Learning Outcomes Assessment of Master and PhD Theses

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Western

Mechanical and Materials Engineering

Introduction

➢ Master and PhD theses comprise a major portion of graduate curriculum

➢ A strong indicator of,

  • technical skills,

  • thinking, analytical and writing/presentation abilities

➢ A key parameter in the overall assessment of graduate degree outcomes

➢ Large variation in the standards used by faculty members to judge theses

Introduction

➢ Thesis work covers all six graduate attributes identified by the Council of Ontario Universities

➢ Hence, a strong indicator of the fulfilment of degree level expectations

➢ Currently, scarcity in the use of quality indicators to assess graduate attributes of theses

Workshop focus

- ➢ Learning outcomes assessment of graduate theses
- ➢ Topics of discussion,
  - Development of assessment rubric
  - Its implementation
  - Data collection and analysis
  - Thesis self-assessment
  - Future directions

Ontario Universities' Degree Level Expectations

➢ Depth and breadth of knowledge

➢ Research and scholarship

➢ Application of knowledge

➢ Autonomy and professional capacity

➢ Communication skills

➢ Awareness of the limits of knowledge

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Learning Outcomes: Evolution of Assessment
Toronto, October 17-18, 2016

Initiative and challenges

➢ Graduate program in Mechanical and Materials Engineering initiated the process of learning outcomes assessment in Winter 2015

➢ Used available resources to develop a rubric for graduate thesis assessment

➢ A major challenge was to keep the rubric general enough to accommodate research diversity

➢ Should cover the overall research expectations i.e. thesis content and oral defense

Further challenges

➢ Thesis quality indicators and related rubrics in the literature are primarily defined based on thesis skeleton i.e.,

  • Introduction

  • Literature review

  • Theory

  • Methods

  • Results/data analysis

  • Discussion and conclusions

➢ No indicators and rubrics for thesis assessment are defined based on six graduate attributes

Approach used

➢ Consulted Graduate Degree Level Expectations guidelines (OUCQA)

➢ Changed from 4-point to 3-point indicators

➢ Research and scholarship divided into two sub-categories

- General

- Critical thinking

➢ Communication skills divided into two sub-categories

- Thesis

- Oral exam

Developed Rubric

Department of Mechanical and Materials Engineering

Student Name:_____

Date:_____

	Does not meet expectations (1)	Meet expectations (2)	Exceeds expectations (3)	Score
Depth and breadth of knowledge	• Poor knowledge base related to the area of research • Lack of understanding of the advancements in the field of research • Poor knowledge of one or more specialized techniques (Analytical, numerical or experimental) in the area of research	• Good understanding of the knowledge base related to the area of research • A clear understanding of the advancements in the field of research • Good knowledge of one or more specialized techniques (Analytical, numerical or experimental) in the area of research	• A firm understanding of a wider knowledge base related to the area of research • An in-depth knowledge of the advancements in the field of research • A thorough knowledge of one or more specialized techniques (Analytical, numerical or experimental) in the area of research	
Research & scholarship (General)	• Review of the relevant scientific literature is limited • Synthesis of recent advancements in the field of research is weak • Incoherent approach to address research objectives • Research results are not presented in a systematic way	• Basic review of the relevant scientific literature • Some synthesis of recent advancements in the field of research • A logical approach to address research objectives • Research results are presented in a systematic manner	• A thorough review of the relevant scientific literature • A careful synthesis of recent advancements in the field of research • A cohesive approach to address research objectives • Research results are presented in a coherent form	
Research & scholarship (Critical thinking)	• Viewpoints presented in the scientific literature are taken as fact, without question • Issue/problem to be considered critically is stated without clarification or description • Research results are not explained • Conclusion is inconsistently tied to some of the information discussed; related outcomes (consequences and implications) are oversimplified	• Viewpoints presented in the scientific literature are somewhat questioned • Issue/problem to be considered critically is stated, described, and clarified so that understanding is not impeded by omissions • Research results are explained in the context of the given objectives • Conclusion is logically tied to a range of information, including opposing viewpoints; related outcomes (consequences and implications) are identified clearly	• Viewpoints presented in the scientific literature are questioned thoroughly • Issue/problem to be considered critically is stated clearly and described comprehensively, delivering all relevant information necessary for full understanding • Research results are critically scrutinized • Conclusions and related outcomes (consequences and implications) are logical and reflect the student's informed evaluation and ability to place evidence and perspectives discussed in priority order	

