# RESEARCH PROPOSAL ACTIVITIES IN AN ADVANCED INORGANIC CHEMISTRY LECTURE AT THE UNDERGRADUATE LEVEL

## Abstract

With cutting edge research comes the expectation that funding is needed. Particularly in the sciences, grant funds can cover the cost of instrumentation, conference travel, summer stipends and the like. At the undergraduate level, it is essential to instill into the students the importance of finding and applying to funding opportunities (particularly for those who wish to pursue graduate degrees). While the Georgia College (GC) chemistry program currently does not have a formal "technical writing class", here are discussed several activities that seek to expose undergraduate students to proposal writing and bettering their technical writing skills.

**Keywords:** Grant writing; advanced inorganic chemistry; research proposal; undergraduate research; capstone course

# ACTIVIDADES DE ESCRITURA DE PROPUESTAS EN UNA CLASE DE QUÍMICA INORGÁNICA AVANZADA A NIVEL PRE-DOCTORAL

## Resumen

La investigación y diseminación de proyectos científicos novedosos requieren fondos monetarios. Particularmente en las ciencias, estos fondos pueden cubrir los costos de instrumentación, viajes a conferencias, estipendios de verano y otros. A nivel pre-doctoral, es esencial inculcar a los estudiantes la importancia de la adquisición de fondos monetarios (particularmente para aquellos estudiantes que desean estudiar a nivel de doctorado). Mientras que el programa de química de Georgia College (GC) no posee un curso de escritura técnica, en este artículo se discuten algunas actividades que exponen a estudiantes pre-doctorales a la escritura de propuestas y el mejoramiento de sus habilidades en escritura técnica.

**Palabras clave:** Escritura de propuestas; química inorgánica avanzada; propuesta investigativa; investigación a nivel pre-doctoral; seminario integrador

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DOI: 10.22201/fq.18708404e.2018.4.64766

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## Introduction

Competence in science is not only a measure of sound, practical laboratory skills, but also technical and scientific communication skills. Particularly for seniors who wish to pursue advanced degrees in chemistry, instilling the importance of communicating their ideas and obtaining funding is essential (ACS Axial, 2017). Several models have successfully attempted to introduce grant writing at the undergraduate level, given the importance of enhancing technical communication skills (Hunter, 1998; Cole, Inada, Smith, & Haaf, 2013; Evans, Heyl, & Liggit, 2013; Evans, Heyl, & Liggit, 2016; McCarthy & Dempsey, 2017). For this work, brainstorming, reflective discussion exercises, and the introduction of digital referencing technology proved to be an effective model in introducing undergraduates at GC to proposal writing. In addition, the small public liberal arts institution nature of GC provides a rich environment to implement such an assignment. The student-to-instructor ratio and interaction, which was key to the success of the work presented, is better in small classroom environments.

## Arguing the need for technical writing skills beyond the laboratory report

Most likely, the first encounter that science students have with scientific writing is through a laboratory report for one of their courses. There have been previous reports that touch upon methods that seek to teach students how to write science (Wackerly, 2017; Rosenthal, 1986). And while a traditional laboratory report might be sufficient to assess writing and understanding of a topic (e.g., perform the experiment → analyze the results → provide a discussion and conclusions), there is a need to expose the students to different writing styles and other scientific documentation. This is evidenced in the differences between a laboratory report and a research proposal (Slocum & Jacobsen, 2010; Weissman, 1990). The traditional laboratory report seeks to discuss results from a particular experiment, while the research proposal encompasses a theoretical argument of plausible work. In addition, some proposals may contain preliminary results that strengthen merit to the research and the theory. It is this notion of "coming up with something novel" or "adding to previous work" that students, at the undergraduate and the graduate level, might struggle. Therefore, students need to be given clear communication on what the purpose of the assignment will be, which is to introduce to them scientific writing at a different capacity.

## Course structure and student population of Advanced Inorganic Chemistry

Currently, GC's chemistry program does not possess graduate degrees. Thus, exposure to advanced topics in chemistry typically come from capstone courses such as Advanced

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Inorganic Chemistry (CHEM4500). The course requires the Intermediate Inorganic Chemistry lecture as a pre-requisite. Previous exposure to inorganic chemistry laboratory is optional, but not required. The course is spread over 15 weeks, offered every two years, and the typical class size consists of 5-10 students. While this may not seem like a large number, the department offers a variety of other capstone courses as options, including study abroad opportunities. Therefore, students tend to enroll in courses which benefit the next step of their career. The typical student population for CHEM4500 includes students who wish to attend graduate school in chemistry or pursue a career in industry (in addition to students who really loved inorganic chemistry). The course structure is discussion based, where students are engaged in debates about current topics in inorganic chemistry. This is a model that has been implemented before for other similar courses in sciences and humanities (McCoy-Wagner & Schwartz, 2016; Brooks & Koretsky, 2011). These topics are usually not covered in the regular inorganic section or are continuations of subjects that they have already had exposure to. In contrast to an introductory level inorganic course, the freedom of content of an advanced course allows for the introduction of non-traditional assignments such as weekly discussion journals, literature critiques, and the research proposal. Typically, the class is 1 hr. 15 mins and meets 2 days a week, which provides plenty of time to cover in-class material and allow students to work on their research proposal. The research proposal weight for this course is 50% of the total course grade (10% first draft, 40% final version).

