Learning how to understand complexity and deal with sustainability challenges – a framework for a comprehensive approach and its application in university education

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Highlights

- Sustainability challenges require both specialized and integrative approaches
- Domination of specialism and reductionism calls for emphasis on comprehensiveness
- The GHH framework can be used as a tool to add comprehensiveness in education
- The framework consists of three dimensions: generalism, holism, and holarchism
- The dialectical approach combines comprehensive and differentiative approaches

Abstract

Sustainability challenges such as climate change, biodiversity loss, poverty or rapid urbanization are complex and strongly interrelated. In order to successfully deal with these challenges, we need comprehensive approaches that integrate knowledge from multiple disciplines and perspectives and emphasize interconnections. In short, they aid in observing matters in a wider perspective without losing an understanding of the details. In order to teach and learn a comprehensive approach, we need to better understand what comprehensive thinking actually is. In this paper, we present a conceptual framework for a comprehensive approach, termed the GHH framework. The framework comprises three dimensions: generalism, holism, and holarchism. It contributes to the academic community's understanding of comprehensive thinking and it can be used for integrating comprehensive thinking into education. Also practical examples of the application of the framework in university teaching are presented. We argue that an ideal approach to sustainability challenges and complexity in general is a balanced, dialectical combination of comprehensive and differentiative approaches. The current dominance of specialization, or the differentiative approach, in university education calls for a stronger emphasis on comprehensive thinking skills. Comprehensiveness should not be considered as a flawed approach, but should instead be considered as important an aspect in education as specialized and differentiative skills.

Keywords

comprehensive approach, sustainability science, complexity, generalism, holism, holarchism

1. Introduction

We live in an epoch of the Anthropocene where human pressure on Earth is the driving force of planetary change (Crutzen, 2002), and societies all over the world are facing complex challenges such as climate change, biodiversity loss, land degradation, rapid urbanization, and conflicts due to resource depletion (e.g., Rockström et al., 2009). These issues are strongly interrelated in complex ways and can hardly be solved or treated only with specialized knowledge within one discipline (Jerneck et al., 2011). Instead they require combining specialized knowledge with comprehensive and systemic thinking, by which we refer to approaches that embrace and integrate multiple viewpoints, subjects, or issues and interrelations at the same time (see, e.g., Ferrer-Balas et al., 2010; Kates et al., 2001; Lewontin & Levins, 2007; Meadows 2008; Ostrom, 2009; Waddington, 1977). Briefly, such approaches aim at seeing a wider perspective and the details simultaneously.

The disciplinary organization of academic knowledge creation has remained relatively unchanged (Holm et al., 2013; Nature, 2007; Warburton, 2003), and specialized skills dominate strongly in university education, whereas comprehensive, integrative skills are considered more marginal. To attend to this imbalance, this paper focuses on comprehensive skills, while recognizing the importance of the dialectical combination of both.

In order to more effectively teach and learn comprehensive approaches, we need to better understand what comprehensive thinking actually is. This paper addresses the question by introducing *a conceptual framework for the comprehensive approach*, called the *GHH framework* after the three elements it consists of: generalism, holism, and holarchism. The framework is not an exhaustive description of comprehensive thinking, but the three elements under examination here are among the central ones. The GHH framework is a general framework that can be applied in university education of sustainability science and other relevant disciplines to increase the understanding of any particular complex phenomenon or situation. It has been created in the department of Environmental Sciences in the University of Helsinki, Finland.

The approach presented here is mainly based on the "systemic" or "soft systems" thinking rather than the "systematic" or "hard systems" thinking (for the differences see, e.g., Flood, 2010; Ison, 2010, 22, 158). What is more, it is based on combining natural and social sciences as well as humanities and philosophy, and sustainability challenges are examined as processes in socio-ecological systems (see Ostrom, 2009) where human societies are understood as subsystems nested within ecosystems (Folke et al., 2016). That is, we emphasize that alongside physical, chemical, and biological processes, there also exists a range of cultural, societal, political, and even cognitive and psychological processes that need to be understood when studying socio-ecological systems (see also Hukkinen, 2014). Although the perspective of systems ecology (see, e.g., Odum, 1983; Hall & Day, 1977) is an important one here, this approach is based more on sustainability science (e.g., Kates et al., 2001) and the roots of our thinking, for instance, go back to *The Limits to Growth* (Meadows et al., 1972).

The paper is structured as follows: In section 2 we define the key concepts and frame the topic by discussing complex sustainability challenges, comprehensive and differentiative thinking and their relation to education and sustainability science. Section 3 presents the GHH framework, and section 4 presents practical applications of the framework in education in the Department of Environmental Sciences in the University of Helsinki. In Section 5, we discuss how the framework could be tested and developed further in the future. Section 6 concludes with some remarks on the role and future challenges of comprehensive thinking in university education.

