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RHETORICAL STRATEGIES IN PHD CONCLUSIONS OF COMPUTER SCIENCE: FROM THE REVIEW OF THE STUDY TO CONSOLIDATION OF RESEARCH SPACE

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Abstract

This study investigates the predominant moves and move patterns used in the separate final conclusion chapters of 48 PhD theses of computer science at a UK university. The focus is on the most salient connections of steps in the review of the study (Move 1) with steps for the consolidation of research space (Move 2). The most common combinations relate (1) a summary of the thesis work to the product and the evaluation of the product, (2) the purpose, thesis statement or hypothesis to the findings or results, (3) the research questions to the methodology, product or claim, (4) a problem or need to a specific methodology, a new product and/or a claim, and (5) a summary of the work done in each thesis chapter to the findings and claims. Some findings are specific of the field of computer science. The study has pedagogical implications for courses of English for Academic Purposes (EAP).

Keywords: PhD thesis, conclusion, move, step, computer science

Este artículo analiza los patrones de movimientos que predominan en los capítulos finales de conclusión de 48 tesis doctorales de informática en una universidad británica. Se centra en la naturaleza y frecuencia de las conexiones entre pasos del Movimiento 1

sobre la revisión del trabajo de investigación y los pasos del Movimiento 2, de consolidación del espacio investigador. Las combinaciones más comunes relacionan (1) el resumen del trabajo de la tesis con el producto y su evaluación, (2) el propósito y la hipótesis inicial con los resultados, (3) las preguntas de investigación con la metodología, el producto y la reivindicación, (4) un problema o necesidad con una metodología específica, un nuevo producto y/o una reivindicación, y (5) un resumen del trabajo realizado en cada capítulo con los resultados y reivindicaciones. Algunos de los resultados obtenidos son específicos del área de la informática. Del estudio se desprenden implicaciones pedagógicas para cursos de inglés para fines específicos (IFA).
Keywords: tesis doctoral, conclusión, movimiento, paso, informática

1. *Introduction*

Generic competence refers to the students' ability to use generic conventions and participate in situations with particular communicative goals as part of a discourse community (Bhatia, 2004). It includes "the ability to use textual, contextual, and pragmatic knowledge to both interpret and create contextually appropriate texts as instances of a particular genre" (Paltridge and Woodrow, 2012, p. 89). The concept is closely related to genre awareness, which is at the basis of English for Academic Purposes (EAP) writing courses for the development of students' effective communicative uses of a particular genre. Writing instruction requires understanding the relationship between the features of a text and the context where it is created or used, and using this understanding to participate in real world communicative practices (Yayli, 2011; Paltridge and Woodrow, 2012).

Research writing poses a great challenge for novice writers (Cotos, 2014, p. 9). Research writing is seen as a constructive process implying a dynamic and highly reflective process on the part of the writer (Dewey, 1997; Badley, 2009). There is individual work based on the writer's knowledge of the topic and writing experience, and related to the establishment of the goals, the generation of ideas and the connection of concepts in a meaningful structure. But specific contextual, disciplinary, linguistic and rhetorical dimensions underpinning research writing of academic genres must also be considered. For graduate students the ability to combine all these different dimensions becomes crucial.

Studies on how these dimensions intertwine in the construct of research writing competence have shown differences between student texts written in English and texts written in other languages by different populations and in different academic settings (Soler-Monreal et al., 2011; Soler-Monreal, 2015; Cumming et al., 2016; Geng and Warton, 2016; Kuteeva and Negretti, 2016). Enhancing these differences is enlightening both from the standpoint of research and that of academic writing instruction. Students need to write effectively in order to be able to be accepted in their discourse community. Practice and exposition to models may arise students' awareness of discourse, culture, and genre conventions. Corpus-based writing courses can assist students in the production of their texts.

The importance given to raising generic competence and genre-awareness has motivated genre-based studies of master's dissertations and PhD theses addressing contextual, disciplinary, and rhetorical dimensions (Dudley-Evans, 1986; Bitchener and Basturkmen, 2006; Kwan, 2006; Samraj, 2008; Basturkmen, 2009; Lewkowicz, 2009; Ridley, 2012; Asunción and Querol, 2013). It has also encouraged authors to explore EAP classes aiming to help students both undergraduate and graduate students

completing doctoral dissertations meet academic progress and success (Johns, 2001, 2002; Johns and Swales, 2002) or to elaborate pedagogical materials useful as a guide for academic writing (Swales and Feak, 2000; Swales, 2004).

Part of the research on the dissertation genre has offered some interesting insights into the most common generic practices of doctoral writers across different disciplines in various academic contexts. For example, Brian Paltridge's (2002) analysis was based on a corpus of theses in different study areas at major research universities in various countries. He found four different types of thesis structures: simple and complex traditional IMRD (Introduction-Method-Results-Discussion) structures, topic-based theses and compilations of research articles. All types had in common an introduction to the thesis as well as a conclusion but diverged from one another in the organization of the contents in the chapters constituting the body of the text. Some other research has analyzed samples of the thesis genre in a variety of disciplines in the same academic context, e.g., David Bunton's (2002, 2005) comparisons of the introductions and the conclusions of 45 PhD theses from the University of Hong Kong. Later studies, on the other hand, have focused on particular disciplines in different academic settings. For example, Jason Miin-Hwa Lim (2014), Lim et al. (2014) and Lim et al. (2015) focused on the introductions of 32 theses on applied linguistics in 32 American universities to ensure that the corpus was not affected by the influence of a specific set of supervisors at a university or the preferred requirements of certain universities. In other studies, Jo Lewkowicz (2012) examined the conclusions of 12 PhD theses from the field of English studies written in English and defended at Polish universities, while Paltridge et al. (2012) described the macrostructure of 36 doctoral theses in the visual and performing arts in Australian universities. They found that while some texts still followed conventional generic structures and moves, others re-contextualized these categories in

a way that better fitted their area of study and particular project. Their results draw attention to varied or emerging discursive strategies in doctoral writing that better suit the particular characteristics of certain fields of study.

The above-mentioned research has revealed that different organizational and communicative strategies can be found, depending on the discipline, the academic and the language context where the research has been undertaken, offering guidelines to both supervisors and students in the writing of specific chapters of the PhD genre. Focusing on one discipline in one specific educational context teaches us about the actual students' writings under particular academic conditions. From a purely genre-analysis perspective, further research of student work may add new and interesting data to the body of research on the rhetorical moves that are used in different sets of PhD theses. From the standpoint of pedagogy, analyzing a range of doctoral work as wide as possible will awake in students the consciousness of the rhetorical conventions of the PhD genre. It will also help them solve the difficulties they might face when constructing the sections of their text according to their communicative purposes in their particular situation.

