This article highlights aspects of an interdisciplinary (chemistry–applied linguistics) English for Specific Purposes (ESP) course- and materials-development project. The project was aimed at raising genre awareness among chemistry students and faculty, in addition to improving students’ disciplinary reading and writing. As part of the project, full-length chemistry journal articles were analyzed. We describe select results of this analysis and the prominent role played by chemists in the process. Emphasis is placed on the organizational structure of chemistry journal articles, focusing on the Abstract, Introduction, Methods, Results, Discussion, and Conclusion (A-IMRDC) sections. Two predominant organizational patterns emerged from our analyses, specifically A-IMR[DC] and A-IM[R(DC)], with brackets signifying sections merged under one major heading. Move-analysis findings are converted into easy-to-interpret instructional tools labeled “move structures akin to flow charts” for two target audiences (chemistry students and faculty). The rhetorical structure of the chemistry journal article is then compared to journal articles published in biochemistry, an overlapping discipline. The article concludes with pedagogical implications and suggestions for ESP professionals engaged in genre analysis.
in biochemistry, an overlapping discipline. We conclude with pedagogical implications and tips for ESP professionals engaged in genre analyses.

2. Background

The ‘Write Like a Chemist’ project was initially conceived as a response to a Northern Arizona University (NAU) mandate to address third-year undergraduate students’ writing needs. Departments had the option of developing third-year writing-intensive courses of their own or requiring students to take English courses. The Chemistry Department chose to develop its own course, but not by itself. The chemistry faculty member who spearheaded the course-development process initiated a “cross-disciplinary alliance” (Wardle, 2004) with an applied linguist in the English Department. The course-development team expanded, at different times, to include two graduate students in applied linguistics and a post-doctoral associate in chemistry.

What has made this project distinct from many others reported in English for Specific Purposes is the predominant role played by chemists. They (a) initiated the project; (b) developed criteria for genre and text selection; (c) selected texts; (d) played a major role in genre analyses, materials development, course design, and assessment; (e) contributed content-area expertise at every stage of the project; and (f) collaborated with applied linguists whose language expertise, among other areas of specialization, was vital for the project (Stoller, Horn, Grabe, & Robinson, 2005, 2006). Furthermore, the project resulted in a unique validation approach to move analysis, which has proven appropriate for understanding and teaching chemistry genres. This is the only genre-analysis effort that we know of which has been reviewed and approved by numerous target-discipline representatives, in this case 30 chemistry faculty from multiple US institutions.

The ‘Write Like a Chemist’ project, driven from the onset by pedagogical aims, targeted two primary audiences. First, we targeted chemistry students (native and nonnative English speakers) at the point in their university studies when they are transitioning to disciplinary reading and writing. Our second target audience comprised chemistry faculty who are not typically trained to teach disciplinary writing; nonetheless, they find themselves doing so when teaching classes with writing expectations, supervising students in their labs, mentoring graduate students, and coauthoring articles with newcomers to disciplinary writing. Chemistry faculty beyond those on the ‘Write Like a Chemist’ project team (n = 30) participated in the project in various ways; they served as informants in early project stages, piloted materials in their classes as they were developed, provided us with feedback, and served as external evaluators.

In line with our commitment to give students access to valued chemistry genres, a read–analyze–write approach to genre-based instruction was developed (Robinson & Stoller, 2007), whereby students read (and reread) authentic texts from the target genre, engage in scaffolded genre-analysis activities, and then write (and rewrite) their own work following predominant disciplinary conventions. With explicit instruction, repeated exposures, practice, feedback, and time, students gradually develop an understanding of disciplinary genres and their layers of complexity (Tardy, 2009). Our efforts led to two tangible outcomes: a textbook (Robinson, Stoller, Costanza-Robinson, & Jones, 2008) and companion website (http://www.oup.com/us/writelikeachemist).

2.1. Genres targeted for analysis

As part of the larger project, four chemistry genres were selected by chemistry faculty for textual analysis and explicit instruction: the journal article, research proposal, conference abstract, and scientific poster. Reasons for selecting these genres varied.

- The journal article is the primary means by which new scientific claims, and the certification of those claims (Berkenotter & Huckin, 1995), are disseminated in chemistry. Furthermore, starting in the third year of undergraduate study, students are often required to read the primary literature (including peer-reviewed journal articles) as part of advanced undergraduate classes, labs, and research. Moreover, if students are research-group members, they sometimes contribute to the writing of a journal article.
- The research proposal represents the most common way for chemists to solicit research support. Many universities and funding agencies permit undergraduate and graduate students (including chemistry students) to apply for support through the research-proposal process. Raising students’ consciousness about the fundamental elements of a research proposal is, thus, pertinent to their needs.
- Posters represent the typical way in which chemistry students and professionals alike disseminate their newest, pre-published research findings at conferences. Furthermore, many institutions (including NAU) showcase student research in annual poster events. To have a poster accepted for presentation requires the prior submission of a conference abstract. By raising students’ awareness about the essential elements of this “genre chain,” with the conference abstract serving as “a necessary antecedent” for the poster (Swales, 2004, p. 18), students gain confidence about submitting abstracts and preparing posters if, in fact, their abstracts are accepted.

