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A Community of Practice Approach to Integrating Professional Skills Training with Graduate Thesis Research

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Dr. Shan Jiang is an Assistant Professor in the Materials Science and Engineering department at Iowa State University. He obtained his Ph.D. from the University of Illinois at Urbana-Champaign, working with Professor Steve Granick on Janus particles. After graduation, he studied drug delivery at MIT Langer lab as a postdoc. He then worked at the Dow Chemical Company Coating Materials as a research scientist. He was the Dow Certified Green Belt Project Leader and worked on binder platform development for different commercial products. Dr. Jiang edited the first book on Janus particles and has published more than 50 peer reviewed journal articles and book chapters. Dr. Jiang was awarded with the Racheff-Intel Award for Outstanding Graduate Research. The technology he participated in developing at Dow received the Presidential Green Chemistry Challenge Award and the R&D 100 Award. He recently received the ACS Younger Chemists Committee Leadership Development Award, the 3M non-tenured faculty award, ACS-PRF New Investigator Award and Dean's Excellence in Learning and Teaching Award. Dr. Jiang has received funding support for both his research lab and education initiative from several federal agencies including NSF, USDA and NASA. He recently received an NSF-IGE award for launching a new Graduate for Advancing Professional Skills (GAPS) education program, which integrates project management training with thesis research for graduate students.

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Abstract

Background. It is well recognized that current graduate education is too narrowly focused on thesis research. Graduate students have a strong desire to gain skills for their future career success beyond thesis research. This obvious gap in professional skill training in current graduate study also leads to the common student perception that professional skills beyond academic knowledge should only be gained after completion of thesis research.
Purpose. A new program is being developed to rigorously integrate professional skills training with thesis research. The approach is to establish learning communities of Graduates for Advancing Professional Skills (GAPS) to incorporate project management skill training from industry into academic research. The GAPS program seeks to address two fundamental education research questions: How can project management skill training be integrated with thesis research in graduate education? What is the role/value of learning communities in enhancing the training and retention of professional skills and the effectiveness of thesis research? Our proposed solution is that graduate student learning communities engaging in a blended online and classroom approach will promote learning of professional skills such as project and time management in thesis research activities. The purpose of this session is to establish the connection between project management and thesis research, and demonstrate the beginning progress of the GAPS program towards.
Methodology/approach. The following progress is being made to establish GAPS learning communities through which to teach and practice professional skills. A website has been developed to introduce the program, recruit participants, provide information on the online modules, and survey results of participants' current levels of knowledge and skills related to project management. A new course, "Introduction of Project Management for Thesis Research", has been added to the course catalog and open to enrollment for students from different majors. In addition, learning modules including project charter, scheduling, communication, teamwork, critical path method, and lean concept are developed. Case studies and examples have been developed to help students learn how to utilize project management skills in their thesis research.
Conclusions. The concept of integrating professional skills training with thesis research through learning communities has been demonstrated. There are multiple advantages of this approach, including efficient utilization of the current resources, and faculty buy-in. Preliminary data from the first cohort are being collected and analyzed to identify students' needs, benefits of the program, and areas of improvement for future cohort iterations.
Implications. The GAPS program will improve professional skill training for graduate students through communities of practice. This new learning model has the potential to fundamentally change the culture of graduate education. We believe the method demonstrated here can be broadly applied to different engineering majors, and even broadly to all thesis research.

Keywords: learning communities, professional skills, project management, graduate education

PART I: Integrating Project Management Concepts with Graduate Thesis Research

Current graduate education puts focus almost exclusively on thesis research to the detriment of students lacking in professional skills training or experience (ACS Presidential Commission 2012, National Institutes of Health 2012, Allum 2014, National Science Board 2015, Wendler 2010, Alan Leshner 2018). A report by the Council of Graduate Schools pointed out that currently most graduate programs do not provide enough training for professional skills (Denecke 2017). A recent survey conducted with STEM graduate students (56 responses from 4 different departments) at Iowa State University (ISU) asked the students to rank the most important skills for future career and thesis research. The top three ranked for future career preparation are Project & Time Management, R&D in Industry, and Presentation Skills; while the top three for thesis research are Critical Thinking, Project & Time Management, and Statistics Analysis (**Figure 1**). A significant finding was that Project & Time Management (PTM) was rated among the highest in both categories. Students were not mistaken. Major companies such as GE, DuPont, Boeing, and Dow also recognize this critical skill and have their own PTM training for new hires. Though students understand that professional skills are crucial for working in industry and desire to prepare themselves, professional skill training is often sidelined due to a lack of resources and faculty buy-in. The training is not commonly embedded in STEM graduate curriculum either.

