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Reconciling Efforts to Understand Engineering Intellect: Research Articles from Linguistic Perspective

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ABSTRACT

Biomedical engineering is a relatively new sub-discipline of engineering. However, this sub-discipline is particularly vital, focusing on improving human healthcare and treatment. Meanwhile, English research articles are increasingly used in advanced education as a means to disseminate and ratify knowledge. Therefore, the understanding of how biomedical engineering research articles are constructed will be beneficial for both students and practitioners in this sub-discipline. This study analyzes a set of the Methods section of biomedical engineering research articles written in English with the objective of elucidating what constitutes appropriate academic style of writing in this discipline and genre. The dataset representing the high quality journals in the field is analyzed, using Swales' genre analysis (2004). The structural organization underlying the Methods section of biomedical engineering research articles is identified, consisting of a set of information elements organized in a particular pattern. The textual organization displays the unique and distinctive nature of academic communication in this sub-discipline. In addition, the findings are pedagogically applicable, providing biomedical engineering graduates with the skills required in disseminating their knowledge and expertise in the academia, and alerting them to the existence of intellectual diversity. The study also demonstrates the role of linguistics to provide an intellectual and holistic understanding of biomedical engineering enterprise.

Keywords: biomedical engineering, English, Methods section, human healthcare, linguistic.

1. INTRODUCTION

International English language journals are considered one of the favored publication outlets. Therefore, a good command of English enhances the ability to share knowledge across languages and cultures. In Asia, English is predominantly used as a lingua franca particularly in academia (□Belcher, 2006). Statistically, English language journals are preferred by 85% out of 585 academics in Hong Kong (Flowerdew, 1999a). Hyland (2006) claimed

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that not only are more than 90% of the journals in sciences printed in English but also the most prestigious and cited journals are in English. Baldauf (2001) suggests that a number of academics would like to publish their research work in English for the sake of wider circulation. As stated by Canagarajah (1996) and later endorsed by Flowerdew (1999a), non-native speakers of English with doctorate degrees from English speaking countries might feel relatively at ease writing research articles in English. These phenomena make some groups of scholars feel disadvantaged when writing research articles in English. To pinpoint specific disadvantages encountered by these scholars, Flowerdew (1999b) found that Hong Kong scholars, although had difficulties with the use of certain expressions and vocabularies, found the task of writing research articles in general quite daunting. Consequently, it is time for students and academics from any language background to gain fluency in the conventions of English academic discourse.

As an initial and reconciling effort to understand how academic intellect is shaped and constructed, Swales' seminal work (1990), currently known as genre analysis or move analysis, lends itself as a device to analyze the Introduction section of research articles from diverse disciplines. In a nutshell, Swales' linguistic approach to scientific discourse allows certain textual components to emerge and be classified as 'moves' and their sub-units as 'steps'. These units of discourse are principally determined by their communicative functions. How these moves and steps co-occur in texts thus forms a rhetorical pattern of texts.

A multitude of studies have adopted Swales' move analysis to identify the structural patterns of research article Introduction texts from diverse disciplines (e.g., Posteguillo,1999 in computer science; Ozturk, 2007 in applied linguistics; Kanoksilapatham, 2003 in biochemistry). A number of studies focus on the Results section (e.g., Brett, 1994 in sociology; Thompson, 1994 in biochemistry; Williams, 1999 in medicine) and the Discussion section (e.g., Nwogu, 1997 in medicine). However, few studies focused on the Methods section (Lim, 2006 in business management), leaving the picture of the structural organization for the entire research articles fragmented. Therefore, this study focuses specifically on the Methods section of research articles. Furthermore, a number of move-based studies of Introductions on different academic disciplines reveal that each discipline has its own preference of structural organization. As a result, studies focusing specifically on certain disciplines are needed. Given the relatively new discipline of biomedical engineering, and its integrated nature of biology, medicine, and engineering, the discipline of biomedical engineering is quite appealing. This study thus aims to analyze the biomedical research Methods section with the objective of identifying their rhetorical structure by using Swales' move analysis. The findings of this study are particularly valuable for non-English speaking biomedical engineers in drafting this particular section. This study

also demonstrates the role of linguistics to understand the biomedical engineering intellect manifested in the Methods section of research articles.

