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Editorial

Overview and Insights from 'Systems Education for a Sustainable Planet'

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Abstract: An announcement by Bosch and Cavana, in Systems, called for new papers to provide updated perspectives about and fresh insights into developments that influence 'systems education for a sustainable planet'. This paper's objective is to provide an overview of the 14 papers that were published in the special issue, and present some insights and findings from their content. It does this by classifying the papers into five distinct themes, then analysing their content and the linkages between the themes. This process revealed that: (1) Specialised systems education at a tertiary level is predominantly at graduate level, using a diverse range of approaches; and (2) Delivering specialised systems education remains a challenge for programs that endeavour to provide an integrated and interdisciplinary learning experience. Barriers include current institutional structures and the need for students to be both big picture thinkers and detail-oriented technocrats; (3) Teaching systems approaches outside of specialised programs for students (both young and mature) help to expose systems thinking to a wider demographic; (4) The strong links that exist between systems approaches and sustainability goals are increasingly being recognised. Systems education can help transition towards a sustainable planet, as it helps people appreciate that individual actions are not isolated events but contribute to an interconnected system that determines both the well-being of humans and the planet.

Keywords: systems education; sustainability; learning; design; systems thinking; system dynamics; system sciences; sustainable planet

1. Introduction

The special issue of Systems—'Systems education for a sustainable planet'—provides a wealth of material on current initiatives to provide people across all age groups with systems understanding and practical knowledge. Different learning approaches are used, but the message is the same—we need to educate people to work with complexity and uncertainty if we are to progress the goal of a sustainable planet [1–15].

How things are interconnected needs to be better understood when working with sustainability goals, and, increasingly, such links are being forged. As Gregory and Miller [3] point out that sustainability and systems thinking are so intimately entwined that it is impractical to focus on one and not the other. Unravelling complex problems and searching for solutions requires understanding of pressures, drivers, causes, and the functional dynamics of the underlying systems. Wells and McLean [14] also highlight the strong link between systems and sustainability. As they say: "It is no coincidence that the contemporary champions and exponents of systems thinking have been drawn inexorably, and seamlessly, to these challenges of sustainability. Nowhere do the qualities of connectedness and complexity come more naturally to the fore than in attempts to nourish those complex living systems that both encompass human community and in which human life on earth is embedded" [14] (p. 71).

The latest Living Planet Report, which is directed at sustainability, observes: "System thinking can help us ask the right questions by examining complex problems layer by layer and then analysing the connections between these layers" [16] (p. 89). Instead of focusing on the size of a nation's Ecological Footprint, this Living Planet Report publication hones in on root causes and how solving problems in a complex world requires knowledge of the hierarchical relationship between events or symptoms, patterns or behaviours, systemic structures, and mental models. Citing the work of Cavana and Maani [17], Maani and Cavana [18], and Nguyen and Bosch [19], the report discusses the need to consider and analyse the relationships in a system to be better positioned to bring about positive change. "To understand where each of us has the greatest leverage to lead toward a systemic transition in favour of sustainable development, it is important to recognise what elements we are working on within the complex system, and that we need to adjust our mental models for problem-solving. Only then can we effect genuine and lasting change" [16] (p. 91).

The range and magnitude of the contributions to this special issue illustrate the diversity of systems education practices and programs (learning systems) in the global systems community, and the relevance of systems thinking and practice to examining issues related to the long-term sustainability of the planet. Many of the widely recognised learning approaches and methodologies applied by the systems community are referred to throughout this special issue, including, for example, the systemic inquiry approaches of C. West Churchman [20] and Peter Checkland [21]; Etienne Wenger's social theory of learning [22]; Stafford Beer's Viable System Model [23]; the Critical Systems Heuristics process of Werner Ulrich [24]; Robert Flood and Michael Jackson's System of Systems Methodologies [25]; and the system dynamics related work by Jay Forrester [26], Peter Senge [27], Dennis and Donella Meadows [28], and John Sterman [29].

