereas the average agreement between the 1482 text and editions outside this group is just 54% in vocabulary, and non-Campanine texts typically have different proposition counts in eleven of the fifteen books. No text in this group modifies the diagram labelling.

Zamberti. Zamberti's text of 1505 (15 books) also defines a clear set of descendants. Zamberti introduced 51 new terms (45% of those he used); for terms present in both texts, the agreement of Zamberti with Campanus is just 53%. A measure of his success in introducing new Euclidean terms is that later texts outside the Campanus and Zamberti groups agree with his vocabulary choices on average 77% of the time, against (as noted) 54% for the Campanine terms.

d'Étaples' 1516 edition removed commentary sections from Zamberti's text, but made no other changes detected here; its 1537 successor substituted Greek letter labels for the original Latin ones and made two changes to vocabulary: *segmentum* for *sectio* at def. 3.6 and *coaptari* for *congruere* at def. 4.7, raising the possiblity that there are other minor changes of wording not detected here. Ramus' 1545 edition (books I–XV, without proofs or diagrams) appears to be a perfect match for the 1505 text.

Fine (1536: books I–VI), meanwhile, matches Zamberti's proposition counts and every item of his vocabulary except for *signum* (def. 1.1), for which it substitutes Campanus' *punctus*. But it is in other respects a new version of the text: definitions and enunciations remain close to Zamberti despite some substitution of inessential terms, but the proofs are new. Commentary is added to the definitions, while Zamberti's commentaries on the proofs are removed (on Fine, who had published his own commentary on the *Elements* in 1530, see Marr 2009).

Zamberti's numbers of propositions proved to match those of Grynaeus' Greek edition of the *Elements* (1533). The same appears to be true of his labelling of diagrams, subject to the transliteration from Greek into Latin, $\alpha\,\beta\,\gamma\,\delta\,\varepsilon$ becoming *a b c d e*. The proposition counts became in an important sense the standard against which later types of text should be compared. On the other hand, few subsequent texts or groups of texts derived their vocabulary straightforwardly from that of either Zamberti or Campanus, and no text outside the group of its immediate successors re-used Zamberti's text *in extenso*.

Rhäticus/Camerarius. The 1549 edition of books I–VI (enunciations only, in Latin and Greek) by Georg Joachim Rhäticus and Joachim Camerarius was

the second most innovative edition with respect to terminology after Zamberti's, introducing 33 new terms (42% of those it used) and agreeing with its predecessors only 47% of the time on average (with Campanus 40%, with Zamberti 52%). The text is unsurprisingly no match in detail for either of its main predecessors, though the letter labels, given in Greek, match those of the Greek text and thus effectively those of Zamberti.

Its innovations were little taken up: most subsequent editions agree with it scarcely more than it agrees with Zamberti (average: 55%). It has just two clear descendants. Nabod (1556: enunciations; only book I included in full) prints the same Latin text without the Greek or the diagrams. Camerarius and Steinmetz (1577: books I–VI), on the other hand, added proofs (definitions, enunciations and diagrams were unchanged): they are broadly similar to Zamberti's, but rewritten or retranslated in detail.

Scheybl. Still more isolated is the text of *Elements* I–VI by Johann Scheybl (1550). The vocabulary is substantially that of Zamberti (85%), with four innovations: *termini*, *obtusiangulum*, *acutiangulum*, *ejicere* (defs 1.3, 1.21, postulate 2), the two last later to be adopted by Commandino and several successors. The proposition counts are those of Zamberti. Definitions and enunciations are broadly similar to those of Zamberti and Rhäticus, but the proofs – which have the peculiarity of using no letter labels to refer to the accompanying diagrams – are new. This version has no close successor in terms of vocabulary.

Mondoré. Mondoré's 1552 edition of book X is another isolated case. Among the eleven terms defined in that book, it introduced novelties in relation to two: ῥηταί as an alternative for *rationales*, and ἄλογοι and *surda* as alternatives for *irrationales* (in both cases it seems to be intended that the Greek term might be adopted for regular use in Latin contexts). Otherwise its terminology was usually that of Campanus where there was any choice to be made; it followed Zamberti against Campanus only in correcting *communicantes* to *commensurabiles*. On the other hand, its proposition count (of 116) matched no predecessor for this book and the text was in detail a new translation. The proposition list would be followed by Magnienus and Gracilis (who also followed the vocabulary choices), Dasypodius (who followed most of them) and Foix (who used a combination of Zamberti's terms and his own). The many successors of Magnienus and Dasypodius (see below), however, tended not to include book X, making Mondoré's choices something of a dead end.