2. MOVE ANALYSIS AND RESEARCH ARTICLES

In order to shed light on how academic discourse like scientific research articles are written, linguistic approaches to the discourse are revealing. For instance, Swales' move analysis has proved to successfully capture rhetorical organization of the research article genre. According to Swales (1990, 2004), a move is a textual unit that has a communicative function. These units are usually more or less conventional, forming a sequence or a rhetorical organization preferred by a specific discourse community. According to Swales' 1990 model, or so-called "Create a Research Space or CARS" model, research article Introduction texts can be made up of three basic moves. They are *Move 1: Establishing a territory, Move 2: Establishing a niche,* and *Move 3: Occupying the niche.* Each move encompasses a series of sub-moves or steps. Thanks to the results generated from a large number of move-based studies, Swales modified his 1990 model in 2004 to empirically and accurately provide an account for variations prevailing in the structure of Introductions across disciplines.

Numerous attempts have been made to verify and extend the model's validity by applying Swales' analysis to RA introduction datasets from diverse disciplines (e.g., Shezard, 2008 in computer science). By extension, the model has been adapted to analyze the structural patterns in the other sections of research articles (e.g., Thompson, 1994; Bruce, 2009 for the Results section; Williams, 1999; Kanoksilapatham, 2005, 2007a; Nwogu, 1997; Posteguillo, 1999 for the Discussion section); Introductions across languages (e.g., Kanoksilaptham, 2007c; Taylor & Chen, 1991); Introductions of research articles across disciplines (e.g., Ozturk, 2007; Kanoksilapatham, 2007b); and research articles in entirety, including the four sections (e.g., Kanoksilapatham, 2003, 2005 in biochemistry; Nwogu, 1997 in medicine). A dearth of studies are conducted on professional discourse (e.g., Bhatia, 1993) and occluded discourse (e.g., Connor & Mauranen, 1999 on grant proposals; Biber et al, 2007 on fundraising letters). As far as research articles are concerned, these findings indicated that each section of research articles has its own structure, displaying a preferred sequence of moves and steps. Moreover, the same section across different languages seems to demonstrate the preference of each target culture (e.g., Taylor & Chen, 1991). Finally, the rhetorical organization of the same section but from different disciplines is not identical either, displaying each discipline's proclivities and unique characteristics.

At this juncture, it is noted that the Methods section has received scant attention. According to Swales (1990: 170), this section is "enigmatic, swift, presumptive of language knowledge, not designed for replication, with little statement of rationale or discussion of the choices made." Because of this nature, this section can be considered too technical for linguists and thus remains relatively less explored, compared with the other research article sections.

3. CONTEXT: BIOMEDICAL ENGINEERING

Biomedical engineering is a relatively new sub-discipline of engineering. Despite its youth, this sub-discipline has been particularly vital, focusing on improving human healthcare and treatment. It is also commonly recognized that research articles have increasingly become a common means of communication among scholars across disciplines, and biomedical engineering is no exception. However, no study has been focused on biomedical engineering yet. Given the unique nature of biomedical engineering as an interdisciplanary discipline, it is interesting to investigate and understand how biomedical engineering research articles are constructed. Moreover, because the Methods section is known to be highly technical and disciplinarily specific; its technicality and specificity is intriguing for linguistic analysis. It is anticipated that move analysis conducted on the Methods texts of biomedical research articles will reveal certain unique characteristics of the discipline.

4. METHODS

This study has the objective of identifying the structural organization of the Methods section of biomedical engineering research articles. Initially, a dataset of research articles in biomedical engineering written in English was compiled. In order to ascertain that the dataset analyzed by this study represents quality journals in the field, the top five impact factors of biomedical journals released in the year 2005 (the most recent available at the time of study) were elicited. Then, twelve articles from each journal published in the year 2006 were randomly selected.

