THE INSTRUMENT DEVELOPMENT FOR FACULTY READINESS ASSESSMENT ON COMPUTATIONAL SUSTAINABILITY

TUAN NURNADZIRAH ‘ASYIKIN BINTI TUAN RAHIM

UNIVERSITI PENDIDIKAN SULTAN IDRIS

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TUAN NURNADZIRAH ‘ASYIKIN BINTI TUAN RAHIM

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ABSTRACT

Computational sustainability involves providing computational solutions to improve the quality of life, protect ecosystems, and preserve natural resources for future generations. The question of how prepared the computing faculty is to shape the next generation to recognize the importance of computational sustainability remains unanswered. This study aims to develop an instrument to assess the readiness of the faculty to offer computational sustainability, either in the form of knowledge or skills to students. Therefore, the study's objective is to investigate and delineate the dimensions and levels of faculty readiness and develop an appropriate assessment instrument. A literature synthesis was conducted to propose suitable dimensions and levels of readiness, followed by developing a draft instrument. This draft was then validated by four experts with doctoral qualifications (Ph.D.) in computer science and information technology who are proficient in English. Subsequently, two rounds of the Delphi procedure were conducted using the Content Validity Index (CVI) with five expert panel members with over 10 years of experience teaching computing courses, sufficient knowledge of computational sustainability, and are currently active in the computing faculty. The study results indicate that, after two rounds of Delphi, five dimensions of faculty readiness were identified: technological knowledge, content knowledge, teaching strategies, training, and equipment and software. A total of 43 elements showed significant agreement among the experts (I-CVI>0.78). In conclusion, the instrument to assess faculty readiness for computational sustainability was successfully developed and validated. The implications of this study are expected to pave the way for greater computational sustainability and provide significant benefits to higher education institutions and students.

PEMBANGUNAN INSTRUMEN UNTUK PENILAIAN KESEDIAAN FAKULTI TERHADAP KELESTARIAN KOMPUTASIONAL

ABSTRAK

Kelestarian komputasional melibatkan penyediaan penyelesaian komputasi yang dapatmeningkatkan kualiti hidup, melindungi ekosistem kita, dan memelihara sumber daya alam untuk generasi masa depan. Sejauh mana fakulti pengkomputeran bersedia untuk membentuk generasi berikutnya agar menyedari kepentingan kelestarian komputasional adalah persoalan yang masih belum terjawab. Kajian ini bertujuan untuk membangunkan instrumen untuk menilai kesediaan fakulti dalam menawarkan kelestarian komputasional sama ada dalam bentuk pengetahuan atau kemahiran kepada pelajar. Oleh itu, objektif kajian ini adalah untuk menyelidik dan menyatakan dimensi serta tahap kesediaan fakulti dan membangunkan instrumen penilaian yang sesuai. Sintesis literatur telah dijalankan untuk mencadangkan dimensi dan tahap kesediaan yang sesuai, diikuti dengan pembangunan draf instrumen. Draf tersebut kemudiaan dinilai kesahannya oleh empat orang pakar yang memiliki kelayakan doktor falsafah (Ph.D) dalam bidang sains komputer dan teknologi maklumat serta mahir dalam berbahasa Inggeris. Seterusnya, dua pusingan prosedur Delphi dijalankan menggunakan Indeks Kesahan Kandungan (CVI) dengan lima orang panel pakar yang berpengalaman mengajar kursus pengkomputeran lebih dari 10 tahun, memiliki pengetahuan mencukupi mengenai kelestarian komputasional, dan masih aktif dalam fakulti pengkomputeran. Hasil kajian menunjukkan, selepas melalui dua pusingan Delphi, lima dimensi kesediaan fakulti telah dikenal pasti: pengetahuan teknologi, pengetahuan kandungan, strategi pengajaran, latihan, dan peralatan dan perisian. Sebanyak 43elemen menunjukkan tahap persetujuan yang signifikan di kalangan pakar (I-CVI>0.78). Kesimpulannya, instrumen untuk menilai kesediaan fakulti terhadap kelestarian komputasional telah berjaya dibangunkan dan disahkan. Implikasi kajian ini diharapkan dapat membuka jalan menuju kelestarian komputasional yang lebih besar dan memberikan banyak manfaat bagi institusi pengajian tinggi dan pelajar.

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LIST OF ABBREVIATIONS

CompSust	Computational Sustainability
CVI	Content Validation Index
SDG	Sustainable Development Goals

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Today, computational sustainability has become a trend (Martin et. al., 2019). There are significant pieces of evidence that show its ability to provide solutions that resolve or manage sustainability development problems (see Gomes et. al., 2019), which supports Chande (2014) study that claimed computational sustainability is emerging research and academic field. Computational sustainability is an interdisciplinary area that integrates computer science, artificial intelligence, and sustainability science methodologies to address difficult environmental and socioeconomic concerns. It brings together computer science, ecology, economics, and other fields to create novel solutions for sustainable resource management, conservation, and social well-being. Using algorithms, machine learning, and simulations, computational sustainability seeks to analyze, forecast, and alleviate environmental challenges while encouraging long-term viability.

According to Gomes et al. (2019) stated that computational sustainability seeks to identify, formalize, and solve computational problems relating to the balancing of environmental, economic, and societal needs for a sustainable future, which highly supports sustainable development, that according to Chande (2014), aims to achieve a balance of social, economic, and environmental goals to ensure the well-being of current and future generations. Conservation planning, sustainable resource management, renewable energy optimization, climate modeling, invasive species control, and biodiversity monitoring are among the projects undertaken by computational sustainability researchers. Computational sustainability strives to create positive change and contribute to a sustainable and harmonious cohabitation between people and the environment by integrating modern computational tools and interdisciplinary collaborations. Computer sustainability is a deliberate attempt to address major environmental and socioeconomic concerns via the use of computer tools, multidisciplinary collaborations, and data-driven approaches. Its fundamental goal is to build a symbiotic interaction between humans and the environment, exploring solutions that support sustainable development, biodiversity protection, and the well-being of ecosystems and communities. One of the key goals of computational sustainability is to handle complicated issues that arise from the interplay of humans and the environment. This encompasses climate change, habitat degradation, resource depletion, biodiversity loss, and natural resource management. Computational sustainability uses modern computational techniques such as machine learning, optimization algorithms, data analytics, simulation models, and geographic information systems (GIS) to analyze large and diverse datasets, understand complex environmental processes, and forecast future trends and impacts.

Sustainable development is very significant. The importance of sustainability education is becoming more widely recognized. Sustainability skills have been successfully integrated into the majority of subjects on the curriculum at schools (López, 2014). By introducing sustainability concepts in most subjects, students are expected to acquire a holistic and integrated perspective. Sustainable development is a comprehensive and forward-thinking approach to societal advancement that tries to meet the demands of the current generation without jeopardizing future generations' ability to meet their own needs. It is a solution to today's most important concerns, such as environmental deterioration, social injustice, economic insecurity, and resource depletion. In practice, sustainable development entails policy reforms, technical advancements, lifestyle modifications, and transformations in economic and societal objectives. To confront the complex issues that we face in the twenty-first century, governments, businesses, civil society, and individuals must work together to achieve a better and more sustainable future for all. At its foundation, sustainable development reflects the concept of striking a delicate balance between economic progress, social well-being, and environmental conservation.

Sustainable development is also very challenging. Assessing and managing sustainability has become a major challenge for our society (Kostoka & Kocarev, 2019). Thus, the need for education for sustainability is being articulated at the highest levels (Podder et al., 2022; Mann et al., 2008). The application of computational approaches to problem-solving and improvement in various aspects of sustainability implies a growing need to increase awareness and application of these techniques to sustainability (Chande, 2014). As computational techniques could be used to address sustainability issues, Chande (2014) has also suggested that computing faculties apply computational sustainability to be a component in Computer Applications, Computer Science, Information Technology, Mathematics, and Statistics programs. These applications show the versatility and importance of computational approaches in tackling complicated issues and expanding knowledge in a variety of disciplines. With increases in processing power and algorithms, the area continues to evolve, providing creative solutions to real-world difficulties. However, as a multidisciplinary field, computational sustainability can be very challenging to be introduced or practiced directly. Computational techniques have numerous applications in a variety of sectors and industries. These approaches use computers and algorithms to solve complicated issues, evaluate data, forecast outcomes, and optimize operations. It poses a challenge to pedagogy across many fields. Mathematical and computational science applications that play a major role in facing realization challenges of sustainable development are also becoming the challenges themselves.

