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REPORT ON LITERATURE REVIEW ON THE THEORY OF COMPLEX SYSTEMS APPLIED TO:

SUSTAINABLE DEVELOPMENT
COMMUNITY DEVELOPMENT
SUSTAINABLE ENERGY

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ABSTRACT

This literature review focuses on articles regarding complex systems, systems thinking and complexity management primarily in the areas of sustainable development, community development and sustainable energy. Furthermore, the literary search identified research publications that were related to the framework governing systems thinking as well as methods of assessment. Each publication was assessed in order to gain a greater understanding of the aspects of complex systems and their educational parameters. The identification of skills required at undergraduate and career level is examined in order to create a greater understanding of systems that need to be applied to vocational and higher level education scenarios in order to help students develop the skills required for a growing economic market. Further this literary review highlights the complexity of work that is needed within the area of sustainability and the difference between multi and trans disciplinary approaches. The development of a skills toolbox is identified through the role of self-directed teaching and the development of local knowledge.

1. Introduction

The Literature review was conducted on a range of articles and papers covering themes related to sustainable development, community development and sustainable energy. These topics were chosen as they align with the UN SDGs [1] very clearly but also given that fact that the interactions between systems are critical to achieve true sustainability. Furthermore, the specific topics are relevant globally and have specific impacts on education, future development approaches and how we engage citizens in the sustainability agenda. Each publication was analysed and critically reviewed concerning its relevance to complexity science and/or complex systems. Subject matter identification was carried out to provide possible insights for the development of a toolbox approach for complex systems thinking within an educational scenario. The results identified in this review are the based on the review of 100 articles with the three highlighted areas being identified:

Sustainable Development: This is the primary driver for meeting global development goals that meet social, economic and environmental balance.

Community Development: This area focuses on where/how/why people come together to take action on issues that are important to them at a local and regional level.

Sustainable Energy: The deals with the use of energy that meets the needs of the present without compromising the requirements of future generations. Sustainable energy is one of the biggest challenges facing countries as they strive to ensure they are able to meet renewable energy needs, ensure reduction of carbon outputs and eliminating energy poverty.

2. Results Achieved

2.1 Complexity Science

In the context of Complexity Science, the primary area which demonstrated most relevant is the field of sustainable energy and energy systems. As energy systems are evolving there are multiple factors affecting the energy systems across the world. The complexity of interactions between technologies, systems and end users is growing and furthermore policy and market interventions are rapidly evolving and changing. Considerable focus is placed on the topic of micro-generation in the literature. This is due to the fact that policy is driving a move from centralized to de-centralised energy production. Praetorius et al [2] maps the functional dynamics of the system (considering the UK and German policies) thus highlighting the interplay between actors in the markets. Within the paper Carlsson & Stankiewicz define technological systems as “networks of agents interacting in a specific technology area under a particular institutional infrastructure for the purpose of generating, diffusing, and utilising technology”.

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2.2 Sustainable development

Education for Sustainable Development (ESD) is a key topic across a wide range of papers and articles. Emerging policy actions are being taken in this regard also [5]. In [4] Glavič identified and discussed the key issues of education for sustainable development (ESD). 12 key issues are elaborated in this study and thus proposes enhancement of content for the field. Glavič proposed key issues of ESD are:

- ESD scope: SD and ESD definitions, education at all the levels (primary-tertiary), life-long, formal, non-formal and informal education, teaching and learning, ESD key milestones, ESD competencies, quality education, and weak and strong sustainability
- ESD policy: vision, mission, peace, justice, and non-violence, democracy, rule of law, strong institutions, public awareness and participation, power and influence distribution, sustainable communities, cities, countries, and regions, and population control (towards zero-growth);
- ESD cooperation: empowering and mobilizing youth and aged people, intergenerational cooperation, cooperation between stakeholders (institutions, companies, communities, etc.), and partnerships;
- Environmental pillar: climate change, adaptation, and mitigation, pollution prevention and zero waste, life cycle approaches, biodiversity, disaster risk reduction, and the six Lisbon principles (responsibility, scale-matching, precaution, adaptive management, full cost allocation, and participation);
- Social pillar: human rights, hunger and poverty eradication, security, clean water and sanitation, health and well-being, reduced non-equalities (gender, income, living standard ones), decent work, social responsibility, quality education, cultural diversity, sustainable urbanization, and sustainable life styles;
- Economic pillar: resources (raw materials, energy, water, air, land) and their efficiency, circular economy, affordable and clean energy, sustainable consumption and production, research and development (R&D), innovations and entrepreneurship of all stakeholders, and economic de-growth;
- ESD methodologies: participatory teaching and learning, student-centered teaching, critical, interdisciplinary, and systems thinking, creativity, and imagining future scenarios (envisioning); Transformative teaching, learning, and training: a holistic approach, digital literacy, infrastructure and environments, developing case studies; Building capacity for educators and trainers at all levels, media, developing pedagogies, ESD tools, literature, project reports and presentations (PowerPoints, videos, etc.), and financing of projects;
- ESD metrics: indicators and indices, sustainability accounting, and reporting;
- ESD documents: international agreements, declarations from Agenda 21 to 2030 Agenda for SD;
- ESD institutions: UN (UNESCO, UNCED, UNEP, UNECE), EEA/EPA, global and regional associations(IAU, CA), national institutions, and NGOs."

Glavič states that the above described issues are the beginning for a new age of ESD and that the topic needs constant updating the remain relevant to the ever changing world.

2.3 Inter-disciplinarity and trans-disciplinarity

The nature of two of the areas considered (sustainable development and community development) are inherently inter-disciplinary whereas energy systems can tend towards a focus purely on technological aspects.

