# Evaluation of the Sustainability of Undergraduate Chemistry Labs at Thompson Rivers University

*A proposal for the review of laboratory procedures as applied in the instruction of undergraduate chemistry*

Proposal submitted in partial fulfillment of the $5000 Student Sustainability Award application guidelines

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## Abstract

This project proposes to develop a specific set of criteria based on the principles of green chemistry that will be used in the evaluation of all undergraduate chemistry labs at Thompson Rivers University. Providing metrics of this type will serve as a management tool for faculty to enable the enhancement of sustainable practices in the laboratory. By making the ratings available to students with their laboratory procedures, concepts of sustainability will be integrated with existing curricula.

# Project Description

## Introduction

Chemistry is a fundamental branch of science that all students in the Faculty of Science at Thompson Rivers University must study to some degree. In addition to the theoretical component to this education, an applied component is taught in the form of compulsory laboratory instruction periods. The importance of sustainable practices has been acknowledged by the chemistry faculty at TRU, who have made it a goal to integrate the principles of green chemistry across the curriculum.

Paul Anastas, a pioneer in the field of green chemistry, has defined the concept as: "the utilization of a set of principles that reduces or eliminates the use or generation of hazardous substances in the design, manufacture, and application of chemical products". (Anastas, Green Chemistry: Theory and Practice 1998)

In the past decade there have been significant advances in the thinking surrounding chemistry through the development of the related fields of green synthetic chemistry and green analytical chemistry. (Anastas and Kirchhoff 2002) (Galuszka, Migaszewski and Namisnik 2013) The significance of these fields is that they are not distinct sub-disciplines of chemistry, but rather comprehensive philosophies which seek to inform the chemist in completing what has traditionally been required of her, while eliminating unnecessary harm that may come about in achieving the desired results. A number of objective rating systems have been put forth in academic literature to aid in the assessment of the overall sustainability of an experimental procedure. (Galuszka, et al. 2012) (Raynie and Driver 2009)

To date there has never been an evaluation of undergraduate chemistry labs at TRU with an eye towards sustainability. Given the discussion in recent literature it seems appropriate to perform an assessment of the entire experimental curricula than to modify a single experiment. By reviewing all labs there are significant potential gains, and TRU may emerge as a leader in the instruction of green chemistry.

## Goals and Objectives

There are two related goals that must be achieved for the successful completion of this project. Firstly, standardized criteria to evaluate the sustainability of a chemical method within the university context must be created. The criteria would include a rating system or systems published in the scientific literature, factors specific to the institution such as the number of students completing a given experiment (which varies greatly by the year of study), and other considerations relating to green chemistry that may fall outside of the literature method or methods selected. The second and ultimate goal of the project would be the application of the standardized criteria to all undergraduate chemistry experiments at Thompson Rivers University that are completed on an ongoing basis.

### Significance

This project will have real and immediate benefits in each of the "four pillars of sustainability" as defined by TRU's Office of Sustainability. Providing a measurement of sustainability that is consistent for each experiment will create a management tool that will easily facilitate decision-making regarding sustainability at the department level. Through the evaluation process the least sustainable experiments will become apparent and potential alternatives to enhance the sustainability of these experiments will be provided. If even one experiment were changed based on these recommendations there would be real benefits for the environment.

Perhaps the greatest benefits would come in the social and cultural areas of sustainability. If the determined ratings were made available to students with the laboratory procedures it would provide an excellent introduction to principles of green chemistry from the first time a student enters the lab. Presenting the ratings and explaining their significance, would introduce concepts of sustainability, even if no changes were made to the actual procedures. By introducing these concepts early and bringing them into consideration any time a student steps into the lab it is possible that students will be empowered to make better choices towards sustainability of their chemistry practice at TRU as well as in their future endeavours. As such, the dissemination of the evaluations that will result from this project represent an excellent tool to advance the education of sustainable principles at TRU in an approach that is fully integrated into the normal pedagogical process pertaining to chemistry. This is fully congruent with the idea that green chemistry is not, and must not be regarded as, an independent sub-discipline of chemistry but rather as an integrated approach.