Computing faculty might be the best place to encourage new generations to be aware, or, better yet, learn and practice computational sustainability to help sustain our world for a very long time. Universities can play an important role in shaping the future of world society in terms of sustainable development by raising sustainability awareness and developing appropriate competencies (Rieckmann, 2012). A computing faculty is a vibrant and essential component of the academic community that is devoted to the study, research, and teaching of many facets of computer science and related subjects. They are frequently located within universities or other educational institutions. By giving students a solid foundation in computer science and related fields and by performing cutting-edge research that pushes the boundaries of knowledge and technology, this faculty plays a crucial role in influencing the future of innovation and technology. Computing faculties play a pivotal role as hubs of technical innovation in the fast-changing digital age. A computer faculty serves as a cornerstone for innovation, preparing individuals to succeed in an increasingly digital environment. They provide a wide array of academic programs and research projects that enable professionals and students to fully utilize the transformative power of computers and information technology.

Introducing sustainable related contents such as computational sustainability to computing education is fundamentally multidisciplinary but might be good for professional and ethical developments, and also the social responsibility of students (Pedro et al., 2019; Gordon, 2010; Roberts, 2011). This perspective acknowledges that computing is not an isolated phenomenon but rather plays a crucial role in tackling some of the most urgent issues of our day, such as environmental sustainability and societal well-being. Computer science education has traditionally focused on algorithms, programming languages, and software development. The inclusion of sustainable-related knowledge, such as computational sustainability, represents a shift in teaching the next generation of computer scientists. Thus, a few researchers such as Fisher et al. (2016) and Robert (2011) discussed the incoming trend of integrating sustainability in computing education such as by introducing new specialized courses, introducing new learning units or using related case studies in existing courses. Fisher et al. (2016), Brooks (2019), Gomes et.al (2019), Pucher (2016), and Penzenstadler et al. (2018) have also discussed other strategies to have such multidisciplinary practice, directly or indirectly, so that the next generations can be exposed to the relevance of computational sustainability, or, better yet, can be encouraged or taught about it during their studies. They may become more aware of or develop an interest in having a role in preserving our environment for future generations. Sustainability issues are complex and connected with many different fields, including environmental science, ecology, economics, and social sciences. Students learn to apply their computational talents to real-world situations by adding sustainable content to computing education, resulting in innovative solutions that benefit society and the environment.

However, how far computing faculty is ready to shape the next generation to be aware of the importance of computational sustainability or, better yet, to encourage their students to learn and practice them, is an open question. This topic is rarely discussed. Many readiness discussions were concerned about organizations accepting new technologies or practicing new approaches such as green computing (Pazowski, 2015; Molla, 2010; Bernaldez, 2019), whereas common readiness studies available in education were about teachers or students' readiness related to their teaching and learning (Martin et. al., 2019; Rohayani et. al., 2015). Up to this date, there is no framework available that can guide us to assess readiness in this context. Readiness in the context of computational sustainability is a fundamental term that emphasizes individuals', organizations', and society's readiness to meet the complex challenges of sustainability through computational methodologies. Access to extensive and high-quality data sets relevant to sustainability challenges is required for computational sustainability readiness. It also entails having the necessary technological infrastructure and computational tools for data analysis, modeling, and simulation in support of sustainability projects.

To provide information that may draw attention to current practices in teaching computational sustainability among computing faculties, it is necessary to find out how to assess computing faculty readiness to foster computational sustainability in computing education. Highly ready faculty may mean that they already have certain practices in their organization. Other faculty may then start to be aware, and might start following the global trend. Preparing the next generation for computational sustainability entails providing education and training programs that provide students with the essential skills and knowledge to address sustainability concerns. In this sense, readiness refers to the development of a professional workforce capable of applying computational methodologies to real-world sustainability concerns. Individuals and institutions must invest in research and innovation to be prepared for computational sustainability. This includes the creation of innovative algorithms, machine learning models, and optimization methods customized to specific sustainability challenges. Staying at the forefront of technical breakthroughs and contributing to the evolution of computational sustainability as a field is what readiness implies.

Using computational techniques and multidisciplinary cooperation, computational sustainability aims to deliver evidence-based solutions that balance environmental protection, economic development, and societal requirements. Its purpose is to promote peaceful coexistence between humans and the environment, ensuring a more sustainable and resilient future for future generations. The goal of computational sustainability readiness is to provide society with the skills, resources, and understanding needed to address urgent sustainability issues in a world where technology is advancing at a rapid pace. It highlights how crucial it is to discover creative solutions that strike a balance between human demands and the preservation of the environment and ecosystems by being proactive, flexible, and cooperative. Being prepared for computational sustainability is essential to creating a more sustainable future in an era where sustainability is of the utmost importance. Thus, having a suitable instrument to assess readiness in this context is deemed important. Nonetheless, the task is not simple and easy as readiness can be very subjective and depending on different contexts. Readiness can also be defined in different dimensions and stages. Therefore, once the readiness stages and levels in this context are successfully investigated and described through an intensive literature study, we are keen to develop and validate a suitable readiness assessment instrument using proper and systematic procedures which will involve a number of expert reviewers.

1.2 Background of study

In September 2015, the United Nations (UNs) has recognized that for the world to sustain, most world issues can be improved with sustainable development strategies such as health and education improvement, oceans and forest preservations, inequality reduction, energy and climate change control and monitoring, and many more (Pallant et. al., 2020). The UNs introduced SDGs 2030, a blueprint containing 17 Sustainable Development Goals (SDGs), as an international agenda to be achieved by 2030 by all developing and developed countries. The Sustainable Development Goals (SDGs) are a worldwide framework that strives to solve some of the world's most serious issues, such as poverty, inequality, climate change, environmental degradation, peace, and justice. They offer a shared vision for a more sustainable and equitable future, and nations, organizations, and individuals throughout the world are working to meet these targets by 2030. According to Hilty et al. (2015), sustainable development is defined as development that meets the needs of the present without jeopardizing future generations' ability to meet their own needs. There are a total of 17 goals, each with its own set of targets and indicators. These goals are interconnected and address a wide variety of social, economic, and environmental development concerns. The 17 Sustainable Development Goals are depicted in Figure 1.1.

Figure 1.1

Sustainable Development Goals (SDG).

Adapted from source: Gomes, 2019, p. 58)

Sustainability development can be very challenging but computational sustainability can address many of the sustainable issues (Gomes et al., 2019). Computational sustainability is about providing computational solutions that can

support life quality improvements, protects our ecosystem, and preserves natural resources for future generations. Computational sustainability refers to the application of computational technology and thinking to promote sustainability, as well as the associated issue of decreasing the negative environmental effects of computer technologies (Chatterjee, 2020). Computational sustainability research focuses on the development of computational models, mathematical models, and related techniques to supportand to solve some of the most complex issues associated with sustainable development (Liu & Jia, 2019). According to Gomes et al. (2019), computational sustainability would provide us with the resources to balance the needs of the environment, the economy and society. To become better problem solvers for a sustainable future, pedagogical goals and tactics must be created for computational sustainability (Chande, 2014). By leveraging the power of data and modern computer tools, computational sustainability provides a potent way to balance the requirements of the environment, economy, and society. We may strive towards a more sustainable and peaceful future by incorporating environmental, economic, and societal issues into models and decision-making processes.

Universities can play an important role in shaping the future of the world society in terms of sustainable development as it will contribute to the development of suitable competencies and boosting sustainability consciousness. Computational sustainability is now taught at many renowned universities within computing curriculum in the US and the UK, such as Cornell University, University of West of England, and Hull University, and has its own dedicated research track at several scientific conferences. Reputable colleges have included computational sustainability into their computer programs, acknowledging the importance of sustainability as a worldwide goal and reflecting the field's changing character. It provides the information and abilities needed to prepare the next generation of computer professionals. Universities are expected to instill in their students, faculty, and staff not only the skills needed to succeed in a globalized world, but also a positive attitude toward environmental issues and cultural diversity (Rieckmann, 2012). The incorporation of computational sustainability into the curricula of prestigious universities demonstrates the growing acknowledgement of the importance of this interdisciplinary discipline in tackling crucial sustainability concerns. It is inclusion in academic curricula is a reflection of the field's growing importance and the demand that aspiring professionals possess the know-how and abilities needed to address sustainability-related challenges.