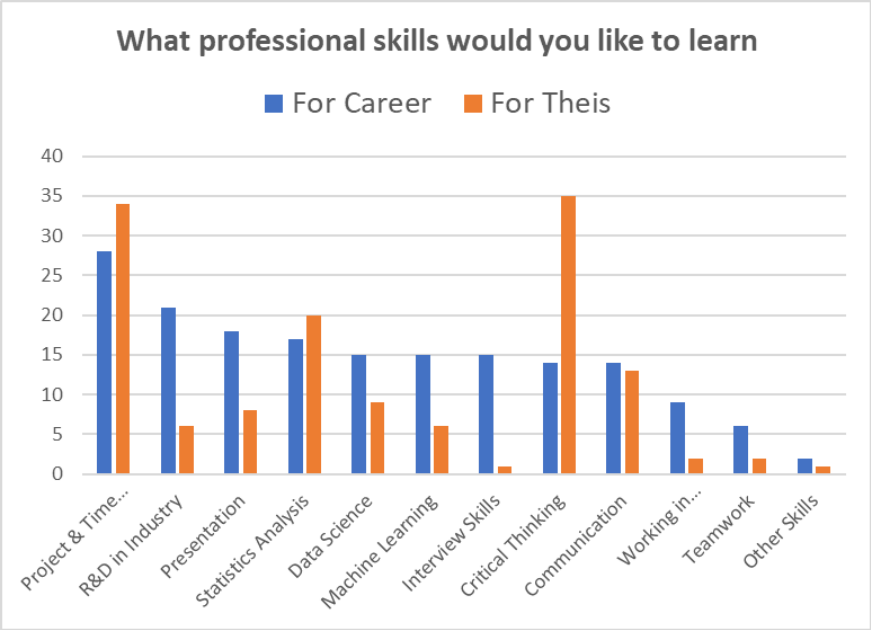

Figure 1. Survey results: skills ranked by ISU graduate students from four departments.

There are many aspects in which academia and industry differ. The fundamental research conducted in universities is more exploratory and non-linear, while industry projects often have relatively clear paths and strict deadlines. In addition, there are usually multiple stakeholders in industry, which requires a high level of organization skills. However, based on the authors' blended experience in both industry and academia, we believe that it is important to provide students opportunities to start professional skill training early during thesis research. This will not only benefit their research but also help students develop PTM skills needed for their future career.

We believe an effective way to teach professional skills to graduate students is to directly incorporate the training into thesis research. As such, we must demonstrate how tools and skills

of PTM adapted from industry can be applied to improve efficiency in thesis research. We will establish connections between validated practice of PTM in industry, including *Six Sigma* and *LEAN* concept, with graduate thesis research, and train students to communicate progress with their thesis advisor through the assistance of the *project charter*. All the important tasks in a thesis research project can be related to the concept and training modules in PTM commonly offered in industry (**Figure 2**), which place emphasis on the clarification of objectives using *project charter* and the streamline through a stage-gate process. Thesis research is indeed a project with timelines that require communication and active management. These PTM models and tools can therefore be very beneficial to help students manage their thesis research more effectively. Because every graduate student will need to complete a thesis, it provides an opportunity for them to implement professional skills in their thesis research. Faculty will also appreciate the program once the students show improvement in efficiency and effectiveness in their thesis research. The synergy between professional skill training and thesis research effort provides the foundation of our approach.