Figure 1 provides a word diagram that was created from the keywords from each of the 14 special issue papers. The size of the word reflects the frequency of that word in the lists of keywords. For example, the central importance of the word 'systems' can be clearly seen, together with the other high frequency words such as education, learning, system, dynamics, thinking, design, systemic, management, sustainability, etc.

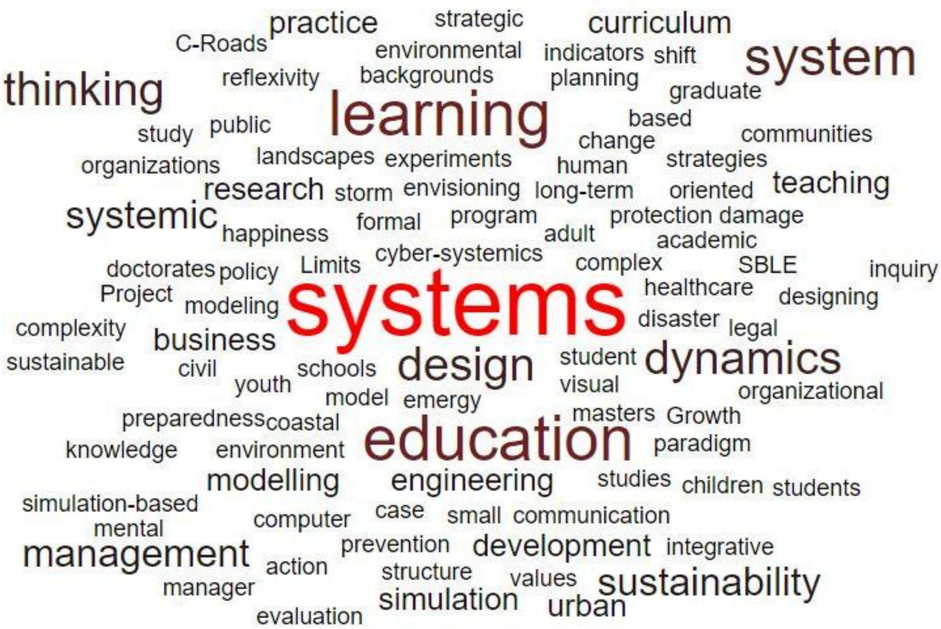

Figure 1. A Word diagram of the keywords from the 14 special issue papers.

The material provided by the authors for the special issue [2–15] discusses the current status of systems education and the extent to which the systems community is delivering on the ambition to provide a systems education for a sustainable planet. For the purposes of this paper, the 14 special issue papers have been classified into five distinct themes, as illustrated in Figure 2. While some of the papers could be classified into two or more themes, each paper has been allocated to the theme it is most closely aligned to. These themes have been identified following similar principles to content analysis as outlined in Cavana et al. [30].

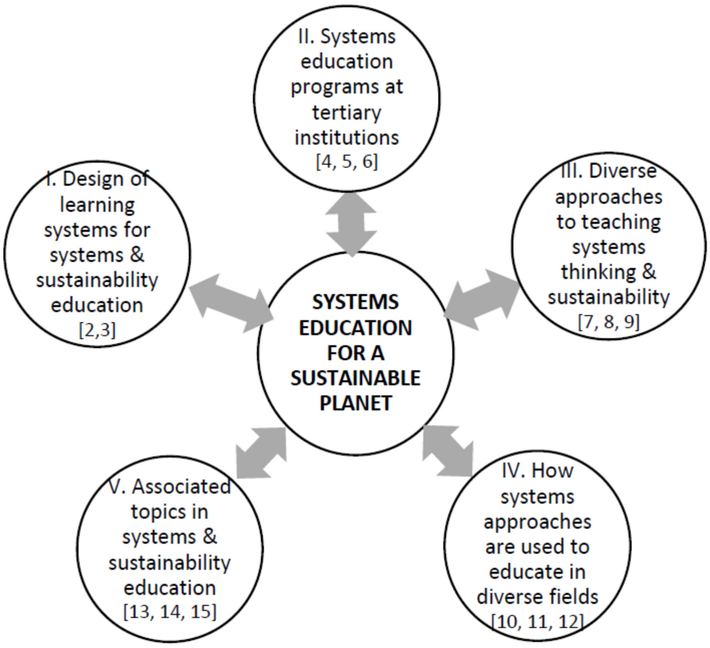

Figure 2. Theme classification of the 14 special issue papers.