Only the Methods section that is clearly and independently delineated was included in move analysis. Out of 60 research articles, 53 research articles were selected for further examination by Swales' move analysis. To achieve the objective of elucidating what constitutes appropriate academic style of writing in this discipline and genre, the structural organization of this section was outlined, displaying the moves and steps in this particular section.

5. RESULTS AND DISCUSSION

The structural organization underlying the Methods section of biomedical engineering research articles consists of a set of three moves organized in a particular pattern. These moves and their constituent steps are illustrated individually by instances taken from the actual research articles. The display of the move/step examples was modified, including the replacement of all citations, be they short or long, with (R), and the highlight of certain linguistic features (in italics) that convey a specific communicative function. At the end of each instance, the abbreviation of the journal source was provided (TBM, AOR, BMR, TMI, TNS), with the numbers from 1 to 12, indicating the actual order of their publication in the year 2006.

The results from move analysis reveal that the Methods section of biomedical engineering consists of three main moves. They are *Move 1: Stating procedures, Move 2: Describing materials, apparatus, participants*, and *Move 3: Stating results*. The results of genre analysis yield the rhetorical pattern of biomedical engineering Introductions delineated as shown below.

Proposed model for biomedical engineering Methods

Move/Step	No. of Articles	Percent
Move 1: Stating procedures	**53/53**	**100.00**
Step 1: Objectives	43/53	81.43
Step 2: Protocolized procedures	26/53	49.06
Step 3: Detailed procedures	53/53	100.00
Step 4: Procedural background	27/53	50.94
Step 5: Procedural justification	33/53	61.11
Step 6: Ethical statement	14/53	26.42
Move 2: Describing materials/apparatus/participants	**27/53**	**50.94**
Step 1: Itemized materials	22/27	81.48
Step 2: Apparatus setting	11/27	14.81
Step 3: Material acquisition	11/27	40.74
Move 3: Stating results	**26/43**	**48.15**
Step 1: Announcing results	26/26	100.00
Step 2: Interpreting results	2/26	7.69
Step 3: Comparing results	2/26	7.69
Step 4: Explaining results	1/26	3.85

Included in the model are the frequency and the percent of occurrence of each move and step. Move 1 is considered essential, with 100% of occurrence acting as an essential move of the Methods section. Meanwhile, the other two moves are not as stable as Move 1, with their frequency of occurrence about 50%. The following sections provide a brief description of individual moves and steps and their frequency of occurrence.

5.1. Move 1: Stating procedures (100.00%)

The communicative function of this first move type is to provide information related to diverse aspects of research procedures. Five steps of this move include *Step 1: Objectives, Step 2: Protocolized procedures, Step 3: Detailed procedures, Step 4: Procedural background, Step 5: Procedural justification,* and *Step 6: Ethical statement.*

To elaborate, *Step 1: Objectives* is for the author to announce the purpose(s) of the research study. *Step 2: Protocolized procedures* presents a brief description including only major characteristics of the procedures that are commonly established and known to scholars in the field. *Step 3: Detailed procedures* provides the description of research procedures in detail. *Step 4: Procedural background* offers background information for certain characteristics of the procedures used. *Step 5: Procedural justification* states reasons why a particular procedure is adopted by identifying advantages and disadvantages of the procedures for the research study. The last step of this move is *Step 6: Ethical statement*, in which certain procedures are undertaken to comply with ethical requirements imposed in the field. The corresponding examples of these steps are illustrated in [1] to [6], respectively.