For each of these target genres, a core set of texts was compiled for analysis and later use in materials-development efforts. In Section 2.2, we describe the steps taken to select chemistry journals and articles within them.
Journal and journal article selection criteria

Journal and journal article selection were conducted principally by two chemists on the project team (a chemistry professor and a post-doctoral research associate). They limited their selections to journals published by the American Chemical Society (ACS), which, at the time, included 45+ journals and more than 395,000 articles, accessible in a 1996-to-Current Issue database (www.acs.org). Ultimately, six journals were selected: Analytical Chemistry, Chemical Research in Toxicology, Environmental Science & Technology, Journal of Agricultural and Food Chemistry, Journal of Organic Chemistry, and Journal of Physical Chemistry (A and B). Another 13 journals were used to a lesser extent to illustrate selected disciplinary conventions and their variations.

The journal selection process was guided by three overarching objectives. First, the chemists preferred journals that adhered as closely as possible to the “standard format for reporting original research” advocated by The ACS Style Guide (Coghill & Garson, 2006, p. 19): abstract, introduction, experimental details (i.e., methods), results, discussion, and conclusions (A-IMRDC, cf. Lin & Evans, 2012). The Style Guide acknowledges that these sections are not necessarily presented in the order specified but that they should be included because they are “suitable for most reports of original research” and parallel “the scientific method of deductive reasoning” (p. 19). We took this approach because our goal, from the onset, was to support chemistry faculty preferences and teach students the more conventional ways (in addition to some common variations) of writing chemistry journal articles.

Second, the chemistry team wanted journals whose primary focus was to describe the results of a single research effort; hence, reviews (e.g., Chemical Reviews), symposia (e.g., ACS Symposium Series), and magazines (e.g., Chemical & Engineering News) were excluded. Journals that were too narrowly focused (e.g., Nano Letters) or too broadly focused (e.g., Journal of the American Chemical Society) were also rejected. Third, the chemists wanted journals in areas of chemistry most familiar to students (i.e., analytical, organic, and physical chemistry) or of potential interest to them (e.g., environmental chemistry, toxicology, and food chemistry).

After the journals were selected, articles within them were chosen. To do this, the chemists reviewed 15–20 randomly selected issues of each journal. As they reviewed each issue, they searched for articles that met these criteria:

1. Conventionality: The chemists had assumptions about journal-article writing practices in chemistry, and they sought articles that validated these assumptions. The goal was not to be comprehensive (as might be the case if an applied linguist had initiated the project) but rather to find articles that best illustrated preferred writing practices that chemistry faculty wanted to teach their students.
2. Topic: They searched for articles with general appeal (i.e., content of potential student interest) and procedures, methodology, and/or instrumentation that would be familiar to students.
3. Currency: They selected articles that were current (published between 2001 and 2004), no more than a few years before analysis.
4. Length: They selected articles that spanned four to eight published pages, average lengths in the journals selected.
5. Challenge: They identified articles that were not too advanced in terms of chemistry content for target students.
6. Authors: They gave preference to co-authored articles, the norm in chemistry.

Following this process, approximately 10 articles were selected from each of the six target journals.

3. Analyses of chemistry journal articles

With the selected journal articles in hand, the applied linguists on the team introduced the chemists to the concept and processes of genre analysis, as defined by the ESP school of genre analysis (e.g., Bawarshi & Reiff, 2010; Swales, 1990, 2004). Serving as background for the applied linguists’ orientation was research on sections of journal articles (i.e., research articles) in a range of disciplines (e.g., Berkenkotter & Huckin, 1995; Brett, 1994; Dubois, 1997; Holmes, 1997; Hopkins & Dudley-Evans, 1988; Huckin, 2001; Peacock, 2002; Samraj, 2002; Swales, 1990, 2004; Williams, 1999; Yang & Allison, 2003; see also Basturkmen, 2012; Bruce, 2009; Ozturk, 2007). At the time of our analyses, little, if any, research had been conducted on full-length articles (cf. Kanoksilapatham, 2005, 2007; Nwogu, 1997; Postegiullo, 1999), which was our aim.

