Digital Supply Chain Curriculum Development to Support the Talent Needs of Supply Chain 4.0

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Abstract

This paper describes the curriculum development methodology for a new programme in Singapore to support the digital transformation toward Supply Chain 4.0. The methodology covered analyzing the industry workforce requirements, creating the contents, designing the teaching, learning, and assessment approaches, industry work study attachment, and curriculum review and improvements. The new programme aims to bridge the educational gap between industry requirements and the academic curriculum with a proposed curriculum development methodology for a new digital supply chain programme. This paper highlighted the need to examine the methodology of developing a digital supply chain programme, and addressed the need for an institute of higher learning to support the talent needs of Supply Chain 4.0.

Keywords
Supply chain 4.0, Curriculum Development, Applied Teaching, Applied Learning, Digital supply chain

1. Introduction
Increased attention and demand for supply chain resilience and agility are at an all-time high, primarily due to the COVID-19 pandemic and geopolitical tensions. The disruptions and complexity of supply chains create significant challenges for companies. Studies on the digital transformation of supply chains are on the rise, and Digital Supply Chain (DSC) is receiving recognition as a holistic digital transformation approach for optimally planning and controlling an entire supply chain.

The supply chain and logistics (SCL) sector is a major contributor to Singapore's economy, generating GDP and employment. Singapore must keep the SCL sector competitive through a competent workforce to allow the industry to continue to be a key sector to sustain the long-term economic growth of Singapore.

In June 2020, a study of the impact of Industry 4.0 on Singapore's logistics workforce was conducted jointly by the Singapore Economic Development Board (EDB), Enterprise Singapore (ESG), Skills Future Singapore (SSG), and Workforce Singapore (WSG) (EDB, ESG, SSG, WSG, 2020). Starting with the Skills Framework for Logistics (SSG, 2020) and an analysis of the workforce capability-building ecosystem, the study revealed that Industry 4.0 technology adoption would transform existing jobs and spur the emergence of new roles.

IMDA and ESG (2020) refreshed the Logistics Industry Digital Plan (IDP), and the new IDP provided a precise digital roadmap for businesses in the logistics sector of Singapore. It highlighted that developing and growing a talent pipeline is critical to success. As most businesses develop digitally, SMEs may use a new Digital Training Roadmap to find relevant training programs to upskill their employees.

Given the surge of talent needed to support the digital transformation of the SCL sector, there is a need to start a Digital Supply Chain degree programme in Singapore that could contribute to the rapid digital transformation of the supply chain and logistics sector.

For Institutes of Higher Learning (IHL), a curriculum guides the creation of the programme, learning and teaching resources, lesson plans and student evaluation, and stakeholder engagement (Adagale 2015). A well-designed

curriculum for a digital supply chain program can ensure students are equipped with both domain knowledge and emerging technologies required in the supply chain. Graduate employability is a central topic of discussion in developing the program curriculum.

This paper is to examine the requirements of the digital supply chain curriculum development and discuss the implications on the function and breadth of the digital supply chain program. The authors of this paper proposed a curriculum development methodology and used it for a digital supply chain curriculum development. The aim is to support the future talent needs for the digital transformation of the SCL sector and prepare students to meet industry employers' requirements.

The rest of the paper is organized as follows: Section II reviews the related works, and Section III describes the methodology of the digital supply chain curriculum development. Section IV discusses the industry engagement of the digital supply chain curriculum, and Section V concludes the paper.

1.1 Objectives

The research objectives of this paper are listed below:

1.1.1 Examine the educational gaps between industry requirements and the academic curriculum;
1.1.2 Describe the curriculum development methodology a digital supply chain program;
1.1.3 Describe the implementation of the methodology for a new digital supply chain program;

2. Literature Review

The need to develop a curriculum for higher education institutes that operates within the larger social, economic, and political framework is becoming increasingly important (Steketee et al. 2013). There is no universally accepted definition and process of curriculum development in higher education.

Some previous research proposed high-level general curriculum development processes. Wolf (2007) defined three general stages as curriculum visioning (evaluating graduate qualities and defining program objectives); curriculum development (mapping and identifying program content and course structure); and course development (writing course learning objectives, learning activities, and assessment). Brown and Slade (2019) proposed an alternative curriculum development model, which adopted the curriculum development processes to reaccredit multiple health-based programs in a large metropolitan university.