Examiner: _____

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Learning Outcomes: Evolution of Assessment
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Student Name:_____   Date:_____

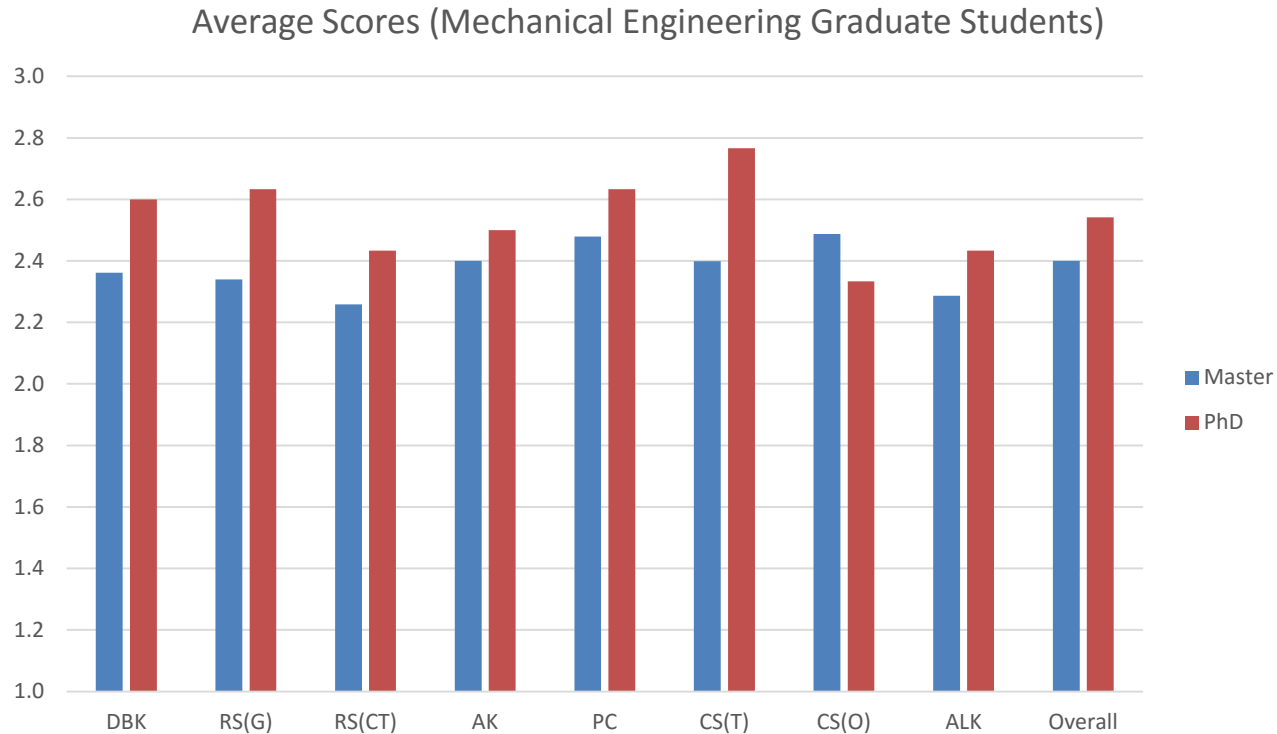|	Does not meet expectations (1)	Meet expectations (2)	Exceeds expectations (3)	Score
Application of knowledge	• The approach to investigate the research problem using existing research tools is incoherent • Inaccurate and inconsistent application of existing knowledge to analyze the research problem	• Approach to investigate the research problem using existing research tools shows coherency • Accurate and systematic application of existing knowledge to analyze the research problem	• Coherent and unambiguous approach to investigate the research problem using existing research tools • Accurate and systematic application of existing knowledge to analyze the research problem	
Professional capacity / autonomy	• Lack of awareness of academic integrity and research ethics • Failure to defend own ideas and conclusions	• Reasonable awareness of academic integrity and research ethics • Defends own ideas and conclusions in a logical way	• Full awareness of academic integrity and research ethics • Defends own ideas and conclusions with proper rationale and reasoning	
Communication skills (Thesis)	• Poorly written and poorly organized thesis • Content unclear, lapses in coherence • The progression of ideas is unsystematic and not logical	• Well written thesis and its organization supports the objectives • Content is clear and coherent • Sequence of ideas is logical and systematic	• Well written and well organized thesis • Content is focused, consistent and very clear • Sequence of ideas is excellent, logical and coherent	
Communication skills (Oral exam)	• No grasp of information and cannot satisfactorily answer questions about the thesis • Explanations of concepts and/or theories are inaccurate or incomplete or unsupported	• Answers expected questions without difficulty • Explanations of concepts and theories are accurate	• Demonstrates full grasp of the topic by answering all questions with explanations and elaboration • Provides accurate and complete explanations of concepts and theories	
Awareness of limits of knowledge	• Lack of awareness of the complexity of scientific problems and limitations of existing tools and techniques to address them • Unable to acknowledge the need of assumptions in complex scientific analyses and their consequences • Failure to acknowledge the limitation of research tools used and its consequences on the research outcome	• Reasonable awareness of the complexity of scientific problems and limitations of existing tools and techniques to address them • Reasonable awareness of the role of assumptions in complex scientific analyses and their consequences • Acknowledges the limitation of research tools used and basic explanation of its consequences on the research outcome	• Fully aware of the complexity of scientific problems and limitations of existing tools and techniques to address them • Fully aware of the need of assumptions in complex scientific analyses and their consequences • Fully acknowledge the limitation of research tools used and detailed explanation of its consequences on the research outcome	

