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RESEARCH ARTICLE

THE IMPORTANCE OF ENVIRONMENTAL SUSTAINABILITY FOR HEALTHY AGEING AND THE INCORPORATION OF SYSTEMS THINKING IN EDUCATION FOR A SUSTAINABLE ENVIRONMENT

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ABSTRACT

Environmental sustainability is important to public health and of particular significance considering the rapidly growing ageing population. While advancement in chemical science has contributed to enhanced quality of life, increasing levels of chemical pollutions and the impact of chemicals on human health and the environment have led to serious concern. The deterioration of environmental quality has been largely due to chemical pollution and the elderly group in the population are more susceptible to the hazardous effects of industrial chemicals and airborne pollutants. This situation also presents uphill challenges to the promotion of healthy ageing which requires a sustainable clean environment, contributed through the advancement of sustainable and green chemistry. However, innovations in green chemistry require a systems thinking mindset which is also important in realizing the impact of chemicals on human health and the environment. The adoption of the Sustainable Development Goals (SDGs) by the United Nations has called for immediate actions in adopting the SDGs as a central concern in the reform of different domains for the invention of a sustainable future. The practice of chemistry has various impacts on many interconnected systems, re-orientation of chemistry education has been proposed with the implementation of inter-disciplinary approaches as informed by systems thinking, with a growing number of reports suggesting its potentials and applications in chemical education. Despite the vast opinions suggesting the promising prospects of applying systems thinking in education, reports on the development of relevant tools and educational resources are only of a limited amount, with recent perspectives identifying the design of educational tools and resources as one of the priority areas. In this study, we report the collaborative work across the disciplines of health and chemical sciences in the pedagogic design of incorporating systems thinking in chemistry education adopting the theoretical framework. The design of a system-oriented concept map extension (SOCME) diagram is described, with reference to a case study of chemicals released from the degradation of plastics. The work presented illustrates the potential of systems thinking in sustainable education and adds to the collections of educational resources for incorporation of systems thinking in teaching and learning.

KEYWORDS

Environmental sustainability, healthy ageing, systems thinking, sustainable education.

INTRODUCTION

A green environment has long been regarded as an important factor contributing to human well-being, with a continued growth of studies reporting the associated psychological and physiological health benefits. [1, 2] In recent years, lower fertility rates and increase in life expectancy have led to the ageing of the world's populations, further intensifying the prominent need for a sustainable green environment. [3] A green environment is essential to support healthy ageing and the sustainability of a healthy environment is considered a top priority of major global health issues. While advancement of chemical technologies and various applications of chemicals have enhanced quality of life with a significantly added level of convenience to the public, the heavy use of chemicals is still of alarming concern and poses global challenges to environmental sustainability. The impact of chemicals on human health and the environment cannot be overlooked despite their versatile functions and various benefits brought to industrial processes and society. Extensive use of chemicals in daily life has led to chemical pollution posing a significant threat to human health. This is especially so for older adults who are more vulnerable to chemical attack, with the higher susceptibility of this population group resulting from weakened bodily functions and degeneration of organs. [4] For example, it has been well documented that exposure to fine particulate matter (PM2.5) is a leading risk factor which contributes substantially to a heavy global disease burden. [5] Long-term exposure to ambient air pollution is also reported to have led to decreased life expectancy and increased incidence of morbidity and mortality from cardiovascular disease, pulmonary disease and lung cancer. [6] In addition and not just limited to air pollution, various types of chemical contaminants released from different sources also contribute to serious water and food pollution, leading to further deterioration of environmental quality. Chemical pollution of water and food has been reported to pose significant health risks. Consumption of chemically contaminated food can have serious health implications ranging from minor gastric problems to fatal diseases. [7] It is noteworthy that one of the major sources of chemical pollution originates from daily consumption of a variety of chemical products. Recently, a comprehensive study has reported the production of greenhouse gases such as methane and ethylene from the widely used plastics. [8] The findings indicate that plastics is a hitherto unrecognized source of climate-relevant gases, with increasing impact on climate variation due to increased production and accumulation of plastics in the environment. In addition, human exposure to microplastics can lead to serious health consequences including disruption of immune systems, inflammatory lesions and neurodegenerative diseases. [9] Overall, the adverse health effects of chemical pollution are significantly aggregated due to population ageing, as well as increasing prevalence of non-communicable diseases over the recent decades. [5]