2. Sustainability science and the comprehensive approach in education

2.1 The main concepts in this study

The terminology in literature covering complex sustainability issues and comprehensive approaches is not yet fully established. Therefore we define and explain here the key concepts related to the approaches we use in this study.

The main concepts of this paper can be organized on three levels. The first level (1) is the most general one. At this level, the central concept is *comprehensive thinking* by which we refer to various approaches that are broad in scope and give strong emphasis on examining reality as wholes and on integrating various subjects and viewpoints. This kind of thinking is thousands of years old (Checkland, 1999, A3) beginning, for instance, from the dialectical thinkers of the Orient and Ancient Greece. Nowadays *systems thinking* especially in the form of *soft systems thinking* (Flood, 2010; Jackson, 2003) is perhaps the most prominent variant of comprehensive thinking.

As an antonym for comprehensive thinking we use the concept of *differentiative thinking* to represent all such approaches that focus on analysis, differentiation, specialization, reduction, mechanist thinking, etc. In these approaches, it is typical to choose only small details of a larger entity for a closer examination and to pay less attention to the links between the parts that create complexity. That is, analysis (that is, differentiation) dominates synthesis (e.g., Cilliers, 2002, 1–2; Gershenson, 2013; Ulanowicz, 2009) and a narrow and deep scope of inquiry is favored as against a broader one. Differentiative thinking has been the classical paradigm in natural science and engineering in Western cultures for the past centuries (Capra, 1982, 37–62; Midgley, 2000, 2–4; Ponting 1992, 147–149).

Obviously, thinking is never purely comprehensive or differentiative; instead, all human thinking encompasses elements of both forms. Thus, the approaches form a continuum, and when we refer to comprehensive or differentiative thinking in this paper, we indicate such forms that place a strong emphasis on either the comprehensive or on the differentiative end of this continuum.

At the next conceptual level (2) are all the different variants of comprehensive thinking, for example systems and systemic thinking, complexity thinking, chaos thinking, and dialectics and their variants. This paper focuses on one of these variants, namely our own approach from which we derive *the framework for the comprehensive approach*, which is a tool for examining any kind of system. In this paper, the main characteristics of this approach and of the concept of *system* are (on different definitions of systems, see, e.g., Backlund, 2000; Dubrovsky, 2004):

- the system is considered to consist of *parts* and *connections* between them
- parts and their connections build up *wholes* which are at a higher *systemic level* than their parts
- there are also relationships between the whole and its parts
- all systems can be examined from many *different perspectives* and none of these is better than the others per se.

At the most detailed level (3) of this work are the three main components of the approach: g*eneralism, holism,* and *holarchism* (see the definitions in sections 3.1–3.3).

In this paper, the term *complexity* is central when describing the character of sustainability challenges. We use a simple definition of complexity: a system is complex if it is formed of strongly interconnected parts (Bar-Yam, 1997; Heylighen, 1996). The more interconnected parts there are in a system, the more complex it is. Already three decades ago Pagels (1988, 318) predicted that complexity would be the central challenge for science. We claim that the statement is also valid for education.

Other important concepts of this study are *sustainability science*, *sustainability challenge,* and *sustainability education*.[1] The concept of sustainable development was introduced in the 1970s and entered into the mainstream through the World Commission on Environment and Development (WCED, 1987). Since then the discipline of *sustainability science* has emerged in response to studying the shortcomings of current attempts to achieve sustainability and to create

[1] We are aware of the multiplicity of different definitions and the criticism towards the whole concept of *sustainability* (see, e.g., Barrett & Grizzle, 1999; Bond & Morrison-Saunders, 2011; Carruthers 2001; Mebratu 1998). Defining sustainability is a difficult task since it is a complex and value-bound concept and its definition is always subjective to a certain extent. In this paper, we do not offer our own interpretation of this concept. Rather, we present the GHH framework as a tool for understanding the interconnections between different elements and levels of sustainability. In this sense, we present a tool that could be utilized in creating more robust definitions of sustainability.

more fruitful approaches (see, e.g., Clark & Dickson, 2003; Jerneck et al., 2011; Kates et al., 2001). Sustainability science is a research field characterized by systemic and interdisciplinary research approaches that aim at promoting sustainable transformations and their research. It seeks to study and solve complex problems comprehensively and aims at recognizing value-boundedness and uncertainties (Clark & Dickson, 2003; Jerneck et al., 2011; Kates et al., 2001). We use the term *sustainability challenge* when referring to sustainability-related complex problems, for example to climate change and the loss of biodiversity, but also to social sustainability challenges like protecting the right to a sufficient income and decent working conditions (Jerneck et al., 2011). The term *sustainability education* refers in this paper to covering sustainability challenges in university education (see Howlett et al., 2016; Warburton, 2003).