With respect to the thesis structure, John M. Swales (2004, p. 118) argued that the conclusion is often seen as the weakest part of the PhD text, because it is the chapter which is written the last and students are under pressure to complete their work. However, the PhD conclusion chapter plays a useful role in providing the examiners with an overall view of the thesis, the study and the contribution. It is important for doctoral writers to demonstrate scientific progress in the conclusion to "achieve their goal of becoming members of their desired academic and disciplinary communities" (Paltridge and Woodrow, 2012, p. 92). Achieving this goal may be challenging for the doctoral writers because it requires using effective rhetorical strategies. It is therefore

worthwhile to conduct research into the conclusions of theses in connection with disciplinary knowledge-making in order to help novice graduate students.

In this article I focus on rhetorical strategies used by doctoral writers in PhD conclusions in the discipline of computer science at Glasgow University. I conduct an investigation on genre competence in a corpus of 48 doctoral conclusions from a single institution and discipline in order to minimize variation. I circumscribe the study to one English university that I view as a reliable educational institution which could serve as a model of doctoral student performance as undertaken within a specific institutional context. I limit the research to the discipline of computer science, a research area with a shorter academic tradition than other knowledge areas in the humanities and sciences domains.

2. *Previous literature*

Genre-based analyses of discussion/conclusion sections in academic texts, especially research articles, have been carried out as early as the 1980s (Peng, 1987; Lindeberg, 1994; Holmes, 1997, 2001; Posteguillo, 1999; Peacock, 2002; Yang and Allison, 2003; Basturkmen, 2009, 2012; Soler-Monreal and Gil-Salom, 2010). A number of studies have also explored the discussion sections of student writings with a focus on the difficulties the students face (Bitchener and Basturkmen, 2006; Basturkmen, 2009; Lewkowicz, 2009; Parkinson, 2011; Geng and Warton, 2016). As for genre-based research on the final conclusion chapters of PhD theses, Bunton (2005) and Lewkowicz (2012) investigated the purposes of the conclusions of selected samples of PhD theses written in English and differences emerged in connection with the discipline and the writer's cultural background.

Bunton (2005) compared the conclusion chapters of the 45 PhD theses belonging to two different domains: science and technology (ST) and humanities and social sciences (HSS). He classified the conclusions into thesis-oriented and field-oriented theses. Most of the field-oriented conclusions had a problem-solution-evaluation structure. The thesis-oriented conclusions followed a five-move model: (Move 1) Introductory restatement, (Move 2) Consolidation of research space, (Move 3) Practical applications and recommendations, (Move 4) Future research, and (Move 5) Concluding restatement. However, Bunton's results showed some disciplinary variation in the frequency and distribution of the various moves and their steps between ST and HSS thesis-oriented conclusions. While the introductory restatement of more than 50% ST conclusions focused on the work carried out, the most frequently used step of HSS conclusions restated the purpose, research questions, or hypotheses. Specific steps of the ST conclusions in the consolidation move referred to the product and evaluation of the product. Finally, there was great emphasis on suggesting future research in ST conclusions, while HSS conclusions more often recommended practical implications and recommendations.

Lewkowicz's (2012) study focused on the conclusion chapters of 12 PhD theses from the field of English studies examined at Polish universities. Although she replicated Bunton's procedure, her analysis revealed that not all the conclusions fitted Bunton's framework. She found that, rather than including a substantial move of consolidating the research space, over 50% of the conclusions by Polish writers were presented as a compilation of chapter summaries, highlighting the main points of each successive chapter, the literature review, the actual study undertaken, and its findings, and acting as reminders of what had been written earlier in the thesis.

Since these two studies on PhD conclusions have identified disciplinary and language-specific variations in rhetorical features, research conducted in other contexts and on other disciplines might show other noteworthy results. This paper aims to provide further insights into students' rhetorical strategies used by doctoral writers in PhD conclusions in the discipline of computer science. The focus is on how the doctoral writers in computer science enhance the thesis contribution to research and consolidate research space. Based on the corpus, the following research questions are posed:

1. What rhetorical strategies are predominantly used in the conclusions of PhD theses in computer science?
2. What rhetorical patterns are used in the conclusions of PhD theses in computer science?
3. What is the nature and frequency of the most salient rhetorical connections of strategies used in the conclusions of PhD theses in computer science for consolidation of research space?

The pedagogical potential of this study is to help students in general, and particularly graduate students in computer science, increase their genre knowledge and, thus, their genre competence in order to develop abilities to produce writings that respond appropriately to the conventions of their disciplinary field and to the actual requirements of their academic institutions.

Globalization is favoring enrollments by international students at universities in English-language countries. The number of non-native speakers of English writing their academic work in English at non English-speaking universities is also increasing nowadays for world-wide recognition and authorial visibility reasons. The results derived from this study are valid for these students because the target community for researchers is an international one. Graduate students could benefit from EAP

instruction based on successful corpora of academic texts related to their own research interests. Based on our findings we make suggestions for applications in the EAP classroom.

3. *Method*

In this section, both the corpus, the framework for analysis and the approach are described.

3.1 *The corpus*

The study was based on a corpus of forty-eight PhD theses in computer science written in English. The theses had been collected from the thesis repository of Glasgow University (see Appendix). The selection had been made randomly according to the criteria that access was free, the theses presented experimental research, they were written in an English medium doctoral program, they had all fulfilled the quality requirements of the Computing Department for the PhD degree, and they had been submitted during the last ten years. No distinction was made between native and non-native writers of English because the purpose of the research was to analyze the theses defended at a specific institution in an English-speaking context which sets specific formatting instructions and offers voluntary training courses to help doctoral students with thesis research methods and layout issues.

Of interest for the study were the separate final conclusion chapters of the theses written in English. I did not take into account intermediate conclusion sections at the end of a chapter. Nor did I consider the separate final future work chapters in six theses in the corpus but focused on the separate final chapters including the word ‘conclusion’ in their titles. Twenty-seven theses (out of 48 theses, 56.25%) have a separate final

chapter titled ‘Conclusion(s)’; the titles of the final chapters of 19 theses (out of 48 theses, 37.5%) combine ‘Conclusion(s)’ with references to future work; and two theses have ‘Discussion and conclusion(s)’titles in their closing chapters (4.17%). Unlike the 12 dissertations in English studies analyzed by Lewkowicz (2012), all the conclusions are numbered chapters at the end the theses, which leads us to assume that they are part of the body of the text.

