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Faculty Readiness on Computational Sustainability: A Literature Synthesis on the Readiness Dimensions

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Abstract

Computational sustainability has become a key topic bridging environmental science, computer science, and sustainability research. This literature review explores the readiness dimensions necessary for advancing computational sustainability projects and examines how computational tools are applied to address sustainability challenges across various domains. This study examines 33 case studies and 56 empirical research papers that demonstrate the use of computational tools to improve readiness in a variety of scenarios, including technology readiness, faculty readiness, teaching readiness, e-learning readiness, and green education. By extensively reviewing previous material, this synthesis identifies recurring themes and emerging trends in readiness assessment across many sustainability sectors, case studies, and empirical research. The study blends several views and approaches, resulting in a better understanding of how readiness aspects might aid in the application and efficacy of computational tools in sustainability research. The literature synthesis highlights the dimensions of readiness in this study, ranking technological knowledge (35%), content knowledge (25%), teaching strategies (20%), training (15%), and equipment/software (5%) based on their significance in determining how well societies are prepared to effectively adopt sustainable practices. This literature synthesis explores readiness factors in computational sustainability, highlighting recent advancements and trends. The review focused on English-language publications from 2018 to 2024, with additional research from 2010 to 2017. This comprehensive analysis of faculty readiness for computational sustainability aims to enhance its effectiveness, paving the way for broader studies that benefit researchers, faculties, students, policymakers, and society.

Keywords: computational sustainability, synthesis, readiness, dimensions, technology.

INTRODUCTION

The vast field of computational sustainability seeks to maximize social, economic, and environmental resources by applying techniques from computer science and mathematics. This multidisciplinary domain focuses on establishing algorithms, models, and simulations to tackle complex challenges in resource management, conservation, and sustainable development. Computational sustainability aims to address issues such as climate change, biodiversity loss, and efficient energy use by utilizing data analysis, machine learning, optimization, and network science, ultimately promoting a more balanced and sustainable interaction between human activities and the natural world. According to Saha (2018), sustainable development is growth that does not jeopardize the needs of future generations. It ensures that present economic, social, and environmental requirements are met without depleting or degrading

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natural resources, allowing future generations to meet their own needs. This approach strikes a balance between advancement and conservation, fostering actions that promote the long-term health and viability of ecosystems, communities, and economies.

Computers, which have long been employed to ease human lives, can also help cultivate a sustainable society (Muñoz et al., 2023; Gomes, 2021). They also encourage breakthroughs in renewable energy, conservation initiatives, and sustainable agriculture, contributing significantly to a more sustainable and ecologically friendly future. Computational sustainability is the use of technology and thinking to enhance sustainability and reduce negative environmental impacts (Chatterjee & Rao, 2020). However, education on sustainability is becoming more and more important. The majority of academic subjects have successfully added sustainability skills into the curricula of schools and universities (Alam & Mohanty, 2023; Sudin et al., 2022). This integration guarantees that students from diverse fields, including engineering, business, and the arts, learn about sustainable practices and concepts. By incorporating sustainability into curricula, educational institutions prepare students to face global concerns such as climate change, resource depletion, and social inequalities. This multidisciplinary approach provides future professionals with the knowledge and abilities required to implement long-term solutions in their respective sectors, nurturing a generation dedicated to promoting environmental and social responsibility.

Poon and Law (2020), and Mulder et al. (2011) argue that technology is crucial for sustainable development, as it impacts both communities and individuals. Technology enhances education, healthcare, and infrastructure, thereby improving the quality of life and economic prospects within communities. It also addresses global challenges such as climate change and resource shortages by facilitating the creation and implementation of sustainable practices, ensuring that both current and future generations can thrive in a balanced and sustainable environment. Students with a comprehensive education in sustainability are better equipped to integrate these principles into software development, resulting in products that are both durable and environmentally friendly (Saqib et al., 2020). This education provides students with the knowledge and skills necessary to create software that optimizes resource utilization, reduces energy consumption, and promotes environmentally responsible practices. By understanding sustainability concepts, these students can develop innovative solutions that minimize technology's environmental impact, ensuring that software development contributes positively to long-term environmental health and sustainability (Zamzuri et al., 2024).