2.2 Dealing with complex sustainability challenges requires comprehensive approaches

The complexity of challenges related to sustainability manifests itself in many ways. Most of the challenges have wide spatial and temporal impacts; they often affect many areas and societies and can be the results of long historical developments and/or reach far into the future. They are highly value-bound, can be formed as the result of joint effects of multiple variables and can consist in various interconnected problems. When the number of these interconnections between problems is high, the result can be complex problems that Rittel and Webber (1973) call *wicked problems*. Sustainability challenges are often wicked problems.

Due to their complex and multifaceted nature, sustainability challenges have multiple possible formulations none of which is definitive. Also, they have no obvious solutions and they might even be irresolvable. A proposed solution might result in unforeseeable outcomes and feedbacks at different systemic levels or over the course of long periods of time. Every attempt to solve a wicked problem can create a new set of wicked problems, where the original solution no longer applies (Rittel & Webber, 1973). This wickedness of sustainability problems still does not mean that there is nothing we can, or should, do about them. Even though we could not eradicate poverty or reverse climate change entirely, we can still mitigate these problems.

The current sustainability crisis can be partly explained by the insufficient understanding of complexity. The differentiative approach has many advantages and it has contributed to scientific and technical progress that have worldwide impacts in everyday lives, for example through curing many severe infectious diseases, mass production of commodities, and advances in electronics, etc. (Gershenson, 2013). However, the dominance of differentiative thinking has also led to a situation where different environmental and developmental problems have been treated as separate and fragmented issues for a long time (Gershenson, 2013). This has resulted in the prolongation and escalation of sustainability challenges.

In addition, research and education have, for decades, even centuries, emphasized differentiative dimensions of thinking. Students have been guided to specialize within traditional disciplines, developing their skills in fragmentation and reductionism at the expense of comprehensiveness and synthesis (Nature, 2007; Warburton, 2003). For example, the criteria for evaluation of theses often disfavors integrative work that is done with a broad research scope. However, one could also claim that an overly narrow research scope is just as fatal as the defect of too broad a scope (Willamo, 2005, 291–293).

The sustainability crisis is a mix of elements from ecological, social, cultural, and societal systems and affects practically all disciplines. Thus, there is a need for both social and natural scientists, but also a need for people who are able to sufficiently comprehend both disciplines, integrate them, and to understand the linkages between society and nature. Comprehensive thinking and integration of different fields of knowledge can be perceived as one leverage point (see Meadows, 1999) for dealing with complex sustainability challenges.

For example, considering humans and their institutions as parts of the examined system implies that there is a need to understand not only the ecological consequences of human action, but also the root causes and fundamental drivers (biological, economic, political, philosophical, technological, etc.) of those actions at the individual, societal, and cultural levels. That is why comprehensive thinking and the integration of different fields of knowledge play a vital role in dealing with sustainability challenges. They are not decision-making methods but, rather, they are necessary conditions for sustainability (although not sufficient in themselves).

Failure to understand the system as a whole has led to difficulties—we continue to try to fix the problems with traditional tools, that is, with the very tools that are partly responsible for creating the problems in the first place. It is important that complex issues are dealt with using appropriate approaches or tools, i.e. there should be a coherent match between the nature of the subject in question and the selected approach (Willamo, 2005, 53–54; see also Flood & Carson, 1988, 19–34 and Midgley, 2000, 1–7). In order to deal with sustainability challenges, we need better skills to manage vast perspectives and to understand and deal with contradictions.

In recent years the scientific community has begun to better understand the interconnectedness and the wickedness of the crisis these problems form together (Komiyama & Takeuchi, 2006). At the same time, many academics have started to underline the significance of systems and complexity thinking in education (Davis & Stroink, 2016; Mason, 2008; Pipere, 2016). In our opinion, overcoming sustainability challenges requires an effective combination of comprehensive and differentiative approaches. Currently the latter dominates, while the former is often sidelined. Therefore, comprehensive thinking should be encouraged more in university education in general, and especially in the context of sustainability. The GHH framework, with its three dimensions and mutual interconnections, provides a powerful tool for understanding complex issues.