Examiner: _____

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Learning Outcomes: Evolution of Assessment
Toronto, October 17-18, 2016

Implementation

➤ Started from April 2015

➤ Thesis + oral defense assessed by all examiners

➤ Each examiner assigned a numeric score against each attribute

Data Analysis
(Sample size=33, PhD=3, Master=30)

Average Scores (Mechanical Engineering Graduate Students)

Legend: Master (blue), PhD (red)

Categories: DBK, RS(G), RS(CT), AK, PC, CS(T), CS(O), ALK, Overall

DBK: Depth and breadth of knowledge

RS(G): Research and scholarship (General)

RS(CT): Research and scholarship (Critical thinking)

AK: Application of knowledge

PC: Professional capacity

CS(T): Communication skills (Thesis)

CS(O): Communication skills (Oral exam)

ALK: Awareness of limits of knowledge
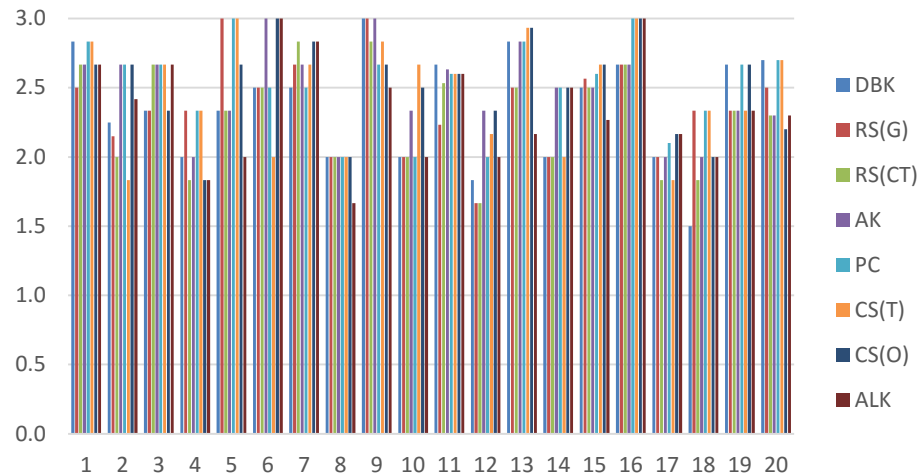
Individual scores in each graduate attribute
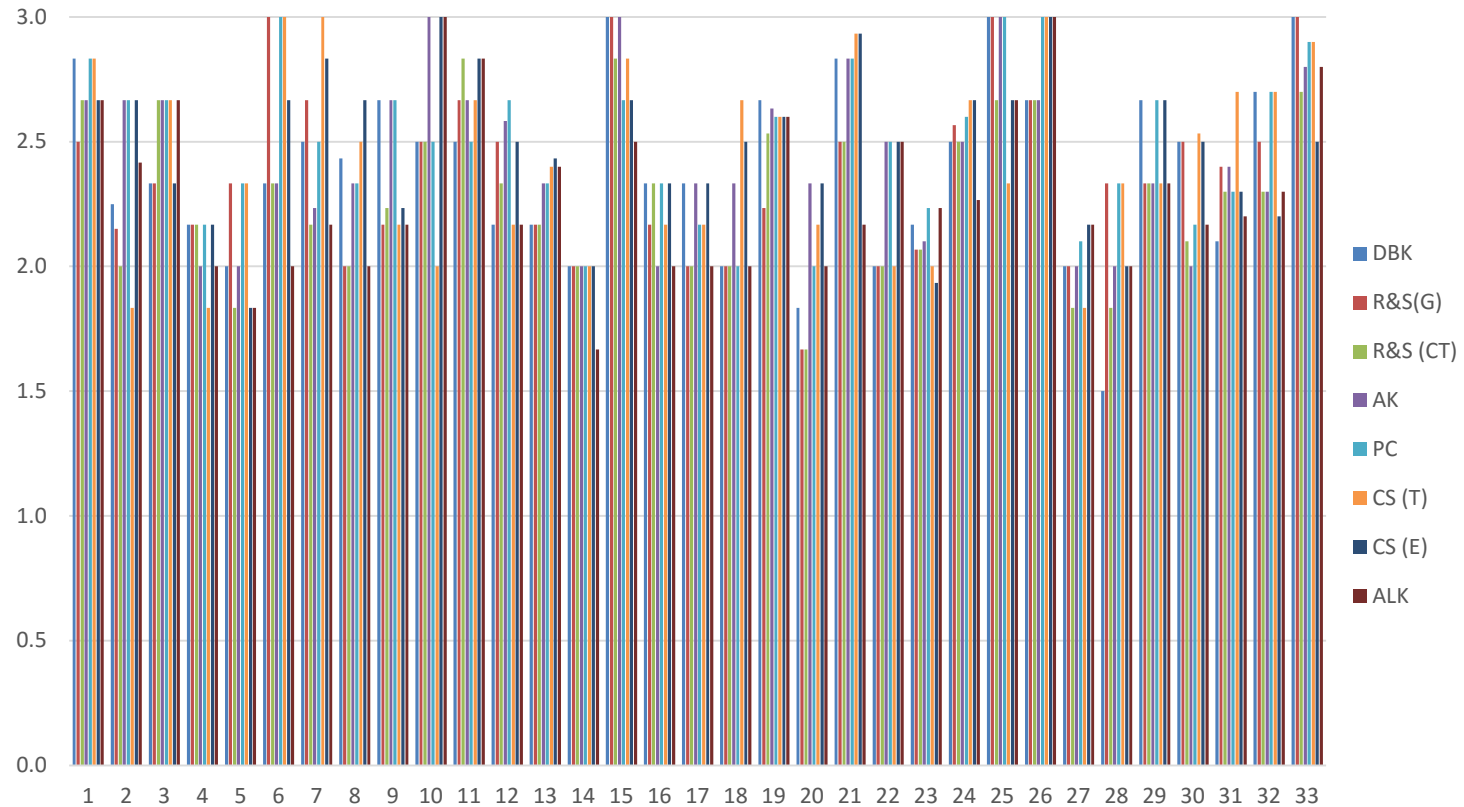
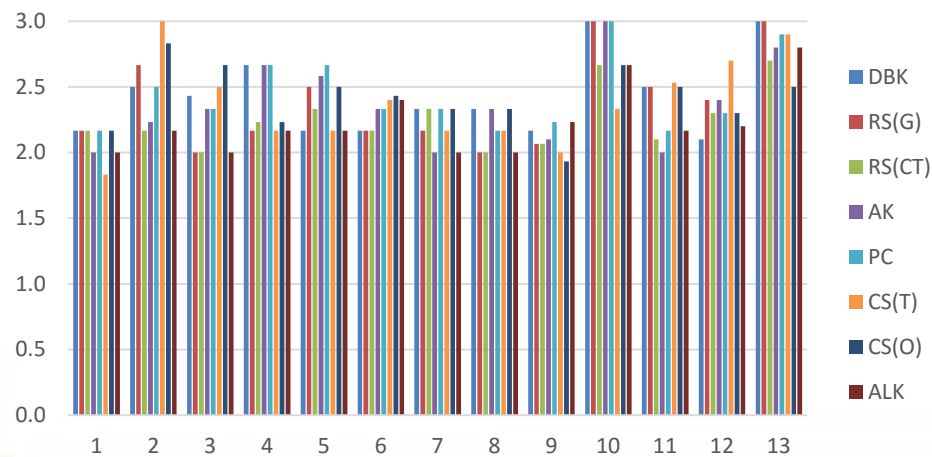# Categorization based on prior degree
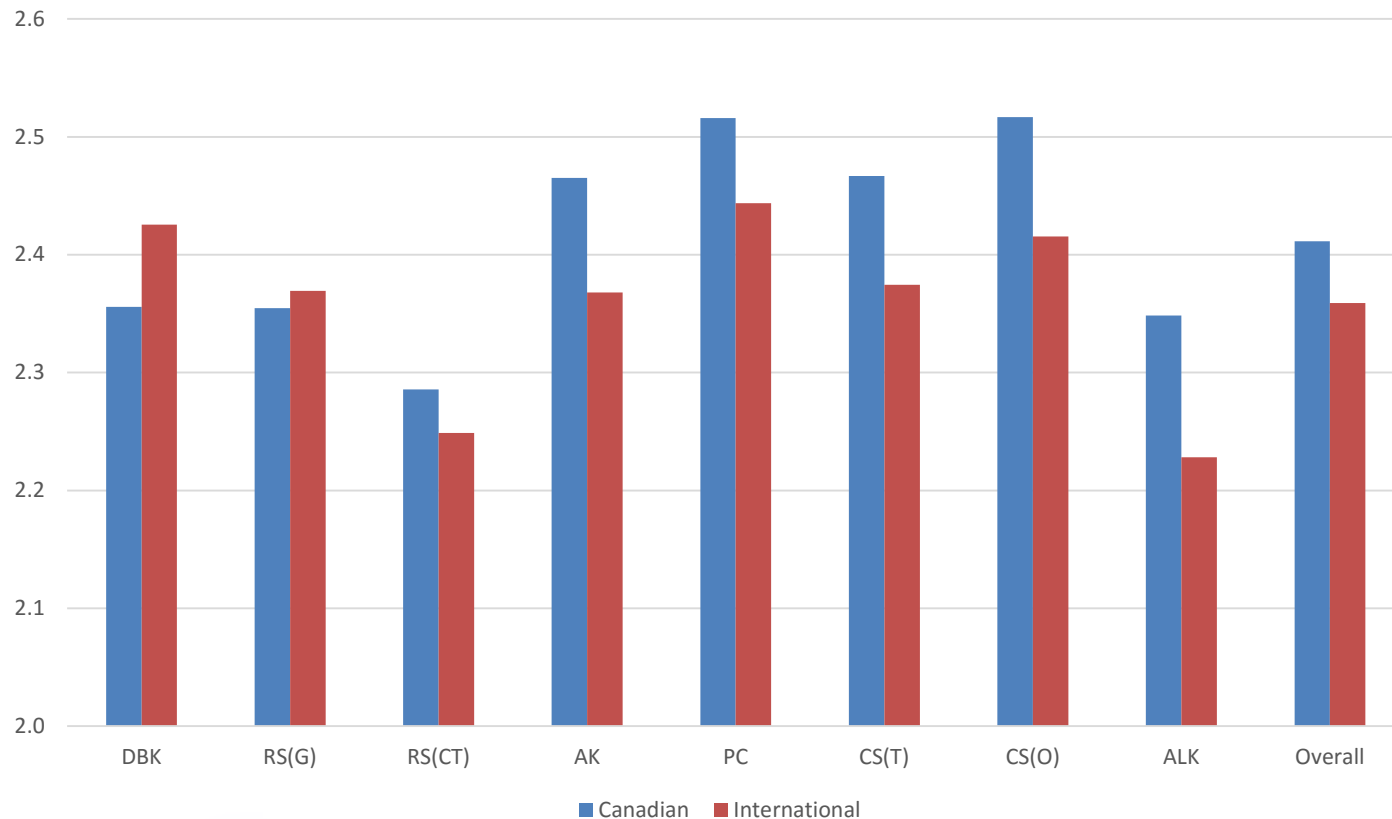
Individual scores based on prior degree

