

North Cross School STEM Capstone Project Guide

Adapted from multiple sources. See references.

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About

Students in the North Cross School STEM certificate program will complete a research-based STEM capstone project that culminates in a paper, a speech, and a poster presentation their senior year. This document outlines the Capstone Project and provides rubrics and guidelines for the completion of the paper and presentation.

Capstone Mission and Overview

The STEM Capstone Project is designed to prepare STEM students for lifelong learning and effective and productive citizenship through the opportunity to plan, complete, and present a self-directed culminating project reflecting their personal interest. Projects may be done in the area of science, mathematics, engineering or computer science. Capstone projects are designed to encourage students to think critically, solve challenging problems, and develop skills such as oral communication, public speaking, scientific writing, research skills, media literacy, planning, self-sufficiency, and goal setting. These skills will help prepare the students for college, modern careers, and adult life.

Required Skills

The STEM Capstone Project is a progressive project, requiring students to demonstrate the ability to apply key knowledge and skills. These core skills include:

1. Thinking critically and creatively
2. Demonstrating flexibility, self-sufficiency, initiative, and the ability to set goals
3. Conducting analysis and research, including proper citation of references
4. Data analysis, including graphical and statistical
5. Communicating ideas through both formal/scientific writing and oral presentation
6. Using technology effectively

Process

The STEM Capstone Project reflects the belief that the processes inherent in learning are at least as important as the products. All STEM students should complete certain common processes. These essential processes include:

1. Developing and implementing a plan of action
2. Conducting research
3. Working with an advisor
4. Presenting research through multiple modalities
5. Reflecting and self-evaluating

Junior Year

1. Develop your own **original idea** for a scientific investigation. Examples include: lab research to answer a scientific question, creating a prototype of a product that serves a defined need and then testing that prototype, creating and testing a computer program that solves a defined problem, or other ideas that are approved by an NCS STEM teacher.
2. Complete Rough Draft of Project Proposal - see appendix A
3. Due June 1

Summer Between Junior and Senior Year:

- Complete revised Project Proposal
- Complete research notes and work cited page from a minimum of three *primary* sources (see Project Proposal for details)
- Due September 1

Senior Year: Create/Experiment, Improve, Communicate

- Create and test multiple iterations of prototypes of product developed to solve a problem, conduct multiple trials of scientific research to answer a question, create and test computer program, etc.
- Gather and analyze data, take pictures of experiments or steps in building of a prototype
- Student will keep a reflective notebook/process log (with diagrams/sketches/pictures as needed) documenting daily work done on the project
- Complete writing formal report and preparing oral presentation
- Due dates based on date of speech and as arranged with STEM teachers and advisor.

FORMAT FOR THE PAPER

Scientific research articles provide a method for scientists to communicate with other scientists about the results of their research. A standard format is used for these articles, in which the author presents the research in an orderly, logical manner. This doesn't necessarily reflect the order in which you did or thought about the work. You wrote some of the following in your proposal, so for those sections just make your final edits and copy into this final document. This format is:

TITLE PAGE

1. Personal data: Name
2. Title of your research/capstone project – should identify the problem/challenge area (15 word maximum)

ABSTRACT

1. The abstract is a description of your project and lays out specifically what you are doing not what the topic is about. Do not write a summary of the entire background of the project. The abstract should be a 1 page paragraph which includes the objective and rationale of the project, the methods you will use to accomplish your objective, the result or product, and a conclusion. The abstract will be completed in two steps. The objective and methods will be presented in the initial proposal. Once you hand in the final proposal, the methods should state exactly what you did, and the results and conclusion should be added.

- a. Objective: What is the problem or main issue? What do you intend this project to do? This first few sentences of your abstract should describe the specific problem your project will address and why you chose to do this specific project. Clearly state your goals for the project (what you hope to accomplish), describe the product you will create, the problem you will solve, etc.
- b. Methods: The method section of the abstract should state the intended methods or process you intend to use for solving the problem or exploring the issue.
- c. Results: What did you find? State what your research found or what you developed in the end.
- d. Conclusion: What did you learn throughout the process of the project. How did you project help a certain population in society. Try to sell you audience on the project so that they might want to investigate it further.