The contents of the theses reflect current areas of experimental research in computer science dealing with artificial intelligence, software development and application, IT system architecture, and computing models and techniques that extend applications or improve existing models. The length of the theses varies from 36 to 343 pages, with an average length of 164.33 pages. Most of the theses (35 theses: 72.92% of the corpus) have between 100 and 200 pages. Three theses (6.25% of the corpus) have fewer than 100 pages while ten theses (20.83% of the corpus) have more than 200 pages.

The length of the conclusions varies from 1 page to 14 pages, showing great variability. Nine conclusions (18.75% of the corpus) have between 10 and 14 pages; 11 conclusions (22.92% of the corpus) have between seven and nine pages; 16 conclusions (33.33% of the corpus) have between four and six pages; and 12 conclusions (25% of the corpus) have between one and three pages. The average length is 6.48 pages (SD: 3.53), which is longer than the average length of 4.9 pages of the ST thesis conclusions studied by Bunton (2005). However, the portion of text in the theses dedicated to the final conclusion chapter seems rather small (total number of pages 311; 3.94% of the overall length of the theses, excluding abstracts, indexes, lists of tables and figures, bibliography and appendices). As argued by Swales (2004, p. 118), the short length of the conclusion chapter can be explained if we place this finding “in the context of dissertation writers’ situations as they are finishing their long texts:” the thesis writers

feel tired after their emotional and intellectual effort of carrying out research and writing their thesis, and they are in a hurry to finish the thesis by the deadline negotiated by them, the advisors and the examiners.

3.2 *Analytical procedure*

Once the conclusions had been identified, they were analyzed with a genre-based approach. The process of analysis required consideration of both lexicogrammatical markers and cotext. The units of analysis could be clauses, sentences, or even groups of sentences with the same communicative function. Coding reliability implied inter-coder consistency in categorizing text segments. A second coder and I conducted a systematic analysis of all the conclusions in the corpus. The second coder is trained in genre analysis and has been my co-author in many of my publications on written academic genres. We separately read each conclusion and coded every text segment manually. We also met every week for over 6 months, checked our individual coding decisions, discussed discrepancies and re-coded text segments to arrive at a consistent categorization. Taking into account Bunton's (2005) move-step model for doctoral conclusions and the actual results of the investigation of the corpus, a framework with five moves was elaborated that reflected the rhetorical strategies used by the doctoral writers of computer science PhD conclusions (see table 1). Each move in the model has a communicative purpose which is further developed through rhetorical steps. The purpose of Move 1 (M1) is to remind the reader of the study, the aim and the work done. The main objective of Move 2 (M2) is to show that the thesis research contributes to the research field. Move 3 (M3) refers to applications and implications from the study. Move 4 (M4) suggests further research on the topic. Move 5 (M5) recapitulates the study and restates what has been presented in the conclusion. A more detailed

description of the framework is provided in Soler-Monreal (2016). For the purposes of this study, the steps of both M1 and M2 involved in M1-M2 sequences will be explained and exemplified with reference to the corpus in section 4.

Move 1: Revisiting the study
Step 1: Presenting the work carried out in the thesis Step 2: Restating the purpose of research/research questions or hypothesis/thesis statement Step 3: Justifying the work carried out in the thesis/chapter Step 4: Restating the territory Step 5: Restating centrality Step 6: Restating the focus of the study Step 7: Restating the problem/need Step 8: Restating the method Step 9: Making references to previous research Step 10: Previewing the chapter or section Step 11: Summarizing the specific work reported in each thesis chapter
Move 2: Consolidating the research space
Step 1: Preview of chapter Step 2: Describing the method of research/procedure Step 3: Presenting findings, results, answers to RQs, confirmation of thesis statement, solutions Step 4: Presenting product (model/approach/algorithm/system) Step 5: Comparing results with those reported in the literature Step 6: Accounting for results Step 7: Interpreting results Step 8: Exemplifying Step 9: Evaluating results Step 10: Establishing the claim Step 11: Evaluating product (model/approach/algorithm/system) Step 12: Indicating significance of product (model/approach/algorithm/system)
Move 3: Suggesting practical applications/implications
Step 1: Proposing applications or implications
Move 4: Extending research in the existing territory
Step 1: Preview of section/chapter Step 2: Indicating limitations Step 3: Relating to existing research Step 4: Planning further actions Step 5: Recommending future work (guidelines for continuing research) Step 6: Overviewing the chapter
Move 5: Recapitulating the overall study

Step 1: Previewing the chapter/section Step 2: Reiterating the overall purpose/research questions or hypothesis/thesis statement Step 3: Reiterating the problem/need Step 4: Reiterating the method Step 5: Recapitulating the work carried out Step 6: Reiterating the significance of the work carried out Step 7: Highlighting overall claims/findings Step 8: Summarizing recommendations for future work

Table 1. Move-step framework of analysis

I used a quantitative approach to identify the predominant moves, move sequences and cycles of move sequences in the corpus. Then, I analyzed the rhetorical steps in the review of the study (M1) and for consolidating the research space (M2) involved in M1-M2 connections both quantitatively and qualitatively.

4. *Results*

To answer the three research questions, in the sub-sections below I present quantitative data and describe patterns found in the corpus. Some general quantitative findings about the frequency, sequences and cycles of moves in the conclusions are reported first. Then, focus is placed on M1-M2 sequences. Extracts from the corpus illustrate the most salient connections of steps of M1 with steps of M2.

4.1 *Quantitative results*

4.1.1 *Moves, move sequences and cycles of move sequences*. Table 2 shows that M1, *Revisiting the thesis work*, M2 *Consolidating research space,* and M4 *Extending research in the existing territory* are obligatory moves in the conclusions of the computer science PhD theses (present in 100%, 100% and 95.83% theses respectively). It also shows that M5 *Recapitulating the overall study* and, particularly, M3 *Suggesting practical applications/implications* are not used with such high frequency and can be seen as optional. This indicates that these conclusions of computer science rely basically

on three rhetorical strategies or moves: the review of the thesis work (M1), the consolidation of the research space (M2), and the recommendations for future research (M4).

Move	N theses	%
M1: Revisiting the study	48	100
M2: Consolidating the research space	48	100
M3: Suggesting practical applications/implications	24	50
M4: Extending research in the existing territory	46	95.83
M5: Recapitulating the overall study	29	60.42

Table 2. Moves used in the conclusion chapters of the computer science PhD theses.