In the ensuing sections, the papers within each theme are briefly discussed along with some of the main insights that emerge. Next, there is a section outlining further integrating insights and issues, followed by some concluding remarks.

2. Design of Learning Systems for Systems and Sustainability Education

The following two papers are on these themes:

Ison & Blackmore [2]—*Designing and Developing a Reflexive Learning System for Managing Systemic Change*.
Gregory & Miller [3]—*Using Systems Thinking to Educate for Sustainability in a Business School*.

Greater recognition that the problems that arise when dealing with sustainability are highly interrelated has not necessarily been accompanied by acknowledgement that managers (in health, social, environmental, cultural, business, etc., areas) need to be educated to work with complexity, as opposed to drawing tight boundaries and applying simplistic, linear solutions. As Ison and Blackmore reflect [2], in most western societies, thinking systematically remains more 'mainstream' than thinking systemically or holistically. This is despite the fact the field of cybernetics and systems has been operational for more than 50 years and systems education has been offered in higher education for over 40 years. Responding to the growing number of significant "wicked problems" and "super-wicked problems" requires an education that teaches systems thinking and practice skills [2]. Super-wicked problems according to Levin et al. [31] are greater than "wicked problems", because they have the following additional characteristics: (i) Time is running out; (ii) Those seeking to end the problem are also causing it; (iii) There is no central authority; and (iv) Policies discount the future irrationally. It is the view of Ison and Blackmore that despite the increased urgency to respond to "super-wicked" problems, higher education institutions are becoming less able to organise the inter and trans-disciplinary ways of working that are required to make progress [2].

Gregory and Miller [3] push the boundaries by challenging faculty to be critical of their own academic paradigm and associated practices. If a systems approach to teaching is to be adopted, the dominant modes of thought and practice (i.e., the existing mental models) have to be questioned. They propose that business schools embed sustainability and systems thinking theory and practice into all modules taught, because just noting the connected nature of management knowledge is not sufficient. Gregory and Miller also advocate a need to equip students to better recognise the more complex and pluralistic views of the world and expose them to the tools to address such complexities [3]. Their view that most programs include systems thinking and sustainability as 'bolt-ons' as opposed to embedding systems thinking and sustainability in an integrated way throughout the curriculum extends to most educational institutions. However, to deeply embed such concepts in a curriculum is no easy challenge. While systems thinking can provide a theoretical basis for discussions about sustainability, both systems thinking and sustainability are conceptually problematic [3]. Another major issue is the current paradigm that we operate, which has a focus on economic growth rather than sustainability. The systems thinker who guides rather than controls and employs a more systemic version of management (as per Senge [27,32]) remains less visible than the transformational, achievement-oriented individualistic leader [3].

Teaching systems thinking and system dynamics is challenging. The human mind struggles to assess the (especially unintended) consequences associated with complex, interrelated components within a system [33–35]. An evaluation of a systems theory and methodology course for graduate students undertaken by Salner [36] found that mature and intelligent students, even when instructed, could not readily grasp and apply systems concepts [2]. Expertise in systems cannot be acquired through rote learning, and the learning process is not linear [3]. A dynamic epistemic learning experience occurs, which, according to Ison and Blackmore, requires a student to progress through periods of chaos, confusion, and being overwhelmed by complexity before reaching a point at which a new conceptual understanding enables a change in their mental models. Without this change it is not possible to move to a higher level of complexity and elucidate previously unclear concepts [2].