Peletier. Another near-isolate from this period is Peletier's 1557 edition of books I–VI. It agreed with Campanus on 67% of vocabulary choices and Zamberti on 80%, and introduced two new terms of its own: *peripheriam* and *accommodari* (defs 1.17, 4.7), both of which also appeared in the Magnienus/Gracilis edition of the same year. (It also referred to the 'parallelogrammic space' of prop. 1.34 as

a mere *parallelogrammum*.) Similarly in proposition counts it is a hybrid: books III and V match Campanus, but book VI has the 33 propositions of Zamberti. Its diagram labels are equally idiosyncratic, matching no predecessor (unlike all other non-Campanine texts it labels six points in diagram 1.1, not just three, four or five). It has only one true descendant, namely the Geneva impression of 1610 which adds Greek texts to the enunciations, definitions and common notions and makes at least minor emendations to the Latin text (among the vocabulary there are differences at defs 3.9 (*in . . . esse* replacing *consistere*) and 5.3 (*proportio* added as an alternative to *ratio*), in both cases apparently to conform to Zamberti). Proposition count and diagram labels are unchanged. No other successor exceeds 85% agreement with the vocabulary of either version of Peletier's text. (On Peletier's Euclideanism, see Axworthy 2013.)

Sthen. A final isolate from the mid-century is Sthen's (1564) edition of book VII: it contains only eight of the definitions collated here, and its vocabulary choices match both Campanus and Zamberti (the only difference among all editions in this book is the rather inessential choice of *inter se* or *adinvicem* to denote numbers 'mutually' prime or composite (def. 7.12)). The text does not seem to be a close match for any predecessor or successor.

Dasypodius. A slightly more sizeable cluster of texts begins with that of Dasypodius in 1564, which includes books I–XIII. This text should be called Zamberti-inflected, with 77% agreement (53% with Campanus); the proofs are recognisably those of the Zamberti tradition and match the lettering of the Greek text. It ranks fourth overall for the introduction of new terms: *aequicrurum*; *quadrangulum oblongum*; *constitutus esse*; *describere*; *extendere*; *areae quae aequidistantibus lineis rectis continentur*; *reversio*; *ex aequo*; *ex duabus medialibus*; *corpus solidum*; *extremitas*. It seems fair to identify this as an eclectic text; among other predecessors there is agreement of 73% with Scheybl, of 68% with Peletier, of 81% with Magnienus and Gracilis, and in book X of 82% with Mondoré. Its proposition counts are those of Zamberti, with the exception of book X which matches Mondoré's list (and where the enunciations seem often similar).

The descendants of this text are the editions of 1566, 1570 and 1599. The 1570 version matches that of 1564 except for removing the diagrams and adding books XIV–XV (with the proposition counts of Zamberti). The only change in detail detected is *quadratum oblongum* in place of *quadrangulum oblongum* at def. 1.22. The 1566 text, on the other hand, is a fairly thorough revision, by Herlin in books I and V, and the remainder by Dasypodius himself. It adds Greek to the definitions and enunciations; there are minor changes such as to the word order in proposition 1.4, and in book V six ratio-related terms are replaced: *proportio* and *analogia*, *comproportionales*, *conversa*, *anastrophe*, *confusa* (none of these are among Dasypodius's innovations), making for a 92% match overall with the vo-

cabulary of 1564. The proofs appear to be a new version, reduced in length but supplemented by a presentation using the form of syllogisms, though the labels – still in Greek – are unchanged. The 1599 text of book I only does not contain the Greek additions or the proofs or diagrams, but the Latin remainder seems to match the version of 1566.

Foix. The text of Foix (1566: books I–XVI) should be regarded as derived from the Zamberti tradition, showing a 92% agreement with the text of 1505 (and definitions and enunciations are often noticeably similar in wording); most of the remaining 8% is accounted for by the seven terms original with Foix: *alterolongius*; *duplex*; *triplex*; *permutata*; *conuersa*; *certa*; *incertae*. Proofs are his own, as is diagram labelling, which displays Foix's awareness of Greek models by adopting the order A, B, G ....

He fairly often matches Zamberti on proposition count, namely in books V, VII, VIII, and XI. In book X he matches Mondoré's vocabulary and count, though not his wording in detail. In books IX and XII he finds an extra proposition compared with Zamberti (neither has any precedent), and in book VI he is distinctly longer than any predecessor (38 propositions). His handling of the books from XIV onwards was consciously innovatory (despite, ironically, a declared intention to purge the Euclidean text of unwarranted accretions); he included 20 and 21 propositions respectively in books XIV and XV; there is no exact precedent for either, but the tendency has something in common with the more extensive versions of these books given by Campanus. Book XVI was his own composition, and had in 1566 37 propositions. In his 1578 second edition he added another proposition to book VI, rewrote his book XVI to have 46 propositions, and added books XVII and XVIII with 28 and 45. On the later trajectory of these additional books, see (Wardhaugh 2024b).

It is noticeable that despite the existence of editions agreeing in part with Foix's distinctive proposition count, no successor other than Foix's second edition of 1578 (a complete match as far as was checked) shows even as much as 85% agreement with his vocabulary: the average agreement of non-Foix successors with Foix is 79%. *Alterolongius* was not taken up at all; neither were *duplex* and *triplex* (admittedly a minor variation on the quite common choice *dupla* and *tripla*). *Permutata* and *conuersa* were taken up by Commandino and successors, but *certa* and *incerta* vanished without trace.

Commandino. The 1572 edition of Commandino (books I–XV) introduced 4 new terms (*fines* (twice); *aptari*; *ex aequali*), agreed with Zamberti (84%) rather more than Campanus (54%), and on propositions matched Zamberti except for giving 33 propositions in book V (no precedent, though clearly this is a slightly truncated version of the Campanine book V), and in book XIV giving 7 (no precedent). There is no closer match with any other predecessor, nor is there any close

identity of wording beyond a very general similarity with Zamberti. The letter labels are those of Zamberti.