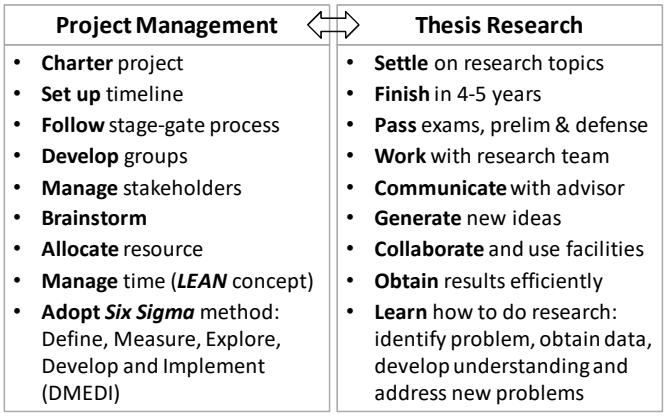

Figure 2. Connections between project and time management with thesis research.

To further assist students with the PTM training, we established a few examples of project charters and work breakdown structures (WBS) based on the PhD theses of the GAPS course instructors. These adapted tools include project charter initiation for thesis, timeline and meeting scheduling tools, expectation management, and communication with advisors. Examples are attached in Appendix 1.

The students will first work on the project charter idea and apply it for their thesis research. The project plan contains the following elements: an overview, a statement of objectives, a description of approaches, schedules of activities, a project budget, resource requirements, evaluation methods, and preparations to meet potential problems. An example written by one of the course instructors is provided in Appendix 1. Students will be asked to begin developing their project charter following the second week of the course. The project charter will be an ongoing assignment which students can adjust as they gain clarity over the focus of their research. Since students may be entering the course at different stages of their PhD programs, it is to be expected that the project charters of some will be more complete than others.

We also developed the examples for Work Breakdown Structure (WBS). A WBS should include clear, organized statements of must be done, by whom, when, and with what resources.

Every task, however small, that must be completed in order to complete the project should be listed together with any required material or human resources. An example derived from the project charter previously mentioned can also be found in Appendix 1.

PART II: Course Plan

The GAPS program aims to establish Communities of Practice (COP) to engage students with self-directed learning activities as they learn from the curated online modules, and practice professional skills within their thesis research (Gray 2004, Hildreth and Kimble 2004, Johnson 2001, Wenger 1998). In relation to this goal, we developed a hypothesis that learning communities engaging in a blended online and classroom approach will promote learning of professional skills such as project management. To test the hypothesis, we initiated a new course "Introduction of Project Management for Thesis Research" at ISU. In this course, we will use the project management examples covered in Part I of this paper along with a lecture series and peer discussions as teaching tools. Recruitment for the course is conducted through the GAPS program website (https:www.GAPS.iastate.edu).

In the course, students will first learn project management concepts through online modules including project charter, scheduling, communication, teamwork, critical path method, and lean concept (Meredith et al. 2010). Students will then practice the PTM skills using their own thesis. They are also given the chance to share their thesis ideas and learning experience in the Graduate for Advancing Professional Skills (GAPS) learning community. At the end, students will be able to present a project charter on their thesis, demonstrate knowledge of related PTM skills and how to utilize these skills for their thesis research. The students will also present their learning experience and the PTM plan for their thesis.

The class will be delivered in a blended lecturing and team-based learning approach. This 1-credit class is offered on a satisfactory-fail basis only. Some major components of the course syllabus are shown in Appendix 2.

The GAPS program and the course detailed in Appendix 2 serve as the primary means to test our hypothesis. It should be noted that in addition to the work done within the course, we will also conduct surveys of the enrolled students to collect data about their perspectives on project management importance, their own capabilities, etc. The data from these surveys along with course work will allow us to assess the initial outcomes of the program.

The new course has just been approved at ISU. The first cohort of eight students with a variety of engineering backgrounds has been recruited. This is the initial stage of the project; we will report more progress once the first cohort concludes. We believe the method demonstrated here can be broadly applied to different engineering majors, and even broadly to all thesis research.

