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Challenges and opportunities for maritime education and training in the 4th industrial revolution

Herbert De Vera Nalupa

WORLD MARITIME UNIVERSITY
Malmö, Sweden

CHALLENGES AND OPPORTUNITIES FOR MARITIME EDUCATION AND TRAINING IN THE 4TH INDUSTRIAL REVOLUTION

By

HERBERT DE VERA NALUPA
Republic of the Philippines

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Declaration

I certify that all the material in this dissertation that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal views, and are not necessarily endorsed by the University.

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Supervised by: **Dr. Inga Bartusevičienė**

Supervisor's affiliation: **World Maritime University**

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Abstract

Title of Dissertation: **Challenges and Opportunities for Maritime Education and Training in the 4th Industrial Revolution**

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For the effective functioning of maritime education and training (MET), understanding of the impact of Industry 4.0 technologies on maritime professionals is essential. This study explored the challenges and opportunities for MET in the 4th Industrial Revolution. Two factors were considered for the research, automation and digitalization, occurring both in the shipping industry and in the MET sector. The purpose of the study is to highlight challenges and opportunities brought about by the rapid advancement of technologies and contextualize them in the experience and foreseen future of maritime professionals. Three methods were employed: content analysis; survey and semi-structured interviews, which involved 127 survey respondents and seven teachers in various specializations. The Extended Leavitt's Model was used as a theoretical framework for exploring MET as a complex adaptive system consisting of interrelated components: organizational culture, people, processes, structures, and technology. Results suggest that automation and digitalization affect *organizational culture* in terms of changing leadership traditions and conventional practices; *people* in terms of teaching-learning interaction, inter-personal relationships, employment opportunities, competence requirements, and gender issues, including generation gaps; *processes* in terms of integration of modern tools and equipment, with the automation and digitalization of procedures; *structures* in terms of new management models; and *technology* itself in terms of changing and transforming configuration and capabilities of devices and machineries. These findings necessitate careful consideration of actions to be taken in addressing identified challenges and opportunities because a change in any of the components always affects the others. The dissertation hopes to open up pathways to understanding the complex adaptive nature of the MET system, an awareness that is essential for sustaining the existing maritime professionals through the challenges of the 4th Industrial Revolution and for taking advantage of developing a new generation of resilient and future-ready professionals for the ever-growing maritime industry.

KEYWORDS:
Maritime Education and Training, Complex Adaptive Systems, Industry 4.0, Industrial Revolution, Automation, Digitalization

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List of Abbreviations

CADE	Convention Against Discrimination in Education
CAS	Complex Adaptive Systems
CS	Complex Systems
IAMU	International Association of Maritime Universities
ICT	Information and Communications Technology
ICES	International Council for the Exploration of the Sea
IMO	International Maritime Organization
MARLEM	Maritime Logistics, Engineering and Management
MET	Maritime Education and Training
MSC	Maritime Safety Committee of IMO
SDG	Sustainable Development Goal
STCW	Standards of Training, Certification, and Watchkeeping for Seafarers
UN	United Nations
UNDESA	United Nations Department of Economic and Social Affairs
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNIDO	The United Nations Industrial Development Organization
WMU	World Maritime University

Chapter 1

Maritime Education and Training (MET) is facing new waves of challenges brought by Industry 4.0 or the 4th Industrial Revolution. Industry 4.0 demands innovation in work processes, which impacts the education, training, skills development and employment of maritime professionals. This dissertation explores the challenges and opportunities for MET in the current era of modern technologies.

1.1 Background and Context

The Universal Declaration of Human Rights proclaims that education is a fundamental human right for all people, and the Convention Against Discrimination in Education (CADE) extensively elaborates the elements of this right. CADE is the first international instrument that comprehensively covers the right to education. It is considered a cornerstone of the Education 2030 Agenda and a potent tool for achieving the United Nations (UN) Sustainable Development Goal (SDG) No. 4, Quality education (UNESCO, 2020).

The 2030 Agenda for Sustainable Development was adopted by the UN General Assembly on 25 September 2015. It aims to secure a sustainable, peaceful, prosperous and equitable life on earth for everyone, now and in the future. Hence, the SDGs cover global challenges that are crucial for the survival of humanity. The SDGs address a range of social needs including health, employment and social protection, while tackling climate change and environment protection (UNDESA, 2021).

As a specialized agency of the UN, the International Maritime Organization (IMO) actively contributes to the 2030 Agenda and the SDGs. The IMO (2019a) considers that most of the elements of the 2030 Agenda will be achieved with a sustainable transportation sector that supports world trade and facilitates the global economy. Its Technical Committee highlights that all SDGs are related to the IMO's activities, but eight are identified as being directly relevant to IMO's mandate and are linked to IMO's Strategic Directions. Among these eight, SDG 4 is highlighted as very important because education and training are crucial in the maritime industry. The significance of MET goes far, even beyond shipping. The competence and skills of seafarers and shore-based maritime professionals are essential for the safety and security of life and property at sea, the protection of the marine environment, and the efficient flow of global trade. The International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers (STCW) establishes the standards of competence for seafarers. Akin to CADE, the STCW is the first international instrument to define the fundamentals and basic rules for education and training of seafarers (IMO, 2019b).

1.1.1 *Development of MET*

One important facet to consider about MET is that the acquisition and application of practical skills has traditionally been the focus of traditional seafarer training. While this method targets some cognitive capabilities, it is primarily concerned with the training of hands-on practical skills for the completion of specific tasks. Academic education, on the other hand, focuses more on the development of in-depth analytical and critical thinking skills. The global trend in MET is to link vocational education that produces specific competence outputs with more general or deeper scholastic components that lead to an academic qualification. This tendency created challenges for international MET frameworks, curriculum creation and achieving desired learning outcomes in the shipping industry (Manuel, 2017).

Another important aspect to take into account is that the contemporary education and training for seafarers is regulated in an international framework governed by public international law. It is, however, implemented through each state's approaches and regulatory initiatives. In an increasingly globalized society, Manuel & Baumler (2020) explained that the international approach has many advantages, but it has not been without drawbacks. The evolution of the international regulatory framework, particularly the STCW Convention, 1978, as amended, provided certain legal issues. Likewise, new and emerging technologies have posed challenges to the relevance of the existing seafarer education and training, and the whole MET system, in general.

1.1.2 *Development of Industry 4.0*

In the context of industrial revolutions, technology and employment are often the subject of intense public discussions as some jobs are created while others are deemed obsolete. For instance, individual occupations in the textile industry were nearly eliminated during the Industry 1.0 that originated in England. Similarly, in Industries 2.0 and 3.0, mechanization in agriculture and steel productions displaced farmers and industrial laborers, having a significant impact on those sectors. In this regard, Industry 4.0 differs from earlier revolutions in that it has been advancing rapidly across various industries while requiring new skill sets, as opposed to displacing people (Baum-Talmor & Kitada, 2022). This is what is happening in modern businesses today and the maritime industry is not an exception.

Automation and digitalization in the shipping industry is causing disruptive changes to vessel construct, operations and crewing. The application of technology and modernization in shipping is intended to complement human capabilities in enhancing maritime safety and efficiency. However, the complexity in shipping logistics, reconfiguration of processes and pursuit of sustainability foist growing concerns in the role of the human element. The imminent impacts of autonomous shipping technology can include changing the role of maritime professionals and the strategies to engage them in the transition from traditional practices to smart shipping. Industry 4.0 is confronted by criticisms for its apparent disregard to the value of the human element and their competences (Shahbakhsh, 2021).

1.2 Problem Statement

The problem to be addressed through this study is the effect of Industry 4.0 on the MET system. Industry 4.0 is the new phenomenon moving modern industries in recent years. It facilitates automation and digitalization systems that have technological and organizational implications (Lazi et al., 2014), which render jobs susceptible to computerization at various risks (Frey & Osborne, 2013).

It is observable that the development of smart and intelligent technologies during the last decades is changing ship and port equipment and facilities influencing the way maritime professionals work. If the current education and training programs will not be innovated, there will be an incompatibility between graduates of MET institutions and the multidisciplinary workforce needed by the shipping industry.

The current body of literature does not adequately address MET issues from a systems perspective. The shipping industry soon needs a skilled workforce taking on new types of tasks because old routines are eliminated as a result of technological advancements in order to operate ships and ports empowered with autonomous, intelligent and smart systems (Jo et al., 2020). A career-focused approach to addressing Industry 4.0 relative to the potential implications of automation and digitalization on maritime professionals was recommended instead of a technology-centered approach (Baum-Talmor & Kitada, 2022). Analyzing political, economic, social and technological factors, Milić-Beran et al. (2021) emphasize the need of transforming the educational and training processes in MET institutions. These issues are reflected even in the discussions of the Human element, Training and Watchkeeping (HTW) and Maritime Safety Committee (MSC) of the IMO. One major consideration is that a crucial segment of the MET is inseparably associated with an international law, the STCW Convention, 1978, as amended. Unless education leaders understand the challenges and opportunities for MET in the 4th Industrial Revolution from a systems perspective, the MET may fall short in producing a maritime workforce with an effective core set of professional skills.

1.3 Purpose of the Study

The research is pursued with the intention to contribute valuable insights into the relevance of MET to the maritime industry. Having this purpose in mind, this study aims to explore the challenges and opportunities for MET in the 4th Industrial Revolution. The vulnerabilities, uncertainties, complexities and ambiguities brought about by the rapid advancement of technologies today is regarded to have significant impact on the education frameworks. Therefore, the researcher believes that the effects of Industry 4.0 to the MET system is worth examining. The results of this work may be useful in advancing policy recommendations, as well as amending existing MET curricula and developing new programs.

1.4 Objectives

This research intends to fulfil the following objectives:

1. to explore the influence of Industrial Revolutions on MET; and
2. to investigate how factors of Industry 4.0 affect components of MET as a system.

1.5 Research Questions

The following research questions will be answered in this study:

1. What factors of Industrial Revolutions are affecting the development of MET?
2. How automation and digitalization as factors of Industry 4.0 are affecting the components of MET?
3. How can MET be described from a systems theory perspective?
4. What Industry 4.0 challenges and opportunities are influencing MET as a system?

1.6 Limitations

For the past decade or more, studies related to the shipping industry have been focused on major topics like maritime safety and security, ocean governance and marine environmental protection, Flag State implementation and Port State Control, automation, sustainability and wellbeing of seafarers. Not much has been studied about the effect of current developments to the system of education and training of maritime professionals. As such, the source of related literature is limited.

The researcher designed the study for a particular educational sector, the maritime education and training system, and within the milieu of the 4th Industrial Revolution. This design limits the applicability of the findings to maritime institutions in general.

The design of the study requires target respondents to provide the necessary information or data during the survey and interview. However, due to the lingering COVID-19 pandemic, the travel protocols, alternative working arrangements and time difference affects data gathering, which impacts the results and subsequent analysis. Further, the research is limited by the use of data gathered only from respondents who decided to participate in the study (self-selection bias). Furthermore, because of the sampling method targeted to maritime stakeholders, the respondents may have provided answers that they believe are constructive to the research rather than an authentic response (social desirability bias).

In mitigating these limitations, the researcher used Likert scale, forced-choice items and self-administered questionnaire that does not require the researcher to be physically present in order to reduce the respondents' discomposure when answering the questions. In the discussion of findings and in making conclusions, the researcher shall endeavor to provide sufficient evidence to demonstrate that careful consideration is taken to mitigate the identified limitations.

1.7 Organization of the Dissertation

This dissertation is composed of six chapters. Chapter 1 presents the background for the significance of the problem. The chapter also contextualizes the work with the purpose and objectives of the study and brief discussion of the limitations of the research. The literature review in Chapter 2 situates the research in the milieu of previous studies relevant to the topic, presents the justification of how the study addresses a gap in the existing corpus of knowledge, and details the theoretical framework used. Chapter 3 presents the methodology, describing the methods used and providing the rationale for using the mixed-method approach. The chapter also explains how the limitations were tackled, including research ethics considerations. Chapter 4 reports the information gathered and salient statistical and narrative data. Chapter 5 contains the analysis and synthesis in line with the dissertation's research questions and theoretical framework. Patterns and themes are highlighted, including controversial findings inconsistent with existing studies. The careful interpretation is the researcher's contribution to the discipline of MET. Finally, Chapter 6 summarizes the main points of the dissertation by direct to the point answers to the five research questions. The chapter closes by recommending research areas for future consideration.

Chapter 2 Literature Review

The preceding chapter contextualized the problems regarding Industry 4.0 in relation to MET. This chapter will expound on the concerns and issues by highlighting the role of MET to the maritime industry, the historical development of MET through the four industrial revolutions, and the reason for taking a systems perspective in exploring challenges and opportunities for MET. Finally, the theoretical framework used for the study will be discussed as the basis for the development of the dissertation and the subsequent analysis of findings.

Throughout history, shipping has connected the world by carrying trade that moves the global economy. Today, shipping has evolved into a vast network of very technical and highly interconnected activities that entail specialized knowledge, skills and competence of maritime workforce. Looking forward, the safety, security and efficiency of the shipping industry can only be ensured by an effective MET that is responsive to the dynamic requirements of the industry. In retrospect, unintended outcomes of shipping processes like faulty documentation, cargo loading errors, grounding, collisions, oil spills, and mishaps at port, among other incidents, often occur in the maritime industry as unpredictable. This is because the demands and performance of duties of stakeholders in today's maritime activities have become very volatile, uncertain, complex and ambiguous. Factors like new technologies, numerous conventions and protocols, multitudes of providers, regulatory constraints and the fluctuations in the international market all contribute to the increasing complexity of the maritime industry.

In the past decades, a number of prominent sources suggest the concept of Complex System as a framework for understanding the characteristics of maritime elements, processes and segments. For example, IMO Resolution A.947(23) states that one of the Principles of the Organization is that "The human element is a complex multidimensional issue that affects maritime safety, security and marine environmental protection. It involves the entire spectrum of human activities performed by ship's crews, shore-based management, regulatory bodies, recognized organizations, shipyards, legislators, and other relevant parties, all of whom need to co-operate to address human element issues effectively." (Annex, Principles (a), emphasis supplied). This complex multi-dimensional issue of human element is supposedly addressed in international regulatory frameworks like the STCW Convention, 1978, as amended, through a "system of training, assessment of competence and certification of seafarers" (Section A-I/7, paragraphs 9.2.3). Hence, the Directive (EU) 2019/1159 of the European Parliament and of the Council dated 20 June 2019 alludes to a "country's system for standards of training, certification and watchkeeping of seafarers" (paragraph 7) fully and completely in effect to ensure maritime safety and prevention of maritime pollution. Thus, Gravador (2016) spoke of the divergent realities in MET practices by various administrations and other important figures in the maritime sector.

System complexity is also suggested as a key reason for the significant unpredictability and variation in operational outcomes across organizations within the maritime industry. The International Association of Maritime Universities (IAMU), SkillSea and the EU – Maritime Logistics, Engineering and Management (MARLEM) have alluded to Complex Systems in their recommendations for future competence needs and delivery of MET (IAMU, 2019; Oksavik et al., 2021; Zec et al., 2020 and de Água, 2020). The reference to Complex Systems by these organizations suggests the value of CS theory for informing maritime research, education and training. Therefore, it is important to consider the theory and application of Complex Systems not only as a key component in the education and training of maritime professionals for roles as administrators, educators, researchers and seafarers, but also, as a context for understanding the implications of the 4th Industrial Revolution to MET.

2.1 MET and its Role in the Maritime Industry

In the early days of shipping, acquisition of competence for water transportation started as actual internship or on-the-job training. Traditional instruction for sailors emphasized experience for the performance of specific onboard tasks. In time and with technological developments, as well as implementation of international regulations, shipping and the maritime industry became more complex, which prompted the education and training related to shipping became professionalized. A certain level of schooling was required in addition to hands-on task-oriented training. Today, the global trend in MET is to integrate basic vocational training with general formal education that leads to an academic qualification. This approach arises from the technological complexity of ship machinery and equipment, the prominence of standards on safety of ship crew, and the strict regulations for environmentally sustainable operations (Manuel, 2017).

In order to clearly understand the role of MET in the maritime industry, it is imperative to start with asking what it is?

At the time of writing this dissertation, a search in the Google Scholar for “maritime education and training” yields “about 387,000 results” in 0.03 second. While this is the case, there is hardly any literature that exacts the definition of MET.

Dong (2014) explained that MET has traditionally been defined as an educational system aimed at training seafarers for merchant vessels; however, as the shipping industry has evolved, it has become necessary to redefine MET from a broader perspective. The proposed new definition is:

> MET is an educational system whose objective is to cultivate people to be competent in areas of ship building and maintaining, ship operation, maritime management and services, including finance, brokerage, maritime law, insurance, as well as maritime teaching and researching. (Dong, 2014, p. 116).

The presented redefinition is reflected in the Global Maritime Professional – Body of Knowledge, a joint project between the Nippon Foundation and the IAMU. Taking into consideration the incessant improvement in the international legal frameworks in response to continuous integration of new developments in the maritime industry, a global maritime professional is described as:

> An individual who is a professional in the maritime industry and who is equipped with all the relevant technical competencies relevant to their specific operational role in the industry and as required by international requirements with high level academic skills including logical and critical thinking and who – in addition to their technical competency – exhibits a high level of professionalism and ethical behaviour, human relations skills, emotional intelligence and multicultural/diversity awareness and sensitivity. Such an individual exhibits significant leadership skill and is able to optimally work with teams and also take personal initiative. They additionally exhibit a high sense of environmental consciousness and the need for sustainable practices and have an excellent grasp of contemporary issues affecting the maritime industry (IAMU, 2019, p. 4).

Another approach in defining MET is by semantics. This is practical because in semantic analysis, the goal is to focus on what the words traditionally imply rather than what a certain speaker would wish them to mean in a given circumstance. This method focuses on general or objective meaning rather than personal or subjective connotation (Yule, 2005). A full presentation for defining MET using the semantic approach is provided in Appendix A.

Taking into consideration the preceding discussion, this dissertation adopts the perspective that MET is a system with subsystems, components and elements characterized by complexity. The complexity originates not only from the internal environment of the MET system but also from inseparable structures affecting its processes and quality, *inter alia*, international regulations and standards (e.g, Regulation I/10, Recognition of certificates), national framework of education system, and requirements of the shipping industry. In fact, the MET is only a small subsystem within an enormous complex system, which is the international maritime industry.

