TLEF Project – Final Report

Report Completion Date: (2024/04/30)

1. PROJECT OVERVIEW

1.1. General Information

Project Title:	Exploring Data in Manufacturing: Enhancing the Manufacturing Engineering Programs		
Principal Investigator:	Christoph Sielmann		
Report Submitted By:	Christoph Sielmann		
Project Initiation Date:	May 2022	**Project Completion Date:**	April 2024
Project Type:	☐ Large Transformation ☒ Small Innovation ☐ UDL Fellows Program ☐ Hybrid and Multi-access Course Redesign Project ☐ Other: [please specify]		

1.2. Project Focus Areas – *Please select all the areas that describe your project.*

☒Resource development (e.g., learning materials, media)

☒ Infrastructure development (e.g., management tools, repositories, learning spaces)

☒ Pedagogies for student learning and/or engagement (e.g., active learning)

☐ Innovative assessments (e.g., two-stage exams, student peer-assessment)

☐ Teaching roles and training (e.g., teaching practice development, TA roles)

☒ Curriculum (e.g., program development/implementation, learning communities)

☐ Student experience outside the classroom (e.g., wellbeing, social inclusion)

☐ Experiential and work-integrated learning (e.g., co-op, community service learning)

☐ Indigenous-focused curricula and ways of knowing

☐ Diversity and inclusion in teaching and learning contexts

☐ Open educational resources

☐ Other: [please specify]

1.3. Final Project Summary – *What did you do/change with this project? Explain how the project contributed toward the enhancement of teaching and learning for UBC students.*

The project involved three overarching objectives related to expanding student access to data-related outcomes in manufacturing engineering at UBC.

1 - Data curriculum for Manufacturing Engineering:

Data science is influencing all aspects of engineering practice, particularly those disciplines that engage in complex optimization problems such as Manufacturing Engineering. New factories are constructed with a data-centric design philosophy that must be understood at all levels by factory designers and planners (Manufacturing Engineers). A comprehensive study was executed examining the narrative of data within the Manufacturing Engineering program, with a particular focus on hidden curriculum. Some opportunities for improvement in the existing curriculum were identified, and a new curriculum, including two new courses, was developed and presented to the MANU Advisory Committee. The revised curriculum is currently under review but has received positive feedback. It is expected that a Data in Manufacturing stream within manufacturing engineering will be available within three years once it is adequately resourced.

2 – Server and historian for Industry 4.0 data collection

Industry 3.0 and 4.0 leverage technology such as historian services to acquire data from manufacturing equipment to enable everything from machine learning for process improvement to predictive maintenance. Several upgrades were made to the equipment used by students in the MANU program. These include:

- Addition of a database and Kepware historian to collect and serve data related to manufacturing equipment in the student lab. Equipment now connected to the historian includes:
    - Industrial Automation Training Kit
    - Ovens
    - NI DAQ equipment used for vacuum forming
    - Instron Machine
    - Injection Moulding Machine and associated robot
- Training materials on how to use the historian in a variety of courses were prepared in consultation with instructors.
- An automation network was expanded, with plans to integrate automation networks between UBCV and UBCO underway.

New lab activities allow the students to automatically route data collected through lab activities to the historian and database, where data can be retrieved using industry-standard tools such as Jupyter Notebooks.

3 – Manufacturing Operational Management (MOM) and Enterprise Resource Planning Framework (ERP)

As part of Industry 4.0, data collected through manufacturing processes, supply chain, inventory management, clients, engineering product development, and financial sources are incorporated into MOM and ERP systems. This project investigated multiple tools that can be made available to students to practice working with MOM and ERP environments. A platform, Odoo ERP, was selected after a detailed review of options, and an arrangement was

made with the company to provide academic licensing to the MANU program. An Odoo ERP instance was created for the MANU program along with a sample manufacturing process for use by students. It is anticipated that this technology will be useful for the new Data in MANU stream.

