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WIP : Impact of supervision and the research group on the growth and development of graduate students in engineering

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Introduction

This empirical research work-in-progress paper explores the bi-dimensional nature of the graduate research training experience.

By fostering growth as researchers and professionals, graduate education in engineering prepares students for careers in either academia or industry. In addition to providing technical training and knowledge, graduate education should help students build confidence in their capabilities, develop specialized research skills, and feel connected to both the academic and professional communities [1]. While these broad goals generally align with established student outcomes, such as those specified by the Accreditation Board for Engineering and Technology (ABET) or the Canadian Engineering Accreditation Board (CEAB), they also reflect the unique challenges of advanced research training.

Works that empirically assess the graduate experience consider different approaches. One of the most influential factors in a graduate student's experience is their relationship with their supervisor. This relationship has been widely studied, with research focusing on how supervisors provide guidance, give feedback, and support students' professional and personal development [2]-[7]. Supervisors can take different approaches—some more hands-on, others more hands-off—but the balance they strike between providing structure and encouraging independence is crucial. Good supervisors nurture their students' development as researchers and their sense of belonging within their field. However, supervisors are not the only ones that shape a graduate student's learning. Many graduate students in engineering are part of a research group, typically a team of peers working under the supervision of the same faculty member. These groups are centered around a specific research focus and provide space for collaborative learning. They can influence how students approach their research, acquire knowledge, develop skills, and feel about being part of a broader academic or professional community [8].

Despite their importance, the role of research groups on a graduate student's experience has not been studied as extensively as the role of the supervisor. Yet, existing research highlights their unique contributions. For example, Pyhältö *et al.* found that while supervisors tend to provide individual mentorship, research groups foster teamwork and intellectual stimulation [9], [10]. They also help students feel like they belong, which is key to their success. Holloway *et al.* similarly emphasizes that research groups play an important role in preparing students for the collaborative nature of professional work [11]. Moreover, when research groups are collaborative and supportive, they can help mitigate feelings of isolation and competition, which are common challenges faced by under-represented graduate students [12]. The graduate experience is shaped by two major influences: the supervisor and the research group. These two dimensions are connected, but they also offer distinct benefits to students. While much of the attention has been on supervisors, it is just as important to understand how research groups contribute to a student's development. This work-in-progress paper reports preliminary results of our study to explore how these dimensions constitute two 'pillars' of the graduate experience. By examining how supervision and research groups each play a role, we can better understand how to support students during their graduate journey and prepare them for their future careers.

Methodology

We developed a questionnaire for a larger study on the growth and development of graduate students, their career aspirations as well as their learning and training environment. Here, we focus specifically on supervision and research group as the two main dimensions of the learning and training environment. We recruited graduate students from two research clusters in information and communications technology and optics and photonics to complete the survey anonymously. Combined, the research clusters involve 12 mid to large size public universities with R1 and R2 designations in the province of Québec, Canada. There are an estimated 550 graduate students and 100 faculty members that are associated with both clusters. The study was approved by McGill University's Research Ethics Board. Participants were invited by email at the end of May/early June 2023 to complete the survey, which was available for a 6-week period; two reminder emails were sent. We received a total of 169 complete responses, corresponding to a response rate of approximately 30%. After removing respondents who were not graduate trainees, i.e., MSc or PhD students or postdocs, the final number of responses used in our study is 157. We asked the participants questions about their supervision and research group experiences, as well as research skills, sense of belonging, and demographics (e.g., gender, program of study, first-generation student status, domestic vs. international). The Appendix lists the questions that were used in this study.

We constructed 4 variables:

- ***Supervision Experience***, measured using 16 questions pertaining to feedback, guidance, relational aspects, etc. (e.g., *my supervisor provides me with constructive feedback*, *my supervisor is supportive through my academic difficulties*). We calculated the average of the 16 questions, where each question ranged from 1 (strongly disagree) to 5 (strongly agree). The average is 4.2 with a standard deviation (SD) = .9.
- ***Research Group Experience***, measured using 5 questions pertaining to interactions with other members in the research group (e.g., *I can ask another student from my research group if I have a technical question or question about my research/experiment*, *I invite people from my research group to do things socially*). The average of the 5 questions is 3.8 (SD = .7).
- ***Sense of Belonging*** to the professional community, measured using 4 questions (e.g., *I feel that I am a member, or have the potential to become a member, of the professional community associated with my field of study*). The average of the 4 questions is 3.8 (SD = .9).
- ***Self-evaluation of Research Skills***, measured using 18 questions on general research skills, knowledge, and communication (e.g., *I can relate my research results to the bigger picture in my field*, *I can communicate orally the results of my research*). The average of the 18 questions is 4.4 (SD = .6).