2.2 Complex Systems

According to Clancy et al. (2008), a Complex System (CS) is an extremely interacting network of entities like objects, people, organizations or communities, from which complicated outcomes emerge. Complex Systems are pervasive in living things, as well as physical and social phenomena, and at all levels of analysis. Systems become complex as a result of different combinations of events at a given point of time (combinatorial complexity); for instance, the thousands of different education and training curricula in the MET system are delivered by multitude of providers to a large number of learners in diverse settings. Different from combinatorial complexity, systems become complex when a simple event is repeated over time (dynamic complexity), such as the communication of a speculation in an organization. Distinguishing characteristics of Complex Systems are unpredictability and nonlinearity (cause and effect are different). For example, the crew management process is very complex and susceptible to risks. A personnel's response to education or training is unpredictable and even a "routine" intervention such as instruction or coaching can generate a serious negative outcome (non-linearity), as well as the simple task of performing a regular daywork onboard can become complex within the socio-cultural systems of team dynamics and daily life at sea.

One special case of Complex Systems is complex adaptive systems (CAS), which is characterized by learning and adapting to change over time, and can potentially change the system structure. For example, maritime logistics is a CAS that adapts to intermodal processes through innovative mechanisms such as automation and digitalization. Physically, the long-term effects of adaptation produce changes in structural design of logistics components, like trailer trucks, container and vessel construct, as well as ship and port cranes. Socio-politically, resistance or substitution may result from the initial reaction to the unavoidable change but, through time, acceptance and adaptation take place. Similarly, these principles are applicable to groups and organizations (Clancy et al., 2008).

2.3 MET as Complex Adaptive System

The redefinition of MET as an educational system aimed at cultivating people to be competent in various fields and activities in order to become a global maritime professional, calls for a novel perspective given the complexities brought about by the 4th Industrial Revolution. From this standpoint, the MET system is hereby analyzed taking into consideration its character as a complex adaptive system in order to determine the challenges and opportunities that Industry 4.0 exposes to MET.

CAS is an extension of the Systems Theory (Hartvigsen et al., 1998). Definitive features of CAS are self-organization, emergence, non-linearity and chaos, which result from the fundamental principles of system dynamics (Clancy et al., 2008). Understanding of these features is very important in examining how the factors of Industry 4.0 are affecting the components and elements of the MET system. A sufficient understanding will help academics and education policy-makers establish measures and strategies appropriate for the complex adaptive nature of the MET system.

Self-organization refers to the process in which the mutually interacting and interrelated parts of an internal organization of a CS increase in complexity without the influence of an outside source. It refers to the ability to develop a new structure resulting from the internal reconstitution within the system and not from external management. Emergence and self-organization are related but they are different. Self-organizing systems commonly, but not always, show emergence. Self-organization occurs without emergence, and emergence happens without self-organization. But in complex adaptive systems, emergence and self-organization exists together (Rotmans & Loorbach, 2009). An example of MET is the possession of mobile communication devices may result in self-organization and may facilitate formation of groups for completing assignment and performance of assessment tasks.

Emergence in CAS is illustrated by new and coherent structures, properties, behaviors and patterns that emerge resulting from self-organization of components (instructors, assessors or learners). Organizational culture is commonly referred to as emergent because it is the sum total values and behavior of each staff member (Clancy et al., 2008). For example, a chain of administrative tasks (such as invigilation and marking of assessment) wherein each task has a distinct distribution of processing time, shows an aggregate pattern different from other tasks. The overall shape of the distribution, like a bell curve, represents the emergent behavior of the entire process.

The nonlinearity behavior of a system can be observed as the different responses to the same stimulus. CAS have feedback loops, both positive (amplifying) and negative (damping). CAS constantly transforms over time because it involves diverse components and interactions among components and with the environment (Rotmans & Loorbach, 2009). This nonlinear behavior produces various outputs from the same inputs, hence, lesser predictability than linear behavior (Clancy et al., 2008). To wit, the workload of a student is usually non-linear. Because of the uncertainty of human response to an instruction, two students with identical assignments can have substantially different workloads.

CAS is characterized by chaos because such systems are often in a period of dynamic equilibrium while simultaneously undergoing variation and selection. Changes to the initial conditions of the system generate distinctive (non-random) but complex behavior. Order or pattern can arise from the seemingly random or complex nonlinear behavior. Non-linear behavior is often evolving. The integrated feedback loops of a CAS usually generate chaos (Rotmans & Loorbach, 2009). For example, the variations in marking of exams and delays in release of grades may look as if unrelated but may essentially reveal a hidden chaotic pattern.

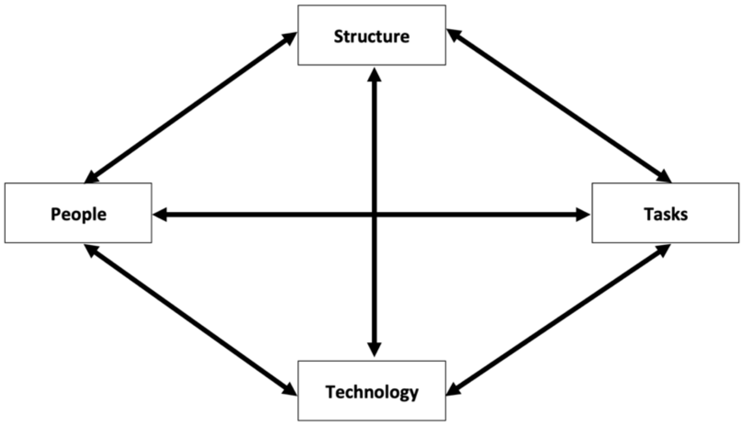
2.4 Factors Affecting MET

As a CAS, the MET system is affected at various levels: individual agents, group of individuals and elements, subsystem level – QSS/QMS, subsystem of admission and retention, curriculum design, development and approval, assessment and grading, information management, among others) by internal and external factors influencing the need for and the structure of the MET system. External factors include international regulations, industry requirements, national provisions and technological developments, and more of the same. Internal factors include the MET institution's program and curriculum standards, facilities and equipment, the competences of the faculty and teaching staff, the background of the learners, among others.

In reality, there exists so many factors that influence any system. Numerous researches explored the effects of identified factors and explained the relationship by developing theories and models. One of these is Leavitt's Diamond (1962), which depicted an organization as a system that consisted of structure, people, tasks and technology as its four definitive elements. The model places the four factors in a square and interconnected, hence the diamond shape (Figure 1). Leavitt illustrated that a change in any of the elements causes changes in others.

Figure 1

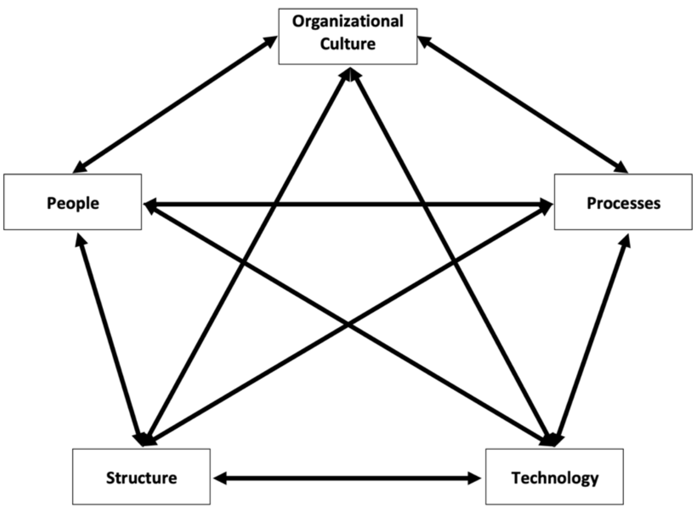
Leavitt's Diamond



The model was later on extended by Kovačič et al. (2004) to include organizational culture and "tasks" was renamed "processes" (Figure 2). The extended model maintains the basic idea that the five elements are interdependent and a change in one cause change in others. Hence, a change in technology causes changes in processes and structures, as well as consequently in people and culture.

Figure 2

Extended Leavitt's Diamond



Using the Extended Leavitt's Diamond, MET is visualized as a system consisting of five interacting elements: organizational culture, people, process, structure and technology. Organizational culture is the pattern of basic assumptions by the people within the MET system as they learn to cope with changes that has worked effectively and considered valid, hence, being taught to new members as the proper way of perceiving, thinking, and feeling in relation to changes (Schein, 2010). People refers primarily to teachers and learners, including school administrators and support staff. Processes include curriculum development, educational approaches and methodologies, learning styles, as well as quality assurance, administration and supervision by the school management. Structure refers to the MET institutions and the governance environment, alongside the design of curricula and program specifications. Technology refers to the equipment, machinery and tools used in delivering MET, thus referring to simulators, training ships, ICT applications and learning management systems.

2.5 MET and Industrial Revolutions

Education plays a major role in meeting challenges brought by inevitable changes and developments. This is the case of MET for the technological advancements in the shipping industry throughout the four industrial revolutions.

"Industrial revolution" is a term conceived by Arnold Toynbee (Wrigley, 1990). The term refers to technological developments which resulted in paradigm shifts in industrial production. The 1st industrial revolution was in the field of mechanization; the 2nd industrial revolution for the powerful use of electrical energy; the 3rd industrial revolution in the field of extensive digitalization; and the 4th industrial revolution for the combination of internet of things and future-oriented technology in the field of "smart" machines and devices (Lasi et al., 2014).

2.5.1 1st Industrial Revolution

The 1st Industrial Revolution is marked by the inventions of steam engine, telegraph (Morse code) and the chronometer, including the rise of iron and steel manufacturing. These innovations reinforced merchant shipping which was already an established industry at that period. The developments brought about steam ships, as well as lighter and stronger materials which allowed the construction of larger vessels. The American SS SAVANNAH was the first to cross the Atlantic Ocean in June 1819 with partial steam engine (Beard, 1927); the British side-wheel paddle steamer SS GREAT WESTERN was the first steamship purpose-built in 1838 inaugurated the era of the trans-Atlantic ocean liner (Zhang & Yang, 2020); and the SS ARCHIMEDES, built in Britain in 1839, was the world's first screw propeller-driven steamship for open sea voyage encouraging the adoption of screw propulsion by the Royal Navy and on commercial vessels (Carlaw & Lipsey, 2022).

The construction of bigger and more ships led to enhancement of port facilities. With bigger and more ships, trading expanded and communications between ships and ports became indispensable. According to Lew & Carter (2006), the telegraph became a boon for shipping. The technology provided the means for ships to have communication while in foreign ports, which enabled shipowners to increase the utilization of ships by redirecting them to sources of cargo and to respond to changing market conditions. As the shipping companies discover availability of cargoes and destinations with demand for cargoes, they could communicate this information to their ships upon arrival in their port of call. The more distant and remote the port of call, the more valuable was this communication link since those ships would take longer to return to home port or even to a familiar port. Visits to remote ports were associated with longer voyages, increased uncertainty for obtaining cargo and therefore reduced utilization. The telegraph compensated for this risk in operations.

In addition to communication, the marine chronometer and sextant became essential tools for navigation. Invented by John Harrison in 1773, the marine chronometer served as a precision timepiece and was used for the determination of the ship's position by celestial navigation. It is used to determine longitude by comparing Greenwich Mean Time and the time at the current location found from observations of celestial bodies. The Sextant was demonstrated by John Hadley and Thomas Godfrey to the Royal Society, London in 1731. It is a device that measures the distance between a celestial object and the horizon using reflecting mirrors in order to determine the latitudinal position of the ship (de Grijs, 2020).

In retrospect, the inception of formal maritime education and training were already visible in some countries at least two centuries earlier. The first Nautical Academy was established in Seville, Spain in 1552. In France, the first naval academy was established in 1627 and 50 years later, the country had established a national maritime education system with the passage of the Maritime Act of 1681. In other countries the system of assessment for seafarers was introduced, for example, the Netherlands appointed an official examiner of mates in 1619, the United Kingdom examination of naval officers started in 1677, and France instituted compulsory examination for seafarers in 1681 (Manuel & Baumler, 2020).

The introduction of MET structures in the shipping industry continued in the 18th century. As early as 1707, the examination for Masters and Mates was instituted in Copenhagen. The examination for Dutch officers started in 1750. Maritime educational institutions established during this period include the "Academy of Marine Guard" in Saint Petersburg (1715) and the Naval Academy in Portsmouth (1733). It is noteworthy that the first Nautical Almanac was published in 1767 (Manuel & Baumler, 2020).

Before the onset of the 2nd Industrial Revolution, the Escuela Nautica de Manila was founded in 1820, and by 1841, five navigational schools were established in Sweden – Malmö, Gothenburg, Gävle, Kalmar and Stockholm. The 1st training ship – HMS Excellent was inaugurated in 1830 and apprenticeship was made compulsory on UK Merchant Ships in 1835. In history, a set of navigational rules was drafted by the London Trinity House in 1840 and the 1st set of regulations for prevention of collision was enacted by the Parliament in 1846 (Manuel & Baumler, 2020).

2.5.2 2nd Industrial Revolution

Fuelled by the game-changing use of steam power, the Industrial Revolution that began in Europe spread to the rest of the world by the middle of the 19th century. The rapid advancement in the transportation, steel and electric industries defined another wave of development which is now referred to as the 2nd Industrial Revolution that happened from the late 19th to early 20th centuries.

MET-related developments during this period include the establishment of MET institutions in Croatia (1849) and the introduction of the examinations for Masters and Mates through the Merchant Marine Act of 1950. This subsequently led to compulsory licensing in the UK the following year, and by 1862, engineer officers were required to have licenses. It was in the 1850s that UK Shipowners allowed employment of "foreign" crew and the HMS Conway opened as pre-sea School Ship for Merchant Navy. In 1864, the first Collision Regulations were established and a decade after, the US Navy was obliged to provide ships to State Nautical Schools. By 1891, all US Mail ships were obliged to carry cadets. Before the turn of the 20th century, the continuous rise of technology made steam overtaken sail ships and the Merchant Shipping Act 1894 required ships over 1000 GT to have a cook onboard.

Chin et al. (2005) explained that the switch from sail to steam entailed elements that were skill-biased and skill-replacing. On the skill-biased side, the introduction of steam generated a new highly skilled career onboard the ship, that of the engineer. Additionally, compared to their counterparts on sail, able-bodied seafarers, mates, and carpenters engaged on steam earned a premium as a reward for skills. On the skill-replacement side, moderately experienced able-bodied seafarers were replaced for technical work by less skilled engine room personnel. Moreover, the wage structure in merchant shipping widened as steam replaced sail at the turn of the century—mates were paid higher on steam than sail, and engineers were paid much higher than mates. On the downside, the sailmaker trade was rendered obsolete by steam.

Technology powered ships to travel longer periods and distances. However, shipowners had to staff ahead of time in anticipation of problems because once at sea, the ship would be unable to recruit immediate assistance. This meant higher demand for engineers in merchant shipping. Fortunately, the industry is inherently international and ships took crew from all destinations. Again, this factor impacted on the wage structure as a particular wage standard was primarily based on existing labor market conditions. For example, Britain was supplying the engineers in steam ships and thus, gained advantage in maritime labor than any other countries during this period. On top of these, part of the wage premium and disparity in steam ships was due to the shortage of qualified engineers (Chin et al., 2005).

2.5.3 3rd Industrial Revolution

Like the 1st and 2nd, the 3rd Industrial Revolution brought in new means of transport, new forms of energy and new methods of communication. During this period, computer and information sciences or informatics made the most profound effect upon everyday life. Education underwent all-important changes to meet the challenges of the information age and to provide the qualified workforce adept in computerized design and manufacturing, data processing, management of integrated production processes and robotics (UNESCO, 1987).

According to Penprase (2018), the 3rd Industrial Revolution brought educators a milieu where access to information is instantaneous and free. This shifted the paradigm toward active learning pedagogies that emphasized collaboration within diverse teams and peer learning environments. The internet expanded the access and participation to higher education, which exponentially increased diversity and globally accelerated academic research. Further, with new technologies that improve oncampus and off-site experience for students like online courses, videoconferencing, and merging social media with webinars, educational institutions were enabled to work together and realize economies of scale. Furthermore, innovative online education enterprises partnered with prominent educational institutions which created new and more interactive delivery of courses, as well as stackable micro-credentials, which constituted a higher-level certification when completed. Nonetheless, Penprase (2018) maintained that the more personal components of the educational experience will become increasingly valuable and will not be easily replaced by technology even in an environment of increasing online content delivery and access to information.

The expansion of educational strategies also meant wide variations in specifications and procedures. In seafaring alone, the standards of training, certification and watchkeeping of merchant marine officers and support personnel were established by each government, usually without reference to the MET system in other countries albeit shipping is an international industry (IMO, 2019c). To address this issue, the STCW Convention was established in 1978 as the first international law setting the basic requirements on training, certification and watchkeeping for seafarers. This was made possible by the creation of the Inter-Governmental Maritime Consultative Organization in 1948, which was renamed International Maritime Organization in 1982 (IMO, 2019d).

2.5.4 4th Industrial Revolution

The 4th Industrial Revolution began at the turn of the 21st century and builds upon the age of information and digital revolution. It is characterized by a digital combination of physical and digital technologies powered with sensors that enables artificial intelligence and learning in machines (Ustundag & Cevikcan, 2017).

Studies have revealed that the first three industrial revolutions are significantly different from the 4th Industrial Revolution. According to Senčila & Kalvaitienė, (2019), the first three happened gradually and there was time for the affected organizations to cope up, while the 4th Industrial Revolution is rapidly ushering in disruptive technologies towards unchartered territories of development. Likewise, Baum-Talmor & Kitada (2022) are saying that Industry 1.0 to 3.0 are different in terms of creating or eliminating occupations due to mechanization of work, whereas, Industry 4.0 is rapidly moving across industries demanding new levels of skills instead of replacing individuals.

Appendix B summarizes the challenges presented by Industry 4.0 to the MET system as identified in selected literatures. The challenges are organized based on the elements of the extended Leavitt's model. On the other hand, the opportunities pointed out in previous studies are presented in Appendix C. These challenges and opportunities reveal how the 4th Industrial Revolution affects the MET system.

2.5.5 Industry 4.0 or 4th Industrial Revolution?

The term "Industry 4.0" is frequently used interchangeably with the idea of the 4th Industrial Revolution (Drath & Horch, 2014; Lukač, 2015; Hwang, 2016; Morrar, 2017; Petrillo et al., 2018; and Koh & Orzes, 2019). Philbeck and Davis (2018) explained that the two concepts are not mutually exclusive, but describe two distinct things. With its narrower, critical focus on the interaction between digitization, transformation of organization, and enhancement of productivity in manufacturing and production systems, Industry 4.0 is an important component within the greater framework of 4th Industrial Revolution.