Academic institutions are beginning to incorporate computational sustainability as an integral part of their curricula (Chande, 2014). Sustainable content, such as computational sustainability, allows students to participate in cutting-edge research. Students can contribute to the newest advances in computing and sustainability by devising algorithms for wildlife protection, estimating environmental implications, or generating renewable energy solutions. A multidisciplinary approach is necessary to handle sustainability concerns, as many prestigious colleges are realizing. The integration of computational sustainability into computing courses promotes cooperation among computer science, ecology, economics, environmental science, and other related subjects. This equips students to work across traditional discipline boundaries in challenging, real-world situations. The development of academic curricula to include computational sustainability emphasizes how crucial interdisciplinary cooperation is to creating a more just and sustainable world.

To assess readiness of university, especially computing faculties, to educate their students on computational sustainability, we need a good, sustainable readiness assessment framework. A framework is a basic structure underlying a concept. It is a structure that consists of important components that efficiently support one other (Zaidi et al., 2021; Abduh et. al., 2018). Readiness assessment framework in our context, is a basic structure that concerns about assessing the ability of faculty to make some changes in order to foster computational sustainability among faculty members. A readiness assessment framework is a structured way of assessing an individual's, organization's, or system's readiness and capability to perform a certain task, initiative, or change. It usually entails a set of questions, criteria, and assessments to determine the present state of readiness, identify strengths and weaknesses, and influence decision-making. It usually become a platform for developing elements and components that can be used to process, to manage, to interact within the context of the chosen concept. To produce a readiness assessment framework, a systematic procedure is required. A readiness assessment framework is a versatile tool that can be customized to meet the needs and conditions of various individuals and organizations. Most researchers have proposed to use Delphi procedure in their studies (Ubaidullah et. al., 2018).

1.3 Problem Statement

The focus of the international community is already on sustainable development (Liu & Jia, 2019). Computational sustainability is now taught at many renowned universities within the computing curriculum in the US and the UK, such as Cornell University, the University of West of England, and Hull University, and has its dedicated research track at several scientific conferences. According to Fisher et al. (2016), this field is maturing in computing education, with at least some sustainable related contents are being integrated at the course-component level.

Figure 1.2 shows some examples of computing topics that are relevant and useful for computational sustainability. Fundamentally multidisciplinary in nature might be a good way to educate our students but to do it without reducing the contents from computer science discipline can be challenging. Roberts (2011) suggested some practical approaches to foster the sustainable related contents such as:

a. Introducing "units" in current courses that relate computer science to other disciplines. As we've seen, they don't have to be long. It may entail team teaching or collaborative preparation with different disciplines.
b. Introduce specialist courses with sufficient material. Computational ecology, computational molecular biology, computational economics, etc.
c. To present seminars or courses on "case studies." These are more applied in

nature and frequently feature guest lecturers from different academic fields or business sectors.

d. Setting up internships for them, such as at government or commercial laboratories where students may work across disciplinary boundaries.

Figure 1.2

Some examples of computing topics that are relevant to computational sustainability

Adapted from source: Gomes et. al, 2019

1.3.1 Application fields related

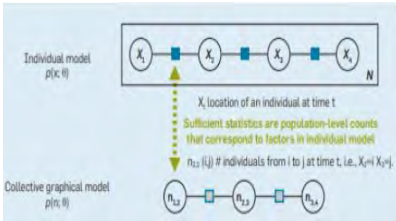
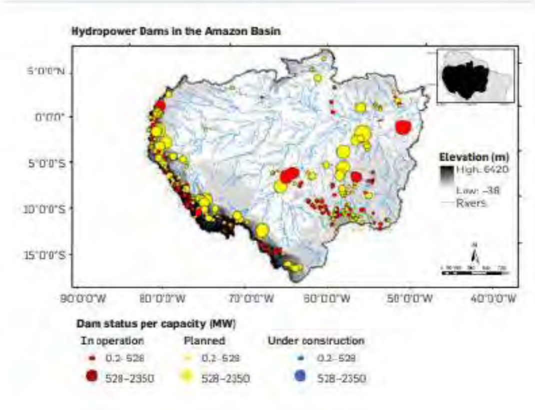
The application fields of computational sustainability are vast and varied. Biodiversity Conservation uses computer models to better understand species distribution, habitat connectivity, and ecosystem dynamics, which aids in the development of conservation strategies and protected area planning. Renewable energy and resource management uses computational tools to maximize energy production, distribution, and consumption while also efficiently managing water resources, waste, and land usage. Urban planning and smart cities may use computational approaches to develop sustainable cities, optimize transportation systems, improve infrastructure, and increase urban living quality while reducing environmental effects.

The development of models to evaluate the effects of climate change, forecast future events, and create mitigation and adaptation strategies such as building robust infrastructure and putting carbon reduction policies into place is made possible by climate change mitigation and adaptation. Computational sustainability is implemented by using computational approaches and tools to address sustainability concerns. According to Gomes et al. (2019), Computational sustainability seeks to discover, formalize, and solve computer challenges relating to the balancing of environmental, economic, and societal concerns for a sustainable future. Table 1.1 below shows some examples of computational sustainability implementation derived from past researcher, Gomes et al., 2014.

Table 1.1

Examples of computational sustainability implementation.

Balancing environmental and socioeconomics needs. a. Solution for issues to balance difficult environmental and socioeconomics needs. b. Cross fields: Optimization, Data Machine Learning, Multi-Agents, Crowdsourcing.	

Biodiversity and conservation a. Solution for conducting probabilistic inference about a large population. b. Cross fields: Multiple sensors, biological and ecological.	
Renewable and sustainable energy and materials. a. Solution for hydropower dam planning in the Amazon basin which will dramatically affect a variety of Amazon ecosystem services b. Cross fields: Dynamic programming algorithms, and biodiversity.	
Games a. Solution for poaching and illegal activities. b. Cross fields: Behavioral game theory, data-driven optimization and Artificial Intelligence (AI).	

Adapted from source: Gomes et. al, 2019

1.3.2 Problem description related to studies

Some institutions such as the Science Education Resource Centre (SERC) at Carleton College, located in Minnesota, United State, provides some supports, resources, and activities for teaching sustainability in the computer science undergraduate program

(Computer science. SISL., 2017). However, it is unknown whether Malaysian universities, especially computing faculties, are aware of these sustainable-computational contents or not. We can achieve a better balance between the requirements of the environment, the economy, and society by using computational sustainability. It provides a strong tool for addressing the complex difficulties of sustainable development and working toward a more sustainable and equitable future. Through the application of cutting-edge computing techniques and multidisciplinary approaches, computational sustainability provides a powerful tool for tackling the complex problems associated with sustainable development. It simplifies the examination of complicated environmental and societal concerns, allowing for the development of data-driven solutions that strike a balance between environmental protection, economic growth, and social equality. Computational sustainability seeks to create and execute solutions that promote a more sustainable, resilient, and egalitarian future for both current and future generations via the use of technology, data analytics, and collaborative efforts across varied sectors.

Other researchers, such as Fisher et al. (2016), Brooks (2019), Gomes et al. (2019), Pucher (2016) and Penzenstadler et al. (2018), have also discussed other strategies to have such multidisciplinary practiced, directly or indirectly. Therefore, fundamentally multidisciplinary may be challenging but it is not impossible. Only now it depends on the readiness of faculties or universities to get involved. Computational sustainability is an emerging subject that integrates scientific research, computational modelling, data analysis, and multidisciplinary collaboration. It provides useful insights and tools for tackling complex sustainability issues and enabling evidence-based decision-making towards a more sustainable future by harnessing computing power and sophisticated analytics. In order to address essential environmental and socioeconomic concerns, the rapidly developing discipline of computational sustainability combines scientific research, computer modelling, data analysis, and multidisciplinary cooperation. It makes use of state-of-the-art computational methods to comprehend complicated systems and provide long-term fixes, including modelling, simulation, and data-driven methodologies.

How far these computing faculties are ready to shape the next generation to be aware of the importance of computational sustainability or, better yet, to encourage their students to learn and practice them, is still an open question. Unfortunately, this topic of readiness on computational sustainability was rarely discussed, either locally or globally. The degree of integration and focus on computational sustainability in educational curriculum varies, despite the rising understanding of the significance of sustainability within computer fields. Aspects of sustainability, environmental effects, and ethical issues are now being included in computer science and associated degrees at several universities. However, there is still a need for more adoption and standardization of computational sustainability themes in computer education. Encouraging students to engage with these concepts necessitates concerted efforts to create specialized curricula, multidisciplinary projects, and research opportunities that emphasize the importance of computational sustainability in tackling real-world problems. As this profession evolves, raising awareness and offering training tools to empower the next generation of computational sustainability experts will be critical to developing a more conscious and knowledgeable workforce to handle sustainability concerns.