To embrace computational sustainability in daily life, one must be prepared on several dimensions. It entails gaining the technological know-how required to solve challenging sustainability issues in fields like modelling, simulation, and data analytics. Understanding the multidisciplinary nature of sustainability, which fosters collaboration across sectors such as environmental science, economics, and policy, is also part of readiness. To encourage sustainable practices and innovations, it is necessary to invest in infrastructure, both technical and informational (Hasbullah et al., 2022). Cultivating a proactive mentality toward sustainability, embracing continuous learning, and adapting to emerging technology are all critical components of readiness for implementing computational sustainability in everyday life. According to Karp and Fletcher (2014), readiness is a broad notion that may be used in a range of contexts, including motivational readiness, organizational readiness, project readiness, technology readiness, and readiness for green education (Bernaldez, 2019). In this regard, a readiness dimension refers to a fundamental aspect that evaluates faculty members' capacity to implement certain modifications aimed at promoting computational sustainability among themselves.

In conclusion, computational sustainability uses computational approaches and multidisciplinary collaboration to develop evidence-based solutions that balance environmental preservation with economic and societal demands. Its goal is to promote sustainable cohabitation between humans and the environment, ensuring a secure future for future generations. The readiness for computational sustainability focuses on providing society with the skills, resources, and knowledge it needs to handle sustainability issues in the face of rapid technological breakthroughs. Researchers conducted a synthesis review of the literature as part of this study to identify factors related to the readiness dimension of computational sustainability. Assessing readiness is critical yet difficult since it can be subjective and context-dependent, with several dimensions and phases. An effective readiness assessment instrument is required, which will be designed and validated through a comprehensive literature study and expert reviews to confirm its applicability for evaluating readiness in this field.

RESEARCH METHODOLOGY

The data collection instruments were based on a synthesis of prior literature. Researchers reviewed previous research papers to identify key concepts, variables and constructs relevant to their study topic. This approach involves examining earlier studies to understand the major components that have been investigated and the conclusions drawn. This thorough assessment enables researchers to enhance their research design, assumptions, and methodologies, resulting in a more robust and trustworthy study (Ghafar et al., 2023). By using specific keywords, researchers searched literature across several disciplines to gather data for this review: computational sustainability, TPACK framework, e-learning readiness, teaching readiness, student readiness, faculty readiness, and computing education. The researchers considered English-language journal publications, books, conference papers, and websites that published original data, descriptions, or theoretical frameworks, including composition, methodology, and results related to computational sustainability. By collecting a diverse set of articles, the researchers ensured a comprehensive overview of the current state of knowledge and practice in computational sustainability. The search was limited to English-language papers published between 2018 and 2024.

However, the researchers also utilized several papers from the 2010-2017 period in this study to ensure a comprehensive and nuanced understanding of the field of computational sustainability. The inclusion of these papers provides essential background and historical context, enabling researchers to grasp the evolution of fundamental concepts and methodologies over time. Moreover, incorporating relevant studies from different periods is crucial for a thorough review. This approach ensures that significant contributions and influential findings from earlier research are not overlooked. Additionally, including papers from both recent and earlier periods facilitates a comparative analysis of how current findings align with or diverge from earlier research, helping to identify gaps, confirm trends, or challenge existing assumptions.

A literature synthesis study on faculty encouraging computational sustainability highlights the need for multidisciplinary cooperation, creative pedagogy, and meaningful research to advance sustainability science. This article explores the opportunities and best practices for integrating computational tools into academic institutions' sustainability initiatives. The researchers aimed to identify crucial dimensions (aspects or components) and items (tools or measures) that have been utilized in other research projects within their area of interest. By employing concepts and procedures that have proven successful in earlier studies, this methodology allows researchers to build on existing knowledge, eliminate duplication, and enhance their study design. This strategy ensures that new research is informed by and integrated with previous findings, resulting in more robust and effective outcomes.

