



## MACROSTRUCTURES AND RHETORICAL MOVES IN COMPUTER ENGINEERING RESEARCH ARTICLES

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### **Abstract:**

Genre analysis has offered us valuable insights into the rhetorical organization of different genres. Regarding the research article (RA) genre in engineering, previous move-based works have shown that disciplinary variation is evident, especially across computer engineering (CE) sub-disciplines which often showcase unique rhetorical structures and patterns due to the newness of the field. Using Swales' seminal move analysis approach (1990) this paper presents a synthesis of move-based works that have explored RA textual structures in CE sub-disciplines. The discipline-specific A-IMRD move/step frameworks and patterns presented in this paper can form the foundation of research-based English for Academic Purposes (EAP) pedagogies and teaching materials tailored to the needs of CE students in academic writing courses.

**Keywords:** genre, disciplinary variation, computer engineering, research articles, rhetorical organization, English for academic purposes

### **1. Introduction**

Genre analysis literature within the computer engineering (CE) technical communication field suggests research articles in CE sub-disciplines exhibit distinctive features (Dugan & Polanski 2006; Luzón 2005; Skinner & Mort 2009; Tricky 2021). The high-variance in the macro-structure and the internal rhetoric of the RA genre within CE sub-disciplines is largely attributed to the “newness” of the CE field. Contrary to other “traditional” engineering disciplines for example chemical engineering, civil engineering, mechanical engineering, and electrical engineering, CE only emerged in the 1940s and 1950s (Jin 2018). In other words, CE is a relatively “young” academic discipline that has not still formed a well-established research paradigm (Carter et al., 2011; Hyppönen & Paganuzzi 2010; Kmiec, & Longo 2017; Orr 1999; Skinner & Mort 2009). Another reason for the CE

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RA peculiar rhetorical structures is the limited guidance on structure planning that can be found within the CE RA publishing landscape. Conference organizers and journal editors from major CE academic publishers and professional organizations such as the IEEE and the ACM fail to provide adequate guidance and restrictions on RAs' macrostructure (Hyppönen & Paganuzzi 2010; Kmiec, & Longo 2017).

For English for EAP practitioners teaching academic reading and writing to EFL CE students designing EAP courses tailor-made to their students' needs means a top-down awareness of discipline-specific rhetorical structures constitutes a necessity. Nevertheless, works incorporating a synthesis of RA move-based works within the CE field to the best of the author's knowledge are non-existent. This paper attempts to fill this gap and presents a review of descriptive genre-based works within CE sub-disciplines.

### **1.1 Move analysis**

From a Swalesian English for Specific Purposes (ESP) perspective, the RA genre-much like all genres- constitutes a cross-disciplinary construct. The most common methodology for the specific genre focuses on teaching the RA based on recurrent organizational patterns in a particular text, i.e. the moves and/or steps of each section and the rhetorical organizing techniques that are used to realize them (van Enk & Power 2017; Triki 2021). ESP school move analysis dates back in 1981, when John Swales developed his first model of RA introductions in order to address the academic writing needs of his NNS students at the University of Michigan. He studied 48 RA introductions from hard sciences, social sciences and health sciences and categorized the units of discourse based on their communicative functions. His findings showed that although the research papers he explored originated from different fields, the concept of an RA introduction as a single genre could be claimed. Since then, a whole field emerged with studies exploring the moves and the steps of various academic genres within different disciplines (Triki 2021). Regarding its pedagogical application, Swalesian move analysis tasks are considered powerful genre awareness-raising tools, especially for novice L2 academic writers, as learners are required to apply their analytical skills and explore the discourse and linguistic properties of genres. Even though concrete ideas about teaching methods to be used when teaching genre in the classroom are not explicitly described, most of the tasks, activities, and text samples presented in Swales' works (1981, 2004) have the potential to raise readers' and writers' awareness of research genres. Knowing the schematic structures and the specific form-function correlations is vital for those who participate in a genre by reading or writing it, but -as novices-are not familiar with the specific patterns (Swales 2004).