Many discussions about readiness that related to this studies were concerned about organizations accepting new technologies or practicing new approaches such as green computing, (Pazowski, 2015; Molla, 2010; Bernaldez, 2019) whereas common readiness studies available in the education field were mostly about teachers or students' readiness related to their teaching and learning (Martin et.al., 2019; Rohayani et. al., 2015). Up to this date, there is no instruments readiness available that can guide us to assess faculty readiness assessment on computational sustainability as the most common readiness from past researcher were come from readiness towards green education (Bernaldez, 2019), faculty readiness to teach online (Martin et.al., 2019), practices on green computing (Pazowski, 2015), green IT readiness (Molla, 2010) and e-learning readiness in higher education (Rohayani et. al., 2015). Without any guidelines or instruments available, the question shall remain unanswered. Thus, this study is planned to propose such instruments that can be purposeful for this issue. Based on Table 1.2 below shows the past studies on related readiness.

Table 1.2

Example of past studies based on their readiness items.

Author	Readiness items involved	Description
Bernaldez (2019)	• Learning content • Learning outcomes • Pedagogy and learning environments • Societal transformation	• The readiness focused on designing education in green curriculum. • The purpose of this studies is designing education in green curriculum serves to prepare students with the knowledge, skills, and mindset needed to address environmental challenges.

Author	Readiness items involved	Description
Martin et al. (2019)	• Course design • Course communication • Time management • Technical competence	• The readiness focused on faculty perception to teach online. • The purpose of study is to understand educators' attitudes, beliefs, and experiences regarding online teaching .
Rohayani et al. (2015)	• Knowledge • Skill • Experience • Attitudes • Motivation • Technology • Infrastructure • Content	• The readiness focused on factors to measuring e-learning readiness. • The purpose of this study is to identify and assess the crucial elements that influence individuals' readiness for engaging in online learning environments.
Molla (2010)	• Attitude • Policy • Practice • Technology • Governance	• The readiness focused on green IT readiness. • This research aims to identify strategies for promoting the adoption of green IT initiatives, ultimately contributing to environmental conservation, resource efficiency, and sustainability in the IT sector.

Based on the Table 1.2 above, we can see the differences in readiness items between different researchers. However, these readiness only consist of a few items of readiness that we can use as a guideline to build our own readiness related to computational sustainability for example technology, knowledge and content related. The main problem towards this study is based on the literature study, resources for determining the readiness dimensions are still lacking, especially related to faculty and computational sustainability. Defining such dimensions would be a huge contribution to the field of study. Additionally, defining levels that can be deemed suitable for each of the readiness dimension would contribute further. Thus, the researcher propose a research on developing the instrument for faculty assessment on computational sustainability that will give opportunity to researcher to make such contributions. Existing instruments that may be used for this study are very limited. Most readiness items, such as those in Table 1.2 above, cannot be used because they are outside the field of computational sustainability. Some purposes based on past researchers were related to the title of our study where the main purpose of this study was to evaluate the readiness and capabilities to adopt sustainable and environmentally friendly information technology practices (Molla, 2010).

In the context of computational sustainability, readiness refers to the condition of readiness and competence to employ computational techniques and tools successfully to address sustainability concerns. Readiness can be very subjective and dependent on different contexts, and it can be defined in different dimensions and stages. Moreover, information related to our focus area is also scarce. Thus, this chosen topic is not simple and easy. However, seeing many great benefits offered by computational sustainability and the incoming trend of integrating sustainability in computing education that will be beneficial to our society and future generations, we are very determined to conduct this study, and thus, should become our novelty contribution to sustainable development and computing education, and also to the society and future generations. The material accessible in our emphasis area on computational sustainability is sparse, implying that diving into this issue is hard and difficult. Regardless of these obstacles, computational sustainability has the potential to provide enormous advantages. With the growing trend of incorporating sustainability into computing education, conducting research in this area becomes critical. Our study seeks to make an exceptional contribution to sustainable development and computing education by venturing into new area. This endeavour is motivated by the notion that our efforts will help society while also paving the way for future generations to address key environmental and socioeconomic concerns via the creative use of computational tools and multidisciplinary approaches.

1.4 Research Objectives

The objective of research project summarizes what is to be achieved by the study. These objectives have to be stated to know whether the guidelines have been followed and the objectives have been successfully achieved. There are three objectives to this research. The objectives are as follows:

a. To investigate readiness dimensions and readiness levels that are deemed suitable for faculty readiness assessment on computational sustainability.

b. To develop readiness instrument for faculty readiness assessment on computational sustainability.

1.5 Research Questions

a. What dimensions and levels are deemed suitable to be used for faculty readiness assessment on computational sustainability?

b. How to develop readiness instrument for faculty readiness assessment on computational sustainability?

1.6 Conceptual framework

1.6.1 Introduction of conceptual framework

In computational sustainability, a conceptual framework provides an organized and systematic method for understanding and addressing complex sustainability challenges. It assembles fundamental concepts, connections, theories, and methodologies to guide the research process and develop knowledge and practice in the discipline. A conceptual framework for computational sustainability gives an organized and complete view of the topic, detailing its essential features, principles, and components. It provides a foundational reference for understanding and solving the difficult challenges at the convergence of computer science, environmental science, and sustainability. It emphasizes the potential of computational approaches to crafting a sustainable future by tackling important concerns and ensuring peaceful cohabitation between people and the environment. Computational Sustainability contributes to the sustainable development movement by creating data-driven solutions (Sakib, 2020). By utilizing extensive computational methods like data analysis, machine learning, and optimization, creative solutions to challenging sustainability problems may be developed. Computational sustainability, in its simplest form, is the application of data-driven solutions to inform, guide, and optimize plans that are meant to build a more resilient and sustainable future for society and the environment. Chande (2014) states that the importance of sustainability education is growing, but sustainable development poses a challenge to pedagogy in all fields. Sustainability education is becoming increasingly important as a means of addressing complex global concerns such as climate change, biodiversity loss, resource depletion, and social injustice. Incorporating sustainability into all sectors of education is critical because it provides students with the information, skills, and mentality required to contribute to a more sustainable future. According to Chatterjee (2020), computational sustainability refers to the application of computational technologies and computational thinking to the advancement of sustainability. Computational sustainability encourages cooperation among computer scientists, ecologists, economists, and politicians to solve important environmental and societal issues using novel computational solutions.

The development of the conceptual study is based on previous studies. The concept analyzes the ethical and social aspects of computational sustainability, stressing responsible technology usage and equitable benefit sharing. This notion emphasizes the significance of addressing ethical standards, societal ramifications, and justice while using computational tools for sustainability. It emphasizes the significance of meeting societal concerns, environmental justice, and cultural viewpoints. The ethical and social dimensions of computational sustainability highlight the responsible and ethical use of technology to address sustainability issues while ensuring that the benefits are distributed equally across varied groups and stakeholders. This strategy is critical to promoting a more inclusive, equitable, and sustainable future. The advanced skills and experience required to implement complex computational and physical technology behaviors, activities, and processes. Implementing complicated computational and physical technology behaviors involves a mix of technical experience, subject knowledge, problem-solving abilities, and the capacity to adapt to changing technological environments. Based on the publication titled "Teacher readiness in accommodating the TPACK framework to meet teacher competence in the 21st century" by Sarwa, A. S., Hasibuan, N. I., & Priyadi, M. (2020), stated the competencies needed for teacher readiness. Figure 1.3 below shows the teacher competencies. However, this study focused on the component’s technology and content, as both of these components link to the three basic dimensions of sustainability, which are environment, economy, and society.

Figure 1.3

Teachers Competencies in TPACK framework

	Component	TPACK Framework		
		Technology	Pedagogic	Content
4 teacher competencies	Professional	computerized	learning orientation	comprehensive coverage
	Pedagogic	use of multimedia	cyber pedagogic	unique and interesting
	Social	wise in social media	interactive	filter information
	Personality	ICT update	patron	tolerance

1.6.2 Existing framework that mapped into conceptual framework

1.6.2.1 Technology and content component

TPACK (Technological Pedagogical Content Knowledge) was a framework in education that describes the complex interplay and integration of three fundamental categories of knowledge that instructors require to effectively incorporate technology into their teaching methods. Teachers who have strong TPACK skills may pick suitable technological tools, align them with specific curriculum areas, and use pedagogical tactics to enable meaningful learning experiences for their students. According to Eichelberger et al. (2019), suggest that understanding technology is a crucial component of teacher expertise. In my review, based on the past researcher statement, as technology grows and influences all aspects of life, including education, educators must educate themselves with the knowledge and abilities required to successfully use technology to improve teaching and learning experiences. Furthermore, comprehending technology necessitates a dedication to lifelong learning and professional growth, since technology evolves and shapes the future of education. However, there are key references that are referred to during the discussion process between technology and content components in the TPACK framework above. The discussion is based on several important components expressed by main reference in this study, Sarwa et al. (2020). The table 1.3 below refers to important components and details that are used as a basic term to develop dimensions related to computational sustainability. Table 1.3 below also states our own review of each component and the details stated by past researcher.