3. The GHH framework for a comprehensive approach

The GHH framework for a comprehensive approach consists of the elements of generalism, holism, and holarchism. It has been influenced mostly by systemic thinking (e.g., Jackson, 2003) and complexity thinking (e.g., Prigogine & Stengers, 1984), but also by chaos thinking (e.g., Gleick, 1987), and dialectics (e.g., Harvey, 1996).

The framework has been developed in several steps, first by Willamo (2005) in his doctoral thesis under the term *generalistic-holistic approach* and later by Huutoniemi and Willamo (2014) under the term *outward thinking*. Also Helenius (2015) and Holmström (2017) have developed it in their Master's theses, which they have written as projects conducted in the

Kudelma network.[2] The three first mentioned studies have mostly concentrated on describing the generalistic and holistic dimensions of the conceptual framework but, in this paper, we introduce a third, equally important element of comprehensiveness: holarchism that describes and organizes reality into hierarchical levels (see Holmström, 2017).

The GHH framework is an epistemological and heuristic tool for studying and understanding complex phenomena. It does not take a stand on the ontological nature of reality and its application is always subjective – every learner uses it in a unique way. This is of course valid for all concepts that describe broad and general approaches. For example, broadly used terms "system" and "emergence" are only ideas, which in an ontological sense do not necessarily genuinely describe reality (Checkland, 2012).

3.1. Generalism

In this paper, *generalism* indicates a broad examination of reality by multiple disciplines and from various perspectives, and the inclusion of multiple items into a research.[3] As an antonym for generalism, we use the term *specialism* which refers to examining reality from a narrow viewpoint and includes only a small number of objects into an analysis. The importance of a generalistic, multidisciplinary approach has often been highlighted in sustainability science (Jerneck et al. 2011; Spangenberg, 2011). For example, an emphasis on generalism can be noted in many environmental textbooks (e.g., Boersema & Reijnders 2009; Miller, 1996).

Generalism operates on two dimensions. On the one hand, there is *object generalism,* which refers to the inclusion of multiple objects or disciplines under examination. For example, extending a recycling campaign in a school from only solid waste to recycling also water represents object generalism, because a new object is introduced into the campaign.

[2] *Kudelma, Network for Comprehensive and Sustainable Systemic Change,* is a network in the Department of Environmental Sciences at the University of Helsinki. In this network students, who are oriented towards the comprehensive approach, have the possibility to write their theses and receive supervision guided by the principles described in this article.

[3] The concept of generalism also has other meanings than the one used in this paper. Perhaps the most common one is to equate generalism with *universalism*: an approach which perceives the reality as a whole that follows universal laws which are similar for all its parts (see Hampden-Turner & Trompenaars, 2000, 13–32).

On the other hand, there is also *viewpoint generalism* which means that a single object is observed from multiple perspectives. This includes not only simultaneous utilization of different branches of science and knowledge, but also comprehending and managing different viewpoints drawing from the wider society. Also extending the observation to values and feelings that lie outside the scope of knowledge and science can be seen as an example of viewpoint generalism. An example of this is the inclusion of various stakeholders, their perspectives and values into decision-making processes (see, e.g., Komiyama & Takeuchi, 2006; Spangenberg, 2011).

The difference between "an object" and "a viewpoint" is often vague and they easily interchange. For example in sustainability science, it is difficult to point out a difference between having, e.g., social and ecological systems as objects of examination and examining something from a social and ecological viewpoint. The value of this classification between object and viewpoint generalism lies in ensuring the efficient use of both of these approaches.

3.2. Holism

The concept of *holism* was first developed by a South-African philosopher Jan Smuts in his book *Holism and Evolution* published in 1926 (Smuts, 1987, 85–117). Like generalism, the meaning and use of the term holism are nowadays interpreted in multiple ways. Perhaps the most widespread interpretation is that in holism *a whole* is considered to operate partly by a different set of rules than its components (see, e.g., Healey, 2016; Smuts, 1987, 98–99). The attributes of the whole cannot be explained only through the attributes of its individual components, nor should the attributes of the component parts be examined only through the attributes of the whole. There are also interactions between the whole and its parts, and these interactions are part of the characteristics of both (Næss, 1973). Longo et al. (2012, 1380) use the concept *Kantian whole* similarly stating that "the whole exists for and by means of the parts, and the parts for and by means of the whole."

The most famous crystallization of the concept of holism stems from Aristotle (1994): a whole is greater than the sum of its parts. We modify these ideas by clarifying that the whole is something other than the sum of its parts: it can also be less or even equivalent (see also, e.g., Armson, 2011, 134–137; Morin, 1985). For example, even if we personally know every single person in a new group of students, we cannot tell how they are going to interact with each other and act as a group. This sudden appearance of new characteristics in an entity is commonly called *emergence* (see Holland, 1998). The significance of an emergence is equally important when moving downwards in a hierarchy from a whole to its parts: the whole cannot be reduced to its parts without losing something significant (Koestler, 1970, 136).