The moves in every conclusion are sequenced and usually integrate move patterns. In most theses, the conclusion chapter first revisits the thesis (M1) and then any noteworthy achievements are restated (M2), forming M1-M2 sequences. A number of theses link this sequence to M3 or M4, forming a three-move pattern. Combinations of M4 with either M1 or M2 are also used. Other sequences of moves involve M2, M3, M4, and/or M5. As shown in table 3, 43 conclusions use the M1-M2 sequence, so that they link the review of the study with the consolidation of research space. Apart from using the M1-M2 sequence, 11 conclusions out of these 43 conclusions also use the M1-M2-M4 sequence and two other conclusions use the M1-M2-M3 sequence. In contrast, four conclusions only use the M1-M2-M4 sequence, thus establishing a connection between the study, the consolidation of space, and the recommendations for future research. Another conclusion only uses the M1-M2-M3 sequence. Some conclusions use these patterns together with other move patterns such as M2-M3-M4, M5-M4, M4-M3, M4-M2, M1-M5, and M4-M2. However, M3, M4, and M5 are most often stand-alone moves, used only once at the end of the conclusion. There are also a few cases of isolated M1 and M2 integrating no identifiable pattern.

Move patterns and isolated moves	N occurrences	N theses	% occurrences	% theses
M1-M2	201	43	48.66	89.58
M1-M2-M4	36	15	8.72	31.25
M1-M4	30	11	7.26	22.92
M2-M4	8	4	1.91	8.33
M1-M2- M3	8	3	1.94	6.25
M2-M3-M4	3	2	0,73	4.17
M5-M4	6	2	1.46	4.17
M4-M3	5	2	1.21	4.17
M4-M2	3	1	0.73	2.08
M1-M5	2	1	0.48	2.08
M5-M3	2	1	0.48	2.08
M4	37	28	8.96	58.33
M5	29	24	7.02	50
M3	22	19	5.32	39.58
M1	10	10	2.42	20.83
M2	11	11	2.66	22.92
Total	413	48	100	

Table 3. Frequency of occurrence of move patterns and isolated moves in the conclusion chapters of the computer science PhD theses.

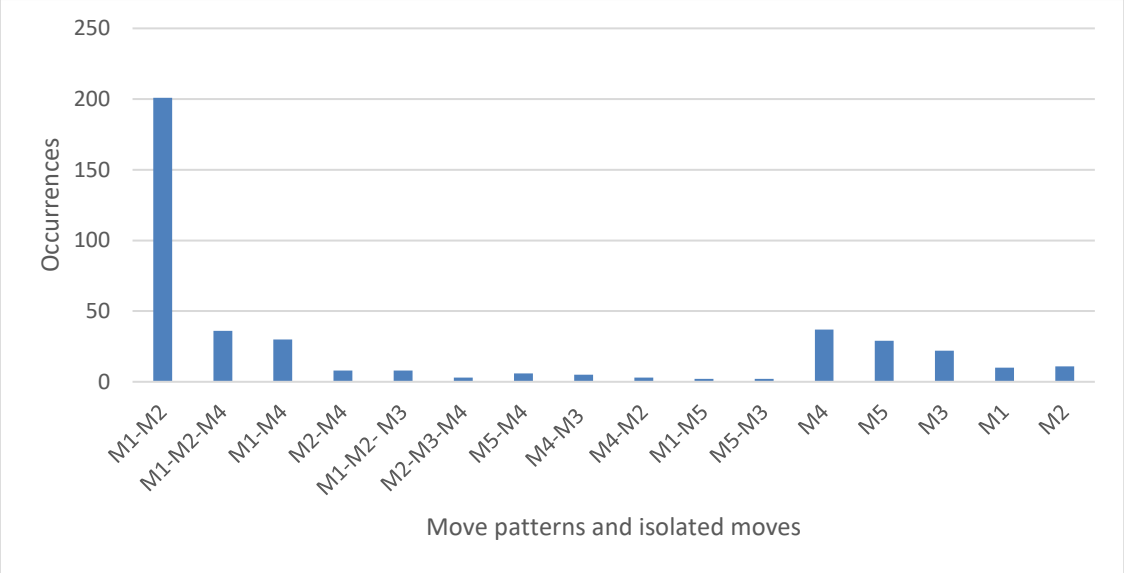

Figure 1. Number of occurrences of move patterns and isolated moves in the conclusion chapters of the computer science PhD theses.

4.1.2 *M1-M2 patterns.* Figure 1 shows that the M1-M2 sequence is by far the most common move pattern in the conclusions. The high number of occurrences also indicates that it is used repeatedly, so that consolidation is created cyclically. Tables 4, 5 and 6 show the number of cycles of the move sequences involving M1 and M2 in the corpus. Five out of 43 conclusions only have one cycle of the M1-M2 sequence. Two out of 15 conclusions use one cycle of the M1-M2-M4. However, in spite of the range

of variation of the length of the chapters, most of the conclusions in the corpus present the M1-M2, the M1-M2-M3, and/or the M1-M2-M4 patterns in cycles. If we consider the total number of patterns of each type, we find that the average number of M1-M2 sequences is 4.67 (SD: 3.88), with 21 theses (out of 43, 48.83%) presenting between one and three M1-M2 cycles and 22 theses (out of 43, 51.16%) using four or more M1-M2 cycles (see Figure 2). The average number of M1-M2-M4 sequences is 2.4 (SD: 0.95) and the mean for M1-M2-M3 sequences is 2.67 (SD: 2.65). According to these data, it seems that 26 conclusions have a rather simple structure while 22 conclusions have much more complex structures.

N cycles of the M1-M2 pattern	N theses
1	5
2	12
3	4
4	6
5	5
6	3
7	2
10	1
11	1
12	1
15	2
16	1
Total 201	43

Table 4. Number of cycles of the M1-M2 pattern in the conclusion chapters of the computer science PhD theses.