1.4. Team Members – *Please fill in the following table and include **students**, undergraduate and/or graduate, who participated in your project.*

Name	Title/Affiliation	Responsibilities/Roles
Vishrut Ohri	Undergraduate Academic Assistant	Historian and database design and implementation Curriculum investigation support Integration of manufacturing equipment into the automation network Building of example Python scripts
Nima Bakhshi	Graduate Academic Assistant	Curriculum review and documentation New courses specification and syllabus development Training material and lab samples for various courses ERP/MOM investigation and demo system
Serene Rodrigues	Graduate Academic Assistant	Supporting data collection and analysis near end of project

1.5. Courses Reached – *Please fill in the following table with **past** and **current** courses (e.g., HIST 101, 2017/2018) that have been reached by your project, including courses not included in your original proposal (you may adapt this section to the context of your project as necessary).*

Course	Academic Year
MANU 330	2023-
MANU 465	2023-
MANU 430	2022-
MANU 386	2022-
MANU 4xx	(projected 2026)
MANU 4xx	(projected 2026)

2. OUTPUTS AND/OR PRODUCTS

2.1. *Please **list** project outputs and/or products (e.g., resources, infrastructure, new courses/programs). Indicate a URL, if applicable.*

Output(s)/Product(s):	URL (if applicable):
Proposal for Data in MANU stream	
Curricular review report, including new recommended data learning outcomes for the MANU program	
Sample lab material, code, and instructions for MANU 386, MANU 230/330, MANU 430, and MANU 465	
Historian Jupyter service	http://192.168.9.2:8888 (from within the automation network)
MANU Odoo ERP proposal, environment, demo site, and corresponding documentation	https://edu-ubcmanu.odoo.com/ (note, may go dormant until used in a course)
Automation network, including equipment in FF219	

2.2. Item(s) Not Met – *Please list intended project outputs and/or products that were not completed and the reason(s) for this.*

Item(s) Not Met:	Reason:
Not as many courses were affected as anticipated	There was reticence on behalf of some instructors to engage with the new technology options. It is anticipated that more courses will adopt the new technology over time and as it matures.

3. PROJECT IMPACT

3.1. Project Impact Areas – *Please select all the areas where your project made an impact.*

☒ Student learning and knowledge

☐ Student engagement and attitudes

☐ Instructional team-satisfaction

☒ Teaching practices

☐ Student wellbeing, social inclusion

☐ Awareness and capacity around strategic areas (Indigenous, equity and diversity)

☒ Unit operations and processes

☐ Other: [please specify]

3.2. Please provide details on each of the impact areas you selected in 3.1. – *For example, explain in which ways your teaching practices changed; how student wellbeing was impacted; how students wellbeing benefited from your project, etc.*

Student learning and knowledge: There are both immediate and long-term impacts to student learning and knowledge. In the short term, students now have access to new, modernized tools to facilitate lab experiences such as databases, historians, Jupyter notebook, and an automation network. Exposure to these tools assist students in preparedness for further academic or industrial work in manufacturing.

Long-term impacts will occur once MANU adopts the Data in MANU stream, which includes two new courses on data science in engineering and Industry 4.0 as developed through this work. These new courses and stream will allow those students with a keen interest in data science in manufacturing engineering to align their learning in the program with that interest, better preparing them for related graduate or industry work.

Teaching practices: Changes to teaching practices are summarized in Section 4 below.

Unit operations and processes: Two substantial proposals were created: One to incorporate data-related learning outcomes throughout the MANU program, and the other to create a Data in MANU stream. With new PLOs determined, the unit (Manufacturing Engineering) is now deliberating on refining its core curriculum to incorporate these program level learning outcomes into the curriculum. This deliberation process impacts the Curriculum Committee, Board of Study, Faculty Retreat, and other unit-level activities. The addition of a Data in MANU stream will also involve the creation of two new courses and the restructuring of MANU to support specializations and streams within the program.

3.3. How do you know that the impacts listed in 3.1/3.2 occurred? – *Describe how you evaluated changes/impacts (e.g., collected survey data, conducted focus groups/interviews, learning analytics, etc.) and what was learned about your project from the evaluation. You are encouraged to include graphical representations of data and/or scenarios or quotes to represent and illustrate key themes.*

It should be noted that the full impact anticipated from these new resources will take additional years to culminate, as the Data in MANU stream has to be fully realized to see many of the benefits from this work.