Furthermore, a literature synthesis study focusing on the readiness component of computational sustainability education and research provides useful insights into several facets of the discipline. It

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investigates the problems that educators and institutions encounter when incorporating computational sustainability into their curricula, suggests areas for improvement and innovation, and proposes ways to enhance classroom and faculty readiness. The present thorough analysis underscores the need for equipping educators with the requisite competencies and expertise, promoting multidisciplinary cooperation, and obtaining institutional backing to proficiently tackle sustainability concerns through the utilization of computational techniques and methodologies. Figure 1 below illustrates the process of searching for past papers conducted in this study.

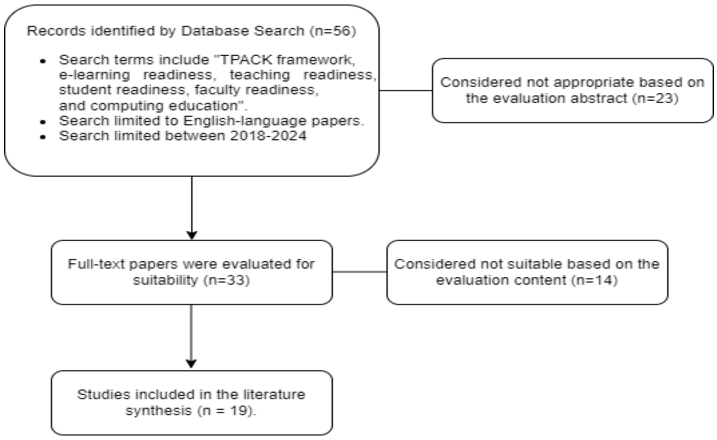

Figure 1: Search process procedure

RESULTS AND DISCUSSION

Out of a total of 19 past papers, 15 were found suitable for identifying readiness dimensions related to computational sustainability. These 15 papers were published between 2010-2023. The selection process ensured that only the most relevant and current research was included, emphasizing the evolving understanding and focus on computational approaches to sustainability over the past decade. This thorough analysis highlights the significance of these readiness dimensions in preparing faculty to successfully incorporate computational sustainability into their teaching and research activities. The findings on the suitable dimensions are presented in Table 1.

Focusing on readiness dimensions ensures that faculty are not only familiar with computational sustainability concepts but also possess the essential skills and knowledge to apply these concepts in practical and innovative ways. This comprehensive approach to faculty readiness is crucial for nurturing a new generation of sustainability-minded professionals capable of utilizing computational tools and methodologies to tackle complex environmental challenges. By concentrating on readiness dimensions, faculty are better equipped to incorporate computational sustainability into their curriculum effectively. Furthermore, this focus promotes an atmosphere of ongoing learning and adaptability, encouraging faculty to remain informed about the latest developments and trends in computational sustainability. Consequently, students benefit from a more comprehensive and up-to-date education, equipping them better for careers in sustainability where they can effectively utilize technology to make a significant impact. This approach enhances the overall quality of education and research in computational sustainability, fostering the development of innovative and practical solutions to environmental challenges. Table 2 presents an analysis of each readiness dimension along with its key essential points.