Under these circumstances, it is therefore not surprising to see the recent development of various strategies to reduce the use of hazardous chemicals, as well as the implementation of regulatory frameworks and policies for new chemicals. [10] In recent years, there has also been a growing amount of research investigating the advancement and applications of green chemistry and emerging technologies in the transformation of the chemical industry. In the interim, there are also emerging studies that have investigated sustainable chemistry and its development for achieving the Sustainable Development Goals (SDGs), as well as moving society towards a sustainable future. [2, 11, 12] While these research investigations are valuable contributions, it is noteworthy that health promotion and education also plays an important role in the achievement of a sustainable environment. Recent studies have also reported the importance of nurturing future global citizens and called for more educational research in the promotion of environmental sustainability through education. In the educational context, increasing studies have identified the promising prospects of incorporating systems thinking in the teaching of core science subjects, especially in chemistry education. [13] Chemistry is a central science and provides the fundamentals which link up different science disciplines. It plays an indispensable role in the contribution of inter-disciplinary efforts from various established and emerging science disciplines leading to the outstanding advancement of human health and well-being in the past decades. [14] While advancement of chemical science has contributed to the development of functional materials, pharmaceuticals, industrial processes and drug production, which leads to substantial enhancement of quality of life, however, attitudes towards chemical science and its practitioners by various stakeholders, including the general public and policy-makers, have been complex and controversial. [15]

Chemistry continues to provide valuable sources of innovative processes and products. On the other hand, it is also criticized as one of the factors inadvertently attributing to the emerging global problems. The adoption of the Sustainable Development Goals (SDGs) by the United Nations has profound impact which calls for urgent actions for adopting the SDGs as a central concern in the reform of different domains for the invention of a sustainable future. [14] Notably, many contributions that chemistry can make for moving towards the SDGs require concerted efforts and close collaborations with other disciplines for identifying the practical and sustainable solutions. Therefore, it has been emphasized that the teaching and practice of chemistry should not be restricted within the specific subject content knowledge, while advocating an in-built consideration and integration of wider perspectives and relationships. [14, 16] This re-orientation of chemistry education has been proposed with the implementation of inter-disciplinary approaches as informed by systems thinking, with a growing number of reports suggesting its potentials and applications in chemical education. [13, 17, 18]

Recently, system-oriented concept map extension (SOCME) diagrams have been proposed as important visualization tools which serve as valuable resources for educators and students to adopt a systems approach in realizing some of the connections between isolated chemistry topics, as well as their dynamic interactions with many other systems. [13, 19] Currently, there are only a small number of studies reporting the pedagogic design of SOCME diagrams. Examples include the creation of two alternative SOCME diagrams regarding the famous Haber-Bosch process, which is a fundamental topic discussed in virtually all general chemistry reference books. [20] The reported SOCME diagrams illustrate the connections of the Haber process with the broader earth and societal systems. The design of SOCME also emphasizes the distinction between the renewable and non-renewable natural resource sub-systems involved in the production of the gas reactants, while highlighting the important linkage to global food security. Typical coverage of the Haber reaction reveals the common adoption of a reductionist approach and presentation of chemical processes as isolated systems, with due consideration of specific chemical principles and mathematical calculations. By adopting the systems thinking approach, the reported visualization tools have significant roles in the introduction of systems thinking to chemistry education which helps the practitioners and students to view a chemical reaction or process from a wider perspective instead of a reductionist coverage, as well as to realize the importance of a molecular basis of sustainability. [20]

The potential of SOCME and the limited reports on the design of relevant resources have prompted our interests in the current study. Here, we report the collaborative work across the disciplines of health and chemical sciences for the pedagogic design to incorporate systems thinking in chemistry education. Based on the theoretical framework of systems thinking in chemical education, an example of system visualization tools is presented based on a case study of chemicals released from the degradation of plastics. The work presented in this paper illustrates the potential applications of systems thinking in the educational context and adds to the collections of educational resources for incorporation of systems thinking in teaching and learning.