With regard to origin, it is generally accepted that the term "Industry 4.0" was first used in Germany in 2011, when the concept was introduced at the Hanover Fair by the working group of Research Union Economy-Science under the auspices of the German Ministry of Education and Research. The term was used to cover two different meanings, according to the final report of the working group: as a synonym for the "fourth industrial revolution," following those triggered by steam-powered mechanization, electricity, and information and communication technologies (ICT), and as a label for Germany's strategic plan to strengthen its international competitive position in manufacturing (Culot et al., 2020).

In consideration of the foregoing discussion, this dissertation work will be using the abbreviation 4IR to allude both the Industry 4.0 and the 4th Industrial Revolution. The subsequent discussions will also refer to various sources which used the terms interchangeably.

2.6 MET and Industry 4.0

UNIDO (2020) observed that the 4th Industrial revolution is differentiated from the 3rd by the fusion of digitalization and automation in order to create intelligent and interactive smart machines that are easy to use for humans. Likewise, the organization said that “Industry 4.0 is gradually implemented, often with digitalization as the first important step” (UNIDO, 2020, p. 2). Similarly, Sima et al. (2020) found that among all the changes brought about by Industry 4.0 in industrial processes, digitalization appears to have the greatest impact on the overall economic and social environment. However, Karacay (2018) noted that recent developments in Industry 4.0 technologies enabled automation and digitalization to take over a group of tasks that previously were performed exclusively by human competence by means of cognitive skills such as sensing, decision-making and reasoning. Further, she cited Autor & Handel, 2013; Frey & Osborne, 2013; and Autor, 2015 in explaining that although some experts and researchers believed that automation will gradually replace human workforce, some others asserted that it is not practicable to substantially substitute human labor by means of automation, and digitalization would serve for only assisting human workforce even in more complex networks of digital platforms. In this regard, Onar et al. (2018) asserted that in order to close the gap, educational systems should be transformed to provide encompassing skill sets and job-specific competences, as well as new formats for ongoing education because the contents of curricula, including the educational approaches to skills development, have to be responsive to the demands for a new generation of workforce. This assertion is supported by Kolesnichenko et al., (2019) stating that given the development of Industry 4.0 is typified by the widespread adoption and intensive use of the internet and sophisticated equipment, the educational system should be adapted to the needs corresponding to the phases of societal development.

In another perspective, Milić-Beran et al., (2021) stated that MET is compelled to develop and offer the knowledge and skills required by the industry. Educators within the maritime sector have to be acquainted with interactive and new modes of teaching. Also, future cadets and apprentices, including management-level personnel, will be required of competences to manage the entire shipping logistics chain, with a particular emphasis on cyber security and operational ethics. Finally, the strategic outcome of reformed maritime education and training is new knowledge and skills that are aligned with Industry 4.0 technologies. These indications were supported in the research of Sharma & Nazir (2021). They found that MET instructors ought to improve on using emerging technologies and a constructivist approach in teaching where collaborative learning techniques would be able to support remote and distributed modes of learning. They also maintained that maritime educators with higher levels of technological self-efficacy could contribute to the education and training of 21st century maritime workforce. Baum-Talmor & Kitada (2022) corroborated saying that automation and digitalization within and beyond the merchant shipping industry have largely implied new skill sets to prepare for Industry 4.0 and for its effects on work. In addition, Hult et al. (2019) affirmed that automation and digitalization will continue to intensify in tandem with changes in how work is perceived and done onboard as well as by shore-based maritime stakeholders. They also stated that the nature of occupations will change due to the stages of transitions to higher degrees of digitalization, which demands for incremental updates in curricula concerning specific competence requirements related to different sectors of the industry. Moreover, Demirel (2020) sustained that automation will require different skill sets at sea, while digitalization will necessitate new approaches ashore. For seafaring, Shahbakhsh et al. (2021) described that the Industry 4.0 penetrated the maritime industry through autonomous shipping, and consequently, the emerging strategies for automation have brought challenges that cause significant concerns for active seafarers certificated under the STCW Convention, 1978, as amended.

The presented literature suggests that the effects of Industry 4.0 to MET can be interrogated in terms of automation and digitalization as elements of the 4th Industrial Revolution. For clarity and for the purposes of this study, the two terminologies are used with the following definitions. Automation is the application of technology in processes and tasks whereby work is performed by advanced technological systems and machines, thus, reducing the need for human labor. On the other hand, digitalization is the process of capturing, storing, transferring and using data or information resources in a way that can be processed by computers.

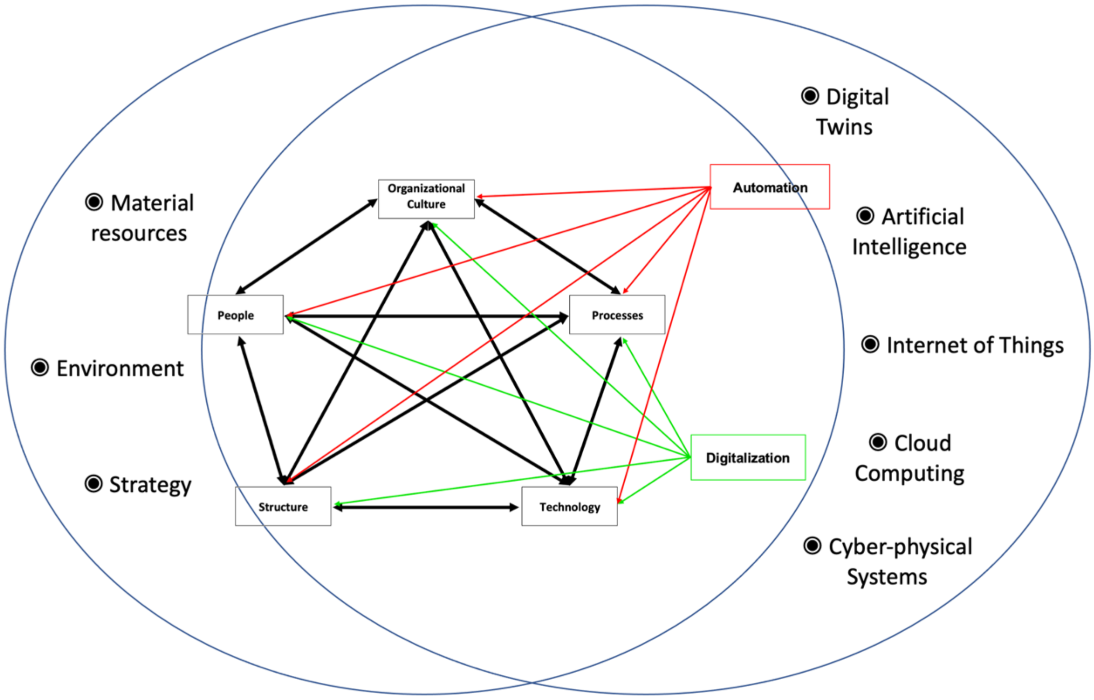
Finally, the interaction between the elements of the MET system and the Industry 4.0 can be illustrated as shown in Figure 3. The illustration depicts various components of the MET System and other factors of Industry 4.0 that are not covered in this study but were included to define the scope of the research.

2.7 Chapter Summary

This chapter reviewed pertinent literature regarding the nature of MET as a CAS characterized by complexity, self-organization, emergence, and adaptation. The evolution of MET throughout the four Industrial Revolutions was also traced in order to investigate the impact of technological advances on the components of the MET system. Lastly, the theoretical framework was introduced to provide context for the scope of the study and guidance for the choice of research methods which will be discussed in Chapter 3.

Figure 3

Interaction of Components of the MET System and Selected Factors of Industry 4.0



Chapter 3 Methodology

This chapter provides the description of the research methodology and the explanation of the alignment between the methodology and the aims of the study. First, the design of the survey instrument is discussed. Then, the concerns on population, sample size, and response rate are described in detail. Also, the justification for convenience sampling is provided. Further, a cursory discussion on data processing and analysis is presented. Finally, the chapter closes with a discussion on the ethical consideration and limitations of the research methods. The schematic diagram of the full methodological framework is presented as Figure 4 at the end of the chapter.

Content analysis, survey questionnaires, and semi-structured interviews were among the qualitative and quantitative methods used in this dissertation. On the one hand, the mixed methods sequencing from content analysis (qualitative) to survey (quantitative) was aimed at exploring and identifying themes and issues that are relevant to be included as variables in the survey, then empirically testing the content analysis results and using the findings to draw inferences for the general population, as well as attributing the qualitative findings to specific population groups like age, gender, and nationality. The sequencing of the mixed methods from quantitative (survey) to qualitative (semi-structured interview, in addition to the short-constructed responses) was intended to interpret the findings and explain the themes or trends in the context of the issues being investigated (Hennick et al., 2020). The sequential mixed methods were applied in order to find out the answers to the research questions and to achieve the stated objectives.

Previous researches concerning Industry 4.0 in relation to the MET system have mostly focused on the concerns of the seafarers, e.g., how the phenomenon affects the practice of seafaring; what changes to competence requirements are expected; and how the existing and incoming sea-based labor force will be educated and trained to be able to deliver the new work demands. To overcome this limitation, the systems and complexity theories were used for the study. Five selected components of the MET system based on the extended Leavitt's diamond (Kovačič et al., 2004) were examined with the perspective that the whole is greater than the sum of its parts (Checkland, 1999). That is, when examining holistically how the components and subsystems influence the totality, certain characteristics of the whole, which is the complex system, cannot be simply rationalized by examining any one of its parts (Gentili et. al, 2020). Specifically, the Complex Adaptive System (CAS) was used as the theoretical framework, wherein the MET system is viewed as adaptive to the environment and its properties are emerging from the interaction of its components (Onik et. al, 2017).

3.1 Content Analysis

From carefully selected studies, a qualitative approach through content analysis was used to determine the challenges and opportunities for MET brought by the 4th Industrial Revolution. Content analysis is used in the social sciences to study social scientific information or data from books, journals, published reports, and other forms of documentation. Stemler (2000) explained that content analysis is used to investigate trends and patterns, as well as to have an empirical basis for observing changes in public opinion. This technique was regarded as appropriate for acquiring a more in-depth understanding of the effects of automation and digitalization on the components of the MET system. Hence, this design is appropriate to use in answering the 1st research question.

Primarily, the researcher explored through Google Scholar, the free web search engine that indexes full text of scholarly literature, and allows searching for educational articles, journals, theses, and books, including conference papers, technical reports, and other scholarly literature from various disciplines. The researcher also looked through printed serials, conference proceedings and dissertations in the WMU Library and Malmö University Orkanen Library.

3.2 Design of the Survey Instrument

The identified challenges and opportunities from selected literatures were filtered to create a group of five statements for each of the five components of the MET system: organizational culture, people, process, structure and technology. Two sets of statements were prepared, one for automation and another for digitalization. Therefore, the research instrument consists of 50 statements carefully designed to be evaluated by respondents using a six-point Likert scale, and six open questions for short-constructed responses. The selected studies with regard to automation are presented in Appendix D and with regard to digitalization in Appendix E. The corresponding survey statements for automation are presented in Appendix F and for digitalization in Appendix G.

The draft questionnaire was pilot-tested for determining the time needed to complete the survey and for adjustment of some terms that were perceived as very technical. Taking into account the comments gathered in the pilot-testing, the instrument was revised and was sent to selected subject-matter experts for evaluation of contents and face validity. The validators are both English Language teachers experienced in design and development of curriculum and educational materials; one has MA in Language education, and the other has MA in Applied Language Studies. The validation tool is presented as Appendix G and the validated research instrument is presented as Appendix H.

After the validation, the instrument was finalized and was submitted to the WMU Research Ethics Committee for approval. Following approval and prior to usage, the survey items were randomized to eliminate order effects: 25 randomized statements about automation were placed before 25 statements about digitalization. Interspersed among the statements on automation were three open-ended questions about automation also, and interposed among the items on digitalization were three open-ended questions about digitalization too. Randomization was aimed at equalizing the context of items across respondents and eliminating satisficing. According to Krosnick and Alwin (1987), satisficing is selecting the acceptable option rather than finding the optimal solution, wherein, respondents tend to select the first option that seems reasonable to them instead of the most suitable option. Likewise, the scale points were truncated to six options (even number) of categories, hence, eliminating the "neutral" or "undecided" alternative and bringing about a forced-choice survey scale (Allen & Seaman, 2007). Using forced-choice helps increase the likelihood of measures to achieve the intended purpose (Murphy & Ermeling, 2016).

3.3 Population, Sample Size, and Response Rate

The originally designed and validated survey questionnaire was administered by stratified purposive sampling and was distributed through emails. Although the researcher personally sent a total of 622 invitations during the period 2 – 6 August 2022, it was not determined how many individuals exactly received the survey link. This is attributed to respondents who were directly invited and then passed the survey to others whom they think could also participate in the study. Consequently, there was no control to whom the link has been shared as it can be easily forwarded not only via emails, but also through instant messaging apps which are commonly used nowadays. It was also admitted by some respondents that even if they did not respond to the survey, they have forwarded it on to their network and requested them to share it to their colleagues. Hence, proper accounting of recipients of the invitation to participate in the survey cannot be performed, and the researcher does not know how many received the link indirectly. Therefore, there was a limitation for calculating the response rate.

3.4 Convenience Sampling

Having in mind the limitation on the time to conduct the study, convenience sampling presented several advantages in terms of amplifying the reach of the survey. Primarily, the survey was distributed in different parts of the world to all possible respondents known to the researcher. The sampling turned out respondents from 45 countries on six continents.

Similar to survey studies that used global convenience sampling, for example, the Seafarers' mental health and wellbeing study by the Seafarers International Research Centre as conducted by Sampson & Ellis (2019) and the Seafarer mental health study by the Seafarers' Trust as conducted by Lefkowitz & Slade (2019), the collected data included a high percentage of respondents from the Philippines. This is expected as the researcher is an employee of the Maritime Industry Authority (MARINA) of the Philippines. Likewise, latest industry statistics estimates the Philippines as the largest seafarer-supplying country (BIMCO/ICS, 2021), hence the high probability of participation from numerous MET institutions and stakeholders.

3.5 Semi-structured Interview

To help reach the objectives, particularly in answering the 3rd and 4th research questions, invitations for interviews were sent to identified MET practitioners with actual experience in MET, including an associated track record of research focusing on technology, as well as social and educational issues relating to technological developments. Invitations were sent to academics of an international association of MET institutions, a regional cooperation network for seafarers, education authorities and higher-ranking officers of selected MET institutions, shipping companies and crewing agencies in the Philippines. The seven persons who accepted to be interviewed were all connected with the WMU. Following ethical protocols, the interviewees shall be anonymized and shall be referred to with coded names as follows: Respondent A, Respondent B, Respondent C, Respondent D, Respondent E, Respondent F and Respondent G.

The interviews were conducted in-person or via zoom following the preference of the interviewees. The expressed consent of interviewees was requested before recording of the conversation was made. The transcript of the interview was analyzed and patterns or themes were extracted. The substantive information was then related with the results of the quantitative and qualitative data gathered through the survey.

3.6 Analysis of Data

Further to the validation process, the collected data was tested for internal consistency. Cronbach alpha was used to determine the extent to which all the items in the survey instrument measure the same concept (the word "construct" was used in the validation tool) and hence, ensuring the inter-relatedness of the items within the survey (Tavakol & Dennick, 2011).

To address the 2nd research question, the inputs of the respondents in the survey questionnaire designed with Likert-type items were analyzed using nonparametric procedures such as frequencies, crosstabulations and chi-squared statistics. The statistical software suite developed by IBM (International Business Machines) called Statistical Package for the Social Sciences (SPSS) was used for data management. Descriptive statistics like median and mode were used to measure the central tendency for the gathered data. This analysis was deemed appropriate because data was taken from the ordinal scale which can be analyzed through central tendencies (Allen & Seaman, 2007).

In addition, the short-constructed responses to the open-ended survey questions and the information learned from the interviews were coded for a thematic analysis. This process is recommended as an effective method for analyzing qualitative data in order to identify patterns or themes, as well as to understand perceptions and experiences of respondents (Maguire & Delahunt, 2017). After the completion of data-processing, the findings were presented in the context of the MET system.

3.7 Ethical Considerations

Prior to collecting the data, the researcher followed the protocols established by the WMU Research Ethics Committee. The request for conducting research involving human participants was submitted, as well as the guarantee to ensure that the data would be strictly protected and deleted upon the completion of the study.