## **2. Macrostructures**

Posteguillo (1999) was from the first researchers who explored CE RAs. More specifically, he analyzed 40 Introduction sections, 22 Result sections, and 34 Discussion/Conclusion

sections. The reason he opted not to analyze M&M sections, as he comments (1999: 154) was that CE research papers typically do not have a separate M&M section. In addition, he notes that it is very hard to analyze the M&M moves in the specific discipline as there were no standards set forth in the genre—at least for the time period examined. Posteguillo further claims that since CE RAs do not fit neatly within the normalized IMRaD structure, describing their rhetorical moves demands collaboration with expert members of the discourse community i.e. researchers in the respective field.

Hyppönen & Paganuzzi (2010) explored the structure of 8,520 computer engineering research papers from the Lecture Notes in Computer Science (LNCS) conference proceedings series published by Springer. The reason the researchers chose LNCS, along with the IEEE and ACM (Kmiec, & Longo 2017), is that it is one of the most influential conference proceedings in the CE field and it includes articles from different CE sub-fields. Their findings revealed that in terms of macro-structure, CE research papers possess a fluid shape which makes it difficult for the reader to follow the writers' thoughts. More specifically, they found that the standard IMRaD structure is uncommon in CE articles even though certain types of sections are stable regarding their location, namely the Abstract, the Introduction, the Related work section, and the Conclusion. Moreover, they found that CE researchers commonly include Motivation, Future work, and Contribution as discreet sections, which are usually not found in natural, social, and health sciences where writers put this information in the conventional sections of the IMRaD structure. Standard IMRaD names were used rarely, in fact, their findings showed that 19,800 different words were used in the headings of their 8, 520 article data set. They conclude that CE authors usually present their scientific findings as a story, instead of strategically structuring the presentation to help their readers. This type of academic writing was also the case in other disciplines, but only in their early years (Hyppönen & Paganuzzi 2010).

Hyppönen Paganuzzi (2010) findings further showed that the macro-structure of CE research papers focusing on systems or architectures usually includes a description of the types of models, and concentrates on the implementation aspects of the system or architecture presented which according to the authors suggests the existence of the full model system/architecture– implementation pattern. Overall, the most common macro-structure patterns found in CE RAs based on their analysis are:

- 1) [Problem–Algorithm–Experiment]
- 2) [Methods–Results–Discussion]
- 3) [Model–System or Architecture]
- 4) [System or Architecture–Implementation]
- 5) [Model–Implementation] (:217).

Kanoksilapatham (2015), analyzed 180 full-length research papers from the top five high-quality journals in the disciplines of civil engineering, software engineering, and biomedical engineering. To minimize subjectivity and reinforce the validity of his analysis in terms of the journals' prestige, he chose the more objective index for quality in the global research arena: the journals' impact factors. Regarding the biomedical and

the software Engineering RAs, the majority of which came from leading IEEE, ACM, and Elsevier journals, he found that even though they did follow the standard IMRaD macro-structure, in many cases they also exhibited ILM[RD]C and IL[MRD]C structures.

Chang & Kuo (2011) analyzed sixty full-length RAs from three leading IEEE journals (IEEE Transactions on Computers, IEEE Transactions on Pattern Analysis and Machine Intelligence, and Computational Linguistics) in order to design an EAP web-based course for Chinese CE students. The selection of the journals was based on the recommendations of the CE faculty members. Since the move structure was intended for pedagogical purposes they preferred a model with a single level of moves, rather than two levels of moves and steps as it was considered easier for students to learn and use (:224). Their self-developed scheme included macro-moves and moves (moves that occur in all A-IMRaD sections and section-specific moves). They found that CE research papers exhibit high variance in terms of macro-structure. More specifically, their analysis showed that the section succeeding the introduction often provides the research method, and then in the following sections, CE researchers present related methodological descriptions or procedures in a more detailed way, often mixed with results in the same sections, occasionally combined with interpretations of results and comparisons with other related works.