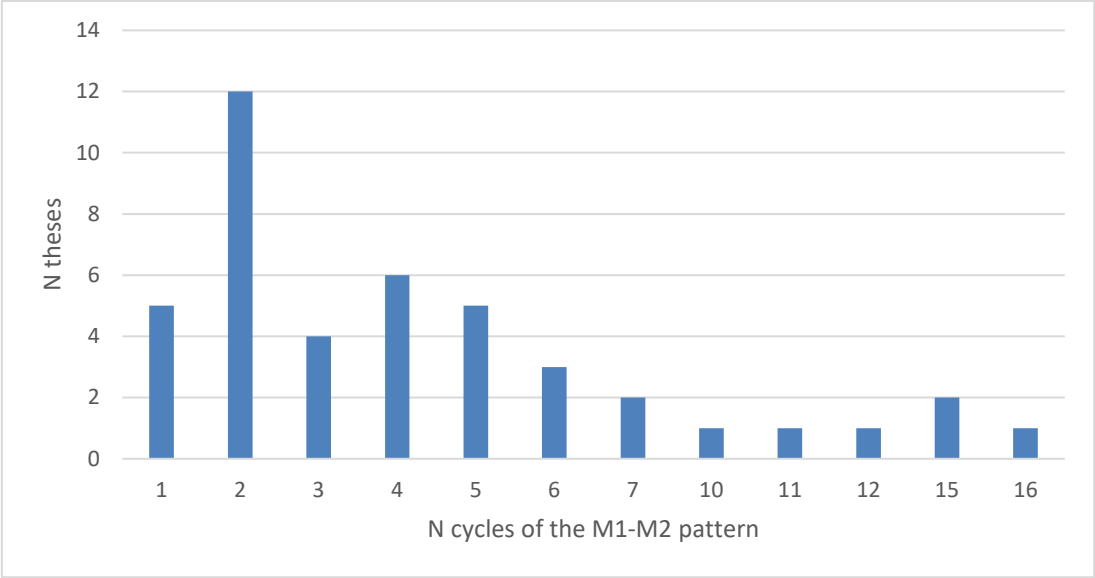

Figure 2. Number of cycles of the M1-M2 pattern in the conclusion chapters of the computer science PhD theses.

N cycles of the M1-M2-M4 pattern	N theses
1	2
2	8
3	2
4	3
Total 36	15

Table 5. Number of cycles of the M1-M2-M4 pattern in the conclusion chapters of the computer science PhD theses.

N cycles of the M1-M2-M3 pattern	N theses
1	1
3	1
4	1
Total 8	3

Table 6. Number of cycles of the M1-M2-M3 pattern in the conclusion chapters of the computer science PhD theses.

4.1.3 *Connections of steps of M1 with steps of M2.* The frequency of move sequences in table 3 shows that the most salient rhetorical connections of strategies involve M1 and M2, thus indicating that the consolidation of research space (M2) is mainly created through the review of the thesis work (M1) in the conclusion chapters of the computer science PhD theses under study. The sequence is found in all the conclusions in the corpus, whether in M1-M2, M1-M2-M3 or M1-M2-M4 patterns. In this section I

examine the rhetorical steps the thesis writers use to establish the connection between M1 and M2 in order to consolidate research space.

Table 7 shows the steps of M1 used immediately before a step of M2. Five steps of M1 are the most common for establishing the link with M2: Steps 1, 2, 7, 8 and 11. They cover 91.43% of all the occurrences of steps of M1 used in close association with the consolidation strategies of M2. One typical strategy of the thesis writers in the corpus is to use Step 11 of M1 to summarize the work done in each chapter (in 30 theses: 62.5% of the corpus). Other common steps of M1 previous to the consolidation of research space restate the purpose, hypothesis, thesis statement and/or research questions (M1-Step 2, found in 19 theses: 39.58%), restate the problem or need (M1-Step 7, in 16 theses: 33.33%), restate the method on which the study relies and which will be applied to new problems or in new conditions (M1-Step 8, in 15 theses: 31.25%) or summarize the work done in the thesis (M1-Step 1, in 13 theses: 27.08%).

M1-Step	N occurrences	% occurrences	N theses	% theses
M1-Step 11	113	46.12	30	62.5
M1-Step 2	45	18.36	19	39.58
M1-Step 7	26	10.61	16	33.33
M1-Step 8	22	8.98	15	31.25
M1-Step 1	18	7.35	13	27.08
M1-Step 6	9	3.67	4	8.33
M1-Step 10	8	3.27	5	10.42
M1-Step 4	2	0.82	2	4.17
M1-Step 5	1	0.41	1	2.08
M1-Step 9	1	0.41	1	2.08
Total	245	100	48	

Table 7. Steps in M1 immediately preceding a step in M2.

The steps of M2 commonly used directly after a step of M1 are Steps 2, 3, 4, 10 and 11. Step 3 *Presenting findings, results, answers to research questions, confirmation of thesis statement, solutions* (in 42 theses: 87.5%), is the most common step of M2, encapsulating any advance reached by the thesis research. Step 2 *Presenting the*

method/procedure proposes the methodology that will permit to fulfill the research requirements (in 28 theses: 58.33%). Step 4 *Presenting a product* is also a common step of M2 in the corpus of computer science theses and refers to any new or update computing model, approach, algorithm or system (in 21 theses: 43.75%). Step 10 *Establishing the claim* (in 12 theses: 25%) and Step 11 *Evaluating the product* (in 8 theses: 16.67%) emphasize the value and advantages of the present research.

Given the various steps of M1 and M2, the thesis writers in this study establish the link between the review of the study and the consolidation of research space in various different ways. The most common connections of steps of M1 with steps of M2 are:

1. M1-Step 1/M2- Steps 4 and 11: a summary of the thesis work is connected with the product followed by the evaluation of the product
2. M1-Steps 2 and 8/ M2-Step 3: the purpose, thesis statement or hypothesis at the outset of the research together with the method are connected with the findings or results
3. M1-Step 2 / M2-Steps 2, 4, or 10: the research questions at the outset of the research are addressed by the presenting a methodology or a new product or making a claim.
4. M1- 7/ M2-Steps 2, 4 and/or 11: a problem or need is solved by using a specific methodology, presenting a new product and/or evaluating it.
5. M1-Step 11/ M2-Steps 3 and/or 10: the work done in each thesis chapter is reviewed, the findings are presented, and claims are made.

4.2 *Qualitative description of M1-M2 sequences: The connections of steps of M1 with steps of M2*

In this sub-section I describe and illustrate the predominant connections of steps of M1 with steps of M2 used in the corpus to enhance the thesis contribution to research,

thus consolidating research space. Linguistic markers are underlined to guide the reader on the communicative purpose of the segments of text.