The chemists played a primary role in the analyses of selected journal articles, unlike much genre research in the field. As established members of the chemistry discourse community, their contributions to analyses were central because of their familiarity with disciplinary genres and understanding of chemistry content (Bhatia, 2004; see also Biber, Connor, Upton, & Kanoksilapatham, 2007). They helped guide the analyses of full-length journal articles, and their sections, from five perspectives:

1. Purpose (in terms of conciseness, level of detail and formality, word choice).
2. Organization (in terms of the broad structure, assumed A-IMRDC as a starting point; and rhetorical moves and steps, following the seminal work of Swales, 1990, 2004).
3. Writing conventions endorsed by The ACS Style Guide (with an emphasis on conventions identified by chemistry faculty as important and revealed by pretests administered to pilot-student participants to be problematic, including abbreviations, compound labels, numbers and units, table formatting).

4. Materials and methods (in terms of familiarity with disciplinary conventions and their variations).
4. Grammar and mechanics (with a concentration on issues that emerged in our pretesting of pilot students and pilot faculty’s reporting of pet peeves, including parallelism, punctuation, subject/verb agreement, word usage).

5. Science content (as expressed in text and graphics).

Later in the project, another 30 university-based chemists reviewed the results of the team’s analyses and found them to be both accurate and appropriate for chemistry writing instruction.

To analyze organization, the focus of this paper, the full team (chemists and applied linguists) worked together to hand-tag the texts and identify moves and steps (which we labeled moves and submoves) in all sections. We aimed to determine the communicative functions of the moves and submoves; the boundaries between them; and their sequencing, preferential patterns, obligatory and optional components, linkages, and potentially repeating parts. Analyses continued until teachable, familiar patterns (with some variations) became evident, as agreed upon by team members and chemistry pilots of our instructional materials.

4. Organization of chemistry journal articles, section by section

We report our findings with “visual representations” of the moves and submoves that were identified (and that 30 chemists validated) in the standard sections of chemistry journal articles. These visual representations, called “move structures akin to flow charts” for our target audiences, were piloted (and refined) in their nascent stages with NAU students (2001–2003). In subsequent years (2004–2005 and 2005–2006), they were piloted with faculty (n = 16) and students (n = 200) in chemistry classes of various types (designated writing courses and classes identified as labs, lectures, and seminars) in 16 US tertiary institutions. The move structures (and accompanying pedagogical tasks) were also evaluated and critiqued by 15 external reviewers (all chemistry faculty) as part of a larger review of Write Like a Chemist materials. Feedback from pilots (faculty and students) and evaluators (Stoller et al., 2006) contributed to the move structures presented here.

We present the results of our analyses following the order in which sections typically appear in chemistry journal articles: Abstract, Introduction, Methods (often labeled Experimental or Materials and Methods), Results, and Discussion. The Conclusion section advocated by The ACS Style Guide is typically included in the Discussion section, thus we cover the Conclusion in our reporting of that section. It is beyond the scope of this article to report the many other features (e.g., word choice and usage, tense and voice, level of detail, distributional characteristics, frequencies) associated with each move. Readers interested in such details are referred to Robinson et al. (2008).

4.1. Adaptations to Swales’ manner of presentation

Before discussing our move structures and the results of our analyses, it is worth noting that chemistry faculty and students have responded favorably to the concept of moves and the manner in which we present them. But our move structures did not start out looking as they do in Figs. 1–5 (discussed in Sections 4.2–4.5); they evolved over time through piloting, evaluation, and the feedback collected throughout the project. We adapted Swales’ often-replicated manner of presentation (e.g., Swales, 1990, p. 141) with the goal of making the organizational features of our target genres more accessible to our target audiences. First, we changed some of Swales’ terminology. Instead of using the terms move and step, we used move and submove. Second, rather than labeling moves and submoves with gerunds (followed by direct objects) or present participles

<table>
<thead>
<tr>
<th>1. State What Was Done</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1 Identify the research area and its importance (optional)</td>
</tr>
<tr>
<td>1.2 Mention a gap addressed by the work (optional)</td>
</tr>
<tr>
<td>1.3 State purpose and/or accomplishment(s) of work</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2. Identify Methods Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>(i.e., procedures and/or instrumentation)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3. Report Principal Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1 Highlight major results (quantitative or qualitative)</td>
</tr>
<tr>
<td>3.2 Offer a concluding remark (optional)</td>
</tr>
</tbody>
</table>

Fig. 1. Move structure of a typical chemistry journal article Abstract.
1. Introduce the Research Area

1.1 Identify the research area
1.2 Establish the importance of the research area
1.3 Provide essential background information about the research area

2. Identify the Gap(s)

3. Fill the Gap(s)

3.1 Introduce the current work
3.2 Preview key findings of the current work (optional)

Cite relevant literature

Fig. 2. Move structure of a typical chemistry journal article Introduction section.

1. Describe Materials
(e.g., materials, chemicals, samples, cultures, sampling sites, general reaction conditions)

2. Describe Experimental Methods

Describe procedure(s) ↔ Describe instrumentation

3. Describe Numerical Methods (if applicable)
(e.g., statistical analyses, theoretical computations)

Fig. 3. Move structure of a typical chemistry journal article Methods and Materials (Experimental) section. [←→ indicates variable sequencing].