It has three clear descendents, namely the 1626 and 1644 Paris editions and that of 1679 at Naples. The 1626 text (probably by Mersenne) omits the proofs and diagrams but appears to reprint the 1572 text of definitions and enunciations exactly; the only vocabulary change is the omission of Commandino's *ex aequali* as an alternative for *aequa* (def. 5.17; it originated with Magnienus). In book XIV, however, 47 propositions are given (against Commandino's 7): there is no exact precedent for this, but Maurolicus is named as a source, and conflation with that edition is evidently the cause of the unusual count. Book XV has 21 propositions (the count of Foix and Clavius, against Commandino's 5). Furthermore, after book XV are added Foix's books XVI–XVIII with the proposition counts of their first (1578) appearance. The text of 1644 (for which Mersenne is explicitly named as editor) appears to match that of 1626 exactly.

The anonymous 1679 edition of books I–VI adopts the omission of *ex aequali* but otherwise matches Commandino's text (including proofs and diagrams), though commentary is removed and some footnotes added. In the limited section I have been able to compare, the 1702 edition (at Naples) appears to be a reimpression of the 1679 text.

To this group should be added as an outlier Lanz's edition of 1617 (books I–VI), which matches Commandino's vocabulary at 89%, marginally better than any other predecessor, takes up *ex aequali*, introduces no new terms of its own, and is followed by no successor even 90% of the time. Definitions are revised, enunciations are close to those of Commandino, and proofs are much changed though recognisably related. Labels match Commandino; commentary is removed.

An outlier closer to the original text is Keill's (1701) text of books I–VI. Keill states that his text is Commandino's ('Ex Versione Latina FEDERICI COMMANDINI'): it makes an instructive study in what that could mean. The match with Commandino's vocabulary is 90%, better than with any other predecessor, and the labels match Commandino's. Keill restores the shorter form of book V but otherwise matches Commandino's proposition counts. The text is recognisably that of Commandino in definitions, enunciations and proofs, but there are fairly frequent single-word changes, and this is quite far from a straightforward reimpression of its section of the 1572 text.

Magnienus/Gracilis/Clavius. By far the largest single group of editions in this period is that associated with the editorship of Clavius, for which an important precursor was the edition of Magnienus and Gracilis (1557). The text of 1557 (enunciations only, books I–XV) is eclectic, agreeing with Zamberti on 79% of vocabulary choices, on letter labels, and all proposition counts; but it is close in detail to no single predecessor. There are nine new items of vocabulary: *in-*

sistere; *homologae/similes*; *alterna*; *inversa*; *ex aequalitate*; *inter se*; *extremum*; *tetraedron*; *solidum parallelis planis contentum*. An exception to this eclecticism is book X, where on both measures the text agrees perfectly with Mondoré and appears to be a close match for the wording of both definitions and enunciations (Greek text is added and commentary is removed in favour of Magnienus' much briefer occasional comments).

Clavius (1574) revised Magnienus' text, removing the Greek and supplying proofs as well as famously voluminous commentary, drawing on various sources (on Clavius and his agendas see in particular Price 2017 and Rommevaux 2005). The letter labelling is new. In the sections of book I compared here, definitions and enunciations are in fact a perfect match for the 1557 text. In the text as a whole Clavius took up 94% of Magnienus' vocabulary choices, including the novelties *insistere*, *homologae/similes*; *alterna*; *inversa*; *ex aequalitate*; *inter se*; *extremum* and *tetraedron*. In book X, however, he followed Zamberti's vocabulary where there was any choice to be made (as opposed to the Campanus-leaning Mondoré-based text of Magnienus). His one novelty of vocabulary was to treat *parallelepipedum* as a noun (his def. 11.30 – not in Heiberg's text) as against Magnienus' *solidum parallelis planis contentum* and Campanus and Zamberti's *solidum parallelepipedum*.

Clavius restored the longer (Campanine) form of book V, and – like Commandino two years earlier – added a proposition to book X, taking it to 117. His books XIV and XV had 32 and 21 propositions respectively; the former had no precedent (it arose from the conflation of texts attributed in earlier versions to Hypsicles and to Campanus); the latter matched Foix. His book XVI was necessarily based on Foix's first edition (1566), but was reduced to 31 propositions against Foix's 37, and is perhaps best characterised as a paraphrase.

Texts with 95% agreement with Clavius' vocabulary appeared in 1589, 1603, 1628, 1634, 1643, 1644, 1645, 1650, 1655, 1661, 1673, 1684 and 1691 (twice). Several of these were clearly intended as new versions of the Clavian text according to statements on the title page or elsewhere in the paratext; others, such as Barrow's edition of 1655, are quite different in detail, making their adoption of a high proportion of the Clavian vocabulary (100% for Barrow) the more striking. In this context it should be recalled that there was no strong consensus about the Euclidean vocabulary in Latin at this stage, with more than a quarter of terms still showing variation.