Table 1.3

A review on TPACK framework literature.

Author	Component	Details	Review
Sarwa et al. (2020)	Technology	Teachers and academics who are proficient in technology should be computer-literate.	We can conclude that teachers and academics who are knowledgeable in technology and computer-literate are more prepared to meet students' changing demands, engage in successful teaching techniques, and contribute to the progress of education in the digital age.
		Aligning teacher competency with the technology framework enables instructors to employ learning resources in various presentation modes, including multimedia.	Educators can explore new avenues for delivering content, designing interactive activities, and assessing student learning outcomes using digital tools and platforms.
		Computer technology is constantly evolving, causing software and programs to become outdated rapidly.	From a positive standpoint, the fast growth of computer technology stimulates creativity and pushes for constant improvement in software and programs.

Author	Component	Details	Review
Sarwa et al. (2020)	Content	In today's world, teachers must be proficient in using software and programs to fulfil their tasks.	By embracing digital tools and resources, teachers can create innovative learning experiences, enhance student engagement and achievement.
		Aligning pedagogically competent instructors with the content knowledge framework allows for the development of distinctive and engaging instructional materials.	The educators can incorporate a variety of teaching methods, such as lectures, discussions, hands-on activities, and multimedia presentations, to address different learning styles and engage students in active learning.
		In the digital age, competent teachers must be tolerant of and respect individual variations.	We conclude that this aspect encourages diversity and actively works to provide an inclusive learning environment in which all students feel valued, respected, and supported. This includes cultivating a culture of acceptance and tolerance, encouraging open discourse, and combating bias and discrimination in all forms.

In content knowledge, indicates a teacher's skill and thorough comprehension of the material they teach. It entails an understanding of the concepts, theories, and basic principles of a given academic or topic field. According to Eichelberger et al. (2019), faculty beliefs about students' readiness to use technology for learning emerged as a prominent theme. As technology becomes more prevalent in society, there is a greater expectation that students will have digital skills and competencies. However, faculty opinions regarding students' readiness to use technology might vary greatly, depending on personal experiences, pedagogical ideals, and institutional support. Content knowledge serves as the foundation for teaching, learning, problem solving, and future inquiry within a certain topic.

1.6.2.2 Teaching strategies component

Moreover, according to Senthamarai et al. 2018, a new level of learning and teaching in general is a top priority in education. Education must develop to suit the changing needs of the modern world. This involves teaching pupils skills for the future workforce, responding to technological changes, and tackling global issues like sustainability and digital literacy. It is consistent with the research study that teaching strategies are an important component in developing an instrument development for faculty readiness assessment on computational sustainability. The teaching strategies are intended to encourage critical and reflective thinking, research, and assessment abilities that will enable students to take positive action (Senthamarai, 2018). Implementing new teaching methods and technology can boost student engagement and knowledge retention. Interactive and tailored learning experiences may accommodate different learning styles, keeping students more involved in their studies.

Teaching practices that promote critical and reflective thinking are vital for creating a better grasp of the subject matter, increasing problem-solving abilities, and enabling students to think critically and independently. Moreover, lecturers employ a variety of strategies to entice students to participate in a learning topic. Next, teachers may equip students to be lifelong learners who can think critically, solve challenging issues, and make wise judgments in a range of situations by helping them develop these cognitive abilities. Organizations need large strategies and resources to achieve the best application (Adiyarta et. al., 2018). Finding the optimal way to use resources and tactics is a continuous process that calls for a dedication to the organization's broad objectives, a focus on efficiency, and a willingness to adapt. It frequently calls for strategic planning, strong leadership, and an acute awareness of the internal and external dynamics of the organization. However, promoting a culture of continual learning will prepare individuals for long-term success in a continuously changing world. It highlights the significance of learning new skills, keeping up with current information, and adjusting to new situations throughout one's life.

1.6.2.3 Training component

Next, according to Golzari et al. (2010), training is a suitable strategy for improving the teaching-learning process quality. Training is an appropriate and successful technique for enhancing the teaching-learning process. Many training approaches include interactive components, including discussions, group activities, and practical exercises. This involvement encourages active participation and a deeper knowledge of the content, making the learning process more meaningful and memorable. With technological improvements, training may now use a variety of tools and platforms to improve the learning experience. Online courses, simulations, and virtual laboratories provide interactive and immersive learning, reaching a larger audience and supporting a variety of learning styles. As to conclude, an effective educator and student training programs can result in improved teaching approaches, increased student engagement, and improved learning results.

Continuous training and professional development are vital for keeping up with the changing educational scene and maintaining the highest quality of teaching and learning. Moreover, past researchers also mentioned that adoption-ready institutions have built procedures for training end-users to provide specialized learning opportunities for new technologies (Karp et al., 2014). The goal of training at adoption-ready institutions is to provide end users with the knowledge and skills they need to effectively use new technologies. This strategy guarantees that end users are comfortable and competent in implementing technologies into their regular activities. Institutions that are prepared for adoption place a high priority on the creation of policies and initiatives that teach end users efficiently. These organizations create an atmosphere where the effective integration of new technology becomes a smooth and long-lasting process by providing specialized learning opportunities, tailoring training programs, encouraging a user-centric approach, and encouraging a culture of continuous learning.

According to past researcher, Schonert-Reichl (2017), the goal of excellent teacher preparation and professional development has been to identify the experiences and courses that will equip educators with the abilities, attitudes, and knowledge necessary to support the academic achievement of all of their students. Effective teacher preparation focuses on acquiring pedagogical skills such as instructional tactics, classroom management, and assessment methods. Teachers were given the necessary tools to create engaging and inclusive learning environments. Teachers were trained to examine student data and make sound instructional judgments. This data-driven approach facilitates the identification of areas for development, the customization of teaching tactics, and the effective monitoring of student progress. The focus of effective teacher preparation and professional development was to provide a comprehensive education that extends beyond subject matter competence. It strives to provide educators with the skills, attitudes, and knowledge required to support each student's academic progress while also promoting an inclusive and effective learning environment.

1.6.2.4 Equipment and software component

The equipment used as teaching materials is significant. Implementation-ready colleges have matured IT infrastructure, including the necessary hardware, software, network capabilities, and human resource capacity to enable the technology's application (Karp et al., 2014). A developed IT infrastructure is a critical necessity for efficiently adopting technology in higher education. It improves educational quality, encourages new teaching techniques, and prepares students for a technologically driven society. It is also necessary to adjust to the changing educational landscape, where online and blended learning are quickly becoming the standard. The efficacy of instructional strategies, student engagement, and comprehension may all be significantly impacted by the choice of teaching tools. In conclusion, choosing and utilizing instructional tools and resources is a deliberate choice that should be in line with learning goals and student requirements. Good instructional resources can raise standards of instruction, facilitate the teaching-learning process, and support students' overall academic achievement. This component also related to environment in three basic dimensions of sustainability. According to Siswanto et al. (2020), improving educational facilities and infrastructure is crucial for enhancing teaching and learning quality in the education field.

Well-designed and well-maintained facilities help to create a good and conducive learning environment. Comfortable classrooms, up-to-date libraries, and contemporary facilities provide an environment that promotes effective teaching and active learning. Investing in infrastructure enhancements that prioritize sustainability guarantees that educational buildings can fulfil the demands of future generations.

Energy-efficient structures and eco-friendly methods help to save long-term costs and promote environmental responsibility. Moreover, increasing educational facilities and infrastructure was critical for increasing teaching and learning quality because it laid the groundwork for a good and productive educational experience. Access to resources, safety measures, technological integration, specialized facilities, and community participation all contribute to a comprehensive strategy that promotes student growth and instructor success. Infrastructure management aims to improve the effectiveness and efficiency of educational equipment by coordinating its utilization (Siswanto et.al., 2020). Educational institutions frequently rely on technology to educate and learn.