TABLE OF CONTENTS

The TOC should include major headings and subheadings, as needed. Tip: Microsoft Word has a Table of Contents feature.

DESCRIPTION OF PROBLEM

This section should elaborate on the statement of the problem presented in the introduction. Thoroughly describe the nature of the problem; including your rationale for believing the problem exists. Describe how the project will address the problem, and clearly state the goals and scope of the project. These goals must align with the literature review and the methodology. 1- 2 pages

REVIEW OF LITERATURE

1. You have already written a draft of this section in your project proposal. Now it is time to review your work one more time and make sure it adequately supports your final project. If you are struggling with this section, please refer to the following website for help:
<http://www.duluth.umn.edu/~hrallis/guides/researching/litreview.html>
2. See the project proposal form for the full description of this section of your paper. As a reminder:
 - a. Include at least 5 sources – at least sources 3 must be primary (other than an electronic/internet/web source). The articles should be fairly current (the majority should have been published within the last 10 years, though some seminal works in the area of interest may be older) and come from peer-reviewed journals. Edited texts or textbooks may also be appropriate source material. Web site should be used with extreme caution. Refer to APA guidelines for how to incorporate in-text citations of the articles you use. Recommended length is 3 to 5 pages.

MATERIALS AND METHODS

1. How did you answer this question? There should be enough information here to allow another scientist to repeat your experiment. Look at other papers that have been published in your field to get some idea of what is included in this section. Referring back to your research notebook will be helpful for this section.
2. If you had a complicated protocol, it may helpful to include a diagram, table or flowchart to explain the methods you used.

3. Do not put results in this section. You may, however, include preliminary results that were used to design the main experiment that you are reporting on. ("In a preliminary study, I observed the owls for one week, and found that 73 % of their locomotor activity occurred during the night, and so I conducted all subsequent experiments between 11 pm and 6 am.")

4. See appendix C for some tips on how to prepare this section of your paper.

RESULTS

1. This is where you present the results you've gotten. Use graphs and tables if appropriate, but also summarize your main findings in the text. Do NOT discuss the results or speculate as to why something happened; that goes in the Discussion section.

2. You don't necessarily have to include all the data you've collected. If large amounts of data were collected in your experiment, sample data can be included in this section and the rest can added to the appendix at the end of your paper.

3. Use appropriate methods of showing data. Don't try to manipulate the data to make it look like you did more than you actually did.

4. Not all experiments involve collecting data. If your project falls into this category, your results section should included descriptions of your final project, be it a computer program, a prototype, etc. Speak with your advisor about how to adapt this section to your project.

4. For more help on writing your results section, see the following: https://mitchell-lab.biochem.wisc.edu/WRITING/sheets/Writing_the_results.pdf

TABLES AND GRAPHS

1. If you present your data in a table or graph, include a title describing what's in the table ("Enzyme activity at various temperatures", not "My results".) For graphs, you should also label the x and y axes.

2. Don't use a table or graph just to be "fancy". If you can summarize the information in one sentence, then a table or graph is not necessary.

DISCUSSION AND CONCLUSIONS

1. Highlight the most significant results, but don't just repeat what you've written in the Results section. It should briefly recap the purpose of the project, as well as summarize and contextualize the major findings/outcomes. How do these results relate to the original question? Do the data support your hypothesis? Are your results consistent with what other investigators have reported? If your results were unexpected, try to explain why. Is there another way to interpret your results? This is the "so what?" part of the paper – the

place where you explain why the outcome matters. What is the impact of the project, what are its limitations, what have you learned, and what are the next steps? What further research would be necessary to answer the questions raised by your results? How do your results fit into the big picture?