Part III: Future Research and Concluding Remarks

The GAPS program is still in its initial stage of development. After our first cohort concludes, we will assess the progress made and make plans for expanding and improving the GAPS program accordingly. The project management course will also act as a seed to grow our GAPS learning community. We aim to broaden the engineering backgrounds represented by students in future cohorts. Additionally, we aim to continue to engage with past cohorts as the program

expands to continuously build the community. As more students graduate from our course, they will join the GAPS community to help other students with their thesis and professional skill training. We will upload on our website examples of utilizing project charter and other project management tools for thesis research. In this way, the learning experience can be shared even beyond the Iowa State campus.

In terms of scalability, the system of the GAPS learning community building – student engagement, evaluation, and website – can be shared easily among universities. The online program will become a self-sustainable learning resource. The database would be set up to accept content from different universities and become a central hub for the professional skills learning community. The long-term result of this program will be more efficient use of time and resources, bridging the skill gap between graduate study and career development. By training our students to be more productive in their time and project management choices they will be better prepared to strengthen the U.S. STEM innovation position.

The training will benefit students joining industry, and those preparing for academic positions, given that teachers with comprehensive professional skills are more capable of equipping their students with similar skills. The program also creates a learning community and promotes communication among students from different majors. It creates an environment for students to share and improve their thesis research with people outside their fields.

The concept of learner-developed courses where students create content and lead their own education can be applied to other training programs as well, which operate in the same environment and under similar time and cost constraints. The PTM training program can also be extended to undergraduate students. GPAS program offers a potential programmatic solution to the challenges of professional skill training in STEM education.

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Appendix 1

EXAMPLE PROJECT CHARTER OF DOCTORAL DISSERTATION

PROJECT IDENTIFICATION	
Description	Recurrent-Event Models for Change-Points Detection
Project Resources	Computing: Computer lab at the Dept. of Statistics

1 OVERVIEW FOR PROJECT
This section contains a brief description of the project and its deliverables (the latter are the project scope), together with a list of the major milestones or significant events in the project schedule and any constraints on the project scope. The driving risk of novice teenagers is the highest during the initial period after licensure but decreases rapidly. This dissertation aims to develop recurrent-event change-point models to detect the time when driving risk decreases significantly for novice teenager drivers. The dissertation consists of three major parts: 1) recurrent-event change-point

models by maximizing the likelihood (MLE) with identical change-points for all subjects; 2) models to allow change-points to vary among drivers by a hierarchical Bayesian finite mixture model; 3) a non-parametric Bayesian model with a Dirichlet process prior.

2 PROJECT OBJECTIVES (PURPOSE)

This is a more detailed description of the project's scope, its deliverables and outcomes, and what will be done to achieve the project's overall objectives.

The models will be based on non-homogeneous Poisson process with piecewise constant intensity functions. The risk change-points will be in terms of cumulative driving hours to maintain high temporal resolution from raw data. The data was collected by the Naturalistic Teenage Driving Study (NTDS), which continuously recorded in situ driving behaviour of 42 novice teenage drivers for the first 18 months after licensure using sophisticated in-vehicle instrumentation.

1) Two recurrent-event change-point models to detect the time of change in driving risks will be developed.
2) Change-points are allowed to vary among drivers by a hierarchical Bayesian finite mixture model, considering that clusters exist among the teenagers.
3) A Dirichlet process mixture model will be proposed, where the change-points are assigned a Dirichlet process prior.

3 GENERAL APPROACH

The technological and managerial approaches to the work are described.

1) Extend the MLE method in (Frobish and Ebrahimi 2009) by:
    - Allow different intensities among subjects
    - Allow more than two change-points
    - Remove the original requirements that all the censoring times are larger than change-points to be more flexible
    - Find the standard error and confident intervals by block bootstrapping on drivers
2) Establish a hierarchical Bayesian finite mixture model in this context. The prior for mixture proportions will be a Dirichlet distribution and a Markov chain Monte Carlo algorithm will be developed to sample from the posterior distributions. DIC will be used to determine the best number of clusters.
3) Establish a Dirichlet process mixture model in this context. A Markov chain Monte Carlo algorithm will be developed to sample from the posterior distributions. Automatic clustering is expected based on change-points without specifying the number of latent clusters.