Table 1: Literature synthesis on different readiness dimensions

	Technological knowledge	Content knowledge	Teaching strategy	Training	Equipment & Software
Sarwa et al. (2020)	Educators need to proficiently utilize technology or software to perform tasks.	Using digital technologies may help instructors develop novel learning experiences, increase student engagement, and improve accomplishment.	Educators can use a range of teaching techniques, including lectures, discussions, hands-on activities, and multimedia presentations to accommodate diverse learning styles.	***Not found***	As computer technology evolves, software and applications quickly become outdated.
Karp and Fletcher (2014)	End-users should grasp how to effectively use the tools, ensuring clarity and utility across all aspects of the product.	Possessing content knowledge to use and support technologies in established IT infrastructure	***Not found***	Training improves the quality of teaching and learning processes.	Technology has a robust IT infrastructure.
Bueno et al. (2023); Redmond et al. (2019)	Any technological tool or resource can be employed to apply specific methods of conceptualizing and interacting with technology.	The instructors' comprehension of the subject matter they are teaching or learning.	Utilize technology to carry out a variety of tasks and to find several approaches to completing a specific task**.**	***Not found***	***Not found***
Tharanganie et al. (2012)			A crucial element of efficient teaching strategies is the integration of theoretical ideas with real-world applications.	***Not found***	Proficiency in computer foundations, fundamental hardware, and operating system functions.
Heilporn et al. (2021); Senthamarai (2018)	Implementing innovative teaching technology can improve student engagement and information retention.	Enhancing learning and teaching content is a primary objective of education.	Teaching strategies have become an essential part of student education.	Implementing training methods to adapt interactive teaching and learning strategies.	***Not found***
Alkandari (2022); AlSabbagh (2019); Al-Awidi and Aldhafeeri (2017)	Using technology in education may enhance student engagement, cooperation, and individualized learning experiences.	Teacher education must shift from its traditional focus on content knowledge and instead explore new methods for presenting subjects to students.	Educators must have a strong understanding of capabilities, including incorporating technology into the curriculum and developing current perspectives on its integration.	Educators need adequate training to effectively use technology for engaging pedagogical practices.	Technology has made it necessary for all sectors, including education, to implement techniques and practices that utilize technical equipment.
Oliveira et al. (2021); Schonert-Reichl (2017)	***Not found***	One of the most important aspects of teaching college students is content knowledge.	Establishing a more engaging and productive learning environment.	Teachers received additional training and taught more lessons, leading to improved student outcomes.	***Not found***
ALhattali et al. (2023); Abugabah and Abubaker (2018); Golzari et al. (2011)	With technological advancements, educators can now utilize a variety of tools and platforms to enhance the learning experience.	***Not found***	Educators must have a strategy to enhance the quality of the teaching-learning process.	Training is an effective method for improving the teaching-learning process.	The goal was to improve the technology infrastructure of public organizations by replacing outdated equipment.

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Table 2: Review each readiness dimension and its essential key point elements

Dimensions	Review	Elements generated	Key point elements	Source
Technological knowledge	By cultivating such technological knowledge, individuals can leverage information technology to perform diverse tasks and innovate new methods for specific activities.	16 elements	• Training module • Write articles • Supervise intern • Supervise final-year project • Review manuscript • Examine dissertation or thesis • Extend new technologies	• Ramazanoğlu et al. (2022) • Kamaruzaman et al. (2021) • Paliwal et al. (2021) • Ayu (2020) • Bernaldez (2019) • Adiyarta et al. (2018) • Roberts (2011) • Molla and Cooper (2010)
Content knowledge	It includes educators' proficiency and comprehension of the specific subject they teach, along with their understanding of related concepts, theories, and skills.	19 elements	• Create a new course • Write articles theme/scope • Supervise intern • Supervise final-year project • Review manuscript • Examine dissertation or thesis • Develop project/class activity	• Zine et al. (2023) • Ramazanoğlu et al. (2022) • Kamaruzaman et al. (2021) • Paliwal et al. (2021) • Ayu (2020) • Martin et al. (2019) • Bernaldez (2019) • Adiyarta et al. (2018) • Roberts (2011)
Teaching strategy	To incorporate technology into the curriculum effectively and foster new approaches to its integration, educators must have a strong foundation of knowledge and skills.	9 elements	• Assignment • Project theme/scope • Final year project • Specialized course	• Kamaruzaman et al. (2021) • Sarwa et al. (2020) • Ayu (2020)
Training	Training was identified as one of the most effective methods to enhance the quality of the teaching-learning process.	5 elements	• Workshop • Conference • Seminar • Certified training • Webinar	• Paliwal et al. (2021) • Oliveira et al (2021) • Abugabah and Abubaker (2018) • Al-Awidi and Aldhafeeri (2017) • Schonert-Reichl (2017) • Roberts (2011) • Karp and Fletcher (2014)
Equipment and Software	Universities that have sophisticated IT infrastructure, including necessary hardware, software, network capabilities, and skilled personnel, are ready to adopt technology effectively.	3 elements	• Laboratories • Existing equipment • Existing software	• Zine et al. (2023) • Kamaruzaman et al. (2021) • Sarwa et al. (2020) • Adiyarta et al. (2018) • Pazowski (2015) • Karp and Fletcher (2014)

The Analysis of Key Readiness Dimensions

The analysis identified five dimensions: technological knowledge, content technology, teaching strategy, training, and equipment and software.