2. End with a one-sentence summary of your conclusion, emphasizing why it is relevant.

ACKNOWLEDGMENTS

This section is optional. You can thank those who either helped with the experiments, or made other important contributions, such as discussing the protocol, commenting on the on your paper, or buying you pizza.

REFERENCES (LITERATURE CITED)

In-text citations need to be included in your paper as well as a references section at the end of your paper:

1. In the text, cite the literature in the appropriate places:

Scarlet (1990) thought that the gene was present only in yeast, but it has since been identified in the platypus (Indigo and Mauve, 1994) and wombat (Magenta, et al., 1995).

2. In the References section list citations in alphabetical order.

Indigo, A. C., and Mauve, B. E. 1994. Queer place for qwerty: gene isolation from the platypus. *Science* 275, 1213-1214.

Magenta, S. T., Sepia, X., and Turquoise, U. 1995. Wombat genetics. In: *Widiculous Wombats*, Violet, Q., ed. New York: Columbia University Press. p 123-145.

Scarlet, S.L. 1990. Isolation of qwerty gene from *S. cerevisiae*. *Journal of Unusual Results* 36, 26-31.

APPENDIX

The appendices contain *supplementary* material, i.e., information that is not essential, but that the reader might find useful for developing a deeper understanding. Appendices can also include high-volume data tables, descriptions, lists, survey questions, etc.

1. If you wrote a computer program, the entire program should be included in this section.
2. Copies of your research journal and photographs you took can also be included in this section.

References

1. Avery County High School's capstone program
(www.ncssm.edu/uploads/files/851997344654734299-stem-capstone-project.pdf)
2. The Writing Center at The University of Wisconsin at Madison
https://writing.wisc.edu/Handbook/presentations_abstracts.html#whatis
3. Capstone Project and Paper Guidelines
http://com.msu.edu/FDLL/Leadership/HPE/Syllabi/OST820_Syllabus.pdf
4. Writing a Scientific Research Article
<http://www.columbia.edu/cu/biology/ug/research/paper.html>
5. American Journal Experts <https://www.aje.com/en/arc/materials-and-methods-7-writing-tips/>

References

- A - Project Proposal - to be used for both rough and final drafts
- B - Project Proposal Rubric - to be used for both rough and final drafts
- C - Tips on preparing your materials and methods section
- D - Helpful Hints for writing your paper
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Project Proposal Template

Your proposal is the first component of the STEM Capstone Project. The Capstone Project proposal should include:

Title Page

- Personal data: Name
- Title of your research/capstone project – should identify the problem/challenge area(15 word maximum)

Review of literature

- The first section is a brief review of the relevant literature pertaining to the proposed problem/project. This should be a short and precise overview about current research pertaining to your project. This site provides an excellent description of how to write a literature review:
<http://www.duluth.umn.edu/~hrallis/guides/researching/litreview.html>
- Carefully select the articles/books you review to inform and/or support the need for your project, past research that has been done that pertains to your project, contain processes or procedures that will help you with your project, etc. For example,
 - Does the literature provide supporting documentation of the existence of the problem you have identified?
 - Does the literature support the methodology/lab procedure/"solution" you have selected to address the problem? It can be helpful to have a template or model to follow.
 - Does the literature point to major gaps that your project can fill?
 - Are there published reports by others who have already done what you propose to do? If so, critique this literature and discuss how your project can improve/expand/build on it.
- Include at least 5 sources – at least sources 3 must be primary(other than an electronic/internet/web source) The articles should be fairly current (the majority should have been published within the last 10 years, though some seminal works in the area of interest may be older) and come from peer-reviewed journals. Edited texts or textbooks may also be appropriate source material. Web site should be used with extreme caution. Refer to APA guidelines for how to incorporate in-text citations of the articles you use. Recommended length is 3 to 5 pages.