1. Set the Stage

1.1 Remind readers (briefly) how you obtained a set of results
1.2 Refer readers to a graphic that displays that set of results

2. Tell the Story of Scientific Discovery

Guide readers through the set of results as you do one or more of the following:

Identify key findings and discoveries
Describe important trends
Highlight unexpected results

Repeat (as needed) for each set of results

Fig. 4. Move structure of a typical chemistry journal article Results section.
(depending how the statements are interpreted), we used imperatives to emphasize writers’ actions. Third, we used terminology that would resonate with undergraduate students (e.g., Set the Stage, Tell the Story of Scientific Discovery). Fourth, to emphasize the progression from one move to the next, we converted our depiction of moves into flow charts, a graphic familiar to chemists, and numbered moves and submoves using common chemistry conventions (e.g., 1, 1.1, 1.2).

Early on, we boxed moves and submoves, and used arrows to highlight information flow. We even attempted to indicate the typical length of each “stretch of text” (Swales & Feak, 2009, p. 5); shorter moves and submoves were placed in more shallow boxes, while longer moves and submoves were placed in deeper boxes. We also attempted to show changing levels of specificity (drawing upon Hill, Soppelsa, & West, 1982; Swales, 1990, 2004) with the width of our boxes; moves with more general information (like the early moves in Introductions and Abstracts) were placed in wider boxes; moves with more specificity (like those at the end of Introductions and beginning of Discussions) were placed in more narrow boxes. We also used dotted lines to indicate optional features. Feedback from chemistry students and faculty at various junctures in the project led to the streamlined move structures discussed in Sections 4.2–4.5. (See the Appendix for an early, but later abandoned, move structure of a chemistry journal article Introduction section.)

4.2. Abstract

The abstract typically includes three moves (Fig. 1). They correspond to statements about what was done, how it was done, and what was found. Move 1 has a single required submove (1.3) that states the purpose and/or accomplishment(s) of the work reported. Some authors (as indicated by the term optional) preface this by identifying the research area and its importance (Submove 1.1) and/or identifying gaps in the field (Submove 1.2), parallel to Moves 1 and 2 of the Introduction (see Section 4.3). Move 2 summarizes research methods and/or instrumentation; the amount of detail provided varies with the goals and emphases of the paper. For instance, the abstract of a paper that describes the use of novel instrumentation likely includes more information about instrumentation than an abstract of a paper that reports the use of standard instrumentation. Move 3, often the longest segment of the abstract, highlights key findings. Some authors conclude with a statement that draws attention to major findings or impacts of the work.

4.3. Introduction

The Introduction typically comprises three moves (Fig. 2). Authors begin with an introduction to the research area (Move 1, Submove 1.1), establish its importance (Submove 1.2), and provide pertinent background information (Submove 1.3). In this move (and the next), authors cite relevant literature (as needed) to support claims being made and connect the work to existing knowledge. (See Berkenkotter and Huckin (1995) and Swales (2004) for more on journal-article citations.) The first two submoves of Move 1 are often achieved in only a sentence or two, as illustrated in an excerpt from Vesely, Lusk, Basarova, Seabrooks, and Ryder (2003, p. 6941):

Submoves 1.1 and 1.2 Carbonyl compounds, particularly aldehydes, are considered to play an important role in the deterioration of beer flavor and aroma during storage.

The third submove, typically a paragraph or two, requires that authors concisely identify the key works that influenced or laid the groundwork for their research. Customarily, multiple works are cited in a single sentence, as illustrated in the following example (Vesely et al., 2003, p. 6941). Note that the italicized numbers in parentheses are in-text citations, directing readers to items 2–4 in the reference list at the end of the article.
Submove 1.3 Several analytical methods have been developed, including liquid–liquid extraction (2), distillation (3), and sorbent extraction (4).

Authors then transition to Move 2, where they identify a gap (or gaps) in the field (e.g., a question that remains unanswered, an area that remains poorly understood or has yet to be studied, a step that needs to be taken, a procedure that needs to be improved, a new hypothesis or observation that requires validation). Like Move 1, authors may cite the literature here as a way to justify claims and/or connect the current work to other activity in the field, as illustrated in this excerpt from Dellinger et al. (2001, p. 1371):

Move 2 Persistent electron paramagnetic resonance (EPR) signals have been reported in coals, chars, and soots (26–29), but PM$_{2.5}$ has not been studied by EPR.

Writers then introduce the current work (Move 3, Submove 3.1) and explain how identified gaps are filled. Some authors conclude with a preview of principal findings (Submove 3.2). The arrow to the right of the move structure captures the general-to-specific pattern of the Introduction.