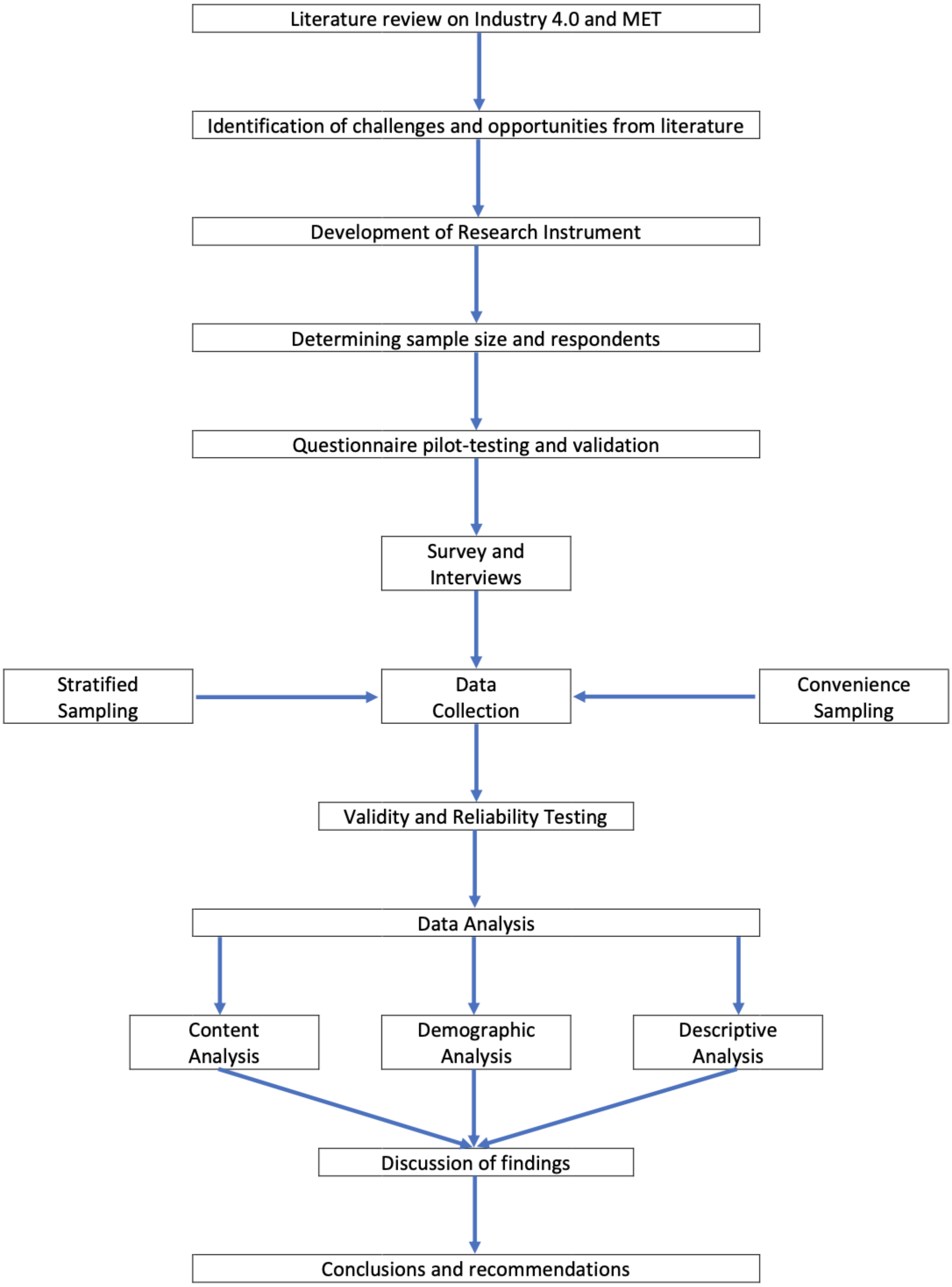
During the data gathering, the researcher informed the participants in advance about the research process, through an invitation email and the cover letter of the actual survey instrument. Expressed consent was sought from interview participants before recording was started.

3.8 Chapter Summary

This chapter discussed the mixing and sequencing of methods used for the dissertation. The development and validation of the research instrument were also explained in detail. The alignment of the quantitative and qualitative methods with the study's objectives and with answering the research questions was thoroughly explained. The reasons for using a mixed-methods approach were given, as were the ethical concerns of the study.

Figure 4

Methodological Framework



Chapter 4 Findings

This chapter presents the findings from the data gathered. First, the qualitative information from the content analysis is introduced as the basis for designing the research instrument. Then, the data resulting from the survey is presented, one part quantitative, which pertains to the responses on Likert-type items, and another part qualitative, the short-constructed responses to the open-ended questions. Finally, the outcome of the thematic analysis is synthesized with the information gathered from the interviews.

4.1 Content Analysis

In order to find answers for the research question: What factors of Industrial Revolutions are affecting the development MET?, a content analysis was used to examine challenges and opportunities reported in academic articles, dissertations and peer-reviewed journals. The researcher limited the search from works published from 2011 onwards in line with the introduction of the concept of Industry 4.0 in Germany. From carefully selected scholarly works, concerns and issues in MET in relation to automation and digitalization were reviewed. The relevant contents were sorted into five components of the MET system: organizational culture, people, process, structure and technology. The summary of the analysis in relation to automation is presented in Appendix D, and in relation to digitalization in Appendix E.

4.2 Quantitative Data from Survey Questionnaire

The collected responses were appraised to ascertain that only professionals working within the maritime sector have answered the survey. After careful review, 127 out of

128 responses were considered valid. One response was excluded because the respondent cannot be identified within the domain of the maritime sector.

After determining the valid responses, a reliability test through Cronbach's α (alpha) was conducted. Chalmers (2018) explains that reliability coefficient assumes that all items in the survey instrument are of equal importance in measuring an unobserved construct, and the statistic is bounded within [0, 1], where measures closer to 1 indicate less sampling and measurement error, hence, better measurement precision. The Cronbach's α based on standardized scale is presented in Table 1. The standardized α is used with the assumption that all the Likert items are parallel and the variance of each item are equal, thus resulting in a more stringent measurement (Chalmers, 2018).

Table 1

Cronbach's α Based on Standardized Scale

	α	N of items
Automation items	0.706	25
Digitalization items	0.714	25
Whole instrument	0.819	50

Different authors reported different acceptable values of Cronbach's α. For Bland & Altman (1997), α values ranging from 0.7 to 0.8 are regarded as satisfactory. Equally, Lavrakas (2008) testified that a critical alpha value of 0.70 has been proposed by some authors, which above this threshold, researchers can be certain that the scale is reliable. Likewise, Nunally (1967 and 1978) maintained and consistently recommended the 0.70 standard cutoff criteria, while expressing that 0.80 reliability standard is ideal for basic research and at least 0.90 reliability standard for applied tests (Nunnally and Bernstein, 1994).

With the cited studies, it can be expressed that the instrument used for this dissertation passed the test of reliability with Cronbach's α values greater than the 0.70 threshold or cut-off criteria. Hence, the survey should be reliable for making inferences in relation to the issues being addressed by the dissertation.

The demographics of respondents is presented in Table 2. and the list of countries of origin or nationality of respondents is shown in Table 3.

There are 127 respondents in this study coming from 46 countries and almost a third (41 individuals, 32.3%) are females. Further, 46 respondents (36.22%) are working in educational institutions, while more than a quarter (34 persons, 26.77%) are working in the Maritime Administration of their governments. Furthermore, four individuals who responded "others" for Sectoral affiliation were identified as follows: one is working with a manufacturer of simulators and supplier of maritime solutions, one is a medical practitioner conducting fitness examinations of seafarers, one is a Naval Officer, and one is working in a seafarer's welfare organization.

As regards the "Nationality" of respondents, 51 individuals or 40.16% come from the Philippines. This circumstance is explained in Section 3.3 and is expected because the researcher also comes from the same country.

Table 2

*Demographics (*N *= 127)*

Age range	n	%
21 – 25 years	4	3.15
26 – 30 years	28	22.05
31 – 35 years	16	12.60
36 – 40 years	22	17.32
41 – 45 years	18	14.17
46 – 50 years	14	11.02
51 – 55 years	11	8.66
55 years and above	14	11.02
Gender		
Female	41	32.2
Male	86	67.7
Sectoral affiliation		
Educational institution – Private	18	14.17
Educational institution – Public (government)	28	22.05
Government Agency – Coast Guard	14	11.03
Government Agency – Maritime Administration	34	26.77
Government Agency – Port Authority	4	3.15
Seafarers	19	14.96
Shipping company, crewing agency, shipping logistics	6	4.72
Others	4	3.15

Table 3

*Nationality of Respondents (*N = *127)*

Angola	1	Mexico	2
Antigua and Barbuda	1	Morocco	2
Australia	1	Namibia	1
Azerbaijan	1	Nigeria	2
Bahrain	1	Norway	3
Bangladesh	1	Pakistan	2
Chile	1	Papua New Guinea	1
China	1	Perú	4
Croatia	1	Philippines	51
Denmark	1	Poland	2
Ecuador	1	Romania	1
Egypt	1	Russia	1
Estonia	3	South Africa	3
Georgia	2	South Korea	3
Greece	1	Sri Lanka	1
Guatemala	1	St. Vincent & the Grenadines	1
India	4	Tanzania	1
Indonesia	3	Thailand	2
Iran	1	Timor-Leste	1
Iraq	1	Ukraine	3
Japan	2	United Kingdom	2
Kenya	2	United States of America	1
Malaysia	3	Viet Nam	2

The distribution of answers to the survey tool is presented in Appendix J for frequency of responses for automation items, and Appendix K for digitalization items. The scale points are designated with the following categories:

1 – Strongly disagree

2 – Disagree

3 – Slightly disagree

4 – Slightly agree

5 – Agree

6 – Strongly agree

4.3 Qualitative Data from Survey Questionnaire

Six open questions were included in the survey instrument. The short-constructed answers of respondents were classified into two: the identified challenges, and the recognized opportunities with regard to automation and digitalization.

The most agreed survey items on automation are presented in Appendix L. The highest count with almost all respondents agreeing (98.43%) is Item 2 (Automation in the shipping industry is an indicator that modern technologies should also be integrated into the MET system). This is followed by the Item 6 (Automation is best taught with the use of computers and simulators) with 95.28% of respondents' agreement; then Item 15 (Simulators and computers are indispensable in teaching automation) together with Item 16 (The MET system will always need human leaders for establishing a clear chain of command) with both 94.49% of respondents agreeing. A thoughtful evaluation of the other most agreed survey items shows that a great majority of respondents agree that automation helps in various aspects of the MET system; for example, E-learning as an effective solution to address geographical and time differences so that students can learn automation updates when and where they are needed (92.91%); Automation of procedures in MET institution helps in identifying conflicts or misalignment between the desired norms and values (92.91%); Integration of Industry 4.0 technologies into shipping signals the coming of e-farers and shore-farers or shore-based seafarers with advanced digital skills (92.13%); and MET institutions that use shipping industry automation to their advantage are likely to receive more recognition and popularity in the academic sector (91.34%).

The most agreed survey items on digitalization are presented in Appendix M. The highest tally with a great majority of respondents agreeing (96.06%) is Item 29 (Digitalization makes it possible to engage education authorities, academic staff and industry partners to co-create effective instructional materials) and Item 46 (E-learning resources and digital educational services optimize learners' opportunities by supporting inclusive and interactive global learning environments). The other survey items on digitalization widely agreed by respondents include: Digitalization of administrative procedures in a MET institution is useful in promoting expectations and norms (94.49%); Digitalization increases learner motivation through interactive teaching strategies such as gamification and simulations (92.91%); Digital technology facilitates efficient assessment of learning, which in turn enables improvement initiatives (91.34%); Digitalization balances gender inequality by bringing in new opportunities for all genders (91.34%); and Digitalization enables collaboration among maritime industry stakeholders for co-creating, co-delivering, and co-funding an effective MET (90.55%).

The most disagreed survey items on automation are presented in Appendix N. The highest count with scores of respondents disagreeing (80.31%) is Item 18 (Automation does not help the MET system promote gender-equal careers in the shipping industry). This is followed by Item 17 (Automation fuels gender inequality because technically-oriented education and the natural sciences are traditionally male-dominated) with 66.14% of respondents' disagreement; and Item 12 (The current national MET curricula in my country is responsive to automation in the shipping industry) with 60.63% of respondents not agreeing.

The most disagreed survey items on digitalization are shown in Appendix O. The highest tally with a majority of respondents disagreeing (75.59%) is Item 33 (Providing capacity building for technological literacy of personnel should not be the responsibility of MET administrators and managers) and Item 48 (I am afraid of being replaced because of the adoption of digital technologies at my workplace). The other survey item disagreed by 71.65% respondents is Item 31 – Digitalization weakens organizational leadership because it undermines the chain of command.

To uphold objectivity in the discussion of findings, the researcher included controversial survey items or the parts where the respondents were almost equally divided. These survey items are presented in Appendix P. The three controversial items touches on the issues of independence and control of educators over the educational process should curriculum development and delivery be automated (agree side = 64, disagree side = 63); digitalization being not favorable for all generations, particularly for those born earlier than 1980 (agree side = 63, disagree side = 64); and that digitalization is blurring the boundaries between academic (bachelor's degree) and vocational approaches to MET (agree side = 68, disagree side = 59).

Since not all respondents have pedagogical background, the responses included general experience or perception, and not particularly focused on the challenges and opportunities for the MET. Thus, to further substantiate the collected quantitative data, a semi-structured interview was added as a third part of the methodology.

4.4 Qualitative Data from Semi-Structured Interview

The semi-structured interviews were conducted primarily to answer the 3rd research question: How can MET be described from a systems theory perspective?

According to Respondent C, generally, when people say MET, many are thinking about seafarer education and training. But when educators say or write MET, they should say the context of the MET they are referring to for clarity because MET is a very generic term that can apply to so many things. It can be denoted as the education and training for the maritime industry, which then covers all the aspects of the maritime industry. So, human resources and development via education and training for the purposes of the maritime industry. Hence, the education and training for maritime purposes which will relate to seafarers, ports, the design of ships, the building of ships, the finance of ships, the market, and so many other endeavors in relation to maritime activities. The respondent explained that broadly speaking, maritime education will go way beyond seafarer education and training. However, for the vast majority of MET institutions purporting to deal with seafarers, that is the narrower definition of MET.

The perspective of contextualized definition of MET is also alluded to by Respondent B, saying that the MET is wider in context than seafarer's education and training. It was clarified that MET refers to education and training of all maritime professionals, which includes the formal and informal education or in-service training, and sometimes, a training ashore in between service at sea for upskilling or re-skilling. As a system, the context to where MET is situated should not be neglected because systems are primarily different by jurisdiction. The respondent emphasized that there is no one standardized system in terms of MET because there are numbers of existing education and training systems in various jurisdictions. The respondent said:

> At the end of the day, we should not forget that MET is a part of a bigger educational system. It is usually bound by certain regulations, like accredited or authorized by the Ministry of Education or Department of Transportation in a country. That is the challenging part to look at, how different functionalities of the system, the governance by different kinds of authorities, with diverse intentions, and their responsibilities (Respondent B, personal communication, August 9, 2022).

Respondent C also expounded in this manner by stating that if seafarer education and training is taken as a reflection of MET or called MET, acknowledging its limitations, then it should be interrogated: in what way is it a system? The respondent elaborated:

> I think that the best way to think about the MET system, with respect to seafarers, is to think about three component parts: one is the legal framework, which allows for international law to be implemented in the relevant jurisdiction, given the nature of seafarer education and training in international shipping. The legal framework at the international level and at the national level is one of the pillars. The second pillar is the administrative processes that implement the legal requirements. This is what we normally see expressed as maritime administration in any jurisdiction. The third pillar entails translating

> the legal framework and administrative processes into the operational functions of an MET institution, which happens in the learning centers, in universities or educational institutions. So, we see three pillars, and like a tree-legged stool, if we take any one of the legs away, we cannot sit on it properly. For the system to work well, these three things have to function in collaboration, in conjunction, and seamlessly together. If we take the example of the STCW, then we have a high-level macro international framework; by ratification, it becomes a legal framework in one country, and then the requirements are translated into administrative processes or quality standards. These three components come together to form the system. This is what I would say is how MET suits itself to be a system. MET is defined uniquely and in a limited way as a seafarer's education and training (Respondent C, personal communication, August 8, 2022)

Guided by the presented insights, MET can thus be described as a system with interrelated components and with a structure contingent on the context in which the MET system is situated. One way to describe the MET system is to look at it as the education and training of seafarers, in which the structure of interconnected parts includes the international and national legal framework, the maritime administration with authority, and the administrative processes or quality standards.

4.5 Chapter Summary

In summary, there were 127 respondents and seven interviewees who participated in this study. The results of the content analysis, quantitative data from the survey, and qualitative data from thematic analysis and semi-structured interviews provide evidence that factors of Industry 4.0 influence the development of MET and affect the components of the MET system. The extent of influence, particularly the impact of automation and digitalization on the components of the MET system, will be explained in Chapter 5.

Chapter 5 Discussion and Analysis

This chapter synthesizes the results from the content analysis, survey and semi-structured interviews. In line with the four research questions of the study, the relevant literatures reviewed and the conceptual framework, the patterns and the themes, as well as ambiguities or inconsistencies are identified. The challenges and opportunities are explained in detail with specific quotes from the data, and the relationships between the findings are also highlighted.

5.1 MET as a System

Dong (2014) explained that MET has traditionally been defined as an educational system aimed at training seafarers for merchant vessels; however, owing to the expansion of the shipping industry, a new definition was proposed encompassing "areas of ship building and maintaining, ship operation, maritime management and services, including finance, brokerage, maritime law, insurance, as well as maritime teaching and researching." (Dong, 2014, p. 116)

A corroborating insight on defining MET as a system was provided by one of the interviewees, Respondent D, saying that the definition of MET has evolved significantly over time. Introducing a historical perspective, the respondent described that MET used to be solely concerned with maneuvering ships and operating engine equipment. Through time, the concept of MET changed, moving from a restricted to a broader notion. The respondent narrated:

> Since the 1990s, MET has expanded from licensing training to other aspects of maritime-related topics such as shipping economics, maritime laws and regulations. However, that is still relatively limited, particularly in those areas

> that should be directly relevant to shipping, in which case we refer to it as part of the MET. The definition is always evolving (Respondent D, personal communication, August 19, 2022).

The evolving and growing concept of MET is indicative of its nature as a CAS characterized by complexity, self-organization, emergence, and adaptation. Today, MET refers to the education and training of all professionals or workforce within the maritime industry. This includes seafarers, naval architects, shipbuilders, administrators in the maritime governments, educators in MET institutions, logistic engineers and port managements specialists, marine software engineers and manufacturers of equipment and simulators, coast guard and port state inspectors, and a wide range of other people with different maritime occupations. Further, MET is offered in various approaches: in vocational and academic arrangements, as well as formal, informal, and even nonformal structures. Furthermore, the range of knowledge and specializations of MET are delivered at various levels, from secondary and higher (tertiary) education up to graduate and post-graduate studies. Therefore, MET can be viewed as a CAS that comprises subsystems, components, and elements that operate in relation to the education aspect of the maritime industry.

5.2 Effects of the Industrial Revolutions to the Development of MET

The answers to the 1st research question (What factors of Industrial Revolution are affecting the development of MET?) were taken from existing literatures through content analysis. It should be noted that the influences of the ongoing 4th Industrial Revolution, touted as Industry 4.0, to the development of MET were studied and are still being investigated in so many ways, from maritime business perspective to educational approach, and even from socio-political standpoint. Hence, the presented summary of information in Annex D and Annex E as a result of the content analysis are simplifications intended to set the context of the research.