4.2.1 *From reviewing the thesis work to presenting and evaluating the product: M1-Step 1/M2- Steps 4 and 11.* One connection of M1 with M2 consists in reviewing the thesis work (M1-Step 1) and progressing to consolidate the research space by presenting and evaluating the new product (M2-Steps 4 and 11). In the example, the product is a new method which yields better results than other processes and is thus presented as a valuable contribution to research:

(1) *M1-Step 1* This dissertation describes a new variation of anisotropic diffusion that uses confidence from the matching cost and the intensity image to diffuse high confidence disparity estimates into neighbouring low confidence regions while preserving depth discontinuities. *M2-Step 4* It accomplishes this by diffusing the intensity image for adaptive gradient support, defining two new diffusion coefficients, and diffusing the confidence map alongside the disparity map. *M2-Step 11* This new process is able to produce more reliable disparity maps than the baseline algorithm. T7

4.2.2 *From restating the purpose and the methodology to presenting the findings: M1-Steps 2 and 8/ M2-Step 3*. A rhetorical strategy used by slightly less than one third of the writers links the purpose (M1-Step 2) and the methodology employed in the study (M1-Step 8) to the findings (M2-Step 3):

(2) *M1-Step 2* The aim was to investigate the everyday use of crossmodal audio and tactile feedback and to study user performance and preference over time. *M1-Step 8* An 8-day field study of CrossTrainer was carried out involving 9 participants […]. *M2-Step 3* This study showed that crossmodal feedback aids users in entering answers quickly and accurately using a variety of different widgets. Furthermore, the results demonstrate that users can switch between modalities and reach 100% recognition rates of multidimensional crossmodal alerts after 2 days of regular use […]. T 13

4.2.3 *From restating the thesis statement and/or research questions to presenting answers to research questions or the claim: M1-Step 2 / M2-Steps 2, 4, or 10*. More than one third of the conclusions achieve consolidation by restating the thesis statement, hypothesis, and/or research questions at the outset of the thesis work (M1-Step 2) and referring to how they have been addressed (by means of a new research procedure, a new product or claiming the relevance of the results: M2-Steps 2, 4, or 10). In some cases, these issues are restated in detail, which suggests that the writers aim to show how their expectations at the start of the research have been fulfilled (in example (3), bold types and italics in the original have been kept):

(3) *M1-Step 2* This dissertation opened by posing two research questions. […] These research questions were stated in Section 1.1:

RQ1. *How can the results of human computation be improved to match the specific needs of other systems?*

RQ2. *How can human computation be extended to collect and classify useful contextual information in mobile environments?*

M2-Step 4 RQ2 was addressed through the creation of EyeSpy: a mobile game with by-products. […]

M2-Step 4 RQ1 was addressed through the creation of Realise and the concept of mutually reinforcing systems. T10

(4) *M1-Step 2* In our thesis statement (see Section 1.3), we hypothesized that user-generated content could increase the accuracy of a real-time news query classifier within a universal Web search engine. *M2-Step 10* Based upon our experiments in Chapter 7, we conclude that user-generated content streams in combination can significantly improve a news query classifier that relies only upon newswire providers to identify news-related queries. This, in turn, enables a universal Web search engine that supports a news vertical to better satisfy news-related queries relating to both breaking and long-running events by classifying them more accurately. T 26

4.2.4 *From restating the problem/need to presenting and evaluating solutions: M1-Step 7/ M2-Steps 2, 4 and/or 11.* One third of the conclusions have M1-M2 connections of a problem/need in the field of study (M1-Step 7) with the product proposed in the thesis as a solution (M2-Step 4). In this way, the importance of the advancement of technology is emphasized:

(5) *M1-Step 7* […] the insatiable demand for more computation in networks and the increasing density of modern devices has driven the need for high-level design environments. These high-level design environments improve productivity and

reduce costs but the validation and verification capabilities are not as mature as the low-level implementation flow.

M2-Step 4 This thesis has presented three techniques for validating and verifying systems created in two high-level design environments called Brace and System Stitcher. T30

Example (6) presents five cycles of introductory restatements of research problems related to the design of games (M1-Step 7), not only at the outset of the research but also during the research process. As new problems emerge, the consolidation of research space is achieved progressively with new solutions or games (M2-Step 4). Finally, even though not all the problems have been solved, the writer highlights improvements (M2-Step 11):

(6) […] the research described in this dissertation attempted to address *M1-Step 7* the problem of creating a mobile game which could create by-products that responded to the immediate needs of another system. […] *M2-Step 4* a game with by-products was built called EyeSpy. […] This system proved successful in producing useful by-products and being enjoyable to play. *M1-Step 7* However, it could not respond to the specific needs of another system and became monotonous over time.

M2-Step 3 In order to address these problems, the concept of mutually reinforcing systems was introduced. This forms the central contribution of this dissertation. […] This required an additional game-play element to be added to EyeSpy in order to incorporate this feature. […] *M1-Step 7* However, this

particular implementation of mutually reinforcing systems had problems of its own which needed to be addressed. […].

M2-4 To address these issues […] a system to achieve this was incorporated into the existing design. This augmentation was called the subjective reward system. […] *M1-Step 7* However, this final aspect of the subjective reward system was implemented incorrectly and a working demonstration of this element was not built and tested within the time limits of this research. *M2-Step 11* It is proposed that, even though further refinements are desirable, the deployed mutually reinforcing systems implementation forms another contribution of this dissertation, by showing concrete evidence that the mutually reinforcing systems concept can be implemented in a useful way. T10

Example (7) justifies the need for further research (M1-Step 7) and is followed by an evaluation of the method proposed in the thesis (M2-Steps 11 and 2):

(7) *M1-Step 7* The need to obtain an overview of data represented in auditory displays has been stressed by various authors […], however most work on access to numerical data has focused on single auditory graphs, in which data points from one-dimensional arrays are retrieved one by one […]. *M2-Step 11* This research is novel in that it tackles the problem of obtaining overview information from complex numerical data sets quickly and easily, *M2-Step 2* by taking a non-visual approach in the solution proposed, while preserving spatial metaphors that are necessary for collaboration with users that utilize visual representations of the same data. T19

4.2.5 *From summarizing the specific work done in each thesis chapter to presenting findings or making the claim: M1-Step 11/ M2-Steps 3 or 10*. Rather than reviewing the whole work done (M1-Step 1), one typical option of the thesis writers is to consolidate research space through reviewing the specific work done in each thesis chapter. The focus is on summarizing and highlighting the main points of each successive chapter, giving prominence to the specific work done in the chapter (M1-Step 11) and to the actual results (M2-Steps 3) or claims (M2-Steps 10) directly related to the contents of the chapter. As most theses are divided into several chapters according to different topics, the writers consolidate research space cyclically, by specifying the contribution of their work to different aspects of research and using recurring steps presenting a finding or a product directly related to the theme reviewed in the chapter. This indicates that most writers perceive that referring to the thesis contributions in detail is one of the main functions of the conclusion. This also explains the high number of occurrences of M1-Step 11 and of M1-M2 cycles in the corpus.

(8) *M1-Step 11* Our first contribution (Chapter 5) is *M2-Step 4* a modular modelling framework for pathways and their cross-talk. […] *M2-Step 3* We demonstrated the framework using a prominent case study: the cross-talk between the TGF-_, WNT and MAPK pathways. […]

M1-Step 11 Our second contribution (Chapter 6) tackles the problem of unstructured signalling networks, i.e. networks with no explicit notion of pathways or cross-talk. *M2-Step 3* We showed how signalling networks can be broken down into a set of signal flows, essentially a (minimal) multiset of reactions that work together to produce some output of interest. […] Then, we showed how to better understand signalling network models using the set of

signal flows […]. Finally, we showed how the set of signal flows can be used to compute several network metrics, and how clustering of signal flows can uncover structure within the network.