## *Activities*

Several activities were developed for this assignment. Activities consisted of brainstorming sections and reflective discussion questions. A timeline for proposal activities was also included in the syllabus (Table 1).

| Week | Activity |
|---|---|
| 1 | Discussion of Proposal Assignment |
| 2-3 | Hand in topic; In-class time to brainstorm specific sub-topics; work on bibliography |
| 3 | Activity 1: Work on Introduction; Abstract |
| 4 | Activity 1: Work on Broader Impacts or Intellectual Merit |
| 5 | Activity 2: Work on Methodology |
| 6 | Activity 2: Work on Methodology, Conclusions, References |
| 7 | First Draft due (mid to end of March) |
| 8 | Work on edits for first draft |
| 9 | Work on edits for first draft |
| 10 | Work on edits for first draft |
| 11 | In-class time to receive feedback from instructor |
| 12 | Activity 3: Reflect on your proposal pre-final version |
| 13-14 | Work on final version |
| 15 | Turn in final version of proposal (Last week of class) |

**Table 1.** Proposal activities timeline

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## Choosing a topic

At the beginning of the semester, students are asked to choose a topic of interest related to inorganic chemistry (they are encouraged to find topics which they can relate to- for example, chemical education in inorganic chemistry or nanotechnology). This is not a simple task for someone who has no research proposal writing experience. Thus, the instructor provided in-class time and advice for this activity and revises the topics chosen (to make sure they fall within the scope of the assignment). Specifically, students were asked to brainstorm 5 topics of interest and specify. It was noted that the topics chosen tended to align with the student's career aspirations. For example, a student whose main goal was to attend medical school tended to choose a topic related to medicine.

Students were allotted roughly 1-2 weeks to choose the topic and write a small paragraph on as to why that interested them. Students were then asked to submit their chosen topic to the online course platform (in the case of GC- Direct2Learn). Students typically chose a broader field, then through a combination of brainstorming, reading references, and guidance from the instructor, honed in on a more specific topic.

## Building up a reference library

A key note on this work was the introduction of referencing technology easily accessible to the students. Students were required to obtain a minimum of 15 scholarly references. This was achieved via the introduction of freeware reference software such as Mendeley (Mendeley Ltd., 2018), and pay to use software such as EndNote (Clarivate Analytics, 2018). Mendeley is a powerful referencing tool that allows students access to their reference library anywhere through the web browser, it is also free of charge. Thus, it makes the assignment more accessible to students who may not own a personal computer where the software platform may be installed permanently. At GC, EndNote is freely available to students and Mendeley is easily accessible via the web.

## Proposal Guidelines

The proposal guidelines were discussed within the first two weeks of class. These guidelines were adapted by the instructor and closely mirrored those of an NSF (National Science Foundation) ("A guide to proposal writing", 2018) or DOE grant ("Research Proposal Guidelines", 2018). Since guidelines for these funding agencies are subject to change year by year, these can be modified to fit the needs of the class. Modifiable proposal guidelines are detailed in Table 2.

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| Sections | Description |
|---|---|
| Cover page | Includes name of the author, institution, course number. |
| Project summary (or abstract) | A succinct paragraph of what is proposed and its importance. |
| Introduction | Introduces the topic (theory and background) |
| Broader Impacts/Intellectual Merit | Disseminates importance of the topic in question. This section convinces the reader that the proposal merits funding. The intellectual merit section seeks to convince the reader of the topic's contribution to the field. |
| Methodology | A general section that details possible experiments that might lead to the proposed results. |
| Budget (Optional) | The instructor might ask you to provide a budget for your activities. |
| Conclusion | Wraps up the proposal and re-states the importance of the proposed work. This section re-states the purpose of the proposal and the need for studying the topic in question. |
| References | At least 15 or more scholarly references. These need to be in ACS (American Chemical Society) format. |

**Table 2.** Proposal sections and descriptions

Individual sections of the proposal were written over the course of the semester in 3 different activities. In addition, students were required to hand in a first draft mid-semester for feedback. The instructor printed the drafts, provided feedback and direction, and returned to the students.

### *Proposal Writing Activity I*

In this activity, students were asked to brainstorm and build upon 5 concepts/subjects/theories that they would include in their introduction and reflect on 5 concepts/subjects/social aspects that they would consider including in their "broader impacts" or "intellectual merit" section. It is believed that limiting the concepts to 5 allowed the students to hone down on what were important items to include. The broader impact can be substituted (at the discretion of the instructor) by "Intellectual Merit", which focuses on the topic's relevance to the field. For this activity, focusing on writing the introduction and broader impacts engaged the students at a deeper level with their topic by exposing them to subject specific theories and the importance of their topic to society.