The results of the content analysis show the complexity of the views of various researchers. In relation to MET, automation and digitalization are deemed within the spectrum of ideas ranging from extremely disadvantageous to exceedingly beneficial, including all the possible variations in between, as well as neither unfavorable nor helpful at the crosspoint. On the negative end of the spectrum, Jo et al. (2020) say that educational needs and new competences in line with Industry 4.0 technologies call for a new generation of seafarers with advanced skills to manage "intelligent" and "smart" ships. This is because innovations are accompanied by apprehension of the unknown and uncertainty regarding future risks. Even the European Union lacks a clear digitalization strategy for its maritime industry (Babica et al., 2019). On the positive end, Hult et al. (2019) declare that the estimated timeframes for automation suggest no threat to the maritime occupations for the coming generation. This is because digitalization has made it easier for government, industry and knowledge institutions to work together (Peeters & Pilon, 2018). This can make it easier to come up with strategies to deal with the vulnerabilities of the maritime sector. In the middle, a moderate analysis is provided by Baldauf et al. (2018), saying that the integration of new technology and the use of modern equipment will require changes in curricula and teacher competence because state-of-the-art machineries and the latest tools will transform the nature of work across industries (Frey & Osborne, 2013). This perspective suggests changes and work to be done but does not indicate a valuation of automation and digitalization either negatively or positively.

The researcher deems it prudent to hold off on making inferences at this juncture. As Manuel (2016) cautioned, "If there is one area where history should teach us clearly, it is to be hesitant in making predictions, particularly with respect to subject areas that are impacted by technology!" (p. 480).

Having in mind the complexity alluded to in previous studies and taking into consideration the findings of this dissertation, the answer to the 1st research question could then be summarized in this manner: Industry 4.0 factors affect the components of the MET system in so many ways. Automation and digitalization are not just innovations in the shipping industry and MET sector but a technological influence that is transforming organizational culture, processes, and structures, with profound effects even on technology itself, thus affecting how MET professionals do their work and the way they interact with each other.

An additional empirical data collection method was used, the self-administered survey composed of 50 Likert-type statements and six open questions to further contextualize the challenges and opportunities collated through the content analysis. The analysis of the data gathered from the survey is presented in the next section.

5.3 How Automation and Digitalization Affect the Components of MET?

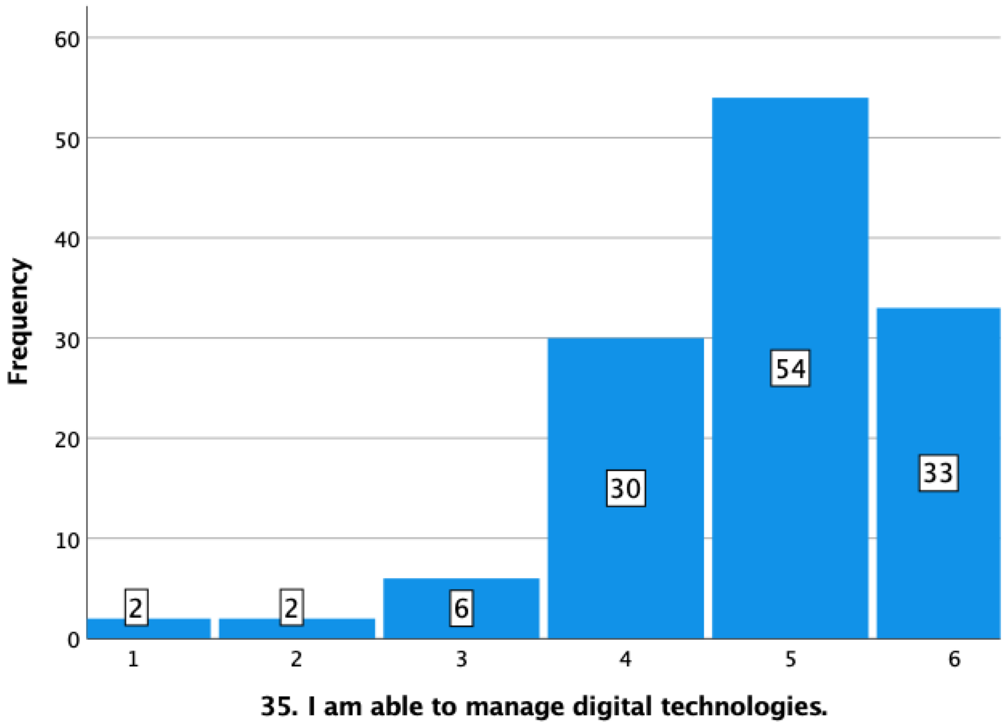
One common theme in existing relevant studies is the effect of automation and digitalization on generations or demographic cohorts. It was alluded to that Shahbakhsh et al. (2021) pointed out that when Industry 4.0 penetrated the maritime industry through autonomous shipping, the emerging strategies have brought challenges that may cause significant concerns for active seafarers certificated under the STCW Convention, 1978, as amended. While the authors identified only seafarers, the concern is true for all maritime professionals.

The current workforce in the maritime industry is obviously multi-generational, having both Gen X or people born starting in 1965, and Millennials, or the demographic cohort born between 1981 and 1995, including some Gen Z, or the age group of those who were born from 1996 to 2010. This is also reflected in the distribution of respondents in this study, as shown in Table 6. While the majority of Gen Z and the incoming Generation Alpha (born 2011 onwards), who will pursue a career in maritime can still be educated in tune with advancements in automation and digitalization, the existing maritime workforce is seemingly disadvantaged. This is evident in the study conducted by Onar et al. (2018), who suggested that in order to close the generational divide, educational systems should be transformed to provide encompassing skill sets and job-specific competences, as well as new formats for ongoing education, because curricula contents, including educational approaches to skill development, must be responsive to the demands of a new generation of workers.

Despite the fact that previous studies have noted generational issues, the survey results of this study show that a vast majority of respondents (92.13%) expressed that they are able to manage digital technologies. The distribution of responses is shown in Figure 5.

Figure 5

Histogram of Responses to Item 35



To determine if the responses to the statement are related to generation, the age range was regrouped into demographic cohorts as shown in Table 4. Relatedly, Table 5 shows the descriptive distribution of Generation against Survey Item 35. Figure 5 and Table 5 show that median = 5 and also, mode = 5. Hence, it can fairly be concluded that both Gen X and Millennials are coping with the advancements in digitalization. It should be noted that all the four Gen Z respondents indicated that they are able to manage digital technologies, while three Gen X expressed negative responses (strongly disagree = 2; and disagree = 1), as well as seven Millennials (disagree = 1, slightly disagree = 6).

Table 4

Demographic Cohorts of Respondents (N = 127)

Cohort	n	%
Generation X	57	44.9%
Millennials	66	52.0%
Generation Z	4	3.1%

Table 5

Crosstabulation of Generation and Survey Item 35 (N = 127)

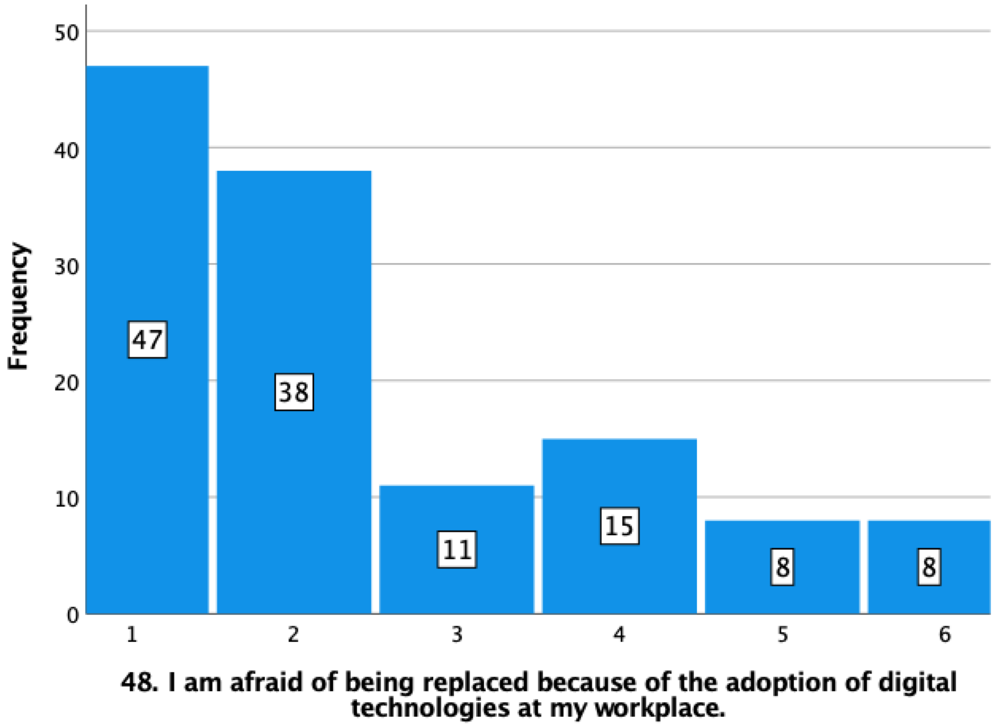
I am able to manage digital technologies.	Gen X	Millennials	Gen Z	n
1 – Strongly disagree	2	0	0	2
2 – Disagree	1	1	0	2
3 – Slightly disagree	0	6	0	6
4 – Slightly agree	15	15	0	30
5 – Agree	31	22	1	54
6 – Strongly agree	8	22	3	33
Total	57	66	4	127

In order to establish if the relationship is significant, the Chi-square (χ^2) test of independence was calculated. Initially, the null hypothesis assumes that responses in Survey Item 35 are not associated with or are independent of Generation. The computed Chi-square (*p*) value is 20.909 with an asymptotic significance (2-sided) = 0.022. Since the significance level is <0.05, it can be inferred that there is enough evidence to reject the null hypothesis and conclude that responses to Survey Item 35 are not independent of Generation. Simply put, there is a significant association between Survey Item 35 and Generation where $\chi^2(10) = 20.909$, $p < 0.05$. It should be noted that because the crosstabulation is a 6x3 table, the degrees of freedom (*df*) for the test statistic was computed as $df = (\text{Rows} - 1) * (\text{Column} - 1) = (6-1) * (3-1) = 10$.

Managing digital technologies is one thing. But perception about what technology may bring in the future is another. Hence, one other item in the survey was intended to determine if professionals working in the maritime industry feel threatened by losing their jobs because of the adoption of digital technologies. According to research such as Frey and Osborne (2013) and Karacay (2018), Industry 4.0 technologies have enabled automation and digitalization to take over a group of tasks that were previously performed exclusively by human competence through cognitive skills, and that automation will gradually replace the human workforce. However, the survey results of this study do not fully align with their findings, with 75.56% of respondents indicating that they are not afraid of being replaced even if digital technologies are adopted at their workplace. Figure 6 summarizes the distribution of responses.

Figure 6

Histogram of Responses to Item 48



Remarkably, albeit 92.13% of respondents expressed that they are able to manage digital technologies and that 75.56% of respondents indicated that they are not afraid of being replaced even if digital technologies are adopted at their workplace, the thematic analysis for short-constructed responses reveals that respondents are experiencing and perceiving that both automation and digitalization have adverse effects on human relationships. There were 58 respondents (45.67%) who stated that automation negatively affects team management and social interaction, including teaching and learning dynamics, the older generation in terms of propensity to learn new technologies, inclination for computing manually, critical thinking and problem-solving (people becoming dependent on technology), and the relevance of knowledge and skills necessitating constant and frequent upgrading of the competence of teachers and workers, which poses risks of losing employment. These undesirable effects were also identified by 39 respondents (30.71%) as regards digitalization. These findings are indicative of the CAS nature of MET as a system.

Another common theme in existing relevant literature is the effect of automation and digitalization on gender inequality in the maritime industry. Kim et al. (2019) expressed that autonomous shipping will generate new functions without a history of male-dominated occupation, which will potentially eliminate the barriers and male-oriented working culture and conditions in the maritime industry. They also noted that the advancement in autonomous technologies will improve gender parity in the shipping industry and help in addressing the strategic direction of the IMO in line with UNSDG 5. In another perspective, while Johansson (2017) acknowledges that there is a school of thought holding that digitalization will eventually enable bodily transcendence, democratize production, and end gender inequality, he maintains that technological advancements may still be a continuation of masculinity. He noted that there is a gender imbalance among young students pursuing careers as algorithm architects and computer scientists.

The divergent ideas on gender issues in relation to automation and digitalization in the maritime industry are reflected in the survey results of this study. Figure 7 shows that the 127 respondents consisted of 41 females and 86 males, while Table 12 shows the crosstabulation of Gender against Survey Item 35.

Table 6 shows that the great majority (92.13%) of both female (75.61%) and male (91.86%) respondents specified that they are able to manage digital technologies. The Chi-square (χ^2) was calculated to determine if the association of responses in Survey Item 35 to Gender of respondents is statistically significant. The computed Chi-square (*p*) value is 11.235 with an asymptotic significance (2-sided) = 0.047. Since the significance level is <0.05, it can be inferred that there is enough evidence to conclude that responses to Survey Item 35 are not independent of Gender. Therefore, there is a significant association between Survey Item 35 and Gender where $\chi^2(5) = 11.235$, $p < 0.05$. The crosstabulation is a 6x2 table, hence, the degrees of freedom (*df*) was computed as $df = (\text{Rows} - 1) * (\text{Column} - 1) = (6-1) * (2-1) = 5$.

Figure 7

Gender Distribution of Respondents

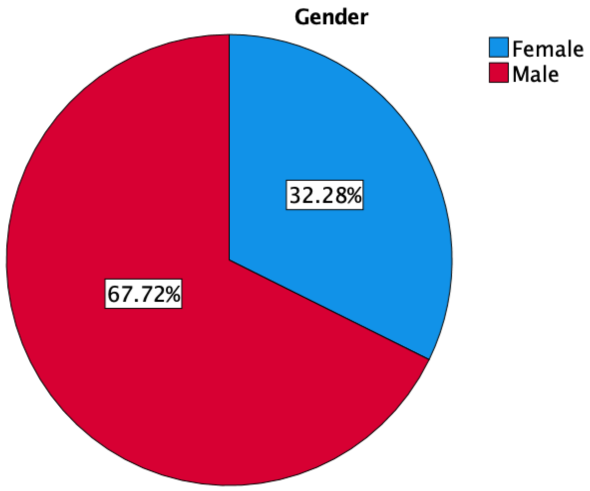


Table 6

Crosstabulation of Gender and Survey Item 35 (N = 127)

I am able to manage digital technologies.	Female	Male	n
1 – Strongly disagree	1	1	2
2 – Disagree	2	0	2
3 – Slightly disagree	0	6	6
4 – Slightly agree	7	23	30
5 – Agree	16	38	54
6 – Strongly agree	15	18	33
Total	41	86	127

The thematic analysis was conducted in line with the four open questions included in the survey: (1) In your opinion, which part of the MET system is severely affected by automation? In what way? (2) What do you think are the advantages or benefits of automation for the MET system? (3) In your opinion, which part of the MET system is significantly improved by digitalization? In what way? and (4) What do you think are the disadvantages or drawbacks of digitalization for the MET system? The results of the thematic analysis are presented in Tables 12 and 13 for automation, and Tables 14 and 15 for digitalization.

Upon comparison, Table 12 and Table 14 show that the respondents believe that both automation and digitalization have the most positive effects on the process component of the MET system. Out of the 127 respondents, 64 (50.39%) indicated various positive effects of automation, while 88 respondents (69.29%) listed an assortment of positive effects of digitalization on the process component of the MET system.

On the contrary, Table 13 and Table 15 show that the respondents deem that both automation and digitalization have the most negative effect on the people component of the MET system. Out of 127 respondents, 58 (45.67%) specified different negative effects of automation, while 39 respondents (30.71%) cited several negative effects of digitalization on the people component of the MET system. In terms of specific aspects of the people component that are adversely affected, the top three mentioned for automation were: team management (15 respondents), learning propensity (6 respondents), and personal interaction (6 respondents). Almost alike, the top three aspects listed for digitalization were: social interaction (8 respondents), propensity to learn technology, and skills development (both by 7 respondents).

More insights on the complexity of how automation and digitalization affect the components of MET can be seen in Industry 4.0 challenges and opportunities influencing the development of MET as a system, which is presented next.

5.4 Challenges and Opportunities Influencing the MET System

According to Respondent E, technology is always ahead of regulations and is always advancing without waiting for regulations. With automation and digitalization, technology is developing so much faster that even education has to catch up. This is a real challenge because most education programs, if not all, are based on some kind of regulation like policies, standards, and guidelines. Inasmuch as the process of amending or replacing existing regulations is commonly bureaucratic and takes time before changes can be implemented, frequent amendments or replacements are also not practical. The challenge of policy reforms, which is a prerequisite for updating education and training requirements, is complicated by the CAS nature of a MET system. Respondent G demonstrated that in a MET system, the changing technological environment has varying effects on different individuals and groups of people. Likewise, at an organizational level, MET institutions in various jurisdictions may be governed by different agencies, in some countries under the Ministry of Education and in others, under the Department of Transportation. As such, the policy landscape where a MET system is situated is a major challenge that influences MET.

Another Industry 4.0 challenge influencing MET as a system is the alteration to established work arrangements as a result of adopting automation and digitalization. Respondent D described a situation wherein the invention of smart and intelligent machines not only poses risks of job loss and displacement of the workforce, as well as diminishes the employability of previously educated and trained personnel, but also that the technological advancement caused by automation and digitalization creates an ever-expanding maritime industry. Thus, the respondent called it a dilemma for the MET system.