Kwan (2017) analyzed RAs from a range of high-ranking Information Systems (IS) journals. His findings showed that in the field of IS, macro-structure is heavily influenced by the epistemological paradigm of the experimental study it reports and that Behavioral science research (BSR) and design science research (DSR) papers within the IS field differ significantly in terms of macro-structure. More specifically, he found that there is a distinctive section found in the BSR RAs related to Research model/Hypotheses and two specific sections only found in DSR RAs named Artefact and Evaluation. His results further showed that DSR papers exhibited similarities with Posteguillo's corpus (1999). He attributes this finding to the fact that the DSR Problem-Solution paradigm has derived from the discipline of CE and as a result, it is heavily influenced by the methods, the techniques but also the discipline-specific conventions of CE.

Using a Swalesian move framework (1990), Maswana et al., (2015) explored the rhetorical structure of sixty-seven engineering research papers from the sub-disciplines of structural engineering, environmental engineering, electrical engineering, chemical engineering, and computer engineering. Researchers from the EAP field worked closely with six engineering researchers with PhDs in their respective sub-disciplines. According to the authors, participation with engineering researchers is crucial to understanding whole engineering RAs due to the inherent technicality of the specific field. The articles were selected in collaboration with the engineering insiders so that the texts chosen would be recognized by the engineering discourse community, and English was appropriate both for research and educational purposes. The articles analyzed were taken from Communications of the ACM (Association for Computing Machinery), Mathematical Programming, Journal of the ACM, and Artificial Intelligence for computer Engineering (ACM). Their findings indicated that the body section of the RAs which

essentially refers to the M&M and the results sections bears a variety of headings and subheadings, making it difficult to compile the results under common headings across articles. More specifically, they found that CE papers frequently include a Materials and Methods or an 'Experimental' section and a Results and discussion section. Some RAs employed a more specific name for the Materials and methods section, such as Computational details. Results further revealed that in terms of macro-structure, only 28 articles (42%) in the study exhibited explicit IMRaD headings. Moreover, the number of articles with abstracts was 57 (85%), with introductions was 67 (100%), and the number with concluding sections was 53 (79%). Despite these results, overall, the writers suggest there is a "*common core of rhetorical structure in writing articles*" (:9) that can be used for introductory EAP courses in which EAP teachers are likely to have students from a range of engineering sub-disciplines. That means teaching materials from any engineering sub-discipline are useful as long as they exhibit the common core of the rhetorical structure.

Overall, quantitative genre analysis findings within the CE field show that three of the IMRaD sections, namely the methods, results, and discussion are commonly diversely labeled and not always stand-alone. For example, the M&M section is labeled as Experiment, Experimental runs and measurements, Study area and instrumentation, and it is often merged with the results section (e.g., Experimental setup and results). Likewise, results are either under other labels (e.g., Experimental setup and results) or merged with the discussion. Discussion is either merged with the results or conclusion sections, or under the labels "Summary and conclusions" (Chang & Kuo 2011; Kanoksilapatham 2015).

## 2.1 Abstracts

Genre-based studies that have focused on CE RA abstracts have shown that usually this specific RA sub-genre includes a Background move, a Purpose move, a Materials and methods move, a Results move, a Conclusion Move, a Literature review or Reference to other studies move, and a Research gap move (Chang & Kuo 2011; Kanoksilapatham 2015; Khaw & Tan 2018).