Preliminary results and discussion

First, we observe a correlation of .289 ($p < .01$) between *Supervision Experience* and *Research Group Experience*. This low correlation coefficient[1] suggests that the two are not equivalent and

[1] We report Pearson's *r*. We also calculated Spearman's ρ to take into account the skewness of the data; the result is very similar with ρ =.61, $p < .01$).

should be considered separately to assess the graduate student training and learning experience. *t*-tests comparing the averages of *Self-evaluation of Research Skills* and *Sense of Belonging* across different groups of respondents (e.g., men and women; domestic and international students; and MSc and PhD/post-doctoral students) shows no significant difference in the averages. However, there is a small but significant difference in the *Sense of Belonging* reported by members of the two research clusters (Cluster1 = 0, Cluster2 = 1) from which respondents were recruited: the averages are 3.6 (SD = .814) and 3.9 (SD = .692), respectively ($t(155) = -2.923$).

Second, we use blockwise (hierarchical multiple) linear regression to gauge the incremental explanatory power of the *Supervision Experience* and *Research Group Experience* when entered in a model with *Sense of Belonging* and *Self-evaluation of Research Skills* as dependent variables. The objective is not to identify all predictors of these dependent variables, but rather to explore further graduate research training as a two-dimensional experience. The first block (Model 1) is made up of control variables, i.e., the demographic ones involved in the group average comparisons described above, to which we add ethnic/cultural background (Non-white = 0, White = 1), reporting a disability, and being a first-generation student (see Appendix for a description of the variables). Then, *Supervision Experience* and *Research Group Experience* are added to the linear regression equation. The results are summarized in Table 1.

Table 1. Results of hierarchical regression analyses for *Self-evaluation of Research Skills* and *Sense of Belonging* to the professional community.

	Model 1		Model 2		Model 3	
Dependent variables / Independent variables	*Self-evaluation of Research Skills*	*Sense of Belonging*	*Self-evaluation of Research Skills*	*Sense of Belonging*	*Self-evaluation of Research Skills*	*Sense of Belonging*
Demographics						
Woman	.012	.010	-.036	-.055	-.037	-.056
Domestic	.093	.091	.102	.103	.108	.116
Master	-.144†	-.157*	-.126	-.133†	-.123	-.127†
Cluster2	.046	.140†	.041	.134†	.020	.085
Disability	-.133	-.193*	-.108	-.161*	-.090	-.120†
White	.105	-.115	.090	-.135	.073	-.172†
First_gen_student	.116	.088	.067	.023	.068	.026
Supervision Experience			.356**	.477**	.329**	.418**
Research Group Experience					.095	.210**
Adjusted R^2	.019	.063	.141	.287	.143	.321
ΔR^2			.122	.219	.007	.036
ΔF			22.088**	47.889**	1.331	8.289**

Coefficients reported are standardized regression coefficients ($N = 157$).
$p < .1$ (†) , $p < .05$ (*) , $p < .01$ (**)

For *Self-evaluation of Research Skills*, the results show that Model 2, in which *Supervision Experience* is added to the control variables, is significant ($\Delta R^2 = .122$, $\Delta F(1,148) = 22.088$, $p < .01$). *Supervision Experience* is significantly associated with *Self-evaluation of Research Skills* (*b*

= .356, t = 4.700, p < .01). On the other hand, the addition of *Research Group Experience* (Model 3) does not significantly increase the value of R^2 ($\Delta F(1,147) = 1.331$, $p > 0.1$). For *Sense of Belonging*, the three blocks of variables significantly contribute to explain the variance. The largest increment is associated with *Supervision Experience* ($\Delta R^2 = .219$; $\Delta F(1,148) = 47.889$, $p < .01$). Adding *Research Group Experience* makes a smaller, yet significant contribution ($\Delta R^2 = .036$; $\Delta F(1,147) = 8.289$, $p < .01$). In Model 3, both *Supervision Experience* ($b = .418$, $t = 5.943$, $p < .01$) and *Research Group Experience* ($b = .210$, $t = 2.879$, $p < .01$) are significantly associated with the perceptions of belonging to the professional community.

Discussions and limitations

Our preliminary results show that it makes sense to consider simultaneously the supervision and research group experiences when evaluating graduate research training. As expected, the two are related, yet play a varying role depending on the outcomes being examined. The supervision experience is key and central in the training given the formal mentorship role attributed to the supervisor. However, we find that *Research Group Experience* is not associated with *Self-evaluation of Research Skill*. This may be due to our measure of *Self-evaluation of Research Skills*, which had the highest average and smallest SD amongst the four variables we used in this study. In the future, it may be better to include objective measures or survey questions targeting actual skills developed as opposed to questions that ask about (or appear to ask about) the potential to acquire these skills, e.g., replacing 'I can develop a methodology…" with 'I have developed a methodology…'. It will also be useful to include questions to clarify whether or not a student has more than one academic faculty member as a supervisor (this was assumed in our study and while it is reflective of practice in the participating institutions and research clusters, it is possible that some students were co-supervised students or had additional advisors, e.g., a collaborator from industry) as well as to ensure that all graduate trainee respondents are considered as those receiving mentorship from their supervisor.

Another limitation of our study is that our questionnaire has not been subject to a robust validation process even though we included questions from validated survey tools. Other limitations of our study are associated with the small sample size and the fact that participants were recruited from two specific research clusters. The fact that participants were recruited from only two clusters makes it possible that *Research Group Experience* registers a significant impact on *Sense of Belonging* due to some unobserved research cluster characteristics. However, the insignificant standardized regression coefficient associated with membership in a particular cluster (Cluster2 in Model 3) suggests that *Research Group Experience* is relevant when assessing the graduate experience.