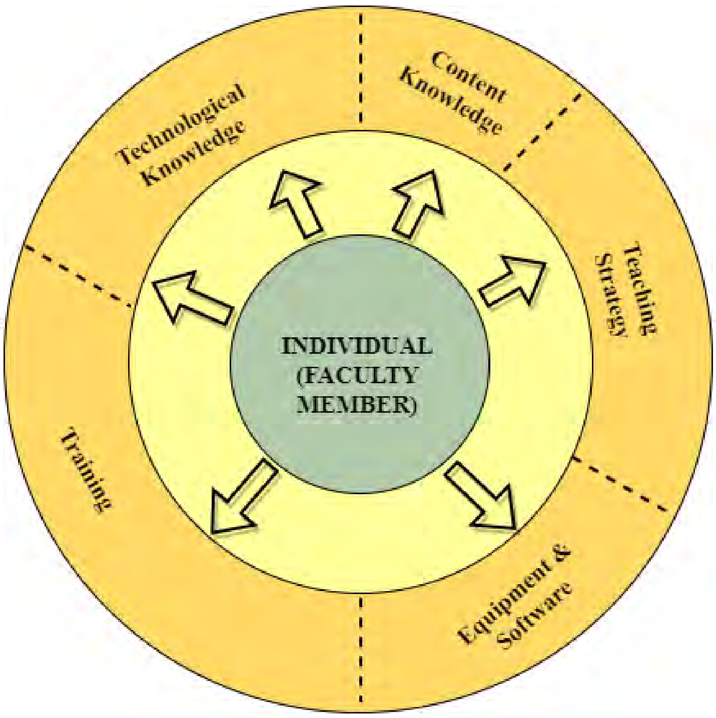
Infrastructure management ensures that technology is integrated into the educational environment by providing dependable internet access, upgrading software, and maintaining working hardware. Infrastructure management seeks to make educational facilities and equipment accessible to all students, regardless of ability or background. This might include incorporating inclusive design principles and ensuring that technology is accessible to students with impairments. Past researchers also agreed that ensuring proper facilities and infrastructure enhances the learning experience and quality (Siswanto et al., 2020). Infrastructure management in education is a deliberate and collaborative approach to improving the efficacy and efficiency of educational equipment. Infrastructure management helps to provide a favourable and well-equipped learning environment by planning, maintaining, coordinating usage, and assisting with technology integration.

1.6.3 Conceptual framework dimensions

With all the articles that the researcher have gone through, it can be determined that there are five dimensions of readiness involved in this research. The dimensions are technological knowledge, content knowledge, teaching strategy, training, and equipment and software. Based on the Figure 1.4 below shows the conceptual framework related to computational sustainability readiness in faculty. The dimensions in the conceptual framework are technological knowledge, content knowledge, teaching strategy, training, and equipment and software.

Figure 1.4

Conceptual framework



1.7 Theoretical framework

A computational framework's theoretical framework comprises the underlying ideas, theoretical notions, and models that support the design, development, and implementation of the computing system. It provides a structured foundation for understanding and addressing complicated issues by specifying the essential ideas, assumptions, and relationships that drive the framework's functioning. Shoolestani

(2015); Chande (2014) stated that sustainability issues are divided into three categories: environmental, economic, and societal. According to Chiamaka (2019), the differences in the various definitions of the term sustainable development are primarily determined by how each of the three objectives: economy, environment, and society, is highlighted. It is a synthesis of issues and requirements for the design of sustainable solutions in the economic, environmental, and societal domains, as well as technological, mathematical, and computational approaches to problem solving. It is vital to have a broader view of the rising complexity of computer infrastructures and to guarantee that the interconnection of IT, society, and the environment is not overlooked (Chatterjee, 2020). Furthermore, a limited viewpoint may overlook the societal consequences of technical breakthroughs, such as privacy problems or socioeconomic inequality. As a result, a broader perspective was required to meet the varied challenges and possibilities posed by the complex interplay of IT, society, and the environment. Understanding this complex link enables more effective and lasting solutions. For example, addressing environmental problems in IT processes, taking into account the societal implications of technological advancements, and encouraging ethical considerations in technology deployment. Recognizing and negotiating these interrelated dynamics allows us to better handle the complexities of the changing IT world, social requirements, and environmental sustainability.

The definition about computational sustainability of (Milano, 2014) is slightly different from the other researchers. Milano (2014) states that, computational sustainability addresses issues in fields as diverse as ecology, natural resources, atmospheric science, materials science, renewable energy, and biological and environmental engineering. Sustainable Computing is a new multidisciplinary topic that tries to integrate techniques from computer science and related fields, such as information science, operations research, applied mathematics, and statistics, to make the world a better place (Shukla, 2015). The goal of sustainable computing is to design and implement technologies that are environmentally benign, socially responsible, and commercially successful. This involves attempts to lessen the environmental effect of computer operations, improve energy efficiency, reduce electronic waste, and address the long-term societal ramifications of technological advances. Sustainable computing seeks to balance technological innovation with long-term environmental and social well-being. Furthermore, many studies have found that information and communication technologies (ICT) play a vital role in achieving sustainability. Socially, ICT improves communication, cooperation, and information exchange, which promotes social growth and inclusion. Furthermore, economically, ICT may stimulate innovation, enhance efficiency in a variety of industries, and contribute to economic growth. The integration of information and communication technology was acknowledged as a critical facilitator of sustainable practices across several areas. IT and communication technology are critical facilitators of sustainability. They provide data gathering, analysis, and distribution tools that improve decision-making and resource management in ways that benefit the environment, economy, and society. Utilizing ICT is a critical technique for tackling many of the difficult issues associated with sustainability. ICT can enhance resource management, increase energy efficiency, and enable sustainable practices by leveraging data analytics, smart systems, and communication technologies. It also facilitates improved communication, cooperation, and information transmission, thereby increasing society's awareness and involvement in sustainable efforts. Organizations and society may use ICT skills to build new solutions to navigate and handle the multiple difficulties related to sustainability. Figure 1.4 above considering the relevant domains on sustainability and computational

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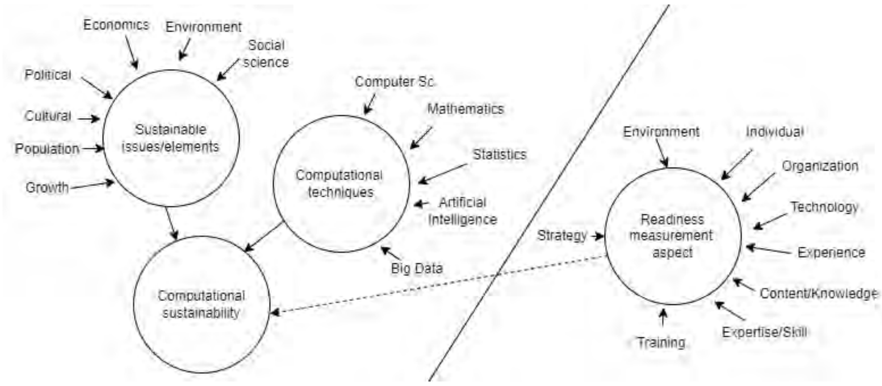
approaches as well as readiness measurement aspect.

The use of computational approaches to problem-solving and improvement in various aspects of sustainability implies a growing need to raise awareness of and apply these techniques to sustainability, including the readiness measurement aspect. The ability to analyze and solve problems that are becoming more complicated and data-intensive requires the use of computational techniques for problem-solving, which are indispensable in the current world. TTN Phan & LTT Dang (2017), defined readiness as being fully prepared for some experience or action. Readiness may be utilized in a variety of contexts, including personal growth, education, and professional settings, where being well-prepared leads to positive results and successful achievements. Readiness of institutional-level practices or cultural characteristics that will influence the college's ability to support and implement reform (Karp et al., 2014). This preparedness was defined by a set of organizational practices and cultural traits that impact the institution's capacity to effectively adopt and implement reform efforts. Clear communication lines, well-defined policies, and strategic planning to aid the reform process are all examples of preparation practices. Cultural traits, on the other hand, refer to the institution's values, beliefs, and attitudes, which can help or impede reform initiatives. A culture that promotes creativity, cooperation, and adaptation is better positioned to successfully implement educational reforms. In summary, institutional preparedness is a vital aspect that defines a college's ability to navigate and adapt to changing educational demands and objectives.

The theoretical framework above is important for this study. A theoretical framework acts as the intellectual underpinning of a research study, guiding the research process and assisting in the interpretation of outcomes within a well-defined context. The theoretical framework is the use of one (or more) theories in research, while conveying the researchers' deepest values and providing a clear signal or lens of how the research will address new knowledge (Collins et. al., 2018). Figure 1.5 below shows the theoretical framework in this study.