Description of the Project

- The second section should describe the proposed methodology and timeline related to how you will conduct the project from inception through the performing of the research and to the completion of your project.
- Complete a planned research procedure(s). What are the major steps and when will they occur?
- Describe the intended methods of data gathering and the controls you will introduce. If completing a program, specify the language(s) intended to be used. Present an algorithm describing classes and methods to be used.
- Include how you will assess the outcome of your project.
- This will be a work in progress allow for changes to be made during the process.
- Doing this section **first** will help you determine if the project is doable or needs to be more focused.
- Develop a timetable (in table format), including the sequence of research phases and estimated time you will need for each phase. It is understood that these are only estimates, but be as practical as possible.

Timetable

- The third section is a timetable outlining the steps needed to complete your project and the approximate dates will be done.
- Clearly indicate start and end dates.
- Include an anticipated number of project work hours each week.
- Provide a week-by-week listing of planned project milestones.
- For example (from: <https://ugradresearch.uconn.edu/surf/sample-surf-timelines/>)

Week	Dates	Hours	Task Description
1	May 23 – May 27	35 hours	Training on new microscope. Synthesize experimental samples with varying ratios using multiple synthesis approaches (as summarized in Figure 2 in proposal).
2	May 31 – June 3	35 hours	Characterize samples using x-ray diffraction (XRD) and scanning electron microscopy (SEM). Analyze data to identify optimal synthesis method.
3	June 6 – June 10	35 hours	Repeat the optimal synthesis method across the ratios and characterize the samples. Compare these results to the first round of samples.

References

- The fourth section provides a list of the references cited in your proposal. Only those sources cited should be included. This section should also be in APA format.
- List academic works mentioned in your research outline as well as other important works that you will refer to during your research.

Submit the next draft of your proposal via email to Mrs. Bagliani and Mrs. Landry by September 1.

Appendix B

	Description	Pass or Needs Improvement?	Comments
Title Page	Includes descriptive title and author's name.		
Review of Literature	Grammatically sound and clear formatting. Includes current state of research, at least 3 sources		
Description of Project	Grammatically sound and clear formatting, includes concise and clear outline or list of your goals and objectives of your project and details of your planned research procedures, methods of data collection and controls for your project..		
Timetable	Grammatically sound table format that includes sequence of research phases and time for each phase that		
References	APA format used consistently and correctly throughout the paper.		

Appendix C

7 Tips for Writing an Effective Materials and Methods Section in Your Research Manuscript:

1. Begin writing the Materials and Methods while you are performing your experiments.

Writing during the research process will prevent you from forgetting important details and save you time when you begin writing the full manuscript. You can also ask co-authors who performed specific experiments to write the corresponding parts of the Methods section.

2. Start with general information that applies to the entire manuscript and then move on to specific experimental details.

Examples of general information that you could begin with are characteristics of the study population, sources and genotypes of bacterial strains, or descriptions of samples or sample sites. Then, you could share more details about your experiment.

3. Match the order in which methods are described to the order of the results that were generated using those methods.

Also, be sure that each method you used is described, even if it is just a quick sentence (e.g., "Toxin assays were performed as described [reference]"). This practice is helpful for transparency, as well as reproducibility.

4. Always include citations for procedures that have been described previously.

If you made any modifications, be sure to list them.

5. Describe statistical tests as fully as possible.

Give as much information about the tests as possible; just mentioning a *t*-test is not sufficient for the reader to determine if the correct statistical analysis was performed.

6. Avoid discussing the pros and cons of certain methods or results of any kind.

Save evaluations for different methods for the Discussion section of your paper.

7. To save space, be concise, yet thorough, when listing the equipment you used.

You might consider listing all of your equipment purchased from a single company in one sentence. Or, you could create a flowchart figure of the steps in an important procedure.

Before you finish your manuscript, ask yourself the following questions about your Materials and Methods section to ensure that you have included all important information.