M1-Step 11 Our final contribution (Chapter 7) was to employ partial order reduction algorithms to improve the efficiency of the RMP algorithm. […]*M2-Step 3/10* An important result was that a previously incomputable model is now computable using partial order reduction. T6

4.3 *Connections of steps of M1 with steps of M2 in M1-M2 cycles*

The communicative strategies chosen by the writers in the corpus to link M1 with M2 do not exclude one another: 43 conclusions use cycles of move patterns and different combinations of steps of M1 with steps of M2 in the M1-M2 cycles are found. Twelve theses with two M1-M2 cycles and two theses with only two M1-M2-M4 cycles show different strategies for consolidation. In one conclusion, in the first M1-M2 sequence, consolidation is created through revisiting the work done (M1-Step1), while in the second M1-M2 sequence, it is created through reviewing the specific work done in each chapter (M1-Step 11). In four conclusions consolidation is created in the first M1-M2 cycle through restating the problem/ need at the origin of the thesis research (M1-Step 7) and re-created in the second M1-M2 cycle through either duplicating the strategy or presenting research questions (M1-Step 2). Five conclusions first reformulate the purpose and then pose research questions (M1-Step 2, four theses) or present the specific work done in each chapter (M1-Step 11, one thesis). One conclusion creates consolidation through presenting a preview of the conclusion chapter (M1-Step 10) in the first M1-M2 cycle and then focusing on the method of research (M1-Step 8) in the second M1-M2 sequence. Two other conclusions consolidate research space

through referring to the specific work done in each chapter (M1-Step 11) in the two M1-M2 cycles.

One conclusion with three M1-M2 cycles consolidates research space through presenting the focus of the study (M1-Step 6) three times. Another thesis uses three identical patterns for consolidation through referring to the specific work done in each chapter (M1-Step 11) three times. Two theses move from the problem to its solution in the first M1-M2 cycle and then to consolidation through the work done in each thesis chapter (M1-Step 11) in the other two M1-M2 sequences. Another conclusion first reviews the literature, then moves to the work done in the thesis and finally reviews the specific work done per chapter.

In 22 conclusions consolidation is repeatedly achieved through four or more M1-M2 cycles. Three theses also have four M1-M2-M4 cycles and one thesis also has an M1-M2-M3 cycle. The more the M1-M2 sequences, the more varied and recurrent ways of consolidation through steps of M1.The writers first move from a thesis summary of the work done, the focus of the research, the thesis statement and research questions, and/or the problem detected to consolidation, then move from each chapter summary to consolidation, and finally move from the thesis statement, research questions/hypothesis addressed in each chapter to consolidation. An example of this process is found in T38, with 16 M1-M2 cycles. T38 starts with a summary of the work done in the thesis (M1-Step 1), the thesis statement and three research questions (M1-Step 2), and how they have been addressed (M2-Step 2). It moves on to review the specific work done in each chapter (M1-Step 11), the results (M2-Step 3) and claims (M2-Step 10). Then it focuses on each of the research questions (M1-Step 2) and how they were answered throughout the study, the results (M2-Step 3) and their interpretation (M2-Step 7). Finally it reviews the method (M1-Step 2) and states results (M2-Step 3):

(9) *First M1-M2 sequence: M1-Step 1* This thesis has investigated the relationship between layout aesthetics, task performance, and preference. *M1-Step 2* In Chapter 1, the thesis statement was as follows:

> An empirically validated framework for aesthetic design of visual interfaces is helpful to understand the relationships between layout aesthetics, task performance, and user preference in Human Computation Interaction.
>
> The thesis statement and the following three research questions have been addressed throughout the thesis:
>
> RQ1: What is the relationship between the aesthetics of interface design and task performance?
>
> RQ2: What is the relationship between the aesthetics of interface design and user preference?
>
> RQ3: Is there any relationship between user preference and task performance?

M2-Step 2 These three research questions have been addressed throughout a series of empirical experiments. […]

Five subsequent M1-M2 cycles: M1-Step 11 9.1 Thesis summary […] Chapter 4 reported an experiment investigating the effect of layout aesthetics on performance and preference, as well as the relationship between preference and performance.*M2-Step 3* Results showed that, regardless of search tool used performance […] increased with higher aesthetics levels, and decreased with lower aesthetics levels. […] *M2-Step 10* The results indicate that the aesthetics design of a computer interface supports both performance […] and preference, and that preference reflects actual performance […]

M1-Step 11 Chapter 5 reported […] *M2-Step 3* Results showed […] *M2-Step 10* These results indicate […] *The same structure is used in chapters 6, 7, and 8.*

Eight subsequent M1-M2 sequences: M1-Step 2 9.2 Research question 1

What is the relationship between the aesthetics of interface design and task performance?

M2-Step 3 Research question 1 is answered in chapters 4, 6, 7 and 8. The experiment reported in Chapter 4 revealed that there was a strong relationship between aesthetics and task performance where it was found that performance increased with increasing aesthetics level […] *M2-Step ~~10~~ 7* This indicates that when the layout of an interface is aesthetically designed, regardless of search tool used […], performance is better with interfaces with higher aesthetics layouts than with those with lower aesthetics layouts.

Same ~~strategy~~ strategies with the results in Chapters 6, 7, and 8.

M1-Step 2 9.3 Research question 2

Same strategies as with Research question 1.

M1-Step 2 9.4 Research question 3

Same strategies as with Research questions 1 and 2.

Two subsequent M1-M2 sequences: M1-Step 2 In Chapter 4, 9 stimuli were used in the preference task. […] *M2-Step 3* Correlation between preference and performance was found with the stimuli used in the first part of the preference task but not with those used in the second part of the preference task.

Same strategy strategies with Chapter 7.

The different patterns can be found no matter the writing styles of the thesis writers. While some writers use a discursive style of writing, other writers use a schematic bullet-pointed style with lists of the main aspects they want to highlight.

5. *Conclusion*

This study analyzed both quantitatively and qualitatively the predominant rhetorical strategies of the separate final conclusion chapters of 48 PhD theses of computer science at a UK university, focusing on how the doctoral writers highlight the thesis contribution to research through connections of rhetorical steps reviewing the study with steps for the consolidation of research space. Three research questions were addressed.

In answer to research question 1--What rhetorical strategies are predominantly used in the conclusions of PhD theses in computer science?--, the study showed that there are three key rhetorical moves in PhD conclusions on computer science: the review of the thesis work (M1), the consolidation of research space (M2), and the recommendations for future research (M4).