As regards opportunities, Respondent D emphasized that whatever trajectory of development automation and digitalization take, the MET system is established on a solid foundation of knowledge and praxis that most maritime professionals, especially the seagoing workers, must learn. The respondent said:

> When we consider these issues, we must remember that knowledge in education and training is divided into two areas or categories: the fundamental part and the application part. The fundamental part or theoretical knowledge is

closely related to basic knowledge such as thermodynamics, electrical equipment, and other fundamental information. This is true for both the deck and engine departments. On the other hand, the application part is much more practical. For example, automation has a fundamental part in electrical engineering, like automation control theory, and that fundamental part will never change. Some dynamics may be altered. Since the beginning of the 17th century in the 1st Industrial Revolution, the fundamental knowledge about diesel engines has remained the same. The fundamental understanding of a steam turbine remains unchanged. Even if automation technology and digital systems are introduced, this type of fundamental knowledge remains unchanged. Only the application is different. Hence, this is an opportunity for MET institutions. The part that MET institutions provide is closely related to basic knowledge. There is nothing to change in the theoretical content. However, it is critical that they demonstrate how to apply this knowledge to the sophisticated emerging automation technologies and digital systems. (Respondent D, personal communication, August 19, 2022)

Another respondent alluded to this insight when asked about the Industry 4.0 opportunities influencing MET as a system. Respondent F stated that automation and digitalization supplement the theoretical education and training provided by MET institutions in the sense that professional development courses provide a person with a broad understanding of general principles, whereas automation and digitalization focus on getting the job done effectively and efficiently. In the context of education and training for seafarers, the respondent gave a concrete example:

I believe the job would be altered. Perhaps people will be out of work because there will be no more seafarers on autonomous vessels. But whether that is true or not, I do not dare to say, but I believe that there is still a need to educate those who are onshore. Of course, we could automate our entire lives, and then robots would take over, and humans would be obsolete because we could

> remove the need for ourselves from the work. Then comes the question of what we should do. At the end of the day, perhaps some still want to work onboard vessels. I believe there will always be a need for work. Perhaps there will be more workers ashore, which may be beneficial to them as well, because it may be more comfortable for them. They will, however, need to consider what they are doing, unless we delegate that to robots, which I would prefer not to see. But we still have to make a choice. How will the ships be operated? What type of energy do we consume? How do we create systems? How will we create safety? Someone must consider it whether it is onboard the ship or ashore. And that is one of the functions of the MET system. (Respondent F, personal communication, August 9, 2022)

5.5 Chapter Summary

The development of MET from the 17th century demonstrates the cumulative effects of the four Industrial Revolutions. Work mechanization, energy innovation, automation, and digitalization all brought challenges and opportunities to the components of the MET system. The MET system evolved into complex configurations of education and training programs as a result of system adaptation, and it continues to evolve in response to technological advancements in the maritime industry.

Chapter 6. Summary and Conclusions

This chapter summarizes the salient points of the study by concisely answering the four research questions. Afterward, recommendations are presented. Finally, the limitations of the work are identified together with propositions for future research.

6.1 Research Conclusions

6.1.1 What Factors of Industrial Revolutions are Affecting the Development of MET

Industrial Revolutions are not just feats of technological innovations. The phenomenon is called that way because of the profound changes it brings to society and the life-changing effects caused by its factors.

The invention of the steam engine was the catalyst for the mechanization of work during the 1st Industrial Revolution. When seagoing vessels were powered by engines, navigation and trading expanded, spurring the establishment of MET institutions and formal competency assessment. During the 2nd Industrial Revolution, the discovery of electrical energy propelled shipping to new markets and trading destinations. The addition of electrical systems to trading ships fuelled demand for engineers and even stewards, necessitating specialization in marine engineering and catering personnel training for the expanding maritime industry. Computers, electronics, and the internet were defining factors of the 3rd Industrial Revolution, allowing educators and learners not only instantaneous and free access to information, but also the use of simulators. The paradigm shifts in MET resulted in wide variations in educational and training standards, resulting in a significant disparity in competences, particularly in the situation of seagoing workforce. The combined effect of these three Industrial Revolutions can thus be attributed to the birth of the STCW Convention in 1978.

In the 4th Industrial Revolution, automation and digitalization, as well as other factors of Industry 4.0, are transforming society by altering how people live and how things are done. When Industry 4.0 factors, such as automation and digitalization, were introduced in the maritime industry, the life and work of maritime professionals were transformed. Also being reformed are the education and training that shape the knowledge, skills, values, and beliefs of the various personnel for the vast array of maritime functions they will perform. Therefore, the changes brought about by automation and digitalization will again increase the disparity of MET content and educational arrangements among maritime nations.

6.1.2 How MET can be Described From a Systems Theory Perspective?

Systems theory is the study of systems and how they interact with one another within a larger, more complex system. The dissertation adopted this perspective and considered MET as a system with subsystems, components, and elements characterized by complexity. The complexity originates not only from the internal environment of the MET system but also from inseparable structures affecting its processes and quality, inter alia, international regulations and standards (e.g., Regulation I/10, Recognition of certificates), national framework of education and training systems, governance or maritime administration, and requirements of the shipping industry.

The data collected, combined with the insights provided by the MET practitioners who took part in this study, provide a sensible approach to how MET can be described from a systems theory perspective. A proper description of the MET system should be based on the context, international and national frameworks, and the net effect of socio-technical development over the four Industrial Revolutions.

6.1.3 How Automation and Digitalization as Factors of Industry 4.0 are Affecting the Components of MET?

MET in the 4th Industrial Revolution is exceedingly complex and is challenged by the ever-advancing Industry 4.0 technologies, and at the same time at a stage of transformation that can bring so many opportunities for the maritime sector.

The automation and digitalization happening both in the shipping and MET sectors are affecting the knowledge and competence requirements for teachers. Based on the study, educational processes were perceived to be most benefiting from automation and digitalization through ease of dissemination of and access to prepared lessons, standardization of delivery, and efficiency of assessment. On the contrary, these factors of Industry 4.0 were deemed detrimental to the human element in terms of depersonalized interaction, disparities in propensity to teach and learn technology, as well as class dynamics.

6.1.4 What Industry 4.0 Challenges and Opportunities are Influencing MET as a System?

Technology is always ahead of regulations and advances without regard for regulations. With automation and digitalization, technology is evolving at a rate that education cannot keep up with.

Because MET is a derived need of the shipping industry, which is governed by various sets of laws and policies at various levels, from international domain to national or domestic jurisdictions, the Industry 4.0 challenges influencing MET as a system are primarily associated with regulations. In addition to the time it takes to develop regulations for new technologies, the process of amending or replacing existing regulations is often bureaucratic and time-consuming. Policy reforms, which are required for updating education and training requirements, thus influences the pace of development of the MET system.

As regards opportunities, whatever trajectory of development automation and digitalization take, the MET system is established on a solid foundation of knowledge and praxis for most maritime professionals, especially the knowledge and competence that seagoing workers must learn. Automation and digitalization do not replace the theoretical education and training that MET institutions offer. Instead, they supplement it by putting the focus on how to do the job effectively and efficiently.

6.2 Recommendations

The researcher explored the effects of Industry 4.0 on MET and investigated how factors of Industry 4.0 affect components of MET as a system. The inspiration came from academics who alluded to the significance of studying the influence of technological advancements on the development of MET (Bolmsten et al., 2021; Manuel, 2017; Scanlan, 2022; and Sellberg, 2020). Likewise, this dissertation would recommend that the investigation of the influence of technological developments on MET be given importance in consideration of the impact of quality and effective MET on the safety and security of the maritime industry. In even-handedness, this dissertation was not able to fully answer all the research questions. As such, future research may be focused on the following areas:

- What subsystems and components make up an effective MET system?
- Which mode of curriculum delivery optimizes the use of Industry 4.0 technologies in MET?
- How can automation and digitalization help the MET system produce an effective workforce for the maritime industry?

Ultimately, the researcher believes that this dissertation has opened up pathways to understanding the complex adaptive nature of the MET system, an awareness that is essential for sustaining the existing maritime professionals through the challenges of the 4th Industrial Revolution and for taking advantage of developing a new generation of resilient and future-ready workforce for the maritime industry.

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Appendix A. Defining MET Using Semantic Approach

MET is a string of three significant words: “maritime”, “education” and “training”. The following discussion provides some details for each concept.

Maritime is a particular term that is often used interchangeably with the word “marine”. For the purposes of this research, the semantic analysis is focused on the definition of “maritime”. Hildebrand, & Schröder-Hinrichs (2014) stated that in the World Maritime University, “maritime” is understood as referring to ships, shipbuilding, shipping and the associated activities. They also noted that in terms of research, the International Council for the Exploration of the Sea (ICES) explains that maritime studies aim at innovative solutions for a better exploration of ocean resources, like the design, building and operation of ships, ports, and platforms, and encompassing all human endeavors centered on sea and ocean resources.

Education is one of the most defined words in the corpus of existing knowledge. In The Republic, Plato stated that (1) education is the underlying understanding of who the student is to be educated; (2) education is the development of man’s personality as a rational and moral being, the right cultivation of the soul, the general harmonious well-being of life; and (3) education is to help the students to grow and develop their character and ability to do good. The British educationalist Thomas Percy Nunn (1920) explained that education is the complete development of an individual in order to make a unique contribution to human life to the best of his or her ability. James Drever, Chair of Psychology in the University of Edinburgh and the first Professor of Psychology at a Scottish university was quoted for saying that “Education is a process in which and by which knowledge, character and behaviour of the young are shaped and moulded” (Ravi, 2011, page 14).

With the examples cited and with so many more in the extant literature, it is practical to allude to the simplified definition of education provided by the United Nations Educational, Scientific and Cultural Organization (UNESCO): “Education is the process of facilitating learning or the acquisition of knowledge, skills, values, beliefs and habits" (UNESCO, 2021).

Training is another word which is explained in so many ways in various dictionaries, encyclopedias, articles, textbooks and researches. Google turns About 5,670,000,000 results in 0.37 seconds for the meaning of "training." Armstrong (1977, 1988, 2001) defined training broadly as the formal and systematic development or modification of knowledge, behavior, skills and attitudes through learning which occurs as a result of education and planned experience, in order for an individual to perform adequately a given task or job. Black (1961) is of the idea that training is imparting particular job knowledge to personnel so that they can perform well, with cooperation and efficiency. This idea is supported by Fuller and Farrington (1999) who explained that training should be designed to increase the knowledge, skills and abilities of people. Davis and Davis (1999) carried this notion in explaining that training is the process by which skills are improved, information is delivered and attributes are cultivated in order to support individuals in organizations to become more effective workers. Having in mind the context of this research, it is noteworthy to mention that Laird (1985) defined training as acquiring technology that allows the workforce to perform according to the standard. Hence, training may be defined as a regimen, a regulation or an experience that causes employees to acquire pre-determined and contemporary behaviors.

To synthesize the semantic definitions of maritime, education, and training, having in mind the systems perspective, the MET system may also be simply defined as the system that facilitates teaching and learning knowledge, skills, values, beliefs and habits, including acquisition of pre-determined and contemporary behaviors for application in ships, shipbuilding, shipping and the associated activities.

Appendix B. Challenges for the MET System

Components	Challenges summarized from previous researches	Sources	Aspect of MET
Organizational culture	Personal initiatives for upskilling by seafarers, vis-a-vis the responsibility of shipping companies toward investing in personnel development	Baum-Talmor & Kitada, 2022	Social Responsibility
	Seafarers' perceptions about seafaring remain oriented on physical equipment and machineries even in the age of automation and digitalization. Adaptation to technological developments will require changing these perceptions	Baum-Talmor & Kitada, 2022	Technological literacy
	Change in managerial approaches necessary to support the innovative solutions required to effectively implement and operate Industry 4.0 concepts	Mohelska & Sokolova, 2018	Leadership
People	A seafarer who stopped his seafaring career 10 years ago and serves as a lecturer today, may prove to be outdated in some important areas of knowledge and competences. Also, in this digital age, educators have to be adept at using modern technologies in teaching	Alop, 2019	Competences (seafarer)
	Requirements for human operators when remotely operating unmanned ships in areas with conventional marine traffic, need for specific training addressing remotely controlling unmanned vessel	Baldauf et. al, 2018	Competences (seafarer)
	Technology-centered approach undermines the human perspective in developing skills and advancing careers as maritime professionals	Baum-Talmor & Kitada, 2022	Competences (teachers)
	New skills and competences necessary for designing, operating and maintaining unmanned ships, automated ports and VTS, as well as developing legislation to manage interaction between manned and unmanned ships	Demirel, 2020	Competences Regulations
	The autonomous ship concept is superficially creating perception that seafarers are no longer needed in the near future	Hult et al., 2019	Career perspectives

Components	Challenges summarized from previous researches	Sources	Aspect of MET
	Millennial seafarers leave the profession before gaining the experience necessary to advance to the management level due to the waning interest in a career at sea	Jaenichen, 2017	Generation Career perspectives
	The idea of replacing active human crew onboard juxtaposed with responding to emergencies and managing inspections dampens the attractiveness of the profession	Kobyliński, 2016	Motivation
	The net impact of frontier technologies may be unfavorable for women	UNCTAD, 2018	Gender
Process	Appropriate understanding of real sea conditions remains as a necessity for navigation officers whether onboard ship or in a shore-based control center. MET institutions should just adjust the curricula for the additional new requirements.	Hult et al., 2019	Curriculum development Regulations
	Creating, approving and implementing new courses and curricula takes time and unable to respond quickly to increasingly rapid changes. Even the updating of existing curricula may take a year, and creating new programs may be even longer due to bureaucratic processes. Consequently, new curricula may already be outdated when start gradates working	Alop, 2019	Curriculum design
Structure	Segmenting of fields of knowledge and topics, and separating one another in the learning process poses a big problem in education. Teachers of one subject do not worry about what or how other lecturers approach their subject matter. Segmentation into topics and subjects is an artificial strategy because the world is a network of complex interconnections by nature, hence the great importance of adopting a holistic perspective in education.	Alop, 2019	Curriculum design
	The level of education and training for smart ship operators with specific ICT specialization related to shipping and ship management will require Master's degree	Alop, 2019	Content of curricula

Components	Challenges summarized from previous researches	Sources	Aspect of MET
	Learning environment should enable learners to create their own personalized routes allowing them to become critical thinkers.	Senčila & Kalvaitienė, 2019	Lifelong learning Learning environment
	The standard for MET institutions in establishing the professional content of the education and training program of seafarers is the STCW Convention, 1978, as amended. Until the STCW Code is amended, there will not be a theoretical basis for future responsibility and competence requirements.	Senčila & Kalvaitienė, 2019	Regulations
	Polarization of employment between low-skilled and high-skilled non-routine occupations	UNCTAD, 2018	Employment opportunities Career perspectives
Technology	Modern complex computer-based navigation and engine-room simulators as effective environment and tools for education and training	Senčila & Kalvaitienė, 2019	Curriculum delivery
	Online Distance Learning and e-Learning initiatives are still beset with numerous political, economic, sociocultural, technological, legal and environmental disadvantages, constraints and challenges due to lack of infrastructures and difficulty of accessing the internet, as well as adaptation towards full digital literacy and learning participation from traditional schools and communities	Masuku, 2021	Infrastructure Educational environment

Appendix C. Opportunities for the MET System

Components	Opportunities summarized from previous researches	Source	Aspect of MET
Organizational culture	Technology facilitates instilling an organizational culture where digital systems can flourish.	Katacay, 2018	Technological literacy
	The most common way of leading in the ship organization culture is a combination between authoritarian, bureaucratic and task-oriented leadership.	Lutzkanova, 2019	Leadership
People	New kinds of maritime-related job onshore will give women more opportunities to pursue a career in the shipping industry	ECSA, 2018	Gender
	Political, economic, social, and technological factors will influence and transform MET to create and deliver the knowledge and skills required for the so-called e-seafarer with knowledge and skills to manage the entire maritime logistics chain, with a special emphasis on knowledge of cyber security and ethics in conducting operations, as well as new knowledge and skills adapted to the digital age, the application of artificial intelligence, blockchain technology, 3D printing, and 3D printing technology.	Milić-Beran et al., 2021	Competences (seafarer)
	Future skills required in the maritime sector can be useful elsewhere providing more latitude to individual career pathways	Vincx et al., 2019	Career perspectives
Process	Connecting ships, both manned and remotely controlled, and training schools to a network. This provides the opportunity for educators and learners to be virtually on the scene, study a real scenario, and vicariously learn how effective solutions get people out of risky situations or how	Alop, 2019	Outcomes-based education Educational environment

Components	Opportunities summarized from previous researches	Source	Aspect of MET
	wrong decisions may result to damage to properties and the marine environment		
	Creates mobility from seafaring to shore-based professions, and from maritime companies to non-maritime organizations	Baum-Talmor & Kitada, 2022	Career perspectives
	Extensive use of distance and e-learning will facilitate the application of Continuing Professional Development (CPD) as a vital tool for delivery of technological developments to maritime professionals deployed at sea and ashore	Demirel, 2020	Curriculum delivery Educational environment
Structure	Labor policy: specially trained smart ship operators will be in very high demand and highly paid professionals in the maritime industry	Alop, 2019	Employment opportunities
	MET institutions generally focus on vocational skills based on navigation and engineering requirements in the STCW Code. Important to shape MET according to the needs of the whole maritime sector, particularly on the content of technology-related courses aimed at preparing professionals for future work in a knowledge driven industry	Demirel, 2020	Content of curricula
	Shareable platforms enable collaboration on common knowledge and the interchange of expertise between MET institutions, business, and other stakeholders. By offering access to a sharable training course, organizations from the industry can help project partners, workforce, and provide their useful expertise back to MET institutions. The MET community can promote and enhance its internal and external	Hieu et al., 2015	Collaboration Educational environment

Components	Opportunities summarized from previous researches	Source	Aspect of MET
	knowledge management processes by leveraging technology.		
	Industry 4.0 revolutionized and integrated modern technologies which improve value chains and creates potential for MET institutions to use automated and data-processing technologies to better its services and to alter their curricula to better meet the needs of the maritime industry and improve student learning outcomes.	Koh et al., 2021	Quality Management Curriculum development
Technology	Modern simulators and simulation software configured with very high level of reliability and functionalities of top-of-the-line simulators can mimic realistic sea conditions. The lay-out of workstations more similar and equivalent to actual bridges and engine control rooms onboard	Alop, 2019	Infrastructure Educational environment
	Modern complex computer-based navigation and engine-room simulators as effective environment and tools for education and training	Senčila & Kalvaitienė, 2019	Curriculum delivery Educational environment
	Drones can perform programmed tasks with precision and replace humans in dangerous situations	UNCTAD, 2018	Safety
	AI has the capabilities in image recognition and logical reasoning that can help humans in solving problems	UNCTAD, 2018	Support to problem-solving
	The Internet of Things supports monitoring and managing the condition and actions of connected equipment and machines, and enables more effective monitoring of people and activities	UNCTAD, 2018	Quality management
	Robotics is exponentially multiplying the potential for production processes and business, particularly in manufacturing	UNCTAD, 2018	Productivity