- 1. Is there sufficient detail so that the experiments can be reproduced?**
- 2. Is there excess information that could be removed without affecting the interpretation of the results?**
- 3. Are all the appropriate controls mentioned?**
- 4. Are all appropriate citations included?**
- 5. Is the source of each reagent listed?**

Tips from American Journal Experts: <https://www.aje.com/en/arc/materials-and-methods-7-writing-tips/>

Appendix D

Helpful Hints

Write accurately

1. Scientific writing must be accurate. Although writing instructors may tell you not to use the same word twice in a sentence, it's okay for scientific writing, which must be accurate. (A student who tried not to repeat the word "hamster" produced this confusing sentence: "When I put the hamster in a cage with the other animals, the little mammals began to play.")
2. Make sure you say what you mean.

Instead of: The rats were injected with the drug. (sounds like a syringe was filled with drug and ground-up rats and both were injected together)

Write: I injected the drug into the rat.

3. Be careful with commonly confused words:

Temperature has an *effect* on the reaction.

Temperature *affects* the reaction.

I used solutions in various concentrations. (The solutions were 5 mg/ml, 10 mg/ml, and 15 mg/ml)

I used solutions in varying concentrations. (The concentrations I used changed; sometimes they were 5 mg/ml, other times they were 15 mg/ml.)

Less food (can't count numbers of food)

Fewer animals (can count numbers of animals)

A large amount of food (can't count them)

A large number of animals (can count them)

The erythrocytes, which are in the blood, contain hemoglobin.

The erythrocytes that are in the blood contain hemoglobin. (Wrong. This sentence implies that there are erythrocytes elsewhere that don't contain hemoglobin.)

Write clearly

1. Write at a level that's appropriate for your audience.

"Like a pigeon, something to admire as long as it isn't over your head." Anonymous

2. Use the active voice. It's clearer and more concise than the passive voice.

Instead of: An increased appetite was manifested by the rats and an increase in body weight was measured.

Write: The rats ate more and gained weight.

3. Use the first person.

Instead of: It is thought

Write: I think

Instead of: The samples were analyzed

Write: I analyzed the samples

4. Avoid dangling participles.

"After incubating at 30 degrees C, we examined the petri plates." (You must've been pretty warm in there.)

Write succinctly

1. Use verbs instead of abstract nouns

Instead of: take into consideration

Write: consider

2. Use strong verbs instead of "to be"

Instead of: The enzyme was found to be the active agent in catalyzing...

Write: The enzyme catalyzed...

3. Use short words.

Appendix E

Content Categories	Comments
Title page <ul style="list-style-type: none"> • Includes full name • Includes descriptive title 	
Abstract <ul style="list-style-type: none"> • Is the objective and rationale of the project clearly described? • Was a succinct description of methods used to accomplish your objective included? • Is there a summary of the results or brief description of the product? • Is there a sentence summarizing the conclusion? 	
Table of Contents <ul style="list-style-type: none"> • Are all major sections included with page numbers? 	
Description of Problem <ul style="list-style-type: none"> • Is the problem clearly defined? • Are goals clearly described and why they were chosen to guide the project? • Was a complete overview of the environmental context of the capstone provided? • Were organizational challenges addressed? • How were goals and objectives chosen to measure the impact of the project? • Is the design adequate for achieving the stated objectives? 	
Review of Literature <ul style="list-style-type: none"> • Was relevant research reviewed? • Did the overview of the research literature provide a critique of the literature that informs this project? • Are in-text citations included? 	
Materials and Methods <ul style="list-style-type: none"> • Is there a complete and accurate list of materials included? • Is the description of procedure/methods clear enough for your project to be reproduced? 	
Results <ul style="list-style-type: none"> • Is there an adequate description of your results? • Are all tables and graphs properly formatted? 	
Discussion and Conclusion <ul style="list-style-type: none"> • Are the conclusions reasonable, given the overview of the project? • Is the project critiqued with lessons learned whether the project is deemed successful or a failure? • What recommendations are made for next steps as a result of this project? 	
Acknowledgements <ul style="list-style-type: none"> • Are proper acknowledgments included? 	