METHODOLOGY

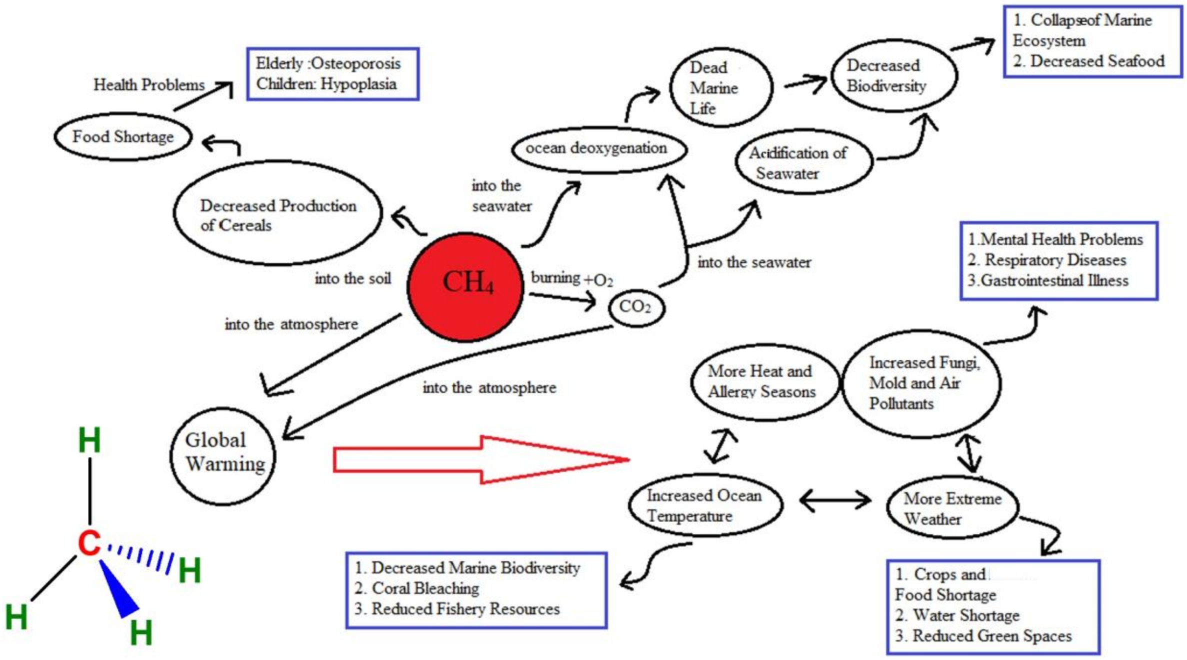
The theoretical framework for developing and incorporating systems thinking in chemistry education, proposed by the Systems Thinking in Chemistry Education (STICE) project team, is adopted in this study. [21, 22] The framework describes the approach of visualizing a learner at the centre of a system with three interconnected subsystems, which are the Educational Research and Theories Node, the Chemistry Teaching and Learning Node, and the Earth and Societal Systems Node. The elements of orienting chemistry education to meet the environmental needs are the focus in this study. This approach is integrated with concepts of a molecular basis of sustainability as proposed by Anastas and Zimmerman which emphasizes the derived environmental concern on the basis of molecular considerations. [23] The material basis in the context of society and economy is considered while educational resources are designed in view of the need for chemistry practice and education to address important aspects related to the sustainability of earth and societal systems. [13] Challenges of applying systems thinking in educational contexts include the intrinsic complexity to both instructors and students. The implementation of systems thinking approaches and the delivery of teaching should be supported by appropriately designed teaching materials for which the development of relevant resources and activities has been identified as one of the priority areas. [22] Regarding the delivery of lecture or learning content, added complexity would lead to difficulty in the expression and visualization of many interconnected ideas thereby leading to reduced learning motivation. Development of tools for visualizing the complex ideas instead of only word descriptions is an important step for implementation of systems thinking approaches in education. Taking reference from relevant studies reporting the creation of SOCME diagrams, a SOCME diagram focusing on methane (CH4), an example of greenhouse gases, is presented in this study. The interconnections between this chemical compound with various systems including those of food supply, ecosystem and human health were identified. Recent findings on the impact of methane on these systems were reviewed and relevant effects were included to give an updated SOCME diagram. The identified components were linked by arrows to indicate the cause-and-effect relationships. In the design of the SOCME, the subject content and learning outcomes of a general-education (GE) chemistry course in the College were considered. The SOCME diagram would be delivered to students in the General Education subject to illustrate the application of systems thinking approach in the understanding of the various impacts that a simple molecule, released from daily consumption of chemical products, can bring to the environment and health systems. The delivery of the systems diagram in the teaching materials would be supported by the use of digital technology adopted in previous reports. [24]