4.4. Experimental (Materials and Methods)

The Experimental section typically comprises two to three moves (Fig. 3). First, the author describes materials (Move 1), which could include chemicals, samples, cultures, and other tangible items used to conduct the work. When different materials are used, bolded subheadings (e.g., Reagents, Samples, Cell Cultures) typically set them off from one another. In Move 2, authors describe their experimental methods (i.e., procedures and instrumentation used to obtain data). The procedures described could be analytical procedures (e.g., steps used to prepare, extract, concentrate, or derivatize a sample), field-collection procedures (e.g., steps taken to collect water samples), synthetic procedures (e.g., steps used to synthesize compounds), or others. Instrumentation is also briefly identified (e.g., a custom-built instrument or a mass spectrometer). Ordinary equipment (e.g., pipettes or heating mantels) are not described. Subheadings, commonly used in Move 2 when multiple procedures and/or instruments are reported, assist readers in locating information of interest (see Berkenkotter and Huckin (1995) for insights on “selective” readers). The ordering of the two submoves is variable; to indicate this variability in the move structure (Fig. 3), the submoves are placed side by side. Move 3 is only included if statistical analyses, mathematical procedures, or theoretical computations are applicable.

The Experimental section is deemphasized in some chemistry journals (as observed in other fields by Berkenkotter and Huckin (1995)). In such cases, it is placed in a footnote, at end of the article, or on the Internet as supporting information. The placement of the Experimental section is not left to the discretion of the writer; rather its placement is specified in each journal’s Guidelines for Authors.

4.5. Results and Discussion

The Guidelines for Authors in our six target journals give authors the choice of presenting results and discussion in separate or combined sections. For example, the Journal of Agricultural and Food Chemistry advises authors to use “whichever format conveys the results in the most lucid fashion without redundancy” (http://pubs.acs.org/page/jafcau/submission/authors.html). Our analyses revealed that Results and Discussion (R&D) sections in chemistry journal articles fall on a continuum bounded by fully separated R&D sections at one end and fully integrated R&D sections at the other. Three combined R&D patterns emerged from our analyses:

- **Blocked R&D:** In this pattern, a single block of results is followed by a block of discussion. For a set of three results, the pattern would be [Results 1, Results 2, Results 3] [Discussion 1, Discussion 2, Discussion 3]. The organization of a Blocked R&D section is identical to that of separate R&D sections; however, the two sections are merged under a single “Results and Discussion” heading.
- **Iterative R&D:** In this pattern, authors alternate between presenting and discussing results. For a set of three results, the pattern is achieved as follows: [Results 1, Discussion 1] [Results 2, Discussion 2] [Results 3, Discussion 3].
- **Integrated R&D:** In this pattern, results are presented and discussed seamlessly, often in the same paragraph or same sentence. The section is written with no obvious delineation between results and discussion.

Despite the growing frequency of combined R&D sections in chemistry journal articles, for pedagogical reasons we decided to analyze and teach the features of stand-alone R&D sections. We believed that it was important for students, unfamiliar with the genre, to understand and be able to distinguish the distinct functions of results and discussion sections (description and interpretation, respectively) as revealed by their conventional moves, even if they ultimately write combined R&D sections. Thus, we analyzed stand-alone and blocked R&D sections to gain an understanding of the conventional patterns followed by chemists who report results and discuss them separately.
4.5.1. Stand-alone Results

The purpose of the Results section of a chemistry journal article is to present results without interpretation. The reader’s attention is guided back and forth between text and graphics (i.e., tables and figures) to highlight important features of the data and tell “the story of scientific discovery” (Fig. 4). Authors condense months (sometimes years) of experimentation and accumulated knowledge, insights, and data into a page or two.

Move 1 “sets the stage” by briefly reminding readers how a particular set of data was obtained (Submove 1.1) and then referring readers to a graphic that displays the data (Submove 1.2). This move is often accomplished in a single sentence (a reminder of the importance of conciseness in chemistry writing), as typified in the following excerpt (Dellinger et al., 2001, p. 1372):

Move 1 The EPR spectra of samples of PM$_{2.5}$ from five different sites in the US are shown in traces A-E of Fig. 1.

Move 2 guides the reader through the data, recounting a highly condensed version of the study. Data are presented in an order that best conveys the story of discovery, not necessarily chronologically. Without repeating the data introduced in the graphic, the writer highlights key findings, important trends, and/or unexpected results. Moves 1 and 2 are repeated for each set of results, commonly signposted with subheadings to direct readers’ attention to each set of results.

4.5.2. Stand-alone Discussion

The Discussion section comprises two moves (Fig. 5). Move 1 briefly reminds the reader which results will be discussed (Submove 1.1). It then proceeds with an interpretation of results (Submove 1.2) that is supported by the study and/or citations connecting the work to a larger body of evidence. Submove 1.2 represents the centerpiece of the Discussion. Reactions are proposed, explanations are offered, and comparisons are made to others’ works, citing appropriately. The two-step mind-and-interpret sequence is repeated for each major finding, paralleling the order in which results are presented in the Results section. Subheadings are often used to help readers locate the discussion for each result.