The 1589 second edition extends, rewords or rewrites commentary but – within the parameters of the present study – leaves the main text and diagrams unchanged. But in 1603–1605, Christoffer Dybvad adopted the Clavian vocabulary and proposition counts (books I–X) – with the exception of restoring the shorter version of book V – but removed commentary, made minor changes to definitions

and enunciations and did more extensive rewriting of proofs, including a completely new labelling of diagrams.

At a still further distance from Clavius' text (or Magnienus') was Rhodius' 1609 edition of books I–XIII, an idiosyncratic text which introduced five innovations of its own (all connected with ratios: λόγος; *analogia*; *multiplicata in sese/quadratè*; *cubicè in se multiplicata*; *directa*; *quantitates denominatores*) and agreed with no predecessor better than its 92% agreement with Clavius. Definitions were close to those of Clavius but not identical; the same is true of enunciations, and the proofs are new. Letter labels are a new set: like Foix he labels only three points in Prop. 1.1, but he uses letters in their natural Latin order. This appears to be the earliest edition to add letter labels within the enunciations, effectively conflating the traditional 'enunciation' and 'setting-out' and thereby reflecting a somewhat modified conception of the structure of a Euclidean proof (see for example Morrow 1992 (introduction by Mueller)). Finally, this text gives book V with 35 propositions, for which there was no precedent.

The 1612 edition of book X by du Puy matches the vocabulary of Zamberti (and Commandino and Clavius) and matches the proposition count of Commandino and Clavius. Based on spot checking, its definitions and enunciations appear to be from Clavius, though the proofs are new. The 1628 text of Doino (books I–VI) has minor changes of word order in definitions and enunciations, removes commentary, and provides proofs that read to some degree like an abridgement or simplification of the Clavian originals, reverting to the lettering of Zamberti and Magnienus. The anonymous edition that appeared at Genoa in 1644 has apparently the same text as Doino's – modified, curiously, to conform to diagrams with Clavius' lettering – with some brief commentary added.

Grienberger's abridgement (1629; books I–VI) is explicitly based on Clavius' edition and agrees with his proposition counts and diagram labels. It introduces one new term and shows 91% agreement with Magnienus, 92% with Clavius. In detail the text is a new version, however: the definitions are similar to Clavius' but the enunciations and proofs are not.

Herigone's Latin and French edition of 1634 (books I–XV) used Clavius' vocabulary, definitions, enunciations and proposition counts, but he provided his own proofs and commentary, with labels as in Zamberti and Magnienus. Books XIV and XV were given in a short form, respectively with 8 propositions (no precedent) and 5 (as Zamberti).

Fournier (1643: books I–VI), like Doino, adopts the Clavian vocabulary, labels and proposition count but makes changes throughout the text; enunciations are similar to their Clavian models, but the proofs are another new version. Melder in 1673 acknowledged a debt to Fournier, and indeed his text is a nearly page-for page reimpression of the 1643 version, abridging the commentary on definitions

(and removing illustrations there); the text of definitions, enunciations and proofs and labels appears to be unchanged.

Richard (1645: books I–XVI) uses the Clavian definitions and enunciations, with new proofs and a new commentary (as is indicated in its title). It reduces book V by one proposition, to 33: the count of Commandino's version. This edition shows some interest in Commandino's vocabulary also, adopting *circumferentia*, *obtusiangulum* and *acutiangulum* as well as introducing the short-lived innovation *hexaedrum* and Rhodius' *denominatores*. The labels match those of Rhodius, perhaps by chance. An anonymous edition of *c.* 1650 also has the Clavian definitions and enunciations (of books I–VI), but without commentary, proofs or diagrams.

Barrow (1655: books I–XV), too has the Clavian definitions and enunciations, without commentary. His proofs are new, his labels those of Zamberti. Like Rhodius, he adds letter labels within the enunciations. Like Hérigone, whose symbolic presentation was clearly a model in other respects, he gave short versions of books XIV and XV, with 8 and 5 propositions respectively.

Schott (1661) gave yet another text (of books I–VI) with the Clavian definitions and enunciations, no commentary, and heavily modified proofs. Like Doino's, the proofs read as a sort of abridgement, though they are not the same as his in detail, and here the labels are those of Clavius. The anonymous text printed at Bologna in 1684 (books I–VI) has slight changes to the definitions and removes their commentary; the enunciations and proofs are those of Clavius, though a different commentary is substituted and the labels are Rhodius'.

The year 1691 saw two new Clavian texts put into print for the first time. Coetsius at Leiden gave definitions and enunciations (books I–VI) closely similar to Clavius'; the commentary on the definitions is different and labels are added to the enunciations (as in Rhodius and Barrow). The proofs are a new version, as are the labels. Astorius at Siena (books I–XV) used Clavius' definitions (without commentary), but both enunciations and proofs are new. Like Commandino he gave 7 and 5 propositions in books XIV and XV respectively. This text has Commandino's *obtusiangulum* and *acutiangulum* and Magnienus' *binomium* and *bimediali* (props. 10.36 and 37), with labels that match Rhodius'.

The sheer number and diversity of recognisably Clavian texts is remarkable, as is the fact that texts declaring an allegiance to the Clavian tradition are in some cases (such as Grienberger in 1629) no closer to that model than texts announcing their novelty (like Barrow's). It is likely that, beyond the scope of this study, identifiably Clavian texts continued to appear in at least the first part of the eighteenth century.