Other research discussed the guiding principles of students learning and teaching. Justice et al. (2009) discussed inquiry-based learning (IBL), which supports students' active learning through a self-directed, question-driven learning opportunity to investigate a subject. IBL, as a learning theory, has its roots in constructivism, which contends that rather than receiving knowledge and skills from lecturers, students create their own knowledge and skills based on their investigations to gain information about the domain under study. The principles of experiential learning design were articulated by Downing and Herrington (2013), who looked at how well they helped students integrate theory with practice and build the abilities needed for the workplace. One of the challenges of experiential learning comes from the indoor learning environments in schools, colleges, universities, and training centers.

However, the literature addressing talent development for the SCL sector is still limited (Birou et al., 2022). Most research works were research-oriented and focused on supply chain technology and process, with little educational implications regarding curriculum design and development. Sinha et al. (2016) addressed the connection between the growing complexity of skills needed in SCM careers and the education process to provide these skills to university students while discussing the topics that are oversupplied and undersupplied in supply chain education. Akalin (2016) suggested that the deficiencies result from some colleges merely converting operations management courses to SCM courses without modifying the course materials. Grogan and Morris (2016) also discussed the importance of incorporating emerging topics into the SCM education process. Ackerman (2022) pointed out that the requirements and abilities needed in SCM have become increasingly sophisticated.

Some research highlighted the need for a framework to map the technical skills training in school with competencies required by practitioners. Sun and Song (2018) provided a guide to the current body of literature for academics and practitioners with a suggested framework for the necessary competencies and skills that could serve as a roadmap for helping students and workers become competent. The curriculum summary and the matrix of connections between

the relevant courses and competencies can be used to enhance logistics and supply chain education. Wang et al. (2018) anticipated an updated framework based on competencies to ensure that undergraduate supply chain students have the digital skillsets they need to compete in a quickly changing environment after graduation.

In summary, little research was found from the perspective of curriculum development methodology related to supply chain 4.0. Most of the literature focused on Supply Chain 4.0-related technologies. Potential gaps were found in traditional supply chain management with the rapid development of Supply Chain 4.0. This paper examined the requirements of the digital supply chain curriculum development and proposed a curriculum development methodology to support the curriculum development of a new digital supply chain program.

3. Methodology

This section describes the curriculum design and development methodology for developing a new digital supply chain program in Singapore. We adopted a constructivist-based consensus curriculum creation process, where the opinions of many internal and external stakeholders are gathered, shared, and valued. The governance procedure ensures that the curriculum design and development process is democratic and collaborative, encompassing the perspectives of most stakeholders and tied to values that promote professional, social, and public welfare. The proposed methodology for digital supply chain curriculum design and development includes the following processes, as shown in Fig.1:

A - Industry workforce requirements: program mission should emphasize the industry trends, employability, and career path.
B - Knowledge, competencies, capabilities: curriculum content should have a fine blend of knowledge, competencies, and capabilities.
C - Teaching, learning & assessment approaches: program pedagogy is designed for applied learning, teaching, and authentic assessment, which are typically defined by tasks that replicate real-world challenges.
D – Industry Work Study Attachment: student work-study programs to provide hands-on and industry-oriented learning experiences.
E - Curriculum review and improvements: three feedback loops for module learning outcomes, student learning outcomes, and program education outcomes.

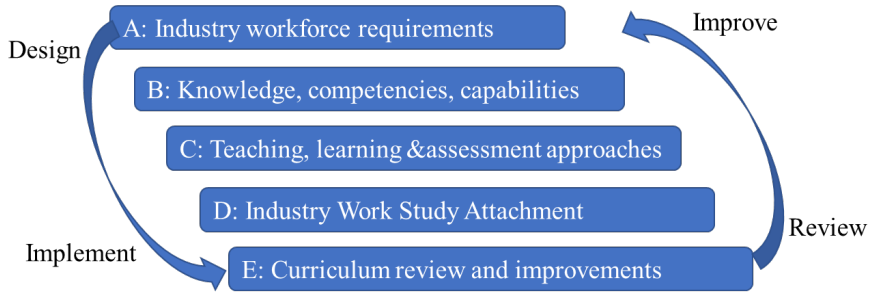

Fig 1. Design-Implement-Review-Improve Cycle for DSC Curriculum Design and Development

A. Industry workforce requirements

As the talent needs for the SCL sector are becoming more complicated, it is critical to prepare the right talents to succeed in supply chain companies. Supply chain skills education must keep up with the discipline's growing complexity and bridge the expanding talent gap.

The DSC industry workforce requirements arose from the crisis of lacking DSC talent to fulfill the industry demand for the SCL sector. The industry demand study can be conducted through industry scans, industry surveys, and industry consultations. During the curriculum visioning, twenty-plus companies participated in industry consultations to ascertain the demand for the program graduates. The company profiles selected for industry scan were shortlisted based on the industries with more substantial digital supply chain expertise and companies where the emerging trends in the digital supply chain are growing.