[1] *To determine* the impact of Zr-ACP and HAP on the stages of cell development, ... [BMR3]
[2] Numerical calculations *were performed* on an IBM compatible PC having a Pentium 4 CPU, and the partial differential equation consisting of sodium and potassium channel current fluctuations was solved with *the Crank-Nicholson method (R)*. [TNS8]
[3] ...the pill *was first immersed* in gastric juice for 45 min, and then directly *transferred* to intestinal juice to simulate the transition from the stomach to the duodenum for another 45 min. [TBM11]
[4] In SENC MRI, *two factors may influence* the ability of the technique to reflect the correct tissue stiffness based on a strain component in one direction only. [TBM7]
[5] *One major advantage of* our system is that all tubes for both circuits are located on a connecting element at the left side of the cylinder. (R). [AOR12]
[6] The study received *Internal Review Board approval* and all subjects signed an informed *consent document*. [TNS3]

This move was found in every Methods section analyzed, suggesting its

indispensable role in this particular section.

In resonance with the global objective of this move, *Step 3: Detailed procedures* is the most frequently used, occurring in every research article. The frequencies of other steps however fluctuate, ranging from 27% to 61%.

5.2. Move 2: Describing materials/apparatus/participants (50.94%)

In this biomedical engineering, this move can be realized by three constituent steps. *Step 1: Itemized materials* lists all the materials, equipment, or human organs used in the study. *Step 2: Apparatus setting* describes how each apparatus is set for the purpose of possible replication and validation by future research. Finally, *Step 3: Material acquisition* provides accounts how the materials are obtained. These steps are exemplified by [7], [8], and [9], respectively.

[7] *The base consisted of* a "U" tube, a diamond plate, a stand adapter piece, and two clamping wheel mounts as shown in Fig. 1. [TNS3]
[8] The source-to-detector distance of a *SkyScan 1076 is 172 mm*, the distance from the rotation axis to the detector center *is 51 mm*. [TMI7]
[9] Articular knee cartilage *from* voluntary donors without known infectious disease *was obtained from* the Musculoskeletal Research Center Berlin, Charite as well as from the Insitute of Experimental Pathology. [AOR10]

Move 2 was not found as frequently as Move 1, with only about 51% of occurrence. Among all of the three steps, *Step 1: Itemized materials* is the most prevalent, with its presence as high as 81.48% of all instances of Move 2.

5.3. Move 3: Stating results (48.15%)

In biomedical engineering, *Move 3: Stating* results can be realized by four constituent steps. *Step 1: Announcing results* explicitly states the findings generated from a research procedure. Scientific procedures usually consist of a number of steps. Each step, in turn, yields results which are reported in this Methods section. *Step 2: Interpreting results* allows researchers to offer scientific interpretation of the results. *Step 3: Comparing results* provides a chance for scientists to compare a number of results generated by the same study and those produced by other studies. Finally, *Step 4: Explaining results* convinces readers that the results obtained can be scientifically accounted for. These steps are exemplified by [10], [11], [12], and [13], respectively.

[10] Grouping images by SNR, *there were 32%, 36%, 21%, and 11%* of images with SNRs near 10, 20, 30, and 40, respectively. [TMI5]
[11] ..., *indicating* no significant alteration in the hydrodynamic function of the device during the testing time. [AOR6]
[12] *Similar observations* were reported *by XXX,* who tested bioprosthetic valves using a similar glycerin solution (R). [AOR6]
[13] This *can be explained by* the low signal-to-noise ratio in one of the images at these extreme levels. [TBM7]

Move 3 was not frequently found, with only about 48% of occurrence. Among all of the four steps, *Step 1: Announcing results* is the most prevalent, being present in every Methods section analyzed. It should be noted that the frequency of occurrence of the other three steps is relatively low, with less than 10%. This finding reveals that biomedical engineering Methods adhere to the conventional boundary between the sections of Results and Discussion to a large extent. Unlike, for example, the discipline of applied linguistics (Yang & Allison, 2002), the boundary between the two sections is more or less blurred.