In [3] applies a participatory multi-modelling process to explore the creation of a boundary object ecology. They state that the participatory process of modelling can act as a leverage point by encouraging dialogue between stakeholders. Cuppen et al introduce the topic by discussing leverage points, models and simulations, and earlier studies on modelling similar circumstances. They then go on to discuss participatory modelling as a process of boundary object ecology creation. The boundary object concept is described here as being regularly utilised in interdisciplinary and transdisciplinary collaboration studies and that they can be physical (e.g. map or digital interface) as well as conceptual (a frame or concept, such as 'leverage point'). Boundary objects provide ground for bridging different social worlds, enabling collaboration between stakeholders within different institutional fields, from different

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organisations, and with different backgrounds, expertise and rationalities. Here, an organisation is said to be embedded into an institutional field. An institutional field is "a recognised area of institutional life: key suppliers, resource and product consumers, regulatory agencies, and other organisations that produce similar services or products". A basic systems map is provided in figure 1 – 3 with more detailed graphic representations following that. The model or at least the concept could be used a method of teaching systems thinking and developing leverage point understanding.

2.4 Students´ understanding

Gamification tools are emerging as useful means to engage students in complex systems and also to enable interdisciplinary approaches to specific topics. [6] describes the Celsius Game which focuses on the issue of climate change and the review portrays a strong consensus that the game acts as an effective means for learning about climate change and sustainable development. Furthermore, an overview of a range of other games used in ESD is provided, thus showing the increasing application of this approach in education. [8] and [9] provides further evidence of this in their assessment of simulation games in business education, with a specific focus on sustainable development concepts.

Further emphasis of the benefits of interdisciplinary approaches is provided in [7]. This study is concerned with the assessment of sustainability audits and their effectiveness as a learning method, with a particular focus on business students. Kay mentions the learning and teaching (L&T) for employment approach and its benefits for providing students with the tools and skills for real-world activities. The L&T method is considered for the application to level 6 business management students. In an audit-based module, the author provides students with a company case study and the task of conducting a sustainability audit. This module is undertaken as a 'Living Lab' and students are asked to reflect on their experience through an audit based learning, teaching, research and assessment (LTRA) approach. Thus, a successful method for active learning at an undergraduate level is proposed and provides a survey design framework for the replication of this research. The survey design method (pre- and post-module) may be a useful tool for the research of a similar topic with students.

2.5 Development of a toolbox

Key challenges for the development goals for society relate to a wide variety of sustainability issues from quality education, climate action, sustainable cities and communities, affordable and clean energy to responsible consumption and production. All these challenges need to be addressed in new and innovative ways utilising a multidisciplinary approach rather then the old silo effect. The reviewed literature highlights the importance of differing student experiences when dealing with climate and environmental research (inclusive of geographical information systems). The role of practical/local applications of research is important as it can create ownership/creativity of the student's personal education. The benefits of self-directed teaching are highlighted in [10] which shows that responsibility is assigned to the student at the inception of the project with a focus on project formulation, preparation and planning being completed by the student themselves, allowing less reliance on the tutor while increasing student participation. These interdisciplinary projects allow for the utilisation of critical thinking, problem solving and originality as part of the research methods. Furthermore, the utilisation of local (within walking distance) field work being extremely valuable as it provides experience without any added transport/accommodation costs. The use of local knowledge was further highlighted in [11, 12] which defined how local knowledge and policy implementation were important for education development but these cases are not widespread but reliant on experienced and knowledgeable practitioners. Utilising self-led research activities with a local knowledge base can be incorporated into a number of different disciplines including environmental, historical, social and economic research.

2.6 Discussions with teachers

The role of teachers and the development of high-level multidisciplinary practices when it came to sustainability were highlighted numerous times throughout the literature review. Indeed, education for sustainability and the role of pedagogical enhancement with sustainability education was identified [13, 14, 15] in Vocational Education and Training and higher education contexts. Furthermore, the role of the teacher and their personal philosophy to the teaching of complex sustainable systems were also highlighted. A number of areas/ideas were highlighted for discussions with teachers:

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- What extent is the teacher's personal philosophy influencing their teaching practices (older teachers versus new teachers)
- How does local/national policy influence teaching in the area of sustainability
- To what extent can you build local knowledge into the lesson plans.
- Is there a need to introduce a life cycle assessment into teaching at higher education now that students are dealing with more complex systems.
- In what ways can creativity around education be developed to enhance the student's experiences
- With the development of new media (i.e. social) are students becoming more involved within sustainability actions

2.7 Discussions with employers

The role of the energy sector is highlighted to continue to grow and develop over the coming years as countries strive to meet their renewable energy targets. Furthermore, complex systems thinking is going to be required in all areas of development from energy systems to circular economy with employers and employees continually requiring upskilling and the development of new skills. A number of research papers highlighted how different countries are facing this prospect and achieving real energy change [16, 17, 18]. Success factors within business have relied on a number of different factors that will continue to influence business practices in the future. Economic policies are being developed to aid in the expansion of enterprises in sustainability sectors, widespread technological advancements and the sharing of technology is important and growing quickly. Additionally, the long term future of increasing renewable energy requirements, circular economy and increased educational levels means that green jobs are rising and the skills required to deal with complex systems and continually expanding. In looking at the needs of companies to benefit for national policy changes, employers will need to examine a number of different aspects when considering potential employees:

- What skills are needed to keep up with changes in automation of sustainable manufacturing
- What skills should be developed in an educational setting in order to be successful in achieving employment in these areas.
- What new areas do you see developing over the coming years and how are businesses adapting to these changes.
- To what extent do you encourage continual professional development in order to upskill/reskill your current employees.
- What skills are need to be able to transfer the knowledge achieved from complex systems to real life scenarios.

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