There are other papers in the special issue that also provide examples of how different systems educators have developed courses to cement the link between working with complexity and sustainability. The Systems Science Graduate Program taught at Portland State University in Oregon, USA has four courses explicitly on sustainability, as well as others that teach the tools methods, models, and concepts that are relevant to working with sustainability [6]. At the Technische Universität München thinking systemically and applying a holistic discipline/sector-crossing assessment approach is taught as a prerequisite to developing strategies for a sustainable built environment [8]. In Sydney, Australia, Gray et al. describe a tertiary level bid to operationalise trans-disciplinary learning that propels students from learning about sustainability to active involvement in formulating solutions [9].

3. Systems Education Programs at Tertiary Institutions

Courses in system dynamics have been offered at tertiary level since the early 1970s. The Open University systems program started in 1971 [2]. Internationally, the majority of formal qualifications provided in the systems field are at the Masters or graduate level. Different learning systems have evolved to meet the requirements of a diverse cross section of students. The following papers provide an insight into the present-day benefits and challenges associated with delivering systems education programs:

Davidsen, Kopainsky, Moxnes, Pedercini, and Wheat [4]—*Systems Education at Bergen*.
Pavlov, Doyle, Saeed, Lyneis, and Radzicki [5]—*The Design of Educational Programs in System Dynamics at Worcester Polytechnic Institute (WPI)*.
Wakeland [6]—*Four Decades of Systems Science Teaching and Research in the USA at Portland State University.*

The University of Bergen in Norway has been a progressive leader in building system dynamics skills and capacity across the world, teaching students from many different countries. This has been done with the establishment of an International Masters Program in System Dynamics in 1995 and a PhD program a few years later. Since 2010, an on-campus European Master Program in System Dynamics has been provided (along with 3 other European universities). System dynamics educators at the University of Bergen also run concentrated short-term courses tailored for government officials from developing countries, teach in different countries, provide on-line courses, and undertake project work that involves applying system dynamics in practice [4].

The Worcester Polytechnic Institute (WPI) is unique in that it provides a complete systems education program. This includes the B.S. in System Dynamics, Graduate Certificate, M.S., and PhD degrees in System Dynamics. There are also courses taught in system dynamics that are open to all students in the university [5]. This allows students to get an exposure to systems approaches but not a formal qualification. WPI also has a distance learning program that attracts primarily mid-career professionals who enrol in courses part-time. More than half are above the age of 35 [5].

Wakeland [6] introduces the Systems Science Graduate Program at Portland State University in Oregon, USA. This was launched in 1970 to cater for PhDs, and in the 1980s it extended to Masters and undergraduate courses. Wakeland notes that only a few of the many systems science programs created during the 1960s and 1970s still remain. Of the programs that remain in the USA, and the degree programs in Europe and Australasia, there is a strong connection with the engineering, computer science, and mathematics disciplines. There is also a practitioner focus. At Portland State University, student numbers peaked over a decade ago. While the students currently undertaking graduate study earned their bachelor's degrees in over 27 different fields, computer science, mathematics, and physics were the foremost. In the view of the systems faculty staff at the university, successful degree completion is more likely when the student has a technical background [6].

The location of systems courses within tertiary institutions influences the educational link between systems thinking and sustainability. Traditionally, many master programs in systems have been based in technical departments because, as noted by Wakeland [6], a technical background aids degree completion. There are efforts underway to change this. The Systems Science Program at Portland State University has recently been relocated in the School of the Environment within the College of Liberal Arts and Sciences, a move that will enhance the scope for students to shift in the direction of environmental concerns and sustainability-related topics [6]. The home of the European Master Program in System Dynamics at the University of Bergen is the Department of Geography [4]. At the Worcester Polytechnic Institute, the systems program is housed in the Department of Social Science and Policy Studies [5]. At the University at Albany, system dynamics is taught by the Rockefeller College of Public Affairs and Policy [7].

4. Diverse Approaches to Teaching Systems and Sustainability

Systems courses and how they are taught is a dynamic problem in itself. As Davidsen et al. [4] comment, there is a need to adapt teaching methods to meet the dynamic and increasing complexity of educational challenges. One response is to use hands-on teaching approaches. The following three papers provide examples of this:

Deegan, Stave, MacDonald, Andersen, Ku, and Rich [7]—*Simulation-Based Learning Environments to Teach Complexity: The Missing Link in Teaching Sustainable Public Management*.