Other stakeholders were also actively involved, including government agencies, the university's senior management, faculty, candidate pool of students and their parents, etc. Industry partners must be confident that DSC programme will produce employable graduates and that they will meet the major professional qualifications.

From the outset of curriculum visioning, stakeholders were identified and engaged throughout the process, and the consensus was pursued by considering stakeholders' requirements and expectations. It is important to start by identifying the needs of a new program based on the industry workforce requirements.

B. Knowledge, competencies, capabilities

Digitalization has had a significant impact on supply chain processes. The transition from a traditional supply chain to a digital supply chain appears to be a competitive advantage that creates long-term value for businesses. To boost organizational effectiveness, digitalization must be included in every process and function of supply chains. The digital supply chain is defined as an "intelligent, customer-centric, system integrated, globally connected and data-driven mechanism that leverages new technologies to deliver valuable products and services that are more accessible and affordable" (Seyedghorban et al. 2019).

Digital supply chains are undergoing rapid change and embarking on innovative paths. However, few businesses are fully utilizing the potential of the digital supply chain (Büyüközkan and Göçer 2018). Traditional approaches to managing supply chains are no longer possible or successful due to technological advancements that are changing and redefining supply chain processes. It is critical to widen the theoretical and empirical spectrum, given the rising theory on the digital supply chain and the growing managerial interest in guidelines supporting the digital transformation of supply chains.

As a result, it desired to obtain a balanced coverage of the digital supply chain from three fundamental knowledge bases, i.e., digital supply chain design, supply chain 4.0 technologies, and system and project management. The focus areas of the new digital supply chain programme can be classified as:

• Digital supply chain design: The DSC design is based on a digital supply network (DSN) structure, which is not a standard linear supply chain but a more dynamic system that integrates supply chain activities for smooth material flows by using information technology. Digital supply chain design prepares students with knowledge in designing and developing digital supply chain solutions.

• Supply chain 4.0 technologies: Foundational computer science and software engineering form the bedrock of the digital supply chain, essential for mastery of supply chain 4.0 technologies. Because digital supply chain jobs are becoming increasingly automated, integrated, and interdisciplinary, digital supply chain students must acquire and develop a diverse set of technical skills, such as:

- Data skills: big data analytics, data interpretation and analysis, data storytelling and visualization.
- Industry 4.0 technology applications: artificial intelligence application, augmented reality application, internet of things application.
- Software development: application development, user experience design.
- Automation design and management: automation management, robotic & automation system maintenance, and technology troubleshooting.
- Technology risk management: cyber-risk management, threat intelligence, and detection.
- Technology usage and integration: advanced digital acumen

• System and project management: To enable the digitization of the supply chain, several dimensions of project management should be integrated. With system and project management tools and methodologies, it is critical to characterize the technology projects in terms of unpredictability, organizational complexity, and degree of innovation. The supply chain should be digitalized while adhering to the technology project's performance requirements regarding cost, time, quality, and stakeholder satisfaction. The lack of system and project management best practices is a roadblock to supply chain digitalization and frequently leads to technology failure.

C. Teaching, learning & assessment approaches

DSC programme aims to provide students with a wholesome education based on a scaffolding approach for gradual learning in the following areas: technical complexity, learning activities, and assessments.

- Technical Complexity. The first two years are critical in building a strong foundation in ICT, Engineering, and Supply Chain Management. It provides students with the confidence to tackle and develop complex supply chain and logistics solutions.
- Learning Activities. The curriculum is designed to include a wide diversity of learning activities focusing on supply chain and logistics domains. It entails self-paced learning for foundation modules, team-based learning for core modules, peer learning for professional modules, and industry-focused project-based learning with practical problem statements for their IWSP and Capstone project.
- Assessments. Foundational modules would assess students to achieve solid technical excellence, and hence with more technical-based assessments. The assessments of specialization modules would move towards larger-scale assignments and projects. These assignments and projects enable students to think beyond the technical, with other considerations, such as working with various conflicting stakeholders to achieve business outcomes.
- There are also university common modules embedded in the curriculum to help students gain a wider breadth of exposure and explore the focused area of interest within the industry. For example, critical thinking and communicating, interdisciplinary design innovation, sustainability measurement and management, etc.

D. **Industry Work Study Attachment**

Dubey and Gunasekaran (2015) suggested that strong collaboration between academia and industry in designing supply chain curricula and programs of study is required if new graduates are to have the skills and abilities to contribute to the workforce. Experience in fieldwork is a crucial component of developing research abilities across a range of fields.