Canadian

International

Thesis self-assessment

➢ The developed rubric serves as an assessment tool for examiners

➢ Students are aware of this rubric

➢ No formal mechanism in place to self assess thesis expectations against the rubric

➢ A thesis self-assessment form is recently introduced

➢ Students self-assess their theses against the rubric indicators

Thesis self-assessment

➢ Students complete this form and submit along with thesis for examination

➢ Key benefits,

- Students can judge the strengths and weaknesses in their theses

- Assist in the preparation of thesis defense

- Provides the examiner a snoop of thesis quality in meeting the expectations before a thorough thesis review

Thesis Self-Assessment Form   **Department of Mechanical and Materials Engineering**

Instructions to complete the form: As part of a successful graduate thesis defence you must demonstrate that your thesis meets or exceeds the expectations concerning your performance and personal development associated with a set of attributes that are listed in the first column of the table below. The second column lists the expectations for each attribute. In the third column you should write one or more bullet points to clearly demonstrate, by providing evidence, how you have met (or exceeded) those expectations.

Student Name: _____   **Supervisor/co-supervisor:** _____

Thesis Title: _____

	Graduate Thesis Expectations	**Thesis Self-Assessment**
Depth and breadth of knowledge	• Good understanding of the knowledge base related to the area of research	•
	• Good understanding of the broader scope of the research problem and how the current research fits into the big picture is demonstrated	•
	• Good knowledge of one or more specialized techniques (Analytical, numerical or experimental) in the area of research	•
Research & scholarship (General)	• Detailed review of the relevant scientific literature	•
	• Synthesis of recent advancements in the field of research	•
	• Adaptation of a logical approach to address research objectives	•
	• Presentation of research results in a systematic manner within the context of the given objectives	•

Research & scholarship **(Critical thinking)**	• Questioning of the viewpoints presented in the scientific literature	•
	• Clear description of the critical issue(s)/problem(s) addressed by the thesis research	•
	• Logically tying of conclusions to the thesis objectives; adapted approach and related outcomes	•
Application of knowledge	• Accurate and systematic application of existing knowledge to analyze the research problem	•
Professional capacity / autonomy	• Demonstration of academic integrity and research ethics	•
Communication skills	• Thesis form and layout is consistent with the SGPS format	•
	• Thesis is free from typographical and grammatical errors	•
Awareness of limits of knowledge	• Awareness of the complexity of scientific problem under consideration and limitations of existing tools and techniques to address it is acknowledged and their consequences on the research outcomes are properly discussed	•
	• Consequences of the assumptions considered in the research work and the uncertainty induced in the results due to the limitations of the research tools are clearly described	•

Additional comments: _____

Student's signature: _____

Date: _____

Example

Instructions to complete the form: As part of a successful graduate thesis defence you must demonstrate that your thesis meets or exceeds the expectations concerning your performance and personal development associated with a set of attributes that are listed in the first column of the table below. The second column lists the expectations for each attribute. In the third column you should write one or more bullet points to clearly demonstrate, by providing evidence, how you have met (or exceeded) those expectations.

Student Name: _____   Supervisor(s): _____

Thesis Title: Characterization of mean and turbulent flow over complex topography under various inflow and geometric configurations

Area	Graduate Thesis Expectation	Thesis self-assessment
Depth and breadth of knowledge	Good understanding of the knowledge base related to the area of research	The graduate courses I took included "Bluff body aerodynamics", "Turbulent flow", "Experimental Measurements in Fluid Mechanics" and "Wind energy". The first two provided fundamental theory in fluid mechanics, while the third provided practical guidance in terms of current experiment design, advantages and disadvantages of various techniques, and associated sources of error. The fourth provided a good overview of the current state of global wind energy as well as theory of wind turbine aerodynamics. Review of graduate-level texts included Turbulent Flow (S.B. Pope), Atmospheric Boundary Layer Flows (J.C. Kaimal and J.J. Finnigan), and Physical Fluid Dynamics (D.J. Tritton).
	Good understanding of the broader scope of the research problem and how the current research fits into the big picture is demonstrated	The main application of my research was related to improving wind resource assessment for wind energy applications in complex terrain. However, there are many other applications to wind flow over topography that may benefit from this research including pollution dispersion modeling and the effects on buildings and other infrastructure located in more complex terrain. Collaboration with colleagues at Technical University of Denmark (DTU) was useful in terms of understanding the broader scope of the research as they are experts in the field and could provide additional resources and insight into the most recent and pressing issues.
	Good knowledge of one or more specialized techniques (analytical, numerical or experimental) in the area of research	I used several techniques related to fluid dynamics measurements and wind tunnel modelling throughout the research process including Particle Image Velocimetry (PIV), flow visualization, and Cobra Probe and hot-wire measurements. Theoretical knowledge of these techniques was gained through the graduate course "Experimental Measurements in Fluid Mechanics", while practical knowledge was gained through conducting my own experiments as well as assisting with those of others in my research group.