Geyer, Stopper, Lang, and Thumfart [8]—*A Systems Engineering Methodology for Designing and Planning the Built Environment—Results from the Urban Research Laboratory Nuremberg and Their Integration in Education*.

Gray, Williams, Hagare, Mellick Lopes, and Sankaran [9]—*Lessons Learnt from Educating University Students through a Trans-Disciplinary Project for Sustainable Sanitation Using a Systems Approach and Problem-Based Learning*.

Deegan et al. [7] in their paper write about how a Simulation-Based Learning Environment (SBLE) was implemented in a first class on modelling methods. This class is part of the core Masters in Public Administration (MPA) program taught by the Rockefeller College of Public Affairs and Policy at the

University at Albany, New York. The authors note that SBLEs have been widely used in business education but are relatively new to public management education programs. The advantage of using a SBLE is that it compresses "the time it takes to 'experience' long-term effects of policy options and allow learners to experiment with different assumptions. Cases can be crafted to ensure that diverse stakeholders' positions are patent and visible, while simulation tools can give students the opportunity to test the effects of diverse alternative interventions" [7] (p. 220).

As part of the Energy-Efficient and Sustainable Building Masters course program at the Technische Universität München, students are taught systems analysis and how to run partial simulations. This program allows students to work with a systems model that supports decision processes. The model was constructed as part of a research project aimed at determining what makes a 'livable city', and it is used to teach students an integrative way to plan a sustainable built environment that will allow them to develop strategies for complex situations [8]. The students, who have Bachelors' degrees in either architecture or civil/environmental engineering, work together in interdisciplinary groups. A lecture series in another module (Sustainable Architecture, City, and Landscape Planning) provides sectoral views, and follow-on seminars are specifically aimed at teaching students how to bridge the sectoral views and take an integrative approach.

Gray et al. [9] describe a practical student learning experience that combines systems thinking approaches with Problem-Based Learning (PBL) interventions. PBL "is a format that encourages active participation by plunging students into a situation requiring them to define their own learning needs within broad goals set by the faculty" [9] (p. 245). As part of their course, students joined a team of researchers working on a trans-disciplinary research project. The participants were undergraduate and postgraduate students who were studying courses in a range of disciplines, and at three different universities in Sydney, Australia. PBL interventions were applied via learning platforms across pertinent aspects of (1) regulation and institutions, (2) visual communication, and (3) technology. Operationalising this applied learning experiment was not without its own PBL for both students and faculty involved [9]. It is argued that this teaching method provides an authentic learning experience bringing together a range of elements considered relevant to educating students about environmental sustainability through a systems thinking approach [9].

5. How Systems Approaches are Used to Educate in Diverse Fields

To embed systems thinking more widely in society and generate the paradigm shift to move towards the goal of a sustainable planet, new initiatives are required. The following papers provide examples of teaching and research initiatives to extend systems education into new or non-traditional areas:

Sun, Hyland and Cui [10]—*A Designed Framework for Delivering Systems Thinking Skills to Small Business Managers*.
Ronan and Towers [11]—*Systems Education for a Sustainable Planet: Preparing Children for Natural Disasters*.
Ratnapalan and Uleryk [12]—*Organizational Learning in Health Care Organizations*.

The Sun et al. paper discusses how many small business managers lack the systems thinking skills required to be sustainable in the long term. To address this short-coming, and extend systems education, the authors developed a dedicated framework for teaching students who are mostly adult learners. The course content aims to provide practical knowledge and encourages considering sustainability more broadly than purely for monetary measures [10]. Developing the framework involved a systems analysis of the needs of small business managers and applying adult learning and teaching theory. Systems skills were taught with the aid of scenarios that encapsulate situations that small business managers regularly experience.