As for the sequence of moves, the three moves displayed in the model seem to occur in the sequence of *Move 1: Stating procedures*, followed by *Move 2: Describing materials/apparatus/participants*, and conclude with *Move 3: Stating results*. Cyclical patterning of these three moves are also observed, with the likelihood of Move 1 and Move 2 being recycled in longer Methods. The constituent steps of each move also displayed a relatively less fixed sequence of occurrence. However, the order displayed in the model seems to be the most common one in the dataset.

To address the attempt to identify the uniqueness of biomedical engineering discipline, the comparison of this study's findings with those on the Methods section of other disciplines (e.g., Kanoksilapatham, 2007a in biochemistry; Kanoksilapatham, 2007d in microbiology) indicates that the step of *Ethical statement* is unique in biomedical engineering Methods. Although its occurrence rate was only 26.42%, a scrutiny of additional instances (14 and 15) of this move/step is elucidating.

[1] All animal procedures were performed in an AALAC-accredited surgical research facility under an *approved protocol* from the institutional animal care committee of the University of Washington. [TBM3]
[2] All their patients or their accountable relatives gave their *informed consent.*[AOR8]

The two instances, in addition to (6) shown earlier, again highlight the prominent characteristic of biomedical engineering research articles. This finding thus demonstrates the power of linguistic analysis in capturing the identity formulation of biomedical engineering. In this regard, the finding corroborates Gee's statement (1990: 155), who remarks that discourses are connected with displays of identity. Along the same line of argument, failing to display an identity in discourse is tantamount to a scholar being excluded from that particular discourse community. Similarly, those who comply with the conventions of the discourse are likely to succeed in their academic endeavours.

Now that the textual organization of the Methods section in biomedical engineering research articles has been delineated, caveats are in order with regard to the application of the model proposed. The moves and steps outlined in the model are suggested as one of the possible means of navigating particular novice scholars in the field to grapple with the challenging task of writing research articles. It is noted that discrepancies in Methods textual structure are discernible, implicating each individual's preferred rhetorical pattern. In addition, variation can take place with regard to the frequency of each move and step, suggesting the flexibility of the model.

Finally, the model does not mean to suggest that all of the steps listed are used in one Methods section. Therefore, the model should be observed with some precautions.

Apparently, rhetorical organizations of texts are helpful, providing the schema of what informational elements or moves are presented. As such, pedagogical implications of this study are evident, highlighting the role of linguistics in understanding scientific discourse. Rhetorical consciousness-raising should be instilled in learners. A number of ways can be implemented to achieve this in an English for Specific Purposes (ESP) classroom. First, learners in a heterogeneous class (in terms of native language backgrounds) should be given ample opportunities to compare and contrast, for instance, Introductions and abstracts written in their own language with those written in English. In so doing, they should be able to observe similarities and differences so that they are prepared to make smooth and successful transitions when they are obliged to write in the English language. In addition, their awareness of the conventions prevailing in each culture will be sharpened.

Second, focusing on the same type of academic writing but on different disciplines, learners are encouraged to make comparison to capture disciplinary variations among text samples. Modeling of rhetorical moves

may be appropriate for learners who have to embark on the task of academic writing. Subsequently and gradually, learners should be exposed to variations that are exemplified to illustrate the fact that a model is not rigid, but flexible and sensitive to a number of factors including disciplines and language cultures.

Finally, academic discourse is dynamic in nature and encapsulates multiple types of genre, be they spoken or written. Understanding the specialized genre forms and expectations will make substantial contribution to being included in the target discourse community.

6. CONCLUSION

This study provides an intellectual and holistic understanding of how biomedical engineering intellect, manifested as the Methods section of research articles, is developed. The rhetorical structure outlined in this paper and the unique feature of the Methods section identified by move analysis interestingly depicts that the endeavor of writing an engineering research article, by its nature, is not purely scientific but rather a humanistic enterprise. Pedagogically, this paper offers one of the ways to reconcile the innovative prospects of science with its much needed linguistic awareness to produce engineering graduates and scholars who have not only the skills to thrive in academia, but also the respect for intellectual and cultural diversity.

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