Jiand and Hyland (2017) analyzed 240 abstracts from "soft" and "hard" disciplines (applied linguistics, philosophy, marketing, electronic engineering and medicine). Electronic engineering journals, included the International Journal of Microwave and Millimeter-Wave, Microsystem Technologies, IEEE Transactions on Microwave Theory and Techniques, the Journal of Microelectromechanical Systems, Solid-state Electronics, Microelectronics Journal, Analog Integrated Circuits, and Signal Processing. They found that overall, the abstracts contained 859 moves, with 91% containing a Purpose move 87 %, a Results move 70%, a Methods move 65%, a Background move, and 56% included a Conclusion move. In these moves, they further identified 824 meta-discursive nouns, averaging 18.8 cases per 1000 words and 3.4 in each abstract. Moreover, they found that whereas soft discipline RA writers use meta-discursive nouns most frequently to convey a purpose, with 32% of all cases, those in electronics use them more in the conclusion move, where they comprise 34% of the total. This difference suggests that expert RA

writers have a heightened awareness of their readers' needs and the accepted epistemological beliefs regarding how knowledge is best represented. On the one hand applied linguists, philosophers and marketers use nouns chiefly to establish background importance and present a valued purpose for their research. In Electronic engineering and medicine, this tends to be less important than projecting the significance of the results to colleagues and those in related applied fields who can actually make use of them as they are highly technical fields.

Moswana et al. (2015) found that CE RA abstracts in top-notch IEEE and ACM journals, include a Background move, a Purpose move, a Methods move, a Results move, and a Conclusion move. Chang & Kuo (2011) discovered that CE RA abstracts usually include an AB (Abstract background information move), an AP (Abstract-purposes or major tasks move), an AM (Abstract-methods or theories move), an AR (Abstract-results move), an AD (Abstract-explanations, implications, comparisons, limitations move), an AC (Abstract-partial or complete conclusions, evaluation move) an AL (Abstract-literature review or reference to other studies move) and an AG (Abstract gap or missing information move).

## 2.2 Introductions

Regarding the introduction sub-genre, findings within the field of CE suggest that there are four discipline-specific genre characteristics that the original CaRS model (Swales, 2004) fails to include, namely examples, definitions of terms, and evaluations (Anthony 1999; Chang & Kuo 2011; Khaw & Tan 2017, 2018). More specifically, Anthony (1999) analyzed twelve "Best Paper" software engineering research papers. His findings showed that overall, the CaRS model was successful in describing the specific section. Other than the Purpose move, Anthony found that the Gap move was very common in his sample, in fact his results showed that 91.7% of the researchers included one or two Gap moves. He notes however two flows in Swales model: i) some difficult, discipline-specific concepts such as definitions and mathematical formulas that were found in some of the papers and for which Swales had not included "steps" and ii) that the vast majority of software engineering writers included an evaluation of their findings. Accordingly, he proposed that for the specific discipline, the CaRs model should include a separate Evaluation move as, in CE disciplines *"a separate 'evaluation of research' is not only obligatory, but a crucial element in achieving the aims of the introduction"* (:45).

Chang & Kuo (2011) found that CE RA introductions include an IB (Introduction background information move) an IP (Introduction purposes or major tasks move), an IM (Introduction methods or theories move), an IR (Introduction results move), an ID (Introduction explanations, implications, comparisons, limitations move) and IC (Introduction partial or complete conclusions, evaluation move) an IL (Introduction literature review or reference to other studies move), an ID (Introduction discussion move), an IO (Introduction local or global organization move), an IG (Introduction gap or missing information move), IF (Introduction reference to tables or figures move), IJ (Introduction justification and reasons move). Similarly, Shehzad's findings (2012)

showed that CE RA introductions followed the CaRS model, in fact, he found that 95% of them included a clear Gap move, but they also included Evaluations of their results and an Outline move which presented the articles' macro-structures. Kanoksilapatham's (2015) findings also suggested that the introduction sections in biomedical and software engineering are compatible with Swales' (1990 & 2004) models, as the vast majority of the RAs he analyzed exhibited the sequence of the three CaRS moves. Kanoksilapatham concludes that *"The introduction section seems to be constructed similarly across the three sub-disciplines, suggesting that, generally, these sub-disciplines share the same goal in introducing their research topics"* (:80).