There are known benefits associated with introducing systems education at a young age—a significant one being that the skills learned can be transferred to many future life situations. Ronan and Tower [11] investigate how hazards and disaster preparedness education programs can be taught as part of a systems-based inter-connected curricula across various ages at primary level. The authors argue that systems education has the scope to make children more resilient and reduce vulnerability by increasing physical and emotional preparedness. In addition, there is the added potential to harness the enthusiasm and motivation of children to mobilise households and communities to become more prepared [11].

The Ratnapalan and Uleryk paper discusses organisational learning in health care establishments. Organisational learning is defined as the "process of collective education in an organization that has the capacity to impact an organization's operations, performance and outcomes" [12] (p. 24). In the health sector, the use of systems approaches allows on-going education and fosters formal and informal learning across teams of people who have occupations that range from cleaners to surgeons. According to Ratnapalan and Uleryk, organisational learning is essential for managing complex interconnected systems where common background knowledge is critical for each staff member to execute their assigned functions and communicate the pertinent information needed for patient safety.

6. Associated Topics in Systems and Sustainability Education

The final three papers introduce novel ideas:

Campbell and Lu [13]—*Emergy Evaluation of Formal Education in the United States: 1870 to 2011*.
Wells and McLean [14]—*One Way Forward to Beat the Newtonian Habit with a Complexity Perspective on Organisational Change*.
Richardson [15]—*Taking on the Big Issues and Climbing the Mountains Ahead: Challenges and Opportunities in Asia*.

The concept of 'embodied energy', i.e., 'emergy', is used by Campbell and Lu to measure the inputs into education subsystems (elementary, secondary, and college/university) between 1870 and 2011 in the USA. Derived by Odum [37] emergy is an equivalence measure (quantified in one kind of available energy, e.g., solar joules) that estimates the units of energy used-up in the process of making a product or service. Campbell and Lu use emergy data to calculate the stock of knowledge in the USA based on the assumptions that (1) the emergy required for much of the information stored in human knowledge can be evaluated through an analysis of the formal education system of a nation; (2) the work performed by individuals in carrying out economic and social activities is primarily a function of their levels of education and experience; and (3) human knowledge does not diminish with use and therefore stays with an individual over their lifetime [13]. The hypothesis is that accumulated knowledge ultimately determines the kinds of economic and social activities that can be carried out within a country [13].

How systems sciences can become more persuasive in bringing about a paradigm change is covered from different angles by the final two papers in the special issue.

Wells and McLean [14] present their 'One Way Forward' model as a way to catalyse the transformational change needed for sustainability. They argue that the poor success rates achieved by current change initiatives make finding new ways of doing things an imperative. Using the 'One Way Forward' model involves unlearning previous knowledge, embracing ambiguity, and adopting an adaptive attitude that allows experimentation with what works and what does not. The One Way Forward model is a facilitated process (likened to Open Space Technology, Appreciative Inquiry, and World Café) that can be used to allow groups to work towards sustainability challenges by operationalising a whole of systems approach. The model is structured with three distinct phases that continually feedback on each other as new learning evolves. These are Envisioning (what we really want), selecting and monitoring Indicators of Progress (what we will see), and Strategic Experiments (iterative cycle of action and reflection to learn what works) [14].

Richardson [15] first describes his experience with system dynamics modelling and education in Singapore and then goes on to name three people who, in his view, respond to the call of Jay Forrester [38] to use systems approaches to "address the big issues" and get the message out:

Dennis Meadows, Junko Edahiro, and John Sterman. Each of these individuals has successfully advocated the use of systems approaches, created new knowledge, and built a public profile for the systems community [15]. Richardson then moves on to work that still needs to be done "to climb the mountains ahead". For him this work includes promoting economic dynamics, providing the visionary leadership required to capture public attention to engage with climate change (through projects such as Sterman et al.'s C-Roads [39]), and actively using system dynamics modelling to provide pathways forward for creating economies and societies that seek to maximise human well-being. This will continue the battle for political break-through that started with the "Limits to Growth" message [28].