4 KEY PROJECT DELIVERABLES

Name	Description
Paper 1	Assume identical change-points among drivers by maximizing profile likelihood.
Paper 2	Allow varying change-points among subjects by hierarchical Bayesian finite mixture model.
Paper 3	Allow varying change-points among subjects by Bayesian non-parametric method.
Dissertation	Summarize the three parts.
Prelim	Demonstrate progress the main results to the committee.
Defense	Present all the results and draw conclusions.

5 SCHEDULES AND MILESTONES		
Item	**Major Events / Milestones**	**Dates**
Literature review		1 month
Develop the model and inference method for paper 1		2 months
Conduct simulation studies for paper 1		3 months
Apply the method in paper 1 to the NTDS data		1 month
Write paper 1		2 months
Develop the model and inference method for paper 2		2 months
Conduct simulation studies for paper 2		2 months
Apply the method in paper 2 to the NTDS data		1 month
Write paper 2		2 months
Prelim		12/2014
Develop the model and inference method for paper 3		2 months
Conduct simulation studies for paper 3		2 months
Apply the method in paper 3 to the NTDS data		1 month
Write paper 3		2 months
Write the dissertation		1 month
Defense		12/2015

6 KEY ISSUES	
SEVERITY (1 - LEAST, 5 - MOST)	**Description**
2	How to simulate data
3	What criterion to evaluate the model performance

1	What baseline to use
3	How to construct the models
1	How to make inference
4	How to check the goodness of fit

7 RISK MANAGEMENT	
Severity	**Description AND contingency plans**
4	If model does not fit well, find out the discrepancy and introduce the empirical fitting

8 PROJECT'S CRITERIA FOR SUCCESS (MUST BE MEASURABLE)

Descriptions of all project evaluation procedures and quality standards.

- The parameter estimates are accurate and precise in the simulation studies.
- The NTDS application results are reasonable and consistent with existing literature.
- The papers are submitted to journals.
- Pass the prelim and defense.
- Finish the dissertation.

9 CRITICAL SUCCESS FACTORS

NA

10 SIGNOFF

Major advisor:

Date:

EXAMPLE WBS FROM DOCTORAL DISSERTATION

1. *Paper 1*
   - *1.1 Literature review*
     - *1.1.1 Review change-point literature*
       - *1.1.1.1 Download all the papers*
       - *1.1.1.2 Go through*

1.1.1.3 Summarize relevant papers

1.1.2 Review recurrent-event literature

1.1.3 Review recurrent-event change-point literature

1.1.4 Review NTDS literature

1.2 Develop the model and inference method

1.2.1 Identical intensity model

1.2.2 Varying intensity model

1.2.3 MLE method

1.2.4 SE and CI

1.3 Simulation studies

1.4 NTDS analysis

1.5 Write the paper

2. *Paper 2*
3. *Prelim*
4. *Paper 3*
5. *Defense*

Appendix 2

Course Catalog Description

Tools and skills of Project and Time Management (PTM) adapted from industry to improve efficiency in thesis research. Project charter initiation for thesis, timeline and meeting scheduling tools, expectation management, and communication with advisors. Practice of the PTM skills using student's own thesis. Presentation of a project charter. Demonstration of knowledge of related PTM skills and the ability of utilizing these skills for thesis research. Sharing thesis ideas and learning experience in the Graduate for Advancing Professional Skills (GAPS) learning community.

The class will be delivered in a blended lecturing and team-based learning approach. At the end, students will be able to present a project charter on their thesis, demonstrate knowledge of related PTM skills and how to utilize these skills for their thesis research. The students will also present their learning experience and the PTM plan for their thesis. This 1 credit class is offered on a satisfactory-fail basis only.

Learning Outcomes

The goal of this course is to educate students with fundamental PTM skills geared towards thesis research. The course will adapt active learning and inductive teaching approaches. Students will practice their learning through group discussion and in-class activities under the guidance of the instructors. Beyond the PTM skills, students will also learn and practice team building and communication skills. The graduate students will benefit from the course in terms of content, knowledge and professional skill sets, to improve their efficiency in design and execution of thesis research, and eventually increase their job readiness and placement upon graduation. More specifically the course will train students with the following:

1. An ability to develop a project charter for the thesis research
2. An ability to set up a communication plan and use scheduling software (Microsoft Project (MSP))
3. An ability to make Gantt charts
4. An ability to utilize the Critical Path Method (CPM) for the thesis research
5. Achieve an understanding of challenges and opportunities associated with PTM in thesis research.