Move 2 (and last move of the journal article) signals the conclusion. Submove 2.1 provides a brief summary of the work. The summary (informally referred to as the “take home message” by chemists) is followed by implications and/or applications of the work (Submove 2.2), thereby moving writers beyond the specifics of the work and toward the study’s broader goals. As suggested to the right of the move structure, the Discussion begins with specifics and becomes more general, reversing the general-to-specific pattern in the Introduction.

5. Discussion of genre-analysis findings

The results of our analyses are discussed from two perspectives. First, we comment on correspondences between our findings and the standard formatting of “scientific papers” endorsed by The ACS Style Guide. Second, we compare our results with those of Kanoksilapatham (2005, 2007), the only recent study we know of that also examined full-length journal articles, which happen to be from an overlapping discipline, biochemistry.

5.1. Correspondences between findings and Style Guide recommendations

The results of our analyses reflect the efforts of an interdisciplinary team that set out to understand better the widely endorsed A-IMRDC format (and some of its variations) advocated by The ACS Style Guide. What we found is that the Abstract and Introduction, as one might expect, are always placed at the beginning of articles. The Experimental (Methods) section followed the Introduction in the articles that we analyzed; nonetheless, its placement is variable, though not left to the discretion of authors. Even though we chose to analyze stand-alone Results and Discussion sections, from the onset of the project, we were aware that authors are often times given the freedom to merge them. What does not differ is the distinction between description (in Results) and interpretation (in Discussion). As it turns out, a Conclusion was present in the journal articles that we analyzed, but it was placed at the end of the Discussion section (forming its second and last move), rather than in a separate section. The predominant patterns that emerged from our analyses can be depicted as follows: A-IMR[DC] and A-IM[R(DC)], with brackets (as used by Lin and Evans (2012)) signifying information merged under one major heading.

It is worth noting that chemistry journal articles do not include Literature Review sections (cf. Lin & Evans, 2012). Our analyses show that references to the literature are incorporated into Introduction and Discussion sections, and they are limited to “truly pertinent literature” (Coghill & Garson, 2006, p. 22).

The ACS Style Guide provides, in prose form, a general description of the contents of the six components of a journal article: A-IMRDC. Our analyses revealed more detailed information not only about the contents of each component but also their sequencing and functions. The pedagogical aims of our project, and our quest for common and teachable organizational patterns, led to the development of move structures (Figs. 1–5) to display the contents, sequencing, and functions of each section of the genre. The move structures, which augment information provided in the Style Guide, serve as practical mechanisms for displaying findings in a manner that is accessible and useful for newcomers to the genre.

5.2. Comparison of findings with Kanoksilapatham

Kanoksilapatham’s (2005, 2007) efforts and ours broaden the scope of move analysis by focusing on one disciplinary domain (biochemistry and chemistry, respectively) and on journal articles in their entirety (with the exception of Abstracts in
Kanoksilapatham’s work). The results of such analyses facilitate “the entry of newcomers to the highly selective academic discourse” (Kanoksilapatham, 2005, p. 288) of their communities. Kanoksilapatham’s corpus comprised 60 articles from five biochemistry journals (12 articles in each) published in 2000. Our corpus contained about 60 articles from six ACS journals published between 2001 and 2004. Kanoksilapatham proposed a two-level rhetorical structure (with moves and steps, the latter akin to our submoves) for Introduction, Methods, Results, and Discussion sections. A comparison between Kanoksilapatham’s findings and ours is interesting for several reasons:

1. Our analytical methods were similar, following Swales (1990, 2004); however, Kanoksilapatham worked with one biochemistry informant to achieve inter-rater reliability, whereas we sought validation by engaging 30 chemistry faculty in a review and approval of our findings.

2. We allowed chemists to select research articles based on their own writing preferences, whereas she selected articles using a more conventional, random-selection approach.

3. Our move structures were intended for and ultimately published in a textbook for novice writers, whereas Kanoksilapatham’s move analysis was intended, we assume, for applied linguistics publications. These different target audiences affected presentation formats and levels of detail.

4. During our journal-selection process, the chemistry team decided to exclude biochemistry journals from its corpus because of different formatting practices in biochemistry at that time. Biochemists have extensive training in biology; hence, they are notably influenced by biology writing conventions, which often differ from those in chemistry (e.g., alternative formatting in tables, table headings, figures, figure captions, headings, and subheadings). These variations (observed even in Biochemistry, a journal published by the ACS) were viewed by the chemistry team as potentially confusing for chemistry students. The team did not, however, compare the organizational structures of chemistry and biochemistry journals. We do this in Sections 5.2.1–5.2.4, noting that the chemistry articles are slightly more recent (2001–2004) than those in biochemistry (2000). What we find is that the organizational structures of chemistry and biochemistry journal articles are largely congruent, although some notable differences exist.