7. Further Issues and Insights

As the focus of the special issue is 'systems education for a sustainable planet', we now move on to discuss some of the key issues observed by the different authors and new initiatives to better align systems education with current needs.

7.1. Teaching Approaches

The use of case studies that involve simulation is increasing in popularity as a teaching mode for systems education. Using integrated system dynamics models is an effective teaching tool to show how policy problems cannot be dealt with in small solvable chunks that are unconnected to broader policy and management [7]. Simulation runs can also demonstrate that multiple pathways can be taken with large and complex policy problems, and unexpected consequences can result from actions.

One of the strengths of the case study/simulation teaching method is, if well structured, it allows links to be made to material presented in other courses that students study and thereby builds a more integrated learning experience. At Rockefeller College, readings are assigned from different core classes to encourage students to cross-connect content [7]. Likewise, at the Technische Universität München the course material from another class provides the background information needed to evaluate the modelling simulation runs [8].

The use of simulation-based learning environments (SBLE) and case studies that cross different core classes can, however, be problematic for student learning. Deegan et al. [7] noted that students can struggle with too many moving pieces and keeping track of information and material provided at different time intervals and in different contexts. Deegan et al. concluded: "Overall, our impression was that the inclusion of this suite of exercises around the Pointe Claire Coastal Protection scenario considerably increased the overall complexity of, and perhaps the workload of, the class. This had the effect of bifurcating student reactions to the class with some students liking the additional sense of challenge, while others just wanted to be done with what, in the end, was just another core class they had to complete" [7] (p. 234).

Large-scale model building approaches are routinely criticised for being unmanageable and not providing outcomes able to be clearly explained. Use of SBLE and case studies for learning does place more importance on interpreting model outcomes but does not necessarily result in better understanding of the model structure and dynamics. Many of the students at Rockfeller College, despite being provided with the model equations and being required to build a simple version of the simulator as an assignment, treated the results as 'black box' [7]. To overcome the 'black box' issue, the Technische Universität München uses problem-specific partial models that the students can more readily understand and interpret. The partial model simulation is used to test alternative scenarios, answer specific questions occurring in the planning process, and provide quantified support for decision-making [8].

The combination of systems thinking and problem-based independent learning described by Gray et al. [9] had diverse learning outcomes for students. The students most happy in the cross disciplinary research project were those working within their known discipline (visual communication) and those who were seeing how this linked to the wider project goals. These students worked in teams, with students doing the same course. The students studying law who were required to move from learning about existing legislation to drafting new legislation found this step too big. The requirement to work independently with just teacher guidance was a challenging learning experience [9].

Different teaching methods are used to broaden the reach of systems education and cater for students with distinct needs. Distance learning poses a unique set of issues. On the positive side, distance learning provides educational opportunities that would not be available if class attendance was required. However, not having face-to-face personal contact can be an impediment to learning for students who enjoy interaction. A considerable amount of effort is required to overcome the disadvantages associated with lack of face-to-face personal contact. At WPI, technology is used for on-line lectures, discussion boards, releasing new material in modules, and providing virtual office hours to emulate the classroom experience. However, this requires additional resources and these need to be budgeted for [5].

7.2. Institutional Issues

"To become systems thinkers requires students to not only understand the commitments but also to be able to practice them when studying other disciplines and also in their own contexts" [3] (p. 321). When students, such as those enrolled in the Open University, study on-line, come from a wide range of backgrounds, are mature, and mostly study while working full time, it is difficult to design learning systems that connect student learning with their own context/lifeworld [2].

Embedding learning systems requires extensive changes to the usual silo student learning experience. Curricular need to be highly integrated so that material introduced at the start of tertiary education is compulsory to apply in later classes. As noted by Gregory and Miller [3], while there are now more programs with systems thinking components, very few programs infuse systems thinking throughout the curriculum. For systems thinking to occupy such an elevated position in the curriculum, a systems approach would need to be adopted at the departmental and ideally institutional levels. As most formal and non-formal education and training settings militate against emergence and self-organisation, this will require different structures and organisation than is currently found [2]. Also as Gregory and Miller highlight, to authentically engage with the challenge of embedding systems thinking and sustainability in teaching programs, both theory and practice need to be implemented in their own operations [3].