Maurolico. Maurolico's text of the books XIII–XV, published in 1575 but composed in 1532, is an isolate. Containing none of the definitions collated here, it cannot be fairly compared for vocabulary, but its enunciations appear to be

those of Zamberti while its proofs are new. Its proposition counts for the three books it contains are highly distinctive: respectively 21, 39 and 13 propositions, the last (only) matching Campanus.

Briggs. Briggs's (1620) Greek–Latin edition of books I–VI is an eclectic text, matching no predecessor even 85% of the time in its vocabulary, introducing four new terms of its own (*oblongum*; *parallelogrammarum areae*; *inversa*; *alterna*), and followed at above 85% only by Gregory in 1703. There are general similarities to Zamberti's proofs and to Clavius' definitions, but it seems clear that this was in intention a new translation from the Greek text, despite Briggs' own acknowledgement of a debt to Commandino. The letter labels are Greek and match those of the Greek text (necessarily, since the diagrams are shared between the two texts). The proposition counts are the same as those of Grynäus and Zamberti.

Montensis. A cluster of related texts is headed by Montensis' edition of 1620 (books I–VI). It matches Magnienus and Clavius at 85% on vocabulary, and introduces just two innovations (*extrema* at def. 1.3 and *protendere* in postulate 2). The text is not close in detail to any predecessor, though proposition counts match Clavius: that is Zamberti's counts except for a longer book V. Labels match Zamberti.

It has no successors at 95%, but Dechales' version of 1660 matches it at 90% of vocabulary, differing by dropping certain terms that appeared as alternatives in 1620 – *ambitus*, *aequicrurus*, *proportio* – and by substituting *continuare* for Montensis' *protendere*, *circumscribi* for *describi*, *parallelogrammum* for *parallelogrammorum spatia*, *proportio* for *proportionalitas* and *ex aequo* for *ex aequalitate*. This is a longer text, adding books XI and XII with the proposition counts of Zamberti and Clavius (and thus matching the book plan of the Tacquet tradition). There is no detailed textual match with any predecessor, though the proofs are recognisably related to Clavius', and the letter labels match his.

In 1674 Dechales published a revision of his version (as part of his *Cursus mathematicus*), with the same vocabulary, labels and proposition counts (it includes *pars aliquota* as an alternative at def. 5.1, a term introduced to the *Elements* by Tacquet in 1654). The definitions are those of 1660, though the accompanying commentary is shortened; the enunciations are reworked, while the proofs are very nearly those of the 1660 text.

Finally, the 1690 edition of Dechales' *Cursus*, edited by Ozanam (see Bernard 2022, 478ff.), extends the Euclidean text of 1674 to include books I–XIV complete, with proposition counts matching Clavius except for book XIV, which most unusually has 27 propositions. Where the two run parallel, this version appears to match the 1674 text exactly, to the point of being a page-for page reimpression. Dechales having died in 1678, the new material is of uncertain authorship, the title page mentioning authorial manuscripts 'aucta & emendata, operâ & studio R.P.

AMATI VARCIN'. (Herigone's attitude to mathematical history is illustrated, and some light shed on his ideas about editorship, in his posthumous 'Tractatus': see Malet 2022.)

Tacquet. Tacquet in 1654 (books I–VI, XI–XII) was the last editor in this study to introduce more than one new term; 6 in total, more than any editor since Foix: *planum* (as a noun); *triangulum* (at def. 1.19, where all previous versions have *trilaterum*/*trilatera*); *multangulae*/*polygonae*; *rectangulum* (with inclusive meaning); *pars aliquota*; and *similes*/*aequales* (of ratios). Agreement with individual predecessors is correspondingly low; like Briggs he matches no earlier text even 85% of the time (it is noticeable that he takes up Montensis' novelty *protendere* for ἐκβαλεῖν (to produce). Proposition counts match Zamberti, except for book V with 35 (the match with Rhodius seems to be coincidental). The text is new in detail, and although proofs are recognisably related to those of Clavius, Dasypodius and Montensis, the highly idiosyncratic letter labels are quite new (the five points in prop. 1.1 are labelled *A*, *B*, *C*, *F*, *L*).

His only descendant is Whiston's version of 1703. Here the text of 1654 is apparently unmodified, as are labels, in the sections compared, except that a corollary is added to proposition 1.1 and at def. 1.7 Whiston drops both *protendere* and the term *planum* used as a noun.

Gregory. Finally, the 1703 edition of Gregory (on which see Beeley 2020). This is sometimes described as following Commandino, but in fact shows vocabulary agreement only at 84% with that text. Closer matches are with Clavius at 92%, and Briggs at 89%. The only absolute novelty in vocabulary detected by this study consists of the remark that *exponentes* is more correct than *quantitates* as an equivalent for πηλικότητες; by this date a much-discussed concept. It seems likely that this was indeed a consciously eclectic text; its proposition counts match no predecessor exactly. Thus, it differs from Zamberti in books X (117 propositions, matching Commandino and Clavius), XIV (7, matching Commandino) and XV (7, for which there is no precedent). The proofs are recognisably similar to those of Zamberti, Clavius and Commandino, and in book X those of Mondoré; there are closer similarities to Briggs in both the definitions and the proofs. The letter labels are those of the Greek text, here majuscules rather than the minuscules of previous Greek impressions.