### *Proposal Writing Activity II*

The activity consisted in the students working through their methodology. Students were encouraged to list up to 10 items, instruments, specialized equipment, etc. that they would need in order to develop their research with succinct explanations as to why and how they would use them.

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*Proposal Writing Activity III*

In this final integrative activity, students were asked to reflect holistically on their final draft by answering a series of questions which were accompanied by a short survey. Students were asked to review the proposal guidelines before answering the questions. The instructor is also encouraged to help students reflect better on their work. Below is an example question:

*1. From 0-5, have I fulfilled the requirements of the introduction? (Circle one)*

| | | | | |
|---|---|---|---|---|
| *1* | *2* | *3* | *4* | *5* |

*What measures should I take to make the introduction better?*

| |
|---|
| |

It is evident that the students might not realize if they have fulfilled the requirements for all the activities (since this might be the first time they are writing such an assignment), thus the instructor needs to critically analyze the answers to the questions and provide further guidance.

## Assessment

A detailed 4-pt. rubric was used to assess the assignment (Table 3). For this particular work, the rubric was built to assess the proposal in general, instead of individual sections. This rubric could be modified to evaluate the individual sections as needed. Informal assessments were also provided during the semester in the form of student-to-student feedback and instructor-to-student feedback.

Historically, students have responded well to the assignment. Through the use of this rubric, and informal feedback from instructor and peer reviews from classmates, ~80-90% of the students (N = 5-15) have achieved a mark of 80/100 or more on the final score for the assignment at the end of the semester. This was after an initial review of the first draft earlier in the semester. Qualitatively, the author believes that this is also reflected in the differences in thoughts and ideas from the beginning of the semester to the completion of the assignment. Meaning that students felt more comfortable discussing their chosen topic at the end of the semester than at the beginning. This is believed to arise as a result of providing in-class time to work on the assignment and the small class size (students tend to interact more, and feel more comfortable, with colleagues in a small classroom environment). Furthermore, this type of assignment differs from traditional testing in the fact that the instructor engages one-on-one with the student when feedback is provided during the semester.

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| Criteria | 4 (100%) | 3 (75%) | 2 (50%) | 1 (25%) |
|---|---|---|---|---|
| Focus and details | The chosen topic has clarity, is well proposed and supported by references. The chosen topic is relevant to the area of Inorganic Chemistry | The chosen topic has focus and clarity, but the supporting information is unclear. The topic is relevant to Inorganic Chemistry | There is one topic with no supporting information. Proposal is unfocused. The topic has somewhat relevance to Inorganic Chemistry | There is a topic, but no supporting information. Details are scattered and no focusing efforts are evident in the proposal. The topic has no relevance to Inorganic Chemistry. |
| Clarity, formatting, and organization | The writing is well introduced and organized by parts. The information presented is well supported. The writing flows like a story in a logical manner. | The writing is acceptably introduced. Individual parts are recognizable. | The writing is scattered and not introduced well. There are no separate sections. There is no chronological flow. | There is no apparent organization. The proposal's sections are scattered. |
| Audience | The proposal is clearly directed towards a scientific audience. The proposal clearly delivers the importance of the topic. | Some parts of the proposal are directed towards a scientific audience. The importance of the topic is mentioned, but not clearly stated. | The proposal is full of misdirection and phrases that do not convey the focus of the topic. | The proposal is not directed towards a scientific audience. A large amount of the writing is inconsistent and not focused. |
| Terminology | The author uses clear and concise vocabulary. Technical terms are related to the topic studied and focused. Technical terms are defined where needed. | There is use of clear vocabulary. Technical terms are somewhat related to the topic under study and focused. Technical terms are seldom defined. | Vocabulary is unclear. There is use of repetitive words. There are non-technical terms that do not belong to the narrative and are not topic specific. Usage of "slang" is very present. | The author uses repetitive words with no meaning. Use of technical terms is there, but with no focus. |
| Grammatical presentation | No jarring grammatical errors. Sentence structure is on-point. | A gamma of well-constructed sentences, with some grammatical mistakes. | There are some sentences that are well constructed. There is use of repetitive language | The proposal is full of grammatical errors. Sentences are not well-constructed. There is use of repetitive language. |

**Table 3.** Proposal grading rubric

## Conclusions

For the past two years, research proposal writing has been implemented at the Advanced Inorganic Chemistry lecture at GC. Significant improvement in writing and correct use of terminology was noted from the first draft (handed in mid semester) to the final draft (handed in last day of class). The students also displayed confidence in explaining their topic as observed in daily classroom interactions. While the assignment targeted seniors in chemistry, it is believed that with slight modifications this assignment can be incorporated in lower level courses.

### *Conflict of interest*

The author of this work declares no conflicts of interest.

### *Acknowledgements*

The author would like to acknowledge the Department of Chemistry, Physics & Astronomy at GC and the wonderful students who worked very hard on their proposal assignments.

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