Glass et al. (2002) explored software engineering introductions. Their findings agreed with the majority of works cited earlier, as they also found that Swales' CaRS model covers the majority of rhetorical moves except for the Evaluation of the results move and the Outline move. They conclude their paper by suggesting that the article outline, along with the other steps, potentially helps CE readers to rapidly locate what they would like to read for further details, expediting the dissemination of research discovery. They also note that based on their analysis, software engineering researchers tend to announce the study's main contribution right in the introduction in order to "sell" their research in a highly competitive and fast-moving field.

Han et al. (2010) explored RA introductions from two CE sub-disciplines, namely computer information security and computer languages, using Swalesian' move analysis. Their results showed that although the CaRS model describes the main rhetorical framework of the CE introductions, there are some extra rhetorical moves that should be included, including an Evaluation of the main results move and a Structure outline move. Moreover, their findings showed that Gap move is an obligatory move and plays role in Move 2. In fact, it appears in M2 not only in a circular form followed by other gaps but also embedded in Indicating a gap, as previous studies are used to justify the building of multiple gaps in a specific research area. Additionally, the Reviewing items of Previous research step is not only a part of M1 Establishing a Territory, but can be employed to realize other steps of other moves. Accordingly, the authors suggest that Reviewing items of Previous research step should not be a part of a specific move but a separate step that can be used to realize any move in the ECE RA introductions.

### **2.3 The materials and methods section**

According to Swales, M&M sections (2004: 220) include *"a cline with heavily clipped texts at one extreme and highly elaborated ones at the other"*. Extensive findings from the CE genre-analysis field support that in the specific discipline, the M&M section belongs to the "highly elaborated" category. CE exhibits significant intra-disciplinary variations in RA M&M structures. This is largely attributed to the fact that it involves different types of research methodologies which heavily influence the Method, Procedure and Materials moves. In CE, the research procedure may essentially refer to implementation, configuration, analysis, or experiment, and the "materials" may be referred to mathematical and computer models, architectures, or algorithms (Chang & Kuo 2011;

Hyppönen & Paganuzzi 2010; Kmiec, & Longo 2017; Kwan 2017). Moreover, the M&M section in CE is essentially the section that RA authors can promote their methodological innovativeness which frequently is the main purpose of writing an CE research paper. The complexity of CE research methodology is mirrored in more than- one method-related section (sometimes more than six or even seven) in a single paper and the mixing of method, results, and discussion (Chang & Kuo; Hyppönen & Paganuzzi 2010; Kmiec, & Longo 2017).

In terms of internal rhetorical structure, CE articles commonly display a very straight-forward problem-algorithm pattern, and a less clear model-system/ architecture pattern. More specifically, authors focusing on algorithms usually test them with experimental procedures. Accordingly, the macro-structure in algorithm-related articles follows a problem-algorithm-experiment pattern. On the other hand, research papers presenting architectures and systems follow a problem-architecture experimental pattern (Hyppönen & Paganuzzi 2010; Kmiec, & Longo 2017). Kanoksilapatham's (2015) study further revealed that even though the M&M sections are highly diverse at the step level, at the move level the vast majority include a set of three basic moves namely Describing procedures, Featuring other methodological issues, and Reporting and consolidating findings. The Describing procedures move is obligatory, with 100% of occurrence across the three sub-disciplines examined. The other two moves are optional, with frequencies from 38% to 51% respectively. Chang & Kuo (2011) report that M&M sections in CE usually include the following moves: Explanations, Implications, Comparisons, or Limitation methods or Theories, Reference to tables or figures, Definitions, Variables, Equations, or Measurements, Literature review or Reference to other studies, Assumptions, Conditions, Criteria, Hypotheses, Purposes and major tasks and Background information for methods or theories.

In terms of headings, RAs in major CE journals from IEEE, ACM, Elsevier, Springer, and Sage usually include headings such as Study design, Study overview, Experimental procedures, Experimental setup, Materials and procedures, Our system, Our game, and other article/theme-based headings and sub-headings (Chang & Kuo 2011; Hyppönen & Paganuzzi 2009; Kmiec, & Longo 2017; Kwan 2017).