Economic sustainability benefits may also arise as a result of this work. In the process of reviewing procedures and recommending changes, costs of chemical reagents may be used as a factor for consideration. Areas of wastefulness will be identified and the improvement of those areas will have a positive impact on cost through the reduction of chemical materials used.

## Theory

A specific set of criteria for sustainability must be developed rather than using an "off the shelf" assessment for a number of reasons. As mentioned above the actual number of students completing a first year lab will be far greater than the number completing a fourth year lab, and thus the impacts will differ significantly. In addition the literature methods for evaluating a synthetic process differ greatly from methods to evaluate an analytical process. Even focusing briefly on the analytical case alone, there are many different methods of evaluation that collect and display information differently. In the Rainey and Driver method a pictogram is created showing a red, yellow or green rating in the five areas: health, safety, waste, environmental impact and energy consumption. (Raynie and Driver 2009) In the

Eco-scale method the calculations are more in depth, and a number is provided on a scale of 100 to judge the sustainability of the method. (Galuszka, et al. 2012) Both methods have their advantages and it is possible that both methods could have a place in the developed assessment criteria, but there are other areas of sustainability that should be considered as well. Additionally, neither of these systems would be suitable for the evaluation of a synthetic process, as they both focus on analytical experimental methodology. This further illustrates the need for a green chemistry metric that is specialized to the undergraduate laboratory setting.

There are many examples in the recent literature of green undergraduate chemistry experiments being developed (Lang, Harned and Wissinger 2011) (Buckley, et al. 2013). To date, there has not been a demonstration of an evaluation of all chemistry labs at an undergraduate institution, as is being proposed for this project.

## Budget and Timeline

Outside of the time spent researching the methodology and implementing it there are no other significant inputs required. The $5000 award would sufficiently compensate for the research to be performed.

Timeline

| **Milestone** | **Target date** |
|---|---|
| Commencement of project | Immediately upon award |
| Finalization of evaluation criteria | May 31, 2015 |
| Application of criteria to labs complete | July 31, 2015 |
| Analysis of data and preparation of reports | August 31, 2015 |
| Presentation of findings | September 2015 |

## Dissemination

The manner in which the results of this research will be disseminated will be key to producing the intended outcomes with respect to the advancement of sustainable practices in chemistry. A report detailing the development of the green chemistry evaluation criteria, and application of the criteria will be made available to the Faculty of Chemistry, the Office of Sustainability and the student body via the TRUSU Chemistry Biochemistry Club. This report will also be submitted to academic journals for publication.

Two supplemental documents will also be developed and submitted to the Faculty of Chemistry. One of these documents will recommend potential alternatives to the lowest rated labs in terms of green chemistry, which would serve to improve the rating under the observed criteria. The other supplemental

document will provide a concise rating for each experiment evaluated, in a format that would be suitable to include in future versions of lab manuals.

A presentation of the findings will also be made. The presentation will be open to faculty, students, representatives from the Office of Sustainability, and other stakeholders at the university.

## Closing Remarks

A novel process to evaluate the sustainability of chemistry labs in an undergraduate university setting has been proposed. This process will provide opportunities for improvements with respect to environmental outcomes, reduction of costs by conserving materials, and most significantly, the advancement of the education of sustainable principles in a manner that could be integrated seamlessly with existing curricula.

In my opinion, I am uniquely qualified to complete this project for the following reasons. Majoring in Environmental Chemistry has given me a solid foundation in physical science as it relates to sustainable practices, and the technical skills required in evaluating a chemical method. Work this semester in the course Selected Topics in Applied Chemistry has focused on the application of standardized criteria to chemical methodologies, and has given me experience with some of the different rating systems available. Pursuing a Minor in Environmental Economics and Sustainable Development has expanded on my knowledge around sustainable practices in an interdisciplinary fashion. This work has included topics of economic theory as applied to the environment, social issues in sustainable development, and environmental ethics. In addition I have four years of work experience in construction management, during which time I completed Built Green builder training and achieved LEED Accredited Professional status. Learning about these systems gave me much insight into standardized methods for evaluating sustainability. Through the application of these systems to real construction projects I have gained a significant appreciation for the challenges that may be present when integrating principles of sustainability into a goal-oriented process.

In contemplation of the benefits outlined above and strong possibility of success in achieving the goals set forth, this proposal is respectfully submitted for your consideration.

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