Next steps/Future work

For our next step, we plan another iteration of our survey. We will use modified questions for self-evaluation of research skills as described above and include questions about research group such as size or organizational structure (e.g., hierarchical vs. flat). We will enlarge and diversify the sample of respondents and finally, examine how the two dimensions can impact other outcomes of the graduate experience, e.g., career aspirations.

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Appendix. Survey questions and description of the variables.

Supervision Experience
The variable is based on the average responses to 16 questions (N = 121, Cronbach's alpha = .971).

My supervisor…
1. provides guidance that matches my needs.
2. adopts different strategies for guiding me in my research work.
3. inspires me to excel.
4. acknowledges positively my work.
5. provides me with constructive feedback
6. encourages me to publish my work or present it at scholarly conferences.
7. provides support for writing papers (journal and/or conference).
8. helps me to make contacts and network with other researchers in the field.
9. is available for regular consultation.
10. helps me use my time effectively to work towards timely and successful completion of my research project.
11. is willing to receive my suggestions on research direction.
12. is supportive through my academic difficulties.
13. is supportive through any personal difficulties.
14. refers me to appropriate student support services and organizations.
15. ensures that I have the appropriate training (e.g., with using equipment, tools, instruments, or software) to conduct my work.
16. helps me to develop my future career in my chosen field of study.

Research Group Experience
The variable is based on the average responses to 5 questions *(*N = 148, Cronbach's alpha = .685)

1. I can ask another student from my research group if I have a technical question or question about my research/experiment.
2. I discuss events which happen outside of my research with other members in my research group.
3. I invite people from my research group to do things socially.
4. I have discussed personal matters with other students in my research group.
5. I rarely talk to other students in my research group. [reverse coding]

The questions on self-evaluation of research skills and sense of belonging are adapted from references [13]-[17].

Self-evaluation of Research Skills
The variable is based on the average responses to 18 questions (N = 139, Cronbach's alpha = .952).

1. I have mastered the primary scientific research literature in my field.
2. I can identify a specific question for investigation based on the research in my field.
3. I can relate my research results to the bigger picture in my field.

4. I can develop a methodology (based on experiment or simulation) to validate a theory or hypothesis.
5. I have confidence in my ability to understand concepts in my field.
6. I can think independently.
7. I can analyze data resulting from experiments (or simulations).
8. I can communicate orally the results of my research.
9. I can write a research paper.
10. I can perform experiments (or simulations) independently.
11. I can work with tools (e.g., computer software, lab equipment) and use them in my research.
12. I can manipulate components and devices.
13. I can assemble things.
14. I can achieve most of the goals that I have set for myself.
15. I can manage to solve difficult problems if I try hard enough.
16. When I am confronted with a problem, I can find several solutions.
17. I am confident that I can deal efficiently with unexpected events.
18. I am able to overcome many challenges successfully.

Sense of Belonging to the professional community

The variable is based on the average responses to 4 questions (*N* = 144, Cronbach's alpha = .811).

1. I feel comfortable in the professional community associated with my field of study (e.g., IEEE, Optica, ACM).
2. I feel that I am a member, or have the potential to become a member, of the professional community associated with my field of study.
3. I feel a sense of belonging to the professional community associated with my field of study.
4. The professional community associated with my field of study is supportive of me.

Demographics

All demographics variables are binary. Respondents who did not answer or preferred not to answer were included in the non-reference category.

1. I am a member of:
   Cluster 1
   Cluster 2 [reference category]
   Both

2. What degree are you completing:
   MEng/MSc [reference category]
   PhD
   PDF
   Other degree or training not listed: _____
   Prefer not to answer

3. Are you
   Female [reference category]
   Male

Other (e.g., trans, non-binary, two-spirit, gender-queer)
Prefer not to answer

4. Are you
A domestic student [reference category]
An international student
Other
Prefer not to answer

5. What ethnic or cultural group do you belong to? Please select all that apply.
Arab
Asian
Black
Indigenous (e.g., First Nations, Métis, Inuit)
Latino/Latina
South Asian (e.g., East Indian, Pakistani, Sri Lankan)
Southeast Asian (e.g., Vietnamese, Cambodian, Laotian, Thai)
West Asian (e.g., Iranian, Afghan)
White [reference category]
Other (please specify): _____
None of the above
Prefer not to answer

6. Are you a first-generation university student? (You are a first-generation university student if neither of your parents graduated from university).
Yes [reference category]
No
I do not know
Prefer not to answer

7. What is your situation? Please select all that apply.
Motor impairment
Visual impairment
Hearing impairment
Organic impairment (e.g. kidney failure, cystic fibrosis)
Chronic medical condition
Learning disabilities (e.g., dyslexia)
Attention deficit disorder
Mental health disorder
Speech and language disorders
Head injury
Multiple disorders and disabilities
Other (please specify): _____
Prefer not to specify

For the variable *Disability*, the reference category comprises all respondents who reported one or more disabilities.