Firstly, technological knowledge emerged as a key dimension in evaluating readiness for computational sustainability. This highlights that among the various dimensions considered, the focus on technological education was particularly significant (Martin & Bolliger, 2023; Paliwal et al., 2021; Ayu, 2020). This emphasis is important because it underscores the crucial role that technological understanding plays in effectively tackling challenges and developing solutions in computational fields. Thus, this aligns with previous research that emphasizes that technological knowledge is a vital component of a teacher's overall expertise (Fahadi et al., 2022; Eichelberger et al., 2019). In areas such as computational sustainability, mastering technological knowledge is crucial for creating innovative solutions and enhancing a deeper understanding of the subject. Moreover, faculty members need to possess the expertise and skills to apply computational methods in practical settings, which supports the integration of technology and sustainability concepts into their teaching and research endeavours (Kamaruzaman et al., 2021). By combining technological knowledge with sustainability principles, students can develop innovative solutions to tackle environmental, social, and economic challenges. Redmond et al. (2019) agreed that acquiring technological knowledge equips individuals to use technology-based tools for diverse tasks and develop alternative methods for achieving specific goals. This approach enhances their understanding of how these issues are interconnected, ultimately contributing to a more sustainable future.

Content knowledge pertains to the depth and breadth of understanding regarding the subject matter. In education, content knowledge is essential for educators because it enables them to teach the subject matter effectively, offer precise explanations, and engage students with pertinent examples and applications. According to Redmond et al. (2019), content knowledge is one of the most crucial aspects of teaching college students, and educators must be well-versed in their subject matter. When educators have a thorough understanding of their subject, they can more effectively promote learning, encourage critical thinking, and motivate students to delve deeper into the material. Essentially, content knowledge enables educators to provide high-quality teaching and effectively support students' academic development. By adopting digital tools and resources, educators can craft innovative content learning experiences that boost student engagement and improve academic performance (Sarwa et al., 2020). These innovations can engage students more effectively, accommodate diverse learning preferences, and offer immediate feedback, thereby deepening their comprehension of the material and enhancing their academic performance.

Next, by implementing their teaching strategies, educators can develop an engaging and impactful learning environment, equipping students with the skills and knowledge needed to tackle key sustainability issues through computational methods. Educators need a solid base of teaching strategies to effectively integrate technology into the curriculum and develop innovative approaches to its application (Alkandari 2022; AlSabbagh, 2019). A robust teaching strategy allows educators to craft engaging and effective lessons that utilize technology to enhance student outcomes. It also empowers them to develop innovative methods that cater to diverse learning styles and needs, thereby enriching the educational experience and promoting student success. Previous researchers support the notion that teaching strategies are essential to student education (Awan et al., 2021; Heilporn et al., 2021; Senthamarai et al., 2018). This aligns with the findings, as teaching strategies are essential for shaping how educators present material, engage students, and assess their understanding. According to Kamaruzaman et al. (2021), as higher education institutions increasingly adopt learning principles and strategies, the fields of teaching strategy and learning are experiencing significant transformations. Consequently, educational practices are evolving to be more dynamic and attuned to students' changing needs, resulting in teaching strategies that are both more effective and adaptable.