Area	Graduate Thesis Expectation	Thesis self-assessment
Research & scholarship (general)	Detailed review of the relevant scientific literature	My literature review covered several different areas and included the following: • Review of 25 papers on field measurements and wind tunnel studies of flow over complex terrain • Review of 15 papers on numerical modeling of flow over complex terrain • Review of 30 papers on atmospheric boundary layer (ABL) flow around bluff bodies and canonical flow over a forward-facing step (FFS) • Review of 30 papers on wind resource assessment, wind turbine and farm performance in complex terrain and effectiveness of commercial tools • Review of 30 papers on experimental and analysis techniques including Proper Orthogonal Decomposition (POD), as well as experimental determination of parameters such as friction velocity, turbulent kinetic energy (TKE) production and dissipation • Review of 25 papers on specific test cases for wind energy resource assessment in complex terrain including Bolund Hill and Askervein Hill • An additional 15 papers were reviewed for the introduction chapter
	Synthesis or recent advancements in the field of research	From the literature review, as well as based on knowledge of supervisors and researchers, several knowledge gaps were identified: • Whether Reynolds number independence is a valid assumption and at what threshold it is achieved • Modification of flow behaviour over topography due to changes in inflow conditions • Conditions under which geometric scaling of complex topography for wind tunnel testing is valid, and whether allowances need to be made to achieve similarity, particularly with respect to treatment of fine features
	Adaptation of a logical approach to address research objectives (numerical or experimental) in the area of research	The research project involved two main objectives: a) To investigate the influence of scaling and inflow conditions on the mean and turbulent flow behaviour over a complex topography b) To investigate the underlying processes associated with this behaviour with respect to the turbulent flow characteristics • It was determined that an experimental approach was the most effective means of address the research objectives, and each of the two content chapters in the thesis is dedicated to one of the objectives. • To fulfill the first objective: the inflow parameters of wind speed (Reynolds number), upstream roughness, and wind shear profile were varied, and the resulting flow over the hill measured. • Two different model scales were tested to further investigate Reynolds number and scaling issues across a wider range. • To fulfill the second objective, the same conditions were varied, as well as the sharpness of the escarpment leading edge; and the turbulent coherent structures, along with key turbulence statistics, above the hill surface were measured.
	Presentation of research results in a systemic manner within the context of the given objectives	• For the second chapter (1st objective), results are presented for the mean flow first, followed by the turbulent flow. Within each of these sections, results are first presented as a comparison with previous work, in order to present the reader with a big picture overview, before examining the detailed flow behaviour as a result of modifying various inflow conditions. • For the third chapter (2nd objective), first the POD results are presented to provide an overall qualitative sense of the coherent turbulent structures and energy patterns contained in the flow. This is followed by quantitative analysis of contour plots and profiles of various turbulent statistics, before a final discussion section intended to provide over-arching summary and additional context into how all aspects of the analysis are related.

Area	Graduate Thesis Expectation	Thesis self-assessment
Research & scholarship (critical thinking)	Questioning of the viewpoints presented in the scientific literature	My research presents two main instances of critical analysis of viewpoints presented in the literature, which have not been adequately addressed up to this point: • The first relates to Reynolds number independence for topographic flows: whether independence is achieved uniformly throughout the flow, and the threshold at which independence is achieved. • The second involves the degree to which geometric scaling-down of topographic models, particularly those with fine features, for the purposes of wind tunnel testing, can be accomplished without losing key behavioural aspects of the full-scale flow.
	Clear description of the critical issues/problems(s) addressed by the thesis research	In addition to the issues in the previous question, the following were also addressed, and clearly stated in the introduction chapter: • The influence of inflow conditions on mean and turbulent flow behaviour over topography was investigated by varying parameters such as upstream roughness, wind speed and the shape of the inflow shear profile • Characterization of the turbulent coherent structures specific to flow over an escarpment, enabling discussion on the extent to which flow over the topography could be considered similar to the classical case of a forward-facing step.
	Logically tying of conclusions to the thesis objectives; adapted approach and related outcomes	Conclusions were addressed as they related to each of the two main objectives. • For the first objective, related to the influence of inflow conditions, conclusions are first discussed for the mean flow behaviour, followed by that of the TKE • For the second objective, related to characterization of the turbulent coherent structures, conclusions were presented in terms of the differences observed in different upstream conditions as well as leading-edge geometries. • Finally, overall outcomes relevant to the wind energy industry are discussed