4 Discussion

It has emerged that the Euclidean vocabulary in Latin was less stable in the early modern period than might have been expected. A thousand years after the mathematical writings of Boethius, and five centuries after the work of Adelard, two-thirds of the core geometrical vocabulary tems still existed in more than one

version across a corpus of texts that specifically purported all to be versions of substantially the same Greek archetype. (It should be mentioned that vocabulary variation is absent, or virtually absent, from the extant Greek versions of the *Elements*). Even by the final decade considered here, 31 terms (27%) continued to exist in more than one version.

A small proportion of that variation may be traced to Arabic loanwords or transliterations introduced in the period of Adelard and still present in the version of Campanus: specifically *helmuaym*, *similis helmuaym*, *helmuariphe*, and perhaps *corpus seratile* (on this phenomenon see Busard 1983, 2005). More was the result of hesitation as to whether or not to adopt a Greek loanword in Latin: *orthogonium*, *rhombus*, *analogia*, and several more. Most, however, amounted to variation between more than one purely Latin option: *tangere* or *attingere*; *segmentum* or *portionum*; *aptari* or *accommodari*; and many more such cases. In certain areas, differences of opinion as to what concept was being defined contributed: the exclusive definition of ἑτερόμηκες [oblong] in the Greek and its occasional replacement by an inclusive definition or by an inclusive term suitably qualified (*quadrangulum oblongum*, for instance) is probably the most prominent example; another is ἐναρμόζομαι [stand upon], where authors vary as to whether the definition says something about a circular segment, a portion of the circumference, or an angle. The particularly unstable area of ratio terminology possessed a long-lived alternation between *proportio*/*proportionalitas* and *ratio*/*proportio* as the pair of terms equivalent to λόγος/ἀναλογία, as well as much hesitation over the best terms for the various properties magnitudes, ratios and proportions could have. The term ὁμόλογα [corresponding] in particular was dogged by uncertainty as to whether what should be defined was a property of magnitudes, of pairs of magnitudes, or of ratios.

Similar remarks might be made about the shape at the text at the level of its list of propositions. Since the work of De Risi (2016), it is well known that Euclidean axiomatics was an area of important early modern instability. What has emerged here is that the proposition list also remained unstable througout the whole of the period studied here. Once again, there is no single cause for this. The sharp divergence of the Campanine text from any version extant in Greek (and which may to some degree have its origin in the lost Greek versions that underlie the Arabic tradition of the *Elements* and, through it, much of the medieval Latin tradition too: see for instance Rommevaux et al. 2001) is one source of variation, particularly of the long-lived hesitation between long and short forms of books V, XIV and XV. But other factors contribute, and, as noted above, a total of ten Latin editors contributed one or more books at lengths never seen before.

Concerning the diagrams, this study has used no more than the most minimal sample, as a means of checking whether the relationships between texts extend to

the diagrams or not. Here, too, variation has proved to be the norm, with nine different traditions of labelling figure 1.1 in the period, each introduced by an editor also known as an innovator with respect to vocabulary and/or proposition list. It is difficult to speak of influence based on such limited data, but it is noticeable that within the larger families of editions there is not necessarily identity of diagram labelling even where there is identity in other parts of the text.

Finally, this study of sixty texts has confirmed that (with the single exception of the 1491 reimpression of Ratdolt's Campanine text) none represents a wholly unmodified reimpression of a previous text. Even those that are close to a particular model are found to innovate by addition, omission, reworking of diagrams, substitution of vocabulary or rewriting of definitions, enunciations or proofs, even within the limited sample of text compared here. Adding to this the 52 texts excluded from this study on the grounds that they are identified by Wardhaugh et al. as reimpressions or reissues, the overall picture of the Latin Euclids of the period amounts to 112 texts of which 59 (53%) are to some degree original and 53 (47%) believed to be reimpressions or reissues.

Thus it emerges that a high proportion of those named as Euclidean editors constructed not copies of a single Latin archetype but consciously eclectic texts, adopting vocabulary choices and proposition lists from multiple sources, quite possibly including the editor's own innovation. This particular finding deserves some emphasis, since it implies that the work of Euclidean editors was more frequently creative and innovative than might have been presumed: that a significant proportion of editors consulted multiple sources in more than a cursory way and made detailed selections between the options they found therein. That Euclidean editors felt authorised to bring to their work not just a philological attitude of textual fidelity but a number of other approaches as well: mathematical correction, supplementation and extension, philosophical coherence (particularly in the axiomatics, at the level of what should be defined and what it meant to define), and pedagogical appropriateness. This finding should be compared with what is known about practices of mathematical reading in this period: see Raphael 2017, Oosterhoff 2015, Beeley et al. 2020, Wardhaugh 2020, 2021. As (Wardhaugh 2021) states, 'early modern readers experienced mathematical text as fragmented and nonlinear, as negotiable and malleable, and as a model for imitation and from which to assimilate praxis'. Evidently such postures extended beyond readership to mathematical editorship, at least with respect to the Euclidean text.