## **2.4 Results and discussion sections**

Chang and Kuo (2011) found that CE RAs usually include an RP move (Results-purposes or major tasks), an RR (Results-results move), RD (Results-explanations, implications, comparisons, limitations move), an RC Results-partial or complete conclusions, evaluation move, an RL (Results-literature review or reference to other studies move), an RO (Results-local or global organization move) and an RF (Results- reference to tables or figures move).

Regarding the Discussion sections, Kanoksilapatham's (2015) findings showed that the discussion section of CE RAs included a Reviewing the present study move, a Consolidating result move, and lastly a Stating limitations and future research move. The only move of the three that was found to include steps was the Consolidating results



move which is usually realized by seven steps: [Step 1: Reporting results]; [Step 2: Explaining results]; [Step 3: Summarizing results]; [Step 4: Interpreting results]; [Step 5: Comparing results]; [Step 6: Exemplifying results]; [Step 7: Claiming values of results]. Based on his results the Reviewing the present study move is considered a conventional move at the rate of about 75% in the fields of software engineering, and biomedical engineering. The Consolidating results move is the central and obligatory move of the section in both software engineering and biomedical engineering (about 92% and 95%, respectively). Lastly, the Limitations move, has a range of frequencies from 69% to 85% in the two sub-disciplines. Given the fact that the discussion section of these two CE sub-disciplines usually consists of a number of sub-sections focusing on individual results or a set of results, recursion of Reviewing the present study move and the Consolidating results move is common.

Koutsantoni (2006) explored the discussion sections of leading CE journals at the micro-level and compared them to CE MSc, MPhil, and PhD theses thesis. The 17 RAs she analyzed were extracted from the International Electronic and Electrical Engineering, (IEEE) Transactions on Communications, Information Theory, Magnetics, Biomedical Engineering, Multimedia, Image Processing, the IEEE Signal Processing Letters, and the International Journal of Electronics, dating from 1996 to 2000. These particular journals were selected as they were referenced in students' work, and most importantly because specialist CE informants recommended them as key journals in their field. Some of the articles that were analyzed were actually referenced in students' work, while others were randomly chosen. Her study focused on the density and function of hedges and more specifically on discourse-based strategic hedges and their personal or impersonal expressions. Her analysis showed that CE students, as novice members of the CE community, hedge more than expert RA authors and essentially refrain from taking personal responsibility for their arguments. Expert CE RA authors, on the other hand, hedge less than the students and often employ personally attributed hedges.

### 3. Conclusion

Schematic structures of RAs within the CE sub-disciplines appear to include diverse moves which correspond to diverse rhetorical purposes and discipline-specific epistemological beliefs, values, and contexts. CE writers tend to employ a variety of rhetorical and structural strategies, especially regarding the highly "technical" M&M section. In this section, they frequently draw on multiple and diverse rhetorical moves and steps in order to construct their arguments and convince their highly competitive readership regarding the innovation of their methods. Abstracts, introductions, results, and discussions appear a bit more stable regarding their rhetoric yet they still display a number of distinct moves and steps that do not appear in other more "traditional" engineering disciplines. This "peculiarity" in terms of structure often causes difficulties to novice readers and writers in CE departments who struggle both to read and write RAs (Seiradakis & Spantidakis 2018a). A solution to this problem could be designing and

implementing EAP courses for CE students taking under consideration corpus-based research from relevant sub-disciplines and incorporating genre analysis tasks that emphasize specific rhetorical structures and linguistic forms derived from corpus analysis (Chang & Kuo 2011; Seiradakis & Spantidakis 2018b; Seiradakis & Spantidakis 2019). EAP genre-based courses employing a one-fits-all approach in academic writing usually end up providing theoretical declarative knowledge regarding genres which usually fails to become procedural outside classroom walls (Lee & Swales 2006). As Lee and Swales (2006) point “*the closer the participants could come to their discipline-specific written discourses, the more engaged with the texts they became and the more time they were willing to spend on them....*” (: 71).

### **Conflict of Interest Statement**

The authors declare no conflicts of interest.

### **About the Author**

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