RESULTS AND DISCUSSION

In this study, we have created a SOCME diagram based on methane, an example of chemical released from daily consumption of chemical products. The current work also represents an example of collaborative work across the disciplines of health and chemistry, contributing to the limited educational resources for incorporating systems thinking to view the big picture of chemical impact on the environment and health systems.

The extensive use of plastic products in daily life has aroused significant scientific and societal concern over human health and environmental sustainability due to the toxicity of plastics. [25] Recently, the study by Royer et al. reported the production of greenhouse gases from plastics which added further concern over the human and environmental health. [8] Methane is one of the greenhouse gases that may be produced in the degradation of some commonly used plastics such as polyethene (PE). PE is a very common polymer with extensive applications in our daily life. Its degradation can result in the release of methane, which is a discrete molecule having a simple structure. However, the release of this simple gas can lead to profound consequences to the environment, which are not easily realized if teaching is confined to restricted discipline with narrow perspectives. A student cannot just learn the scientific knowledge of chemicals without looking at the impact of extensive productions and uses of these chemicals. In addition to the teaching of specific subject content knowledge, emphasis should also be put on how the production and use of chemical products can have adverse effects on human health and the environment, as informed by systems thinking and facilitated with specific visualization tools. The linkage to other systems should be realized and reflected in the graphical tool to accomplish widened viewpoints in the process of learning. In addition to human health aspects, the impacts of methane on the atmosphere and marine systems are also considered. [26] These form the basis for the design of a SOCME diagram which considers the interconnections between this chemical release with various systems including the food supply, ecosystem and human health. The developed SOCME diagram is presented in Figure 1. The interconnections of the chemical system with specific components in dynamic systems of human and environmental health are indicated. The extent of boundaries was decided with reference to the subject content and learning outcomes of a general-education chemistry course in the College. The associated topics include chemicals in daily life and polymer materials.

FIGURE 1: SYSTEM-ORIENTED CONCEPT MAP EXTENSION (SOCME) DIAGRAM ILLUSTRATING THE INTERCONNECTIONS OF METHANE (CH_4) WITH OTHER SYSTEMS.



FUTURE WORK

While there is increasing advocacy for applying systems thinking in education for a sustainable future, reports on the development of relevant tools and educational resources for specific topics are only of limited amount. Future work includes further development of systems thinking resources for educators and students. [22] Furthermore, the possibility of supporting the implementation of systems thinking with emerging technologies in the digital era should be explored. [27] Teachers, researchers, academic and educational institutions, and government should work towards the adoption of systems thinking approach in school, college and community education for the promotion of population health and sustainability development of the world. Global citizens, particularly younger generations, must learn the significance and impact of health and the environment on lives on earth.

CONCLUSION

In this paper, we have demonstrated an example of collaborative efforts from health and science disciplines in applying systems thinking in the context of sustainable education. A SOCME approach and diagram, which signifies the interconnections of a chemical system with human health and environmental systems, has been developed and is presented. Further development of systems thinking visualization tools and resources for educators and students, as well as evaluation of the teaching practice, are worth investigating. Understanding the interconnections of the chemical system with the environment and health systems is important for sustaining a clean environment, which is an essential component for the promotion of healthy ageing. More concerted efforts across disciplines are imperative for incorporation of systems thinking in education for a sustainable future.

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