Course Format

The class will meet once a week for one hour. Virtual learning modules will be developed to adapt the transition to online teaching if necessary. Activities will be designed for each class. Students will work on both individual assignments and group projects. At the end of the semester, students will present the results of their assignments and group projects. The presentation will also include a project charter on how they plan to implement professional skills into their thesis research over the next 6-12 months.

Recommended textbook

Project Management in Practice, Fourth Edition, by Jack R. Meredith, Scott M. Shafer, Margaret M. Sutton, Samuel J. Mantel Jr., 2010, Wiley. (https://learning.oreilly.com/library/view/project-management-in/9780470533017)

Supplementary:

- "Strengths-Based Leadership" by Tom Rath with free CliftonStrength training code
- Project Managment: A Systems Approach to Planning, Scheduling, and Controlling, by Harold Kerzner, 2017.
- The Six Sigma Handbook (4th Ed.), by Thomas Pyzdek and Paul A. Keller, McGraw-Hill Education
- The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer, 2003, by Jeffrey Liker, ISBN-13: 978-0071392310
- https://agileleanlife.com/best-time-management-guide/
- The Lean Turnaround, by Art Byrne, 2012, ISBN: 0071800670

Topics Covered

Week	**Topic**
1	Intro and pre-survey
2	Where to start: Project Charter
3	Individual Development Plan - Training
4	Sorting Out the Project: The Work Breakdown Structure (WBS)
5	Software and tools
6	Team building and character test
7	Communication
8	Case study 1
9	Critical path and lean concept
10	Evaluating and terminating the project

11	Guest lectures: invited speakers
12	Reflective writing

Assignments, due dates (Friday 5:00 pm) and Assessments

Assignment	**Due (Week)**	**Points (pts)**	**Percentage (%)**
Homework	3, 8, 10, 14	10	10
Midterm A project charter for thesis	7	25	25
Group project A case study of learning materials	10	25	25
Final A case study of student's own thesis research	14-15	25	25
Attendance		15	15

Rubric to evaluate the case study and project charter.

Originality 20%	Relevance 20%	Format 20%	Measurable 20%	Completeness 20%
Whether the content is new, e.g. the case is original	Whether the content is closely related to guideline	Whether the content is easy to follow and presented in a good format	Whether the outcome can be easily assessed with the created content	Whether the content covers all the major concepts

Satisfactory if total score $\geq$ 60 pts. Fail otherwise.
Students will be provided with rubrics that define what they need to do to earn the points for the assignments.

Group project. Groups of 2-4 students will be formed in the first two to three weeks of the course. These groups are responsible for proposing, developing, and delivering a virtual presentation to the class on a topic relative to PTM. The group project will include a lecture slides, supplemental materials, a virtual presentation, and leading a follow-on question and answer session relative to the presentation. Project proposals and team compositions are due on Friday of Week 4. More details of the group project will be provided during the first day of class.

A successful group project will require significant effort outside of class. Your efforts will entail collaborating with group project team members in determining a group project topic and submitting a proposal for the topic, conducting appropriate background research relative to the approved topic, and putting together the group project presentation.

Peer evaluation. There will be a peer review process at the end of the semester that will count towards your grade. The peer evaluation will consider the contribution to the team effort in the project. Students only evaluate members of their team. If it becomes clear that the project workload was unbalanced, your instructor may assign different project grades to different team members. Each student will submit the peer evaluation in Canvas. The due date is the same as the project. The evaluation will have the following simple form:

Your Name: XX Percentage Contribution: Y%

Team Member Name: XX Percentage Contribution: Z%

Team Member Name: XX Percentage Contribution: W%

Team Member Name: XX Percentage Contribution: V%

Optional comments: yyyyyy

The percentage contributions of team members toward the project (e.g, Y%, Z%, W%, V%) must add to 100%.