Appendix D. Challenges and Opportunities for MET in Relation to Automation

Component	Challenges and Opportunities	Source	Aspect of MET
Organizational Culture	The MET system will always need human leaders for establishing law and order, ethics and values, as well as for people management.	Nafchi & Mohelská, 2020	Leadership
	Integration of automation technology could also mean that the maritime industry develops into a highly technical and information technology-dependent domain, which may still favor males due to the current gender imbalance in the talent pool for skilled workers.	Kim et al., 2019	Norms
	Automation has to meet both pedagogical and commercial benefits because it is related to the reputation of the educational institution, which is judged in society by increasing the number of graduates and post-schooling job performance.	Dreher et. al, 2011	Reputation
	Autonomous shipping will generate new functions without a history of male-dominated occupation, which will potentially eliminate the barriers and male-oriented working culture and conditions in the maritime industry.	Kim et al., 2019	Stereotypes
	Automation can help in identifying conflicts or misalignment between the desired culture and the organizational structure, systems and technology.	Nafchi & Mohelská, 2020	Values
People	Simulation and simulator equipment for monitoring and remote controlling unmanned ships navigating in a coastal area covered by VTS will require changes in curricula and teacher competences.	Baldauf et al., 2018	Competences (seafarers, teachers)
	Computerization and automation allow advanced equipment and machines to perform a broader scope of manual tasks, which will likely change the nature of jobs across industries and occupations.	Frey & Osborne, 2013	Employment opportunities

Component	Challenges and Opportunities	Source	Aspect of MET
	Advancement in autonomous technologies will improve gender parity in the shipping industry and help address the strategic direction of the IMO in line with SDG 5.	Kim et al., 2019	Gender
	Lifelong learning can bridge generational gaps and help seafarers and shore-based maritime educators adapt to and lead technological and innovative growth within the maritime industry.	Sogor, 2021	Generation
	Estimated time frames for automation suggest no threat to the maritime occupations for the coming generation.	Hult et al., 2019	Motivation
Process	Content of MET will change due to the phase of implementation of degree of digitalization, in response to the required knowledge and understanding, calling for updates of curriculums in MET institutions concerning specific competence requirements related to different concepts.	Hult et al., 2019	Curriculum development
	Requirements and standards for human-machine interface like IMO A.1021(26), ISO 2412:1982, ISO 8468:2007 and ISO 9241-210:2010 informs alignment in MET curricula.	WMU, 2019	Instructional design
	Simulators are used in training for all navigational and engineering competences from pure technical to procedural skills both at individual and team levels.	Homlong et al., 2016	Educational strategy
	The (non)neutrality of technology is reflected in e-learning technologies. The question of technological neutrality centers on whether or not technology is objective and whether or not biases originate from devices themselves or just from ways in which teachers and students utilize them.	Jamil & Bhuiyan, 2021	Assessment
	Independent of availability of human instructors, either in person or across a network, new forms of interaction and	Mallam et al., 2019	Certification and licensure

Component	Challenges and Opportunities	Source	Aspect of MET
	integrated assessment methodologies between student and instructor can be developed. Mobile systems with integrated monitoring sensors can offer objective evaluation and feedback on the exercises that trainees undertake.		
Structure	All maritime regulations should ensure that the person in charge of the ship operations resides onboard the vessel.	WMU, 2019	Standards and regulations
	Industry 4.0's digital revolution entails networking, enabling human-machine interfaces, and the vocational training system has potential qualification-base to successfully deliver future digital requirements.	Gebhardt et al., 2015	Program orientation
	Advances in automation should be taught in modular courses rather than being integrated into academic programs in order for education to cope up with technological developments.	Katranas et. al, 2020	Learning environment
	In relation to technological development, it was observed that the current trend in MET is from vocational to academic approach.	Manuel, 2017	Curricula
	Simulator-based training is one of the primary considerations in MET institutions. Procurement of simulators is costly and may lead to insufficiency of training.	Ibrahim & Tawfik, 2015	Equipment, facilities and infrastructures
Technology	‘Smart ships’, or ‘intelligent ships’, are more appropriate terms than ‘autonomous ships.' Ships can, and eventually probably will, be given the full right or condition of self-government.	Hult et al., 2019	Simulators
	Simulations allow personnel training and test incident response practices as part of crew training and awareness programs, while personnel gain first-hand experience of realistic incidents in the safety of a simulator.	Scanlan, 2022	Educational environment

Component	Challenges and Opportunities	Source	Aspect of MET
	The issue with synchronous methods is that online students frequently have radically different commitments and schedules; some even reside in different time zones.	Kearns, 2012	E-learning and Virtual classrooms
	The concept of “smart ship” and “smart port” relate to the high level of automation in line with the application of modern intelligent technologies in ship and port operations.	Alop, 2019	Competences (seafarers, teachers)
	In spite of social, legal, and technological issues, the introduction of autonomous merchant vessels to the global shipping sector appears imminent.	Wróbel et al, 2017	Career perspectives

Appendix E. Challenges and Opportunities for MET in Relation to Digitalization

Component	Challenges and Opportunities	Source	Aspect of MET
Organizational Culture	The control of ships has historically been seen as a human prerogative. In the age of digitalization, there will be a fundamental shift in how leadership is demonstrated on board and how each task is assigned to the members of a shipboard organization.	Kitada et al., 2018	Leadership
	Management of human resources and cultural diversity as part of a core competency of a shipping company provides opportunities like competitive advantage and excellence in organizational performance.	Progoulaki & Theotokas, 2016	Norms
	The reputation or image of an institution has a significant impact on school selection. Students place significance on an institution's reputation, and they consider it to be a deciding factor when choosing a college.	Edirisinghe et al, 2016	Reputation
	Even in the maritime industry, different generations, such as Gen X and Millennials, have distinct characteristics that are reflected in the types of leadership behaviors they prefer and the general expectations of the team members with whom they work.	Ozdemir & Albayrak, 2019	Stereotypes
	Science and policy knowledge from the private sector and public sector should be integrated through dialogue and communication. Partnership in designing research and in producing new knowledge facilitate change that is framed at the proper organizational level and reinforced by appropriate governance structure.	Claudet et al., 2020	Values

Component	Challenges and Opportunities	Source	Aspect of MET
People	Future navigation and engineer officers should be well equipped with appropriate digital and engineering competences, cyber-attack defense abilities and software engineering skills to be able to manage the challenges brought by diverse forms of equipment and systems to be used onboard.	Sharma & Kim, 2021	Competences
	Innovation in the maritime sector may have an economic value-added objective of employment or substitution of labor by capital, while the social value-added objective is creating new employment opportunities.	Acciaro & Sys, 2020	Employment opportunities
	One school of thought holds that digitalization will eventually enable bodily transcendence, democratize production and end gender inequality. Other viewpoints express that it is a continuation of masculinity. There is a gender imbalance among young students pursuing careers as algorithm architects and computer scientists.	Johansson, 2017	Gender
People	Educational needs and new competences in line with Industry 4.0 technologies call for e-farers or seafarers with advanced skills to manage "intelligent" and "smart" ships	Jo et al., 2020	Generation
	The vast maritime industry, which includes vessel construction, ship repair and recycling, as well as equipment manufacturing, is undergoing unprecedented change as a result of exponentially increasing technological development, necessitating a greater role for postgraduate education to accommodate the evolution of the maritime business, as well as postgraduate student motivation in the field of MET	Lau & Ng, 2015	Motivation

Component	Challenges and Opportunities	Source	Aspect of MET
Process	Implementing technologies at all levels of the education process necessitates extensive research, beginning with the strategy of education process modeling and its key factors and progressing to the process of evaluating and assessing the efficiency of technologies in the context of developing professional competences.	Voloshynov et al., 2021	Assessment
	Empowered by digitalization, the triple helix collaboration between government, industry, and knowledge institutions can create opportunities for developing strategies to address maritime sector vulnerabilities such as crime, piracy, and smuggling.	Peeters & Pilon, 2018	Instructional Design
	E-learning, mobile-learning, and distance education in maritime reveal drawbacks, as it requires students to organize their own learning activities, be self-motivated, and evaluate the need for learning on an individual basis, which may result in questionable outcomes and poor learning progress. Self-paced learning requires students to have self-direction, motivation, advanced computer skills and knowledge of web-based services, as well as self-discipline, independence, and tenacity in completing tasks.	Galić et al., 2020	Educational strategy
	Maritime safety culture is under-researched. It should be investigated further to increase competence and enable actors to make better decisions through an effective design and delivery of quality education and training that focuses on safety requirements and the rate of technological advancement.	Lützhöft & Vu, 2018	Curriculum development
	The inefficiency of current transaction processes and data flows, as well as the emergence of cybersecurity threats and fraud, against the backdrop of environmental standards and local,	Green et al., 2020	Certification and licensure

Component	Challenges and Opportunities	Source	Aspect of MET
	national, and international regulations, relates to the challenges and opportunities of incorporating blockchain technology into regulatory frameworks.		
Structure	The European Union lacks a clear digitalization strategy for the maritime industry. Innovations are accompanied by apprehension of the unknown and uncertainty regarding future risks. The primary obstacle to adopting digitalization is conservatism and a traditional mindset of maritime stakeholders.	Babica et al., 2019	Standards and regulations
	Alternative forms of educational delivery like Massively Open Online Course directed at lifelong learning can play a role in supporting future scenarios such as digitalization	Wróbel et al., 2017	Program orientation
	Disruptive innovations alter how modern technologies are used in teaching and learning. Maritime schools face new challenges brought by Industry 4.0. Advantages of online learning are globalization and overcoming geographic restrictions. Schools, however, encounter challenges implementing online learning due to a lack of preparation for learning materials adjusted for online learning and lack of successful strategy to maintain student motivation and interest in a virtual learning environment.	Koh et al., 2021	Learning environment
	"No time" is the defining phrase of the Fourth Industrial Revolution because there is not enough time to even comprehend what is happening, let alone formulate and implement strategies and policies that adequately address the challenges, particularly in the education and training sector.	Alop, 2019	Curricula

Component	Challenges and Opportunities	Source	Aspect of MET
	While opportunities for new or product-service systems are emerging, it is unclear how digitization and the institutionalization of digital capabilities, particularly within maritime organizations, may affect product-service system implementation, potentially leading to transformational changes in the organization.	Pagoropoulos, 2017	Organization
Technology	Subject bias exists in the assessment using simulators in MET. There is a necessity of clearly defined assessment criteria for human assessors to produce more accurate performance evaluations. Additionally, incorporating inter-subjective viewpoints into the development and weighting of assessment tools may help to reduce biases.	Ernstsen & Nazir, 2020	Simulators
	E-learning is changing MET systems and is becoming an important part of technical vocational education and training. Even though it was observed that the students in the virtual classrooms were motivated and interested in learning, the successful integration of ICT and learning theories in MET depends on a number of factors.	Kitada et al., 2017	Virtual classrooms
Technology	In e-learning, the opportunity to cheat to obtain the passing score to prove knowledge is becoming easier given the distance between the teacher and the learner. Online fraud techniques include buying answers, faking errors during tests, and even conspiring with others. Concerns about this academic dishonesty are of particular importance when it comes to assessment.	Vagle, 2018	Educational environment
	Digital technologies are reliable in remotely monitoring tasks in both deck and engine departments.	ITF, 2019	Career perspectives

Component	Challenges and Opportunities	Source	Aspect of MET
	Simulators can be as simple as apps for smartphones and tablets or as complex as full mission systems that make a 1:1 copy of the work environment and its tools. In comparison to actual training, MET simulators may have drawbacks such as oversimplifying marine systems and procedures or flaws in the code that makes up the virtual models.	Mallam et al., 2019	Simulators Educational environment

Appendix F. Survey Statements About Automation Articulated From Content Analysis

Component	Elements	Leads	Survey statements
Organizational Culture	Leadership	Leadership and chain of command	The MET System will always need human leaders to establish a clear of chain of command
	Norms	Expectations that are socially enforced	Automation does not help the MET system promote gender-equal careers in the shipping industry
	Reputation	Widespread belief that someone or something has a particular characteristic	MET institutions that use shipping industry automation to their advantage are likely to receive more recognition and popularity in the academic sector
	Stereotypes	Shift perspective to generational issues, use gender issues in norms	Because of automation, age discrimination in the maritime industry will worsen
	Values	Vision, mission and core principles	Automation of administrative procedures in a MET institution helps in identifying conflicts or misalignment between the desired norms and values
People	Competences	Ability to do something successfully or efficiently	The tasks I am performing in my workplace can be automated for optimum efficiency
	Employment opportunities	Job creation, provision of specialized training to leverage hiring, transfer or mobility, retention and promotion	Integration of Industry 4.0 technologies in shipping signals the coming of e-farers and shore-farers (shore-based seafarers with advanced digital skills)
	Gender	Traditionally referring to sex distinction between male and female, social and cultural differences	Automation fuels gender inequality because technically-oriented education and the natural sciences are traditionally male-dominated

Component	Elements	Leads	Survey statements
	Generation	Demographic cohorts	Automation in shipping signals the era for e-farers and shore-farers, which favors younger generations
	Motivation	Reasons for thinking, deciding, acting or behaving in a particular way	Estimated timeframes for automation suggest threats to existing maritime professionals
Process	Curriculum development	Planning, situation analysis, needs assessment, design and development	Automation in the shipping industry is an indicator that modern technologies should also be integrated automation into the MET system
	Instructional Design	Creation of instructional materials	The automation of curriculum development and delivery negatively impacts the independence and control of educators over the educational processes
	Educational strategy	Mode of delivery	Simulators and computers are indispensable in teaching automation
	Assessment	Measuring learning	Automated delivery of education and training through e-learning modules and simulators eliminates subjectivity in assessment
	Certification and licensure	As educational outcomes	Automation reduces corruption in the certification and licensure systems
Structure	Standards and regulations	Specifications used as requirements or guideline for enforcing rules	All maritime regulations should ensure that the person in charge of the operations of a ship should reside onboard that ship
	Program orientation	Technical, Vocational, Academic	Advances in automation is best taught through a vocational approach (not bachelor's degree)
	Educational approach	Traditional, modern	The current national MET curricula in my country is responsive to automation in the shipping industry

Component	Elements	Leads	Survey statements
	Curricula	Planned learning opportunities including experiences encountered during implementation	In order for the MET system to simultaneously cope with technological developments, advances in automation should be taught by MET institutions in tailor-made courses rather than being integrated into academic programs.
	Organization	Management, resources and events	The technological infrastructures in my country is not yet mature enough to support the inclusion of automation in maritime education and training
Technology	Simulators	Equipment or machine designed for education and training purposes	Automation is best taught with the use of computers and simulators
	Virtual classrooms	Classroom management, classroom technology to manage lesson plans	Virtual classrooms require intensive management in order to facilitate a safe learning environment.
	E-learning	Personally-paced learning, independent of geographic location and time	E-learning is an effective solution to address geographical and time differences so that students can learn automation and technological updates when and where they are needed
	Internet of things	Addition of electronic devices and sensors to devices. The purpose is for the data collection, analysis, and automated actions	Considering international operations, smart ships or intelligent ships are more acceptable than fully autonomous ships (no human intervention).
	Artificial Intelligence	Theory and development of computer systems able to perform tasks	Ships can, and eventually will, be given the full right or condition of autonomy

Component	Elements	Leads	Survey statements
		normally requiring human intelligence, such as visual perception, speech recognition, decision-making, and translation between languages	

Appendix G. Survey Statements About Digitalization Articulated From Content Analysis

Components	Elements	Leads	Survey statements
Organizational culture	Leadership	Leadership and chain of command	Digitalization weakens organizational leadership because it undermines the chain of command.
	Norms	Expectations that are socially enforced	Digitalization of administrative procedures in a MET institution is useful in promoting expectations and norms.
	Reputation	Widespread belief that someone or something has a particular characteristic	Cyber security breaches pose a threat to data privacy, learning management systems and knowledge management measures, which may damage personal and institutional reputation.
	Stereotypes	Age and gender	Digitalization can be an effective tool to address the generation gap in the maritime sector.
	Values	Personnel support and capacity building	Providing capacity building for technological literacy of personnel should not be the responsibility of MET administrators and managers.
People	Competences	Ability to do something successfully or efficiently	I am able manage digital technologies.
	Employment opportunities	Job creation, provision of specialized training to leverage hiring, transfer or mobility, retention and promotion	I am afraid of being replaced because of adoption of digital technologies at my workplace.
	Gender	Traditionally referring to sex distinction between male and female, with reference	Digitalization balances gender inequality by bringing in new opportunities for all genders.

Components	Elements	Leads	Survey statements
		to social and cultural differences	
	Generation	Demographic cohorts	Digitalization is not favorable for all generations, particularly for those born earlier than 1980.
	Motivation	Reasons for thinking, deciding, acting or behaving in a particular way	Digitalization increases learner motivation through interactive teaching strategies such as gamification and simulations.
Process	Curriculum development	Planning, situation analysis, needs assessment, designing, knowledge triangle	Requirements and standards for human-machine interface like IMO regulations and ISO standards informs alignment in MET curricula.
	Instructional Design	Creation of instructional materials	Digitalization makes it possible to engage education authorities, academic staff and industry partners to co-create effective instructional materials.
	Educational strategy	Mode of delivery	Easy access to digital applications such as e-learning resources and simulation do not guarantee effective teaching and learning.
	Assessment	Measuring learning	Digital technology facilitates efficient assessment of learning, which in turn enables improvement initiatives
	Certification and licensure	As educational outcomes	Digitalized certification and licensure systems are vulnerable to corruption, including cybercrimes.
Structure	Standards and regulations	Specifications used as requirements or guideline for enforcing rules or directives	International unmanned ships will be allowed for commercial operations within the next 20 years and therefore, the current MET system has to take actions immediately.

Components	Elements	Leads	Survey statements
	Program orientation	Technical, Vocational, Academic	Digitalization is blurring the boundaries between academic (bachelor's degree) and vocational approaches to MET
	Learning environment	Traditional, virtual	E-learning resources and digital educational services optimizes the learners' opportunities by supporting inclusive and interactive global learning environment.
	Curricula	Planned learning opportunities including experiences encountered during implementation	The current national MET curricula in my country is not responsive to the digital needs and requirements of the shipping industry.
	Organization	arrangement of management, resources and events	The organization where I work has established a strategic plan to address competence needs in line with challenges of digitalization.
Technology	Simulators	equipment or machine designed for education and training purposes	Biases among simulator developers and users pose risks to the effectiveness of MET.
	Virtual classrooms	Classroom management, classroom technology to manage lesson plans	Virtual classrooms offer a setting in which MET can progress from memorizing information to creating and assessing knowledge in the maritime domain.
	e-learning	personally-paced learning, independent of geographic location and time	Compared to traditional setting, e-learning is more prone to cheating.
	Internet of things	the addition of electronic devices and sensors to devices. The purpose is for the data collection, analysis, and automated actions	Digitalization enables cooperation among maritime industry stakeholders for co-creating, co-delivering and co-funding an effective MET.