Of these innovators, a few (Scheybl and Briggs in particular) found little or no uptake among other editors. Others stand at the heads of identifiable families, whose numerical size and chronological range are listed in Table 6. In one sense, this is the best explanation for the degree of variation found in the Latin tradition of the *Elements* in this period, the variation in vocabulary, proposition count and

Family	Number of texts	Date range
Campanus	6	1482–1537
Zamberti	7	1505–1612
Rhäticus/Camerarius	3	1549–1577
Scheybl	1	1550
Mondoré	1	1552
Peletier	2	1557–1610
Magnienus/Gracilis/Clavius	18	1557–1691
Dasypodius	4	1564–1599
Foix	2	1566–1578
Commandino	6	1572–1701
Montensis	4	1620–1690
Briggs	1	1620
Tacquet	2	1654–1703
Gregory	1	1703

Table 6: Families of editions.

diagram labelling reflecting the fact that even in the final decades of the period five distinct families were visible in print (Clavius, Commandino, Montensis, Tacquet, Gregory), and indeed that in no quarter-century after 1500 were fewer than two represented in print.

On the other hand, it has been emphasised above that variation within families is also important, with a substantial number of the editors of Clavian texts, in particular, willing to rewrite proofs, modify vocabulary, or adopt a different labelling of diagrams from that in their received text. In all of these cases, editors' reasons for what they consulted and what they did with it, which ranged across the philosophical, philological and pedagogical, belong outside the scope of the present study, and to the detailed investigation of the work of specific editors.

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Appendix 2. Terms collated

Plane geometry

σημεῖον (def. 1.1): punctus/punctum; signum
γραμμή (def. 1.2): linea
πέρατα (def. 1.3): extremitates, limites, terminant, termini, fines, extrema
εὐθύς (def. 1.4): recta
ἐπιφάνεια (def. 1.5): superficies
πέρατα (def. 1.6): termini, extrema, terminant, fines
ἐπίπεδος (def. 1.7): planum; superficies plana
γωνία (def. 1.8): angulus
εὐθύγραμμος (defs. 1.9, 19): rectilineus, rectarum linearum
ἴσος (def. 1.10): aequales, aeque
ὀρθός (def. 1.10): rectus
κάθετος (def. 1.10): perpendicularis
ἀμβλύς (def. 1.11): obtusus
ὀξεῖα (def. 1.12): acutus
ὅρος (def. 1.13): terminus, finis
σχῆμα (def. 1.14): figura
κύκλος (def. 1.15): circulus
κέντρον (def. 1.16): centrum
διάμετρος (def. 1.17): diameter, dimetiens
περιφέρεια (def. 1.17): circumferentia, peripheriam, ambitus
ἡμικύκλιον (def. 1.18): semicirculus
τρίπλευρος (def. 1.19): trilatera, trium laterum, triangulum
τετράπλευρος (def. 1.19): quadrilatera, quatuor laterum
πολύπλευρος (def. 1.19): multilatera, multorum laterum, multangulae, polygonae
πλευρά (def. 1.20): latera
τρίγωνον (def. 1.20): triangulus
ἰσόπλευρος (def. 1.20): habens tria latera aequalia, aequilaterum, aequalium laterum
ἰσοσκελής (def. 1.20): duo habens aequalia latera, isosceles, duo aequalia crura habere, aequicrurus
σκαληνός (def. 1.20): trium inaequalium laterum, scalenum, varium
ὀρθογώνιος (def. 1.21): orthogonium, rectangulum, à recto angulo

ἀμβλυγώνιος (def. 1.21): amblygonium, ab obtuso, obtusiangulum

ὀξυγώνιος (def. 1.21): oxygonium, acuti anguli, acutiangulum

τετράγωνον (def. 1.22): quadratum

ἑτερομήκης (def. 1.22): tetragonus longus, altera parte longius, quadrangulum oblongum, alterolongius, quadratum oblongum, rectangulum (inclusive)

ῥόμβος (def. 1.22): helmuaym, rhombus

ῥομβοειδής (def. 1.22): similis helmuaym, rhomboides, rhombi similis

τραπέζιον (def. 1.22): helmuariphe, trapezia, mensulae

παράλληλοι (def. 1.23): aequidistantes, parallelae, aequabiliter ductae

ἄγω (post. 1): duco, describo

ἐκβάλλω (post. 2): protraho, produco, ejicio, extendo, protendo, continuo

γράφω (post. 3): designo, describo

βάσις (prop. 1.5 enunciation): basis

παραλληλόγραμμον χωρίον (prop. 1.34 enunciation): superficies equidistantium laterum, superficies equidistantibus contenta lateribus, parallelogrammorum locorum, locorum quae aequalibus lineis descripta sunt, parallelogrammo, parallelogrammorum spatiorum, areae quae aequidistantibus lineis rectis continentur, parallelogrammarum arearum

παραλληλόγραμμον (def. 2.1): parallelogrammum, figura aequabilium linearum (cum angulo recto)