In answer to research question 2--What rhetorical patterns are used in the conclusions of PhD theses in computer science?--, the analysis revealed that there are usually sequences of two and three moves which integrate move patterns. In particular, the M1-M2 pattern, which links the review of the study with the consolidation of research space, is by far the most common in the computer science PhD conclusion chapters of the corpus.

As for research question 3--What is the nature and frequency of the most salient rhetorical connections of strategies used in the conclusions of PhD theses in computer science for consolidation of research space?--, the results indicate that certain steps of

M1 are directly associated with steps of M2. The most common combinations relate (1) a summary of the thesis work to the product and the evaluation of the product, (2) the purpose, thesis statement or hypothesis at the outset of the research to the findings or results, (3) the research questions at the outset of the research to the methodology, product or claim, (4) a problem or need to a specific methodology, a new product and/or a claim, and (5) a summary of the work done in each thesis chapter to the findings and claims.

The findings are partly congruent with Bunton's (2005) and Lewkowicz's (2012) results, who found that most of the conclusions they analyzed began by either summarizing the work carried out or restating a research problem and the consolidation move was accomplished by either presenting results, products, or solutions to a research problem, and/or claims. However, some findings in this study could be explained by the specific characteristics of the discipline of computer science. For example, it was found that showing the extent to which the purpose, hypothesis, thesis statement, and/or research questions at the outset of the thesis have been addressed is also perceived as a good opportunity to consolidate research space by the writers of the theses in computer science, a step which Bunton identified as the most common in the HSS conclusions but not in the ST conclusions. It was also found that presenting the methodology and the new product are particularly prominent steps for consolidation in M2 in the computer science conclusions. Although the finding corroborates Bunton's results for more than half ST conclusions, it teaches us about the specificity of the research in computer science, which involves not only obtaining results by using a particular technique but also developing new products, namely novel computing models, algorithms, system architectures, or techniques that solve problems or improve the performance of existing products.

Over half conclusions have relatively simple structures with between one and three cycles of the M1-M2 sequence, while 45.83% conclusions have a higher number of M1-M2 cycles and present more complex structures where consolidation is achieved repeatedly and through different strategies. Thus, rather than regarding the conclusion as a mere compilation of chapter summaries as concluded by Lewkowicz (2012) for a corpus of thesis conclusions from English studies at Polish universities, it seems that the writers of the theses in computer science are conscious that the role of the conclusion is to emphasize the importance to consolidate the research space and highlight the contribution to the field.

On account of the local influences reported by Lewkowicz (2012), the disciplinary variation in the conclusions reported by Bunton (2005) and the discipline specificities detected in this study it could be concluded that there are different valid organizational patterns to consolidate research space in a thesis. Pedagogical implications are related to issues that students need to understand in order to construct a successful text in their particular academic context. Doctoral students express themselves and decide on their own rhetorical strategies in their writing bearing in mind their goals and audience. The findings of this study could be used in genre-based courses of academic writing to relate students' perceived rhetorical practices in the conclusions--and specifically for consolidating research space--to appropriate genre features and the actual contextual requirements of disciplinary communities and institutions (Yayli, 2011; Kuteeva and Negretti, 2016). As Lewkowicz (2012, p. 123) reminds us, "even theses that have been successfully defended may have room for improvement and students need to appreciate this". By learning about how students create meanings and where students need support, teachers could help students increase their genre awareness of the conventions used in

particular disciplinary fields and contexts and help them to use the most appropriate conventions in their own writings.

The rhetorical patterns and connections analyzed in this study may be enlightening to novice writers if they encounter difficulties in establishing rhetorical transitions to depict the process of their research in computer science. Instructors could discuss samples with the learners, explain, and recommend certain strategies to highlight the contribution to research. For example, in an EAP course, instructors could use the results of this study to enlighten novice writers conducting research in the field of computer science in the final process of thesis writing. They may recommend novice students to summarize the specific work done in each thesis chapter and then state the result or present the new product so as to cyclically insist on the thesis contribution to the field of computer science. Instructors may also recommend to describe an unsolved problem or the need for a new technique thus paving the way for presenting the thesis research as the solution to the problem or the fulfillment of the need. Another suggestion to novice writers could be to direct reader's attention to how the purpose, thesis hypothesis and research questions have been addressed.

Teaching materials devised to ask learners identify the rhetorical moves and steps by which the contributions to research are being enhanced may stimulate learners' genre awareness. Exercises for computer science students requiring learners to achieve communicative purposes, like presenting a problem and its solution or presenting a product and evaluating it, may raise their genre knowledge of typical rhetorical patterns for consolidating research space in computer science.

The results presented, however, must be taken cautiously due to the limitations of the study. The theses in the corpus were collected from only one university in the UK. The theses defended at other universities may show different structures, both of the

theses as a whole and of their chapters. Other universities may also have specific requirements for students to organize their theses. Another limitation of the study is that it does not distinguish the native speakers from the non-native speakers of English. Although the purpose of this study was to analyze the theses defended at a specific institution in an English-speaking context, it remains to be seen whether the provenance of the students has an impact on the findings.

This work has investigated the rhetorical associations between the review of the study and the consolidation of research space in the conclusion chapters of a corpus of PhD theses in computer science in a British context. Studies like this one can provide insights into the practices of disciplines and support doctoral students "as they work towards membership of their desired academic community" (Paltridge and Woodrow, 2012, p. 101). Future research might include a comparison with the conclusions of PhD theses in computer science from non-British institutions. It could also investigate how the variable of the cultural variation of the students with different nationalities affects the general organization of the thesis and its chapters.

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Appendix

List of the 48 computer science PhD theses defended at the University of Glasgow.

T1. Arapakis, I. (2010). *Affect-based information retrieval.*

T2. Blanke, T. (2011). *Theoretical evaluation of XML retrieval.*

T3. Cahir, C. (2014). *Approaches to adaptive bitrate video streaming.*

T4. Crawford, H. A. (2012). *A framework for continuous, transparent authentication on mobile devices.*

T5. Dempster, M. A. (2013). *An information analysis of the interaction between sensory signals and ongoing cortical activity using a novel mechanistic cortical model, behavioural and MEG studies.*

T6. Donaldson, R. (2012). *Modelling and analysis of structure in cellular signalling systems.*

T7. Dooner, M.T. (2012). *Towards a robust, passive stereo depth sensor with confidence and intensity guided anisotropic diffusion disparity refinement.*

T8. Elliott, D. (2011). *An empirical analysis of information filtering methods.*

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