Figure 1.5

Theoretical framework



In the context of computational sustainability, readiness measurement refers to determining the readiness of a plan or effort to handle sustainability concerns using computational methodologies and technology. This element entails assessing several parameters to ensure that the plan is successful and viable within the computational sustainability framework. Assessing the availability and sufficiency of computing resources, such as hardware, software, and data storage, in order to facilitate the implementation of sustainability strategies. Next, examine how computational sustainability techniques might adapt to changing environmental circumstances and developing sustainability concerns. This entails incorporating flexibility into models and techniques to handle shifting problems. Moreover, take into consideration people's knowledge and commitment to ethical principles while using computational approaches for sustainability. This includes ensuring responsible and transparent data processing and decision-making. Investigating people's adaptation to new technology and creative techniques in the continually changing field of computational sustainability. The capacity to adopt new methodologies and technology aids in staying at the forefront of research and application. Organizations and educational institutions may better prepare workers to contribute to the junction of computational approaches and sustainability concerns by taking these individual-level factors into account when measuring readiness.

Assessing technology's readiness for ongoing upgrades, maintenance, and adaptation to developing computational methodologies. This guarantees that sustainability solutions are both relevant and successful over time. Evaluate the incorporation of machine learning and artificial intelligence (AI) techniques into computational sustainability models. These technologies improve the predictive and analytical capability of sustainability applications. In the context of computational sustainability, readiness evaluation based on experience entails examining the collective knowledge, skills, and lessons acquired from previous efforts to apply computational tools to address sustainability concerns. By taking these experience-related aspects into consideration when measuring readiness, organizations and practitioners can tap into the collective wisdom gained from previous efforts, fostering a more informed, adaptive, and successful approach to using computational methods in the pursuit of environmental sustainability. Identifying and recording learning from prior experiences with computational sustainability. These insights assist in fine-tuning plans, optimizing procedures, and avoiding typical errors. Assessing the capacity to integrate information from other fields and creating a comprehensive approach to computational sustainability that takes into account both environmental and computational aspects. Through the assessment of these content knowledge-related elements in readiness measurement, people and institutions can guarantee a solid basis for utilizing computational techniques to tackle sustainability issues, promoting well-informed choices and efficient problem-solving in this multidisciplinary domain.

Readiness measurement in the context of expertise or skill knowledge related to computational sustainability refers to determining an individual's or a system's ability to successfully contribute to sustainable practices via the use of computational methodologies. It entails assessing the competency, knowledge, and skills of individuals, teams, or technology in using computational methodologies to address sustainability issues. For example, by assessing the capacity to adapt and apply computational solutions to growing sustainability difficulties while taking into account the dynamic nature of environmental and societal issues. Moreover, evaluating the ability to cooperate with specialists in many domains is important since computational sustainability frequently requires an interdisciplinary approach. Readiness measurement ensures that individuals and systems are well-equipped to use computational tools and approaches to address sustainability issues, resulting in effective and sustainable solutions. In the context of computational sustainability training, readiness measurement focuses on analysing training programs' readiness and efficacy in providing individuals with the skills and knowledge needed to handle sustainability concerns using computational methodologies. For example, assessing if the training program was consistent with the core concepts, methodologies, and applications of computational sustainability and ensuring that participants obtained relevant and current information. In order to guarantee that participants are adequately equipped to make a significant contribution to computational sustainability initiatives, readiness measurement in training assesses these elements. This helps to cultivate a workforce that is both knowledgeable and proficient in this crucial area of computing and sustainability.

1.8 Scope

This study only covers developing an instrument that can assess readiness among faculty members to educate students on computational sustainability. This study involved expert reviewers from three local universities in Malaysia, comprised of lecturers and senior lecturers with at least 5 years of experience in computing-related education.

1.9 Definition of term

1.9.1 Framework

The framework is defined as the abstract, logical structure of meaning that guides the study's development. A framework is a reusable software structure or collection of tools that serves as a basis for constructing applications or addressing specific challenges in a given domain. It acts as a skeleton or blueprint for software development by offering preset functions, and rules that developers may utilize to expedite the development process. Frameworks are created to give structure, consistency, and direction, lessening the need to start from the beginning for every issue or circumstance. They provide a shared language, practices, and framework of reference to help with decision-making, problem-solving, and collaboration in a particular field or discipline. Across different fields, a framework offers a shared structure and comprehension among practitioners, researchers, and developers. It assists in organizing intricate information, ideas, or techniques into a logical and organized approach. The purpose of a framework will determine whether it is conceptual, theoretical, or practical.

1.9.2 Instrument

Instruments is defined as a concise and detailed description of how the instrument will be used to measure or evaluate a specific occurrence or variable in a scientific or research context. This concept highlights the critical role instruments play in ensuring the reliability and validity of data obtained during research projects. This section describes the specific methods, criteria, and methodology used to ensure consistent and accurate measurements or assessments. They are necessary for gathering information, performing experiments, and assessing many elements of the natural or social environment. They provide accurate measurement, observation, and modification of variables or events, hence facilitating data collection, experimentation, and analysis. The instrument also helped to gather data and analyze human behavior, attitudes, and interactions. Surveys, questionnaires, interviews, and observation protocols are common instruments used in social research.

1.9.3 Computing faculty

Computing faculty is defined as the academic unit responsible for computer science education and research. Undergraduate and graduate programs in computer science, computer engineering, information technology, or related subjects are often offered by the faculty. They frequently work with industrial partners and government organizations to solve real-world problems and advance science. Computing faculty members are usually employed by universities, colleges, or other educational establishments. The computing faculty is essential in furthering knowledge and expertise in computing-related fields and educating the next generation of computer scientists and professionals. They are tasked with creating and teaching courses, creating curricula, guiding students, and researching various sub-areas of computer science, including artificial intelligence, algorithms, software engineering, data science, cybersecurity, and more. Computing faculty members are expected to remain up-to-date with the most recent developments in their field, engage in scholarly pursuits, and continually refine their teaching approaches. They are essential for creating a setting that encourages imagination, analytical thinking, problem-solving abilities, and ethical behavior among students studying computer science or related fields.

1.9.4 Readiness

Readiness is the state of being ready or prepared to perform something. A condition of preparedness or readiness to deal with a certain event or job is referred to as readiness. It denotes possessing the requisite information, abilities, resources, and mentality to confront and respond to a specific scenario or opportunity. Readiness is frequently connected with being well-prepared, organized, and equipped to handle difficulties or capitalize on opportunities when they present themselves. Readiness involves being proactive and prepared rather than reactive or ill-prepared. This entails anticipating potential difficulties, obtaining the required resources and knowledge, and cultivating a mindset of readiness and flexibility. Being prepared is essential for effectively dealing with uncertainties, taking advantage of opportunities, and successfully navigating through various situations. Readiness also means an individual's ability to cope with a particular situation or assume a certain role. It requires having the aptitude, understanding, expertise, and attitude to successfully address issues or prospects. For example, someone may need to hone their technical abilities and obtain the necessary qualifications to be prepared for a new job or a career switch.

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1.9.5 Computational sustainability

Computational sustainability is defined as a principle that encompasses a wide range of policies, processes, initiatives, and attitudes that cover the entire spectrum of information technology use. It focuses on using computational methods and tools to create long-term solutions and inform decision-making processes. It uses computational tools and data-driven methodologies to balance and maximize environmental, economic, and societal problems. Computational sustainability is an interdisciplinary field that applies computational techniques, data analysis, and modeling to tackle intricate environmental, economic, and social issues related to sustainability. This field combines computer science, artificial intelligence, machine learning, optimization, and ecological and social sciences to create novel strategies and solutions for sustainable resource management, conservation, and decision-making. Computational sustainability seeks to bridge the gap between scientific research and practical solutions by providing tools and approaches for dealing with the complex and interlinked concerns of sustainability. It highlights the significance of multidisciplinary collaboration and the use of computational tools in order to generate new, data-driven solutions for a more sustainable future.