5.2.1. Introductions in chemistry and biochemistry journal articles

Chemistry and biochemistry journal article Introductions each comprise three moves. Although labeled differently by us and Kanoksilapatham (2005), many components are similar. In Move 1, authors establish the importance/centrality of the research topic and make reference to previous research as a way to provide background information, connect the current work to earlier work, and contextualize the article.

Similarly, in Move 2, a gap is indicated, providing justification for the study. A gap statement was included in all the chemistry articles analyzed but was present in only 66% of Kanoksilapatham’s corpus. In the chemistry articles, several ways to indicate a gap were observed (e.g., identifying a step that needs to be taken, a question that needs to be answered, or an area that needs to be better understood). Kanoksilapatham (2005, p. 275) quoted two excerpts with similar gap statements (identifying an area that has “not been characterized” and a mechanism that “is unclear”). However, the biochemistry articles also included a less common (15%) second step, Raising a question, where authors explicitly list one or more unresolved questions (e.g., “Why are both strands required in the trigger RNA?”) (Kanoksilapatham, 2005, p. 275). Listing explicit questions is uncommon in chemistry and was not observed in our corpus.

In both fields, Move 3 serves as a transition to the current study. In chemistry, Move 3 comprises Submove 3.1, which introduces the current work and its purpose (i.e., how it fills the gap), and optional Submove 3.2, which previews key findings. Biochemistry is similar but has three steps. Step 1 (Stating purposes) parallels chemistry’s first submove. Step 2 (Describing procedures) is also part of chemistry’s first submove. Chemists do not actually “describe” procedures here (this occurs in the Methods section), but techniques are often identified. Step 3 in biochemistry (Presenting findings) is analogous to chemistry’s preview of findings, but in biochemistry, this step is not optional. In both fields, the preview serves as an “attention getter” and only briefly highlights key findings. Neither chemistry nor biochemistry Introductions conclude with outlines of the remainder of the article (cf. Swales, 1990).

5.2.2. Methods sections in chemistry and biochemistry journal articles

Methods sections in chemistry and biochemistry articles are also similar even though they have a different number of moves (three and four, respectively). In both fields, the Methods section begins with a description of materials. According to Kanoksilapatham (2005), biochemists first list the materials (Step 1), detail the source of the materials (Step 2), and provide background about the materials (Step 3). In chemistry articles, the materials are described and vendor/background information is identified (in parentheses) all in the same sentence; hence, we did not break these actions into submoves. Moreover, in chemistry, no lists are used. Kanoksilapatham refers to a “list” in Step 1 and includes an excerpt that refers readers to a table with a list of bacterial strains. In chemistry articles, lists of materials (in prose or tables) are strongly discouraged; complete sentences should be used. (This is important to us because chemistry students are accustomed to listing, literally, chemicals in lab reports and often incorrectly carry over this practice to more formal writing.)

The next move in both disciplines involves describing experimental methods or procedures. In chemistry articles, descriptions of procedures and instrumentation, which are sequenced variably, are depicted as components of a single move (see Fig. 3). In biochemistry articles, Detailing procedures is a separate move from Detailing equipment; the latter occurred only 10% of the time. In chemistry, “equipment” is not described (a term that connotes items such as glassware, rotov evaporators,
or heating mantels) but instrumentation is, particularly custom-built or commercial instruments (e.g., mass spectrometers or spectrophotometers). The examples cited by Kanoksilapatham (2005) (e.g., a spectrophotometer) suggest the same is true in biochemistry. In both disciplines, authors include only essential information and refer readers to the literature rather than repeat details that have been previously described. In chemistry, a new procedure is described in detail only in the first publication, which is then referenced in subsequent manuscripts.

Both Methods sections end with a description of numerical methods (chemistry) or statistical procedures (biochemistry). "Numerical methods" is a general term that includes all computational methods used by chemists. In biochemistry, the inclusion of statistical procedures was rare and thus considered optional. In chemistry, we replaced the word “optional” with the phrase “if applicable” to make it clear that if numerical methods were used, they should be described.

5.2.3. Results sections in chemistry and biochemistry journal articles

Chemistry and biochemistry Results sections are different in several noteworthy ways. First, as described in Section 4.5, combined Results and Discussion sections are becoming increasingly common in chemistry journal articles, even though we opted to treat them as stand-alone sections in our analyses (and instruction). One notable exception is the ACS-published journal Biochemistry, which prefers stand-alone R&D sections; this is true even today, as indicated in its 2012 Author Guidelines (http://pubs.acs.org/page/bichaw/submission/authors.html). The biochemistry articles analyzed by Kanoksilapatham (2005), all published in 2000, also had stand-alone R&D sections, but it is not clear whether this was solely the result of Kanoksilapatham’s text-selection criteria or the preference of the journals from which her texts originated.