DSC programme set up an Industry Advisory Committee, with which the curriculum will be periodically reviewed to ensure its continued relevance to the prevailing needs of the industry and thereby to ensure that graduates of the programme keep up with changes in market demand. In addition, DSC engaged industry experts for curriculum development, co-teaching, giving industry talks, and supervising students for project-intensive modules.

Applied learning will be emphasized throughout DSC curriculum through industry attachment such as Integrated Workplace Learning (IWL), Integrated Work and Study Program (IWSP), and Capstone projects. The programme curriculum structure facilitates the Term-In-Term-Out pathway to ensure that every year students have one trimester to be attached to the industry for on-job training and industry project. IWL and IWSP aim to equip students with industrial knowledge by bringing them out of campus and being involved directly in real-world projects. Due to the international cross-boarding nature of the supply chain and logistics industry, it is also planned with industry partners to support students to undergo their IWSP overseas.

Higher education may increasingly be viewed as learning laboratories rather than the typical classroom learning setting. Students must apply their newly acquired and developed knowledge to real-world settings. Industry work study attachments are valuable opportunities to obtain experience in the real world of work while gaining knowledge and skills by applying theories to real-world challenges.

E. Curriculum review and improvements

Walden (2020) highlighted the need to conduct curriculum reviews regularly to ensure the best possible education of SCM students with the latest knowledge of supply chain systems. He suggested that the curriculum can be improved with regular review by providing exposure to as many of the systems used in the industry as possible.

Under our framework, the curriculum review and improvement processe consists of three feedback loops to ensure the curriculum is aligned with the state of art supply chain skillsets and concepts to guarantee that graduates are prepared to meet the dynamic supply chain talent needs. As shown in Fig 2, the first inner loop assesses the effectiveness of teaching and learning at the individual module level, the second middle loop assesses the Students Learning Outcomes (SLO), and the third outer loop assesses the Programme Education Objectives (PEO). The third outer loop is closed over a longer cycle through external assessment and review with various stakeholders, including industry partners, industry advisory committees, focus groups, etc.

Surveys will be conducted for employers and alumni after students graduate and enter the workforce. The data gathered from surveys will be used to verify PEO achievements. The surveys will ask employers and alumni questions about their perceptions of their abilities and attributes as programme graduates. These survey data will be mapped to

the programme PEOs and used for analysis as an indicator of the attainment of PEOs as perceived by employers and alumni.

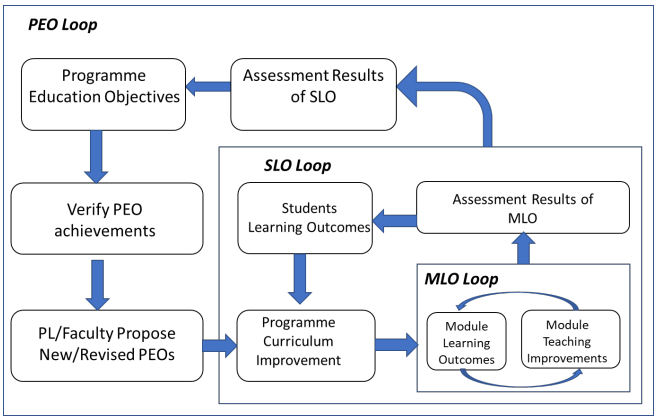

Fig 2. DSC Curriculum Review and Improvement Process

4. Conclusion

This paper addressed the potential gaps of the methodology of curriculum design and development in preparing students to meet industry employers' requirements related to the digital supply chain domain. The methodology was used for developing a new digital supply chain programme, which mainly focuses on the industry workforce requirements, curriculum contents, pedagogy, teaching philosophy, curriculum review and improvements. The digital supply chain degree programme is the first such programme in Singapore, with the mission to prepare a pipeline of talents to support the digital transformation of the supply chain and logistics industry.

The digital supply chain degree programme is highly industry-oriented and practical skills-focused, linking academic study closely with real-world supply chain and logistics practices. The importance of industry engagement and the approaches to engaging industry partners were discussed. We engaged the industry from the onset of the programme preparation and throughout the curriculum development, course delivery, PEO assessment, and continuous improvement. The practice-based and project-based applied learning approach is embraced to train graduates to be industry-ready and armed with the relevant skillsets and knowledge valuable to their career path.

Future works are planned to verify the curriculum design and development through curriculum review and improvement. The surveys for graduates' employers and alumni will be conducted, and the results collected will be further analyzed and summarized for future programme improvement.

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Biographies

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