While increasing graduate expertise to use a simulation-based learning environment has the potential to extend the scope for systems approaches by, for example, engaging the public in decision making using system dynamics simulation models, there are still bridges to cross. Resources need to be made available. Teaching using SBLE requires access to faculty who are well trained in complex modelling and have access to up-to-date relevant case studies [7]. There is also a need for both the simulator and the supporting material to be thoroughly developed and tested before use [7].

7.3. Specific Demand for Students with Systems Qualifications

As noted by many authors, systems approaches still do not infiltrate most decision-making processes. Consequently, the demand for graduates with systems skills and capabilities is not strong. Ison and Blackmore [2] note the lack of institutionalised demand-pull for systems thinking expertise illustrated by the lack of advertised positions with this skill specification. Many of the students engaged in distance learning are already employed and undertake study, because they see it as an option to improve their career opportunities.

The situation appears to be different in Singapore. Richardson's explanation is: systems thinking was used by the founding political leaders to shape the political-social economy, and this has been continued by successors [15]. In Singapore, a country that is highly planned and regulated, systems thinking has become institutionalised. This has been aided by having top leaders, especially those in government, with degrees that combine science, technology, and engineering, augmented by graduate work in public administration and management. As a consequence, when system dynamics models are effectively presented, management can see their usefulness for aiding public policy and decision-making. The strong emphasis on science and technology in Singapore's secondary schools also means that students are well equipped for the technical requirements of systems modelling [15].

Despite the established need for more systems approaches to the wicked problems that society faces, there is still no strong body of empirical evidence for how to design learning experiences that equip systems thinkers for diverse roles [2], and no consensus on what the core skill set should be [5].

8. Concluding Comments

A possible explanation for the difficulties that arise with systems learning may be that educators do not teach in a way that allows a cross disciplinary team approach. There is an internal inconsistency in expecting big picture issue thinkers to be the same people as detailed technocrats. Not a lot of people have this ability. Sterman [39], in his later career, has moved in this direction, but the discipline is expecting these diverse skills in students learning at tertiary levels.

Maybe the best way to teach 'systems education for a sustainable planet' is in 'teams' as described in the PBL paper of Gray et al. [9]. Everyone in the team can work to their strength, as long as they are taught and understand the same common shared 'systems language, structure and methods' as a vehicle for working together towards shared values and objectives. For example, the social and environmental scientists can bring their understanding of the impact cause by social and environmental issues, and the engineers and mathematicians can work to their strengths building intricate models. We cannot expect the same tertiary student to be an expert in all these areas, but we can expect students to be educated to the same level of 'systems understanding' and then appreciate their strengths and limitations in working on multi-disciplinary projects with other team members.

Looking ahead, if simulation-based learning environments are as useful as the papers here suggest, building up a library of generic models that can be used for teaching across tertiary programs is an option. These can be tweaked for specific case study situations. The availability of such models will allow more time and effort to go into understanding and explaining the outcomes from a systems model. If a modeller cannot do this to a high standard, the not insignificant amount of resources and effort that go into constructing a customised model will be wasted.

This paper has drawn on the papers published in the special issue of Systems on 'systems education for a sustainable planet' for its insights and findings. There are many other sources of information and programs that teach systems education. Information on these can be found, for example, at the following websites:

International Society for Systems Sciences (ISSS)—http://isss.org/world/
System Dynamics Society (SDS)—https://www.systemdynamics.org/

Nevertheless, we highly recommend the papers in this special issue as an excellent resource for students evaluating their options for systems study or, alternatively, for any teachers/instructors wanting to establish new courses or extend existing programs. The papers collectively provide some very useful insights into how to design and deliver comprehensive systems education to better achieve a more sustainable future for the planet Earth!

Conflicts of Interest: The authors declare no conflict of interest.

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