The fourth dimension, training, is crucial as it serves as a valuable method for improving the quality of the teaching and learning process (Martin & Bolliger, 2023; Paliwal et al., 2021; Awan et al., 2021; Ayu, 2020). By consistently enhancing their training skills, educators can provide more effective instruction, adjust to new educational challenges, and effectively support student learning outcomes. Additionally, training enables educators to improve their teaching methods and research approaches to

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integrate new tools and techniques, thereby enhancing their effectiveness in advancing sustainability and better-preparing students for future challenges, especially relating to computational sustainability. In this context, training involves participating in workshops, conferences, and seminars to stay updated on the latest advancements in their field and innovative teaching methods related to computational sustainability. This aspect of training aligns with previous research, which highlights that training programs aiding faculty in developing or revising curricular materials, lesson plans, and projects related to computational sustainability are essential for effective preparation (Al-Awidi & Aldhafeeri, 2017). Training received by educators is crucial for developing projects that align with the latest research and practices in computational sustainability, enabling students to engage with current and relevant challenges.

Finally, a crucial dimension of this study is equipment and software. They are essential dimensions of modern technological infrastructure, facilitating a broad array of operations and functions across various sectors (Kamaruzaman et al., 2021). Equipment refers to the physical hardware and devices required to execute tasks, whereas software encompasses the programs and applications that operate and control these devices. However, Modanval et al. (2020) emphasize that enhancing the technological infrastructure of public institutions by upgrading outdated equipment is vital for improving overall performance. Therefore, educational institutions must invest in technology infrastructure to ensure that educators have access to the latest tools and methods for teaching in a digital world (. Moreover, aligned with previous research, colleges with advanced IT infrastructure including the necessary hardware, software, network capabilities, and human resource expertise are well-equipped to support and utilize technology for sustainable development (Webster & Gardner, 2019; Samuri et al., 2016). This comprehensive IT infrastructure enables educational institutions to excel in the field of computational sustainability, equipping students with the knowledge and skills needed to address real-world sustainability challenges using advanced technological tools.

CONCLUSION

In this study, data collection tools were developed through a thorough synthesis of existing literature, enabling researchers to identify and incorporate essential ideas and constructs relevant to the research issue. This synthesis contributed to the improvement of the research design, assumptions, and procedures, thereby increasing the study's robustness and trustworthiness. Researchers gathered a diverse array of sources by employing specific keywords across various disciplines, including computational sustainability, the TPACK framework, e-learning readiness, teaching readiness, student readiness, faculty readiness, and computing education. By integrating insights from these varied sources, this study enhances our comprehension of readiness dimensions within computational sustainability, highlighting the significance of interdisciplinary viewpoints and methodological versatility in progressing in this field. This foundation can guide future research to explore readiness assessments further, with the aim of enhancing the implementation of computational approaches in sustainability research and applications.

In summary, this study has successfully identified and examined essential readiness dimensions for enhancing faculty readiness in computational sustainability. These dimensions include technological knowledge, content knowledge, teaching strategies, training, and equipment and software. By detailing these critical factors, the study provides valuable insights into the readiness required for faculty members to effectively participate in computational sustainability initiatives. These findings underscore the importance of comprehensive readiness assessments in equipping faculty to integrate computational approaches into their teaching and research endeavours. Consequently, educators will be better prepared to equip students to address complex environmental challenges through computational methods, thereby broadening the impact of computational sustainability across diverse fields. Improved faculty readiness will lead to more comprehensive and effective teaching and research, ultimately advancing sustainability practices within academic settings and extending their influence to wider society.

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

AUTHOR CONTRIBUTIONS

Tuan NurNadzirah 'Asyikin Tuan Rahim: Conceptualization, Methodology, Analysis, Writing-Original draft preparation. **Azniah Ismail**: Supervision, Conceptualization, Validation, Reviewing, Editing. **Nor Hasbiah Ubaidullah**: Conceptualization, Methodology, Validation, Reviewing. **Nur Saadah Fathil**: Conceptualization, Methodology, Validation, Reviewing. **Kamalia Azma Kamaruddin**: Conceptualization, Validation, Reviewing. **Aznida Hayati Zakaria@Mohamad**: Validation, Reviewing. **Nurul Akhmal Mohd Zulkefli**: Reviewing.

DATA AVAILABILITY STATEMENT

Data is available on request due to privacy/ethical restrictions.

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