References <ul style="list-style-type: none">• Are in-text citations included where necessary throughout the paper?• Are the references at the end of your paper properly formatted?• Are at least five sources included?• Are at least three of your sources primary?	
Appendix <ul style="list-style-type: none">• Is necessary information included in your appendix?	

Appendix F

Capstone Poster Presentation

A scientific research poster is a tool that researchers, both students and professional, use to present information in a structured way. These are often presented at conferences or in collegiate classes.

All graduating STEM certificate students will be expected to present their project in poster form on a night in the spring.

Posters will be printed either on campus or at an off-site printing company. You will need to give your digital file to be printed to Mrs. Landry or Mrs. Bagliani two weeks before the presentation. Following are a few guidelines and helpful links for the posters.

Poster should include:

Purpose/Problem

Introduction/Background Research

Steps/Procedure

Data/Data Analysis

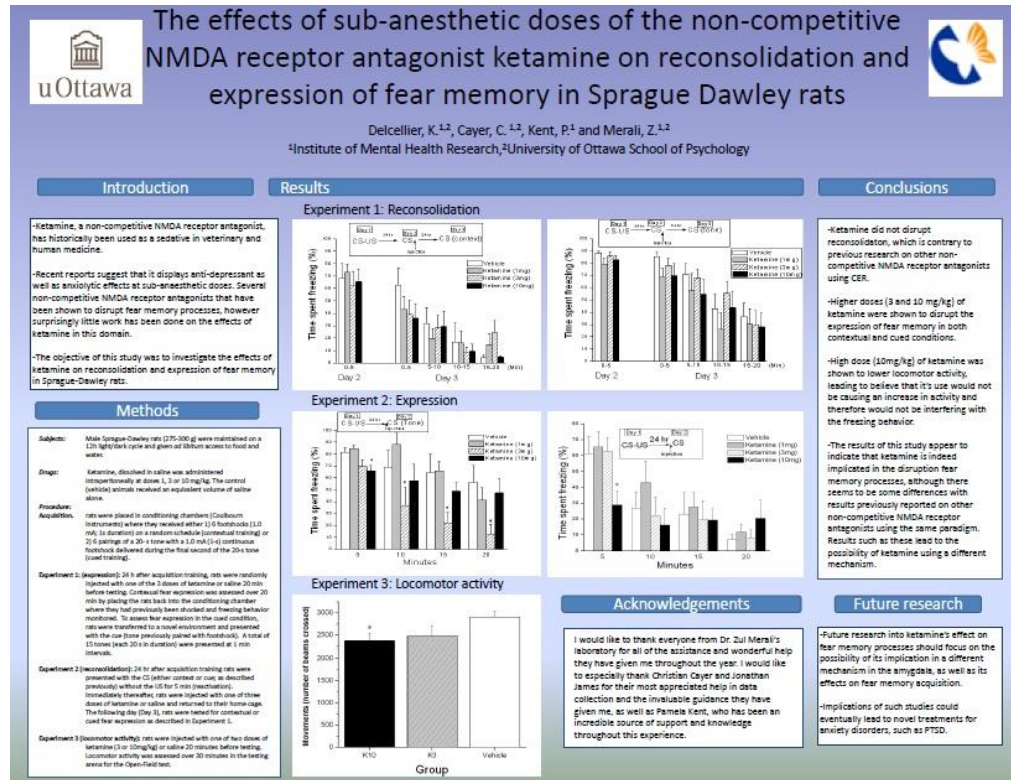
Solution/Conclusion

Acknowledgements

Future Research Ideas?

It should also include any charts, graphs, pictures, and/or small portions of code that serve to illustrate the main ideas of your project.

Example:



Helpful links:

<http://reasoniamhere.com/2014/07/04/how-to-design-attractive-scientific-posters-that-are-also-effective/>

<https://hsp.berkeley.edu/sites/default/files/ScientificPosters.pdf>
 (this one is long, but really gives good points on how to make your poster look good)

<https://guides.nyu.edu/posters>