There are three methods used to evaluate impact on learning enhancements realized as of 2023W:

1. Student feedback surveys
2. Instructor feedback surveys
3. Instructor interview and informal discussion

Student feedback surveys: Surveys were provided to students participating in classes where the new learning tools were deployed. Unfortunately, the response rate was quite low (n=9), with Likert (1-5) responses to questions listed in the following:

Question	Mean average with standard deviation (1 = Strongly Disagree, 5 = Strongly Agree)
Using the automation network, I believe I have a better understanding of what data are in a manufacturing environment, how they are collected, stored, and later retrieved for further analysis.	4.22 with σ = 0.916
Using the MANU Historian gave me greater exposure to different ways of storing data in manufacturing applications.	2.86 with σ = 1.25
The resources developed for training users on the systems (for example lecture, video tutorial and manual) are adequate and overall useful.	3.89 with σ = 1.00
The Historian and data collection/retrieval process is relevant and helpful to my career aspirations.	3.71 with σ = 1.03
Overall, I find the development of the new infrastructure for MANU program useful and effective for my learning.	4.33 with σ = 0.667

As indicated in the above, the overall sentiment is positive for all changes, with improvements expected for the Historian as more features are integrated into courses.

Instructor feedback surveys: Although distributed, no instructors completed the instructor feedback surveys for this project, preferring to share feedback directly (see the following).

Instructor interview and informal instruction:

- One instructor was quite pleased by the new technology as it would simplify the process of data collection for students engaging in machine learning projects. Training a machine learning system requires large datasets which previously had to be created by students by hand. Integrating the Injection Moulding Machine into the automation network combined with the database and historian allow for the automatic generation, collection, and retrieval of batches of data.
- A second instructor was excited to use the technology as part of training students to work with more common tools and technologies found in industry.
- A third instructor had difficulty using the technology in his course as some of the instructions were unclear and require refinement prior to the students realizing the full benefits of the new resources.

4. **TEACHING PRACTICES** – *Please indicate if **your** teaching practices or those of **others** have changed as a result of your project. If so, in what ways. Do you see these changes as sustainable over time? Why or why not?*

There have been changes to teaching practices. Most noteworthy is the use of databases and an historian for data collection and analysis in the design spine of MANU as well as some core courses (e.g. MANU 386) and electives (e.g. MANU 465). Exposing students to databases, including SQL queries, is new to instructors as well as students in most

cases but serves to better reflect the needs of industry. Pedagogically, it involves transitioning students from writing down measurements in notebooks or Excel spreadsheets to setting up a database reference to collect the data through the lab network. Data are then retrieved and analyzed using Python and Jupyter instead of Excel. Learning these tools better prepare students for both academic and industry work.

It is expected that these changes will be sustainable over time once instructors better familiarize themselves with the tools and the technologies involved. They are open source and easy to upgrade as needed.

5. **PROJECT SUSTAINMENT** – *Please describe the sustainment strategy for the project components. How will this be sustained and potentially expanded (e.g., over the next five years). What challenges do you foresee for project sustainment?*

Project sustainment is a challenge for the technology components of the project. Robert Cieniawski, the lab manager for the FF219 lab used by the MANU program, has elected to sustain some aspects of the project, including the Odoo instance and software code base. The project PI, Christoph Sielmann, along with APSC IT services will maintain the Kepware Historian server, automation network, and database for the foreseeable future as all components are used in at least one course he teaches. Additional support may be required in the future to adapt lab and demo materials to changes in lab technology and IT infrastructure. The Data in MANU stream is currently under consideration by the MANU Program and is now championed by the Data in MANU subcommittee.

6. **DISSEMINATION** – *Please provide a list of scholarly activities (e.g., publications, presentations, invited talks, etc.) in which you or anyone from your team have shared information regarding this project. Be sure to include author names, presentation title, date, and presentation forum (e.g., journal, conference name, event). These will be included on the TLEF scholarly output page.*

Sielmann, C., Bakhshi, N. (2023) Data in Manufacturing Engineering. CTLT Learning Week. Vancouver, BC.

Sielmann, C., Bakhshi, N., Hunter, C. (2023) Data Sustainability in Manufacturing Engineering. *Proceedings of the Canadian Engineering Education Association (CEEA)*. Kelowna, BC.