1.9.6 Delphi technique

Delphi is an organized and iterative strategy for gathering and distilling expert viewpoints in order to make educated judgements or forecasts on difficult or ambiguous matters. It is a consensus-building strategy in which a group of experts anonymously and iteratively provides their thoughts with the purpose of gaining convergence and establishing a collective worldview. This system is intended to help build consensus and make decisions in scenarios where there is uncertainty or a lack of comprehensive data. The facilitator creates a questionnaire or survey with open-ended or closed-ended questions on the subject of interest. These inquiries might be about making forecasts, making judgments, evaluating things, or seeking expert advice. This technique also enables the systematic collection and assessment of multiple perspectives, which can help to reduce bias and improve the quality of decision-making. The questionnaire is distributed to the experts, who respond independently. Following the first round, the facilitator gathers the replies and presents a summary to the panel without revealing individual names. Experts are then requested to reevaluate their positions or give additional insight based on the aggregate comments gathered. The Delphi approach seeks to generate a group consensus or prediction from the different viewpoints of experts, assisting in the identification of areas of agreement, disagreement, or uncertainty. It does not seek complete agreement but rather seeks to reduce severe differences of opinion. It is especially beneficial when dealing with complicated, ambiguous, or future-oriented situations when typical data collection approaches may fall short. The process's organized and anonymous nature helps to eliminate biases and encourages the consideration of a variety of expert opinions. The Delphi approach attempts to establish a group agreement or viewpoint. This agreement is frequently stated statistically as a median, mean, or range of expert opinions.

1.9.7 Content validity index (CVI)

The Content Validity Index (CVI) is a statistical metric used to evaluate the relevance and representativeness of a measuring instrument, such as a survey or questionnaire, to determine its validity. It quantifies how well the items in the instrument capture the construct or subject of interest. CVI is typically calculated by a panel of experts who rate each item for content validity. The experts assessed whether the items adequately represented the content domain that they intended to measure. CVI is based on the proportion of experts who agree that an item is relevant or representative of the construct being measured. The CVI (Content Validity Index) boosts content validity and enhances the quality of the measurement instrument by incorporating expert opinions. Item-level Content Validity Index (I-CVI) and scale-level Content Validity Index (S-CVI) are the two most commonly utilized forms of Content Validity Index. I-CVI and S-CVI are both useful in determining content validity. They aid in ensuring that the items on a scale or assessment instrument accurately represent the construct or idea being measured, as determined by a panel of subject matter experts. This index examines the relevance of individual items or questions inside a measuring instrument for the Item-Level Content Validity Index (I-CVI). It is calculated by assigning a score to each item based on its relevance to the topic under examination. Experts typically use a scale (such as a 3-point or 4-point scale) to assess items' relevance. Items having higher I-CVI scores (usually a set cutoff value, generally 0.78 or 0.80) are seen to have acceptable content validity. Scale-level Content Validity Index (S-CVI) is an index that evaluates the overall content validity of a scale or instrument.

1.10 Limitation of study

Computational sustainability is strongly reliant on data, and data quality and availability can be substantial constraints. Relevant data may be limited, fragmentary, or of varied quality in many circumstances, making it difficult to construct reliable models and forecasts. Access to high-quality and diverse datasets was crucial for computational research. Previously, data availability constraints, particularly for specific ecosystems or geographic locations, might have limited the scope and depth of computational sustainability research. Access constraints to previous research on computational sustainability challenges can be a significant obstacle for researchers to understand and address these issues. The computer techniques and models used in sustainability studies require a large amount of processing power. Previously, limited computational capabilities may have prevented researchers from undertaking complicated simulations or thorough studies. The multidisciplinary characteristics of the area necessitate collaboration among professionals from various backgrounds. However, the scarcity of professionals competent in both computational methodologies and sustainability sciences may have limited the breadth and effect of previous research initiatives. In the past, access to cutting-edge equipment and infrastructure for performing computational experiments and analysis may have been limited, thus limiting the development and scale of research projects. The fact that a large number of earlier publications were not published under open-access models might hinder the dissemination of information to a wider audience by limiting access to the study findings. Paywalls, requiring readers or institutions to pay for access to full articles, are common in scientific publications. This may restrict access to important research, particularly for those people or institutions lacking subscription access. A large number of earlier publications were not released in open-access formats, which limited who could access the study results. This may restrict the amount of information that is shared with a larger audience.

The second limitation was that researchers in computational sustainability have resource constraints, such as a limited number of experts skilled in these studies, which can restrict the range and impact of research studies. A restricted number of knowledgeable specialists might limit the diversity of viewpoints and expertise accessible for study. This may limit the depth and breadth of research on a given topic. To handle numerous challenges in computational sustainability, collaboration and multidisciplinary effort are essential. However, the low number of specialists may limit prospects for cross-disciplinary collaboration. This constraint may result in insular research endeavours and impede the study of various views. Since computational sustainability is still an emerging and developing topic, there aren't many organized training and educational programs available. There are thus fewer specialists with substantial experience. Proficiency in several fields is necessary for computational sustainability, such as computer science, ecology, environmental science, economics, and the social sciences. It might be difficult to find people who are knowledgeable in each of these fields. Computational sustainability is an ever-changing area. The lack of competent professionals may limit the breadth and depth of computational sustainability research investigations. This constraint has the potential to prevent the discovery of novel solutions to complicated sustainability concerns, thereby reducing the overall effect of research on the subject. As it evolves, there may be a scarcity of professionals who are up-to-date on the latest methodologies and technology. Transferring knowledge and competence in computational sustainability from existing professionals to the next generation can be difficult since knowledgeable people in computational sustainability are scarce. To solve these issues, it may be necessary to engage in education and training programs, promote multidisciplinary collaboration, and foster the creation of a diverse and talented workforce in the field of study. Increasing the number of specialists can help create a more lively and influential research ecosystem.

The third limitation highlighted throughout this research is that some of the experts on the panel took a long time to answer the assessment instrument in the Delphi approach. The Delphi technique frequently comprises several rounds of questionnaires or polls sent among experts. Each round necessitates some time for participants to answer, and this iterative process can last multiple cycles. Time restrictions may limit the number of rounds feasible, impacting the depth or accuracy of the established agreement. Coordination of expert availability for numerous rounds within a given timeframe might be difficult. Conflicting schedules and the availability of busy experts might make it difficult to complete each cycle on time. Experts may have hectic schedules and restricted availability, making it difficult to form a panel and collect their feedback in a timely way. This can cause content validation to be delayed. Even when experts are accessible, it is possible that they may need more time to properly study and offer useful input on the evaluation tool. Rapid replies may not accurately reflect their genuine expert judgment. It might be cognitively tiring to review and provide feedback on a large number of objects or questions. As the review process progresses, experts may become tired or lose focus, thereby impacting the quality of their judgments. Some evaluation instruments may contain difficult or technical things that take a large amount of time to comprehend and completely analyze. Experts may require additional time to correctly appraise these goods.

1.11 Significance of study

This study will benefit where this study is to generate meaningful new knowledge of the extensive and national research community, including the education, computing, and sustainability of computing education. Computational sustainability research encourages innovation in computer technology. It promotes the creation of novel algorithms, machine learning methodologies, data analytics, and computational models that are especially designed to address concerns about sustainability. Besides, in the future, students also may gain an awareness of and desire to participate in sustainable development activities and create better generations that can sustain the world. The proposed framework can provide information that should increase attention to current practices used in educating computational sustainability among computing faculties. It may also support our Malaysian government's Shared Prosperity Vision 2030 (SPV 2030), which is in line with the 17 Sustainable Development Goals 2030 (SDGs 2030) at the international level. Thus, this research outcome should benefit researchers, faculty, students and policy makers, as well as our society and future generations.

The relevance of computational sustainability research extends to teaching possibilities inside the computer faculty. These programs allow students to engage in multidisciplinary research, preparing them for employment that entails using computational abilities to tackle real-world sustainability concerns. Thus, we hope that we can create better future generations that can sustain our world. In conclusion, computational sustainability research within the computing department is critical because it provides novel solutions, fosters multidisciplinary cooperation, advances computing methodologies, and contributes to the worldwide quest for sustainability. The results of research on computational sustainability might have a significant worldwide influence. These studies support international efforts to create a sustainable future by tackling social and environmental challenges.

1.12 Summary

The introduction is a critical element of a document or research paper that offers an overview of the work's topic, setting, and goal. Its purpose is to orient the reader, establish the stage for the next topic, and emphasize the importance of the subject matter. The introduction starts by explaining the background information and context for the issue. This includes describing any relevant ideas, concepts, or past research in the area, as well as discussing the importance of the subject matter, documenting its historical evolution, or outlining any relevant theories, concepts, or prior research in this field of study.

In the next part, the introduction outlines the problem statement related to the study field as well as defining the research objectives and research question for this study. The conceptual framework and theoretical framework are also stated in this chapter. A brief definition of the term was also provided. Last but not least, the significance of the study is stated at the end of this chapter. Overall, the introduction establishes the tone for the document, attracts the reader's attention, and conveys a clear knowledge of the work's goal, context, and relevance. It assists the researcher in understanding the significance and motive behind the research or paper, allowing them to connect with the material in a meaningful way.

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