Components	Elements	Leads	Survey statements
	Artificial Intelligence	Theory and development of computer systems able to perform tasks normally requiring human intelligence, such as visual perception, speech recognition, decision-making, and translation between languages	Mobile applications support only memorization and not deep understanding and effective use of complex mechanisms in automation and digitalization in the shipping industry

Appendix H. Validation Tool for the Research Instrument

Validation Rating Scale for Survey Instrument:
“Challenges and Opportunities for Maritime Education and Training in the 4th Industrial Revolution”

Instruction: Please indicate your degree of agreement or disagreement on the statements provided below by encircling the number which corresponds to your best judgment.

1	2	3	4	5	6
Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree

The items in the instrument are relevant to the development of materials that will be used to answer the objectives of the study.	1	2	3	4	5	6
The items in the instrument can obtain depth of constructs being measured.	1	2	3	4	5	6
The instrument has an appropriate sample of items for the constructs being measured.	1	2	3	4	5	6
The items and their alternatives are neither too narrow nor limited in its content.	1	2	3	4	5	6
The items in the instrument are stated clearly.	1	2	3	4	5	6
The items on the instrument can elicit responses which are stable, definite, consistent, and not conflicting.	1	2	3	4	5	6
The layout or format of the instrument is technically sound.	1	2	3	4	5	6
The responses on the instrument can show a reasonable range of variation.	1	2	3	4	5	6
The instrument is not too short or long enough that the participants will be able to answer it within a given time.	1	2	3	4	5	6
The instrument is interesting such that the participants will be induced to respond to it and accomplish it fully.	1	2	3	4	5	6
The instrument as a whole could answer the basic purpose for which it is designed.	1	2	3	4	5	6
The instrument is culturally acceptable on how it will be administered in the local setting.	1	2	3	4	5	6

Please indicate your other comments and suggestions below:

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____

____
Signature over printed name of the validator

Appendix I. Originally Designed and Validated Research Instrument

Survey on Challenges and Opportunities for Maritime Education and Training in the 4th Industrial Revolution

Dear Respondent,

Thank you for participating in this survey. This is carried out in connection with the dissertation, which will be written by the researcher in partial fulfilment of the requirements for the degree of Master of Science in Maritime Affairs at the World Maritime University (WMU) in Malmö, Sweden. The survey seeks responses from educators, policy-makers and professionals in the maritime sector about the impact of Industry 4.0 on the Maritime Education and Training (MET) system.

Dissertation topic: Challenges and Opportunities for MET in the 4th Industrial Revolution.

All the information you will provide in line with this survey will be exclusively used for research purposes and the results will form part of a dissertation, which will later be stored in WMU's digital repository (maritime commons) and made available to the public subject to final approval of the University. Your personal information will not be published. Anonymized research data will be temporarily archived on a secure virtual drive linked to WMU's email system and all the gathered data will be deleted as soon as the degree is awarded.

For the purposes of this study, please take note that two terminologies are used with the following definitions. Automation is the application of technology in processes and tasks whereby work is performed by advanced technological systems and machines, thus reducing the need for human labor. On the other hand, digitalization is the process of capturing, storing, transferring and using data or information resources in a way that can be processed by computers.

Responding to this survey would take 20-30 minutes.

Your participation is highly appreciated.

For the following items, please rate the statement by ticking the scale corresponding to your level of agreement or disagreement. The scale points are designated as follows:

1 = Strongly disagree

2 = Disagree

3 = Slightly disagree

4 = Slightly agree

5 = Agree

6 = Strongly agree

Automation items	**1**	**2**	**3**	**4**	**5**	**6**
1. All maritime regulations should ensure that the person in charge of the operations of a ship should reside onboard that ship.						
2. Automation in the shipping industry is an indicator that modern technologies should also be integrated into the MET system.						
3. Integration of Industry 4.0 technologies into shipping signals the coming of e-farers and shore-farers (shore-based seafarers with advanced digital skills).						
4. Considering international operations, smart ships or intelligent ships are more acceptable than fully autonomous ships (no human intervention).						
5. Estimated timeframes for automation suggest threats to existing maritime professionals.						
6. Automation is best taught with the use of computers and simulators.						
7. MET institutions that use shipping industry automation to their advantage are likely to receive more recognition and popularity in the academic sector.						
8. Automation reduces corruption in the certification and licensure systems.						
9. Automation in shipping signals the era of e-farers and shore-farers, which favors younger generations.						
10. E-learning is an effective solution to address geographical and time differences so that students can learn automation and technological updates when and where they are needed.						
11. Ships can, and eventually will, be given the full right or condition of autonomy.						
12. The current national MET curricula in my country is responsive to automation in the shipping industry.						
13. In order for the MET system to simultaneously cope with technological developments, advances in automation should be taught by MET institutions in tailor-made courses rather than being integrated into academic programs.						

Automation items	**1**	**2**	**3**	**4**	**5**	**6**
14. Because of automation, age discrimination in the maritime industry will worsen.						
15. Simulators and computers are indispensable in teaching automation.						
16. The MET system will always need human leaders to establish a clear chain of command.						
17. Automation fuels gender inequality because technically-oriented education and the natural sciences are traditionally male-dominated.						
18. Automation does not help the MET system promote gender-equal careers in the shipping industry.						
19. Advances in automation are best taught through a vocational approach (not a bachelor's degree).						
20. The technological infrastructure in my country is not mature enough to support the inclusion of automation in maritime education and training.						
21. The automation of curriculum development and delivery negatively impacts the independence and control of educators over the educational process.						
22. The tasks I am performing in my workplace can be automated for optimum efficiency.						
23. Virtual classrooms require intensive management in order to facilitate a safe learning environment.						
24. Automation of administrative procedures in a MET institution helps in identifying conflicts or misalignments between the desired norms and values.						
25. Automated delivery of education and training through e-learning modules and simulators eliminates subjectivity in assessment.						

Digitalization items	**1**	**2**	**3**	**4**	**5**	**6**
26. Digital technology facilitates efficient assessment of learning, which in turn enables improvement initiatives.						
27. The organization where I work has established a strategic plan to address competence needs in line with the challenges of digitalization.						
28. Digitalization is not favorable for all generations, particularly for those born earlier than 1980.						
29. Digitalization makes it possible to engage education authorities, academic staff and industry partners to co-create effective instructional materials.						

Digitalization items	1	2	3	4	5	6
30. The current national MET curricula in my country is not responsive to the digital needs and requirements of the shipping industry.						
31. Digitalization weakens organizational leadership because it undermines the chain of command.						
32. Digitalization enables collaboration among maritime industry stakeholders for co-creating, co-delivering, and co-funding an effective MET.						
33. Providing capacity building for technological literacy of personnel should not be the responsibility of MET administrators and managers.						
34. International unmanned ships will be allowed for commercial operations within the next 20 years, and therefore, the current MET system has to take action immediately.						
35. I am able to manage digital technologies.						
36. Digitalization is blurring the boundaries between academic (bachelor's degree) and vocational approaches to MET.						
37. Digitalization increases learner motivation through interactive teaching strategies such as gamification and simulations.						
38. Mobile applications support only memorization and not deep understanding and effective use of complex mechanisms in automation and digitalization in the shipping industry.						
39. Digitalization balances gender inequality by bringing in new opportunities for all genders.						
40. Digitalized certification and licensure systems are vulnerable to corruption, including cybercrimes.						
41. Compared to traditional settings, e-learning is more prone to cheating.						
42. Requirements and standards for human-machine interfaces like IMO regulations and ISO standards inform alignment in MET curricula.						
43. Digitalization can be an effective tool to address the generation gap in the maritime sector.						
44. Biases among simulator developers and users pose risks to the effectiveness of MET.						
45. Digitalization of administrative procedures in a MET institution is useful in promoting expectations and norms.						
46. E-learning resources and digital educational services optimize learners' opportunities by supporting inclusive and interactive global learning environments.						
47. Easy access to digital applications such as e-learning resources and simulations does not guarantee effective teaching and learning.						

Digitalization items	1	2	3	4	5	6
48. I am afraid of being replaced because of the adoption of digital technologies at my workplace.						
49. Cyber security breaches pose a threat to data privacy, learning management systems and knowledge management measures, which may damage personal and institutional reputation.						
50. Virtual classrooms offer a setting in which MET can progress from memorizing information to creating and assessing knowledge in the maritime domain.						

Short-constructed response items:

1. In your opinion, which part of the MET system is severely affected by automation. In what way?

2. What do you think are the advantages or benefits of automation for the MET system?

3. Please provide any insight or thoughts you might have about automation. Your views are very much appreciated.

4. In your opinion, which part of the MET system is significantly improved by digitalization. In what way?

5. What do you think are the disadvantages or drawbacks of digitalization for the MET system?

6. Please add any comments or ideas you might have about digitalization. Your views are very much appreciated.

Appendix J. Frequency of Responses to Survey Statements About Automation

	1	2	3	4	5	6
Organizational culture						
7. MET institutions that use shipping industry automation to their advantage are likely to receive more recognition and popularity in the academic sector	0	1	10	27	54	35
14. Because of automation, age discrimination in the maritime industry will worsen	3	14	25	47	26	12
16. The MET system will always need human leaders for establishing a clear chain of command	1	0	6	10	40	70
18. Automation does not help the MET system promote gender-equal careers in the shipping industry	31	39	32	17	5	3
24. Automation of administrative procedures in MET institution helps in identifying conflicts or misalignment between the desired norms and values	1	4	11	49	42	20
People						
3. Integration of Industry 4.0 technologies into shipping signals the coming of e-farers and shore-farers (shore-based seafarers with advanced digital skills)	1	2	7	25	46	46
5. Estimated timeframes for automation suggest threats to existing maritime professionals	4	17	20	31	37	18
9. Automation in shipping signals the era of e-farers and shore-farers, which favors younger generations	0	6	12	33	48	28
17. Automation fuels gender inequality because technically-oriented education and the natural sciences are traditionally male-dominated	32	32	20	26	14	3
22. The tasks I am performing in my workplace can be automated for optimum efficiency	10	23	20	31	24	19
Process						
2. Automation in the shipping industry is an indicator that modern technologies should also be integrated into the MET system	0	0	2	11	31	83
8. Automation reduces corruption in the certification and licensure systems	1	14	9	31	32	40
15. Simulators and computers are indispensable in teaching automation	1	1	5	13	40	67
21. The automation of curriculum development and delivery negatively impacts the independence and control of educators over the educational process	7	23	33	31	30	3
25. Automated delivery of education and training through e-learning modules and simulators eliminates subjectivity in assessment	4	6	13	35	47	22
Structure						
1. All maritime regulations should ensure that the person in-charge of the operations of a ship resides onboard that ship	10	11	17	33	28	28
12. The current national MET curricula in my country is responsive to automation in the shipping industry	19	26	32	32	13	5
13. In order for the MET system to simultaneously cope with technological developments, advances in automation should be taught by MET institutions in tailor-made courses rather than being integrated into academic programs	7	5	16	31	41	27
19. Advances in automation are best taught through a vocational approach (not bachelor's degree)	12	20	37	24	23	11
20. The technological infrastructure in my country is not mature enough to support the inclusion of automation in maritime education and training	11	12	20	35	30	19
Technology						
4. Considering international operations, smart ships or intelligent ships are more acceptable than fully autonomous ships (no human intervention)	0	6	8	27	43	43
6. Automation is best taught with the use of computers and simulators	0	2	4	34	42	45
10. E-learning is an effective solution to address geographical and time differences so that students can learn automation and technological updates when and where they are needed	2	4	3	25	60	33
11. Ships can, and eventually will, be given the full right or condition of autonomy	5	6	24	41	39	12
23. Virtual classrooms require intensive management in order to facilitate a safe learning environment	2	6	14	34	40	31

Appendix K. Frequency of Responses to Survey Statements About Digitalization

Organizational culture	1	2	3	4	5	6
31. Digitalization weakens organizational leadership because it undermines the chain of command	17	41	33	22	9	5
33. Providing capacity building for technological literacy of personnel should not be the responsibility of MET administrators and managers	35	40	21	16	9	6
43. Digitalization can be an effective tool to address the generation gap in the maritime sector	0	2	16	44	50	15
45. Digitalization of administrative procedures in a MET institution is useful in promoting expectations and norms	1	0	6	35	57	28
49. Cyber security breaches pose a threat to data privacy, learning management systems and knowledge management measures, which may damage personal and institutional reputation	2	8	9	21	49	38
People						
28. Digitalization is not favorable for all generations, particularly for those born earlier than 1980	6	25	33	30	21	12
35. I am able to manage digital technologies	2	2	6	30	54	33
37. Digitalization increases learner motivation through interactive teaching strategies such as gamification and simulations	1	3	5	32	52	34
39. Digitalization balances gender inequality by bringing in new opportunities for all genders	2	1	8	31	41	44
48. I am afraid of being replaced because of the adoption of digital technologies at my workplace	47	38	11	15	8	8
Process						
26. Digital technology facilitates efficient assessment of learning, which in turn enables improvement initiatives	2	2	7	28	59	29
29. Digitalization makes it possible to engage education authorities, academic staff and industry partners to co-create effective instructional materials	0	0	5	30	53	39
40. Digitalized certification and licensure systems are vulnerable to corruption, including cybercrimes	9	13	21	36	33	15
42. Requirements and standards for human-machine interfaces like IMO regulations and ISO standards inform alignment in MET curricula	1	1	16	51	40	18
47. Easy access to digital applications such as e-learning resources and simulations does not guarantee effective teaching and learning	6	9	13	32	38	29
Structure						
27. The organization where I work has established a strategic plan to address competence needs in line with the challenges of digitalization	7	14	18	31	43	14
30. The current national MET curricula in my country is not responsive to the digital needs and requirements of the shipping industry	5	17	20	38	35	12
34. International unmanned ships will be allowed for commercial operations within the next 20 years, and therefore, the current MET system has to take action immediately	3	4	9	23	41	47
36. Digitalization is blurring the boundaries between academic (bachelor's degree) and vocational approaches to MET	6	27	26	28	32	8
46. E-learning resources and digital educational services optimize learners' opportunities by supporting inclusive and interactive global learning environments.	2	1	2	33	58	31
Technology						
32. Digitalization enables collaboration among maritime industry stakeholders for co-creating, co-delivering, and co-funding an effective MET	2	1	9	18	57	40
38. Mobile applications support only memorization and not deep understanding and effective use of complex mechanisms in automation and digitalization in the shipping industry	4	17	30	45	21	10
41. Compared to traditional settings, e-learning is more prone to cheating	4	20	22	43	23	15
44. Biases among simulator developers and users pose risks to the effectiveness of MET	3	8	23	38	37	18
50. Virtual classrooms offer a setting in which MET can progress from memorizing information to creating and assessing knowledge in the maritime domain	2	5	8	39	51	22

Appendix L. Most Agreed Survey Items on Automation

*Most Agreed Survey Items on Automation (*N = *127)*

	4	5	6	n
2. Automation in the shipping industry is an indicator that modern technologies should also be integrated into the MET system.	11	31	83	125
6. Automation is best taught with the use of computers and simulators.	34	42	45	121
15. Simulators and computers are indispensable in teaching automation.	13	40	67	120
16. The MET system will always need human leaders for establishing a clear chain of command.	10	40	70	120
10. E-learning is an effective solution to address geographical and time differences so that students can learn automation and technological updates when and where they are needed.	25	60	33	118
24. Automation of administrative procedures in MET institution helps in identifying conflicts or misalignment between the desired norms and values.	49	42	20	118
3. Integration of Industry 4.0 technologies into shipping signals the coming of e-farers and shore-farers (shore-based seafarers with advanced digital skills).	25	46	46	117
7. MET institutions that use shipping industry automation to their advantage are likely to receive more recognition and popularity in the academic sector.	27	54	35	116

Note. 4 = Slightly agree; 5 = Agree; and 6 = Strongly agree

Appendix M. Most Agreed Survey Items on Digitalization

*Most Agreed Survey Items on Digitalization (*N *= 127)*

	4	5	6	n
29. Digitalization makes it possible to engage education authorities, academic staff and industry partners to co-create effective instructional materials	30	53	39	122
46. E-learning resources and digital educational services optimize learners' opportunities by supporting inclusive and interactive global learning environments.	33	58	31	122
45. Digitalization of administrative procedures in a MET institution is useful in promoting expectations and norms	35	57	28	120
37. Digitalization increases learner motivation through interactive teaching strategies such as gamification and simulations	32	52	34	118
26. Digital technology facilitates efficient assessment of learning, which in turn enables improvement initiatives	28	59	29	116
39. Digitalization balances gender inequality by bringing in new opportunities for all genders	31	41	44	116
32. Digitalization enables collaboration among maritime industry stakeholders for co-creating, co-delivering, and co-funding an effective MET	18	57	40	115

Note. 4 = Slightly agree; 5 = Agree; and 6 = Strongly agree

Appendix N. Most Disagreed Survey Items on Automation

*Most Disagreed Survey Items on Automation (*N *= 127)*

	1	**2**	**3**	**n**
18. Automation does not help the MET system promote gender-equal careers in the shipping industry	31	39	32	102
17. Automation fuels gender inequality because technically-oriented education and the natural sciences are traditionally male-dominated	32	32	20	84
12. The current national MET curricula in my country is responsive to automation in the shipping industry	19	26	32	77

Note. 1 = Strongly disagree; 2 = Disagree; and 3 = Slightly disagree

Appendix O. Most Disagreed Survey Items on Digitalization

*Most Disagreed Survey Items on Digitalization (*N *= 127)*

	1	**2**	**3**	**n**
33. Providing capacity building for technological literacy of personnel should not be the responsibility of MET administrators and managers.	35	40	21	96
48. I am afraid of being replaced because of the adoption of digital technologies at my workplace.	47	38	11	96
31. Digitalization weakens organizational leadership because it undermines the chain of command.	17	41	33	91

Note. 1 = Strongly disagree; 2 = Disagree; and 3 = Slightly disagree

Appendix P. Controversial Survey Items

Controversial Survey Items (N = 127)

	1	**2**	**3**	**4**	**5**	**6**
21. The automation of curriculum development and delivery negatively impacts the independence and control of educators over the educational process.	7	23	33	31	30	3
28. Digitalization is not favorable for all generations, particularly for those born earlier than 1980.	6	25	33	30	21	12
36. Digitalization is blurring the boundaries between academic (bachelor's degree) and vocational approaches to MET.	6	27	26	28	32	8

Note. 1 = Strongly disagree; 2 = Disagree; 3 = Slightly disagree; 4 = Slightly agree; 5 = Agree; and 6 = Strongly Agree