περιέχομαι (def. 2.1): contineor, includor

γνώμων (def. 2.2): gnomon, norma

ἐφάπτω (defs. 3.2, 3): contingo, tango, attingo

(ἴσος) ἀπέχω (def. 3.4): disto, absum

τμῆμα κύκλου (def. 3.6): portionum circuli, sectio circuli, segmentum circuli

βαίνω (def. 3.9): consisto, in ... sum, obeo, insisto, constitutus sum

τομεύς (def. 3.10): sector

ὅμοιοι (def. 3.11): similes

ἐγγράφομαι (defs. 4.1, 3, 5): inscribor, describor

περιγράφομαι περί (defs. 4.2, 4, 6): circumscribor, describor

ἐναρμόζομαι (def. 4.7): congruo, coaptor, apta descriptione inducor, accommodor; aptor

ἀντιπεπονθώς: μυτυορυμ λατερυμ, ρεσιπροσαε, ρεταλιαταε

ἄκρος καὶ μέσος (λόγος) (def. 6.2): habentem medium et duo extrema, extremam & mediam

ὕψος (def. 6.3): altitudo

Ratio and proportion

μέγεθος (def. 5.1): quantitas, magnitudo

μέρος (def. 5.1): pars; pars aliquota

πολλαπλάσιος (def. 5.2): multiplex
λόγος (def. 5.3): proportio, ratio, λόγος
(λόγον) ἔχω (def. 5.4): habeo
ἐν τῷ αὐτῷ λόγῳ (def. 5.5): similes, aequales, eaedem
ἀναλογία (def. 5.18): proportionalitas, proportio, analogia
ἀνάλογον (def. 5.6): proportionales, in proportione
μείζων (def. 5.7): maior
διπλάσιος (def. 5.9): duplicata, dupla, duplo maiorem, duplex, multiplicata in sese; quadratè
τριπλάσιος (def. 5.10): triplicata, tripla, triplo maiorem, triplex, cubicè in se multiplicata
ὁμόλογα (def. 5.11): in proportione una, similis, congruentes, homologae, comproportionales
ἐναλλάξ (def. 5.12): conversa, alterna, permutata, inversa
ἀνάπαλιν (def. 5.13): permutata, uicissitudinis, inversa, conuersa, alterna
σύνθεσις (def. 5.14): coniuncta, composita
διαίρεσις (def. 5.15): disiuncta, divisa
ἀναστροφή (def. 5.16): eversa, conversio, inuersio, reversio, anastrophe, compositione
δι᾽ ἴσου (def. 5.17): aequa, exaequationis, ex aequalitate, ex aequo, ex aequali
ordinata proportio: ordinata; directa
τεταραγμένη (ἀναλογία) (def. 5.18): perturbata, inordinata, confusa
πηλικότητες (def. 6.4): quantitates, quantitates denominatores, denominatores, exponentes

Number theory

μονάς (def. 7.1): unitas
ἀριθμός (def. 7.2): numerus
ἄρτιος (def. 7.6): par
περισσός (def. 7.7): impar
πρῶτος (def. 7.11): primus
(πρῶτοι, σύνθετοι) πρὸς ἀλλήλους (def. 7.12): contra se; adinvicem, inter se
σύνθετος (def. 7.13): compositus
τέλειος (def. 7.22): perfectus

Irrational lines

σύμμετρα (def. 10.1): communicantes, commensurabiles
ἀσύμμετρα (def. 10.1): incommensurabiles
δυνάμει (σύμμετροι) (def. 10.2): potentia

ῥητός (defs. 10.3, 4): rationalis, ῥηταί, certa
ἄλογοι (defs. 10.3, 4): irrationales; surde, ἄλογοι, incertae
μέση (prop. 10.21): medialis, media
ἐκ δύο ὀνομάτων (prop. 10.36): binomium, ex binis nominibus
ἐκ δύο μέσων (prop. 10.37): bimediali, ex binis mediis, ex duabus medialibus
μείζων (prop. 10.39): maior
ἀποτομή (prop. 10.73): residuum, apotome
ἐλάσσων (prop. 10.76): minor

Solid geometry

στερεός (def. 11.1): corpus, solidum, corpus solidum
πέρας (def. 11.2): terminus, extremum, extremitas
κλίσις (defs. 11.5, 6): inclinatio
στερεὰ γωνία (def. 11.11): angulus solidus, angulus corporeus
πυραμίς (def. 11.12): piramis laterata, pyramis
πρίσμα (def. 11.13): corpus seratile, prisma
σφαῖρα (def. 11.14): sphaera
ἄξων (defs. 11.15, 19, 22): axis
κῶνος (def. 11.18): piramis rotunda, conus
κύλινδρος (def. 11.21): columna rotunda, cylindrus
κύβος (def. 11.25): cubus; hexaedrum
τετράεδρον: pyramidem quatuor basium triangularium et equilaterarum, tetraedron
ὀκτάεδρον (def. 11.26): corpus octo basium triangularium & equilaterarum; octaedrum
εἰκοσάεδρον (def. 11.27): corpus viginti basium triangularium & equilaterarum; icosaedrum
δωδεκάεδρον (def. 11.28): corpus duodecim basium pentagonarum equilaterarum atque equiangularium; dodecaedrum
στερεός παραλληλεπίπεδος (prop. 11.25): solidum paralellogramum, solidum parallelepipedum, solidum parallelis planis contentum, parallelepipedum