Second, in stand-alone chemistry Results sections, there are two moves, which are repeated, in turn, for each set of results. In contrast, biochemistry Results sections comprise four moves (Kanoksilapatham, 2005). In Move 1, both Results sections begin with a reminder of how results were obtained. In chemistry, this reminder is brief and also refers readers to a figure or graph that presents the data. In biochemistry, this move is more extensive and can (a) include a description of the study’s aims and purposes, (b) state research questions, (c) make hypotheses, and/or (d) list procedures or methodological techniques. This is followed by a second move, Justifying procedures or methodology, which is absent in chemistry. Kanoksilapatham acknowledges that this move is “rather unique in biochemistry research articles” (p. 280).

In Move 2 of chemistry Results sections, the results are presented. Authors “walk” readers through the data, without interpretation and without references to the literature, to identify key findings, describe important trends, and/or highlight unexpected results. The corresponding move in biochemistry (Move 3) involves Stating results. In most respects, these moves are similar. What appears to be different, however, is that in biochemistry journals, authors can also offer generalizations, subjective commentary, and interpretations in this move; such features are typically deferred until the Discussion section in chemistry articles (although combined R&D sections blur this distinction).

5.2.4. Discussion sections in chemistry and biochemistry journal articles

The chemistry journal article Discussion comprises two moves, corresponding to the interpretation of results (Move 1), repeated for each set of results, and a conclusion that summarizes the current study and presents the broader implications and/or applications of the work (Move 2). Kanoksilapatham (2005) did not mention Conclusions; hence, we discuss only Move 1 here. In Move 1 of chemistry Discussion sections, readers are reminded briefly of results and then the results are interpreted. We use the term “interpret” broadly, to include actions such as proposing mechanisms, comparing results with previously published works, and refuting or corroborating others’ findings, with citations to relevant literature as appropriate. Kanoksilapatham details similar functions but in two moves (Contextualizing the study, Consolidating results) and eight steps (e.g., presenting claims, restating methodology, referring to previous literature, and explaining differences in findings, to name only four). Biochemistry articles include two additional moves in the Discussion, absent in the chemistry corpus: (a) Stating limitations of the present study (observed in 80% of Kanoksilapatham’s corpus) and (b) Suggesting further research (optional, 53%).

6. Conclusions

In this article, we have described our interdisciplinary approach to genre analysis, reported the predominant organizational features of the chemistry journal article, and compared our findings to Kanoksilapatham (2005, 2007). The results of our analyses have been converted into easy-to-interpret move structures that have served as effective pedagogical tools for introducing and reinforcing widely accepted organizational conventions (and some of their variations) in chemistry. The move structures and related genre-analysis tasks, see Robinson et al., 2008 developed for classroom use raise chemistry students’ consciousness about common discourse patterns in the articles that they read and guide students in their writing. The move structures are not intended to represent all the variations that exist in chemistry journal articles, but rather provide students with a “safe” place to start and with skills to identify (and later build) more complex organizational patterns (Ferris & Hedgcock, 2005) as they progress in their disciplinary studies and professional lives. Organizational differences between chemistry and biochemistry journal articles, although not as extensive as might exist between two unrelated disciplines, were notable, and suggest that newcomers to these genres be introduced to model texts from their own fields, rather than a collection of articles (or sections of those articles) from other fields. (See Paltridge (2001), Paltridge et al. (2009), Swales (1990), and Tardy (2009) for discussions of the role of model texts in ESP instruction.)

As part of our larger project, we analyzed three other disciplinary genres for organizational features as well as audience and purpose, disciplinary conventions, grammar and mechanics, and content. For each of these areas, we developed tools and
tasks to guide chemistry students in discovering the features that define the genres valued in their field of study. Similar steps could be taken by applied linguists and ESP practitioners who work in other disciplinary domains. Based on our experiences, we propose the following guidelines for such genre-analysis work:

1. Establish interdisciplinary partnerships to tap the linguistic and disciplinary expertise of participating members.
2. Select and analyze full-scale samples of target genres in collaboration with partners from the target discipline.
3. Translate findings in ways that best reach target audiences.
4. Develop instructional tools and tasks that not only introduce students to the defining features of target genres but that also guide students in analyzing excerpts and full texts for themselves.
5. Keep in mind that students benefit from explicit instruction, discussion, practice, feedback, and time to develop the analytical skills needed for access to and control of the genres that will be important in their lives. Even if we cannot predict exactly what students will be reading and writing in their futures, we can provide them with analytic tools that will help them determine the disciplinary expectations that must coalesce for successful written communication to take place (Johns, 1997, 2007).

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Appendix A

see Fig. A1.
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