Area	Graduate Thesis Expectation	Thesis self-assessment
Application of knowledge	Accurate and systematic application of existing knowledge to analyze the research problem	Knowledge gained from several different areas was applied to the research problem: • From knowledge of bluff body aerodynamics - analysis of flow separation and reattachment, comparison to FFS, computation of friction velocity, other characteristics of boundary layer flow and wind tunnel modelling. • From knowledge of turbulent flow theory - calculation of length-scales., higher-order statistics, components of the TKE budget, spectral analysis • From knowledge of experimental techniques in fluid mechanics - limitations and sources of error for different techniques such as PIV and Cobra probe measurements.
Professional capacity/autonomy	Demonstration of academic integrity and research ethics	• One aspect of academic integrity that arose during the research project was how to properly distribute publication rights for shared experimental work conducted with our colleagues at DTU. This has been accomplished successfully to date by delineating in advance the specific areas to be covered by each group. • Otherwise I was careful to properly cite the work of others.
Communication skills	Thesis form and layout is consistent with the SGPS format	• During preparation of the thesis document, I was careful to adhere to the SGPS guidelines and provided templates. • In addition, I reviewed the published thesis documents from members of my research group to obtain recent examples of proper formatting.
	Thesis is free from typographical and grammatical errors	• Multiple people reviewed the text of the thesis document, including for spelling and grammar, as well as clarity and style. • Further improvement to my writing was gained through experience as a teaching assistant for the "Engineering Communication" graduate level course.

Area	Graduate Thesis Expectation	Thesis self-assessment
Awareness of limits of knowledge	Awareness of the complexity of scientific proble3ms under consideration and limitations of existing tools and techniques to address it is acknowledged and the3ir consequences on the research outcomes are properly discussed	During the research project limitations arose in several places and were documented in the relevant section of the thesis document: • Measurement resolution, and the limitations of different methods i.e. PIV and Cobra probe, both in time and spatially. • Measurement uncertainty was not uniform throughout the domain, and was higher in regions with high gradients, for example • Assumptions relating to dimensional similarity for wind tunnel testing were discussed.
	Consequences of the assumptions considered in the research work and the uncertainty induced in the results due to the limitation of the research tools are clearly described	• The consequences of the assumptions related to the issues raised in the question above were generally thoroughly discussed in the thesis document • The appendix included an error calculation for PIV measurements, but this did not necessarily account for various other sources of error involved throughout the experimental process • These sources are mainly related to experiment calibration i.e. alignment of cameras, laser and model, model details such as surface roughness, as well as convergence error due to sampling size • In addition to the limitations of the research tools, other issues of significance involved repeatability of the experiment and limitations in terms of what can reasonably be concluded from the results of a single experiment. • These broader issues may be under-represented in an integrated article format, and perhaps could have been expanded further in an appendix

Additional comments:

Student signature: _____ Date: _____ (mm/dd/yr)

Future directions

➢ Separate rubrics for Master and Doctoral theses

➢ Collection and analysis of the assessment data

➢ Identification of any shortcoming and necessary corrective action

➢ Incorporation into the overall curriculum mapping of the graduate programs

References

➢ Lovitts, B. E. (2007). *Making the Implicit Explicit: Creating Performance Expectations for the Dissertation*. Stylus Publishing, LLC.

➢ Lovitts, B. E., & Wert, E. L. (2008). *Developing Quality Dissertations in the Sciences: A Graduate Student's Guide to Achieving Excellence*. Stylus Publishing, LLC.

➢ Maki, P., & Borkowski, N. A. (2006). *The Assessment of Doctoral Education: Emerging Criteria and New Models for Improving Outcomes*. Stylus.

➢ Appendix 1: OCAV's Undergraduate and Graduate Degree Level Expectations, Ontario Universities Council on Quality Assurance (http://oucqa.ca/framework/appendix-1/)

Questions for table discussion

➢ Strengths and shortcomings of the thesis assessment rubric

➢ Other aspects of data analysis and comparison

➢ Utilization of results from the collected data

➢ Strengths and shortcomings of students' thesis self-assessment

Thank you