There are several concepts used as antonyms for holism: e.g., reductionism, merism, and atomism. We use the latter in this paper. *Atomism* originates from Ancient Greece where it meant an idea, according to which matter consists of particles that cannot be divided into any smaller parts (Berryman, 2016). Nowadays, it also refers to the conception that a whole can be explained exhaustively by means of its parts.

3.3. Holarchism

The third dimension of the framework for a comprehensive approach is *holarchism*. We have derived this term from Koestler's (1967) idea of holarchy (see below). Holarchism refers to an approach whereby systems are perceived as emergent, hierarchically layered structures (Holmström, 2017). Holarchistic thinking considers systems as structures in which some entities are located at the same systemic level, whereas others are located at different levels (higher or lower, depending on the way the system is viewed). Thus systems consist of both parts and wholes. Actually this approach is very common for systems and systemic thinking (e.g., Armson, 2011, 134–137; Geels, 2005, 683–686; Ison, 2010, 21), but also for science and life in general. Take for example the taxonomy in biology, or the arrangement of computer files.

There is no specific definition of the relation between the part and the whole in regard to the term "hierarchy." Instead, the term *holarchy* refers to a form of hierarchy in which every element is at the same time 1) a part of a larger whole, and 2) a whole itself which can be divided into smaller entities at a lower level of the system. The term was introduced by Koestler (1967) in his publication *Ghost in the Machine*. In holarchy, there is a strong sense of holism and emergence: the whole at the higher level is something other than just a sum of its parts at the lower level (Checkland, 1981, 3–5, 74–82).

The concept of *complexity threshold*[4] is central in holarchism. Complexity thresholds are situated between system levels. When such a threshold is crossed, emergence occurs: the degree of complexity changes and the laws of the lower level no longer explain rigorously enough the operations of the higher level. And vice versa: when coming downwards across the complexity threshold, some details become visible that could not be seen at the upper level. This kind of knowledge processing occurs, for example, when reading a book. At the same time, one should move up and down between systemic levels and cross complexity thresholds—adopt both the details and the overall picture in order to enhance learning.

The structures of the levels and complexity thresholds in holarchistic thinking are not absolute, however, since they depend on the chosen point of view. But ignoring them completely leaves something essential out of the system description. A good example is the common misuse of the concept pair human-nature. In Western thinking humans and nature are often perceived as being separate from each other and even as polar opposites at the conceptual level, and this is perhaps one of the most startling and profound category errors of our time (Helenius, 2015, 59). How much more would we be able to develop our understanding of the human-nature relationship by merely perceiving that "nature" is something that is located on a higher systemic level than "human"? How much more would we be able to develop our understanding by this relationship, if every teacher or news anchor would always say "human and the rest of nature," instead of reinforcing the dichotomy between "human and nature"?[5]

In this paper, we use the word *"planism"* as an antonym of holarchism. We have derived this word from the Latin *planus* (flat, planar). In a "planistic" approach, all objects are viewed as existing at the same level (or plane). There are at least two ways this can be done. On the one hand, one can focus one's attention on one level of a holarchy and leave the other levels out. On the other hand, one can take a holarchical system—which makes an explicit distinction between the whole and the parts—and flatten it to a one-levelled structure where the whole and the parts are mixed at the same level. (Or, if one prefers to perceive the holarchical structure as a nested

[4]"Complexity threshold" is, naturally, a figure of speech. Actually, the changes in complexity take place on a steady continuum rather than as a sudden drop or rising from one level to another. The term complexity threshold was apparently first introduced by the Hungarian-American mathematician John von Neuman in the 1940s, when lecturing about the development of mechanical systems that could reproduce, such as self-copying robots (Kabamba et al., 2011, 123.)

[5] For an elaboration on the relationship between humans and nature, see Fiscus et al. 2012.

system, a “planistic” approach would result in the disintegration of the nest.) Either way, complexity thresholds and emergence are not taken into account in “planism.”

3.4. The framework assembled and illustrated

Figure 1 illustrates the use of GHH framework. In the first column, the stages of the comprehensive approach are described, proceeding from top to bottom. Only object generalism is included in the illustration. In the second column, the process is visualized. In the third column, the stages of the differentiative approach proceed in the opposite direction. In the last column, the dialectical process is illustrated as a constant and balanced upward and downward movement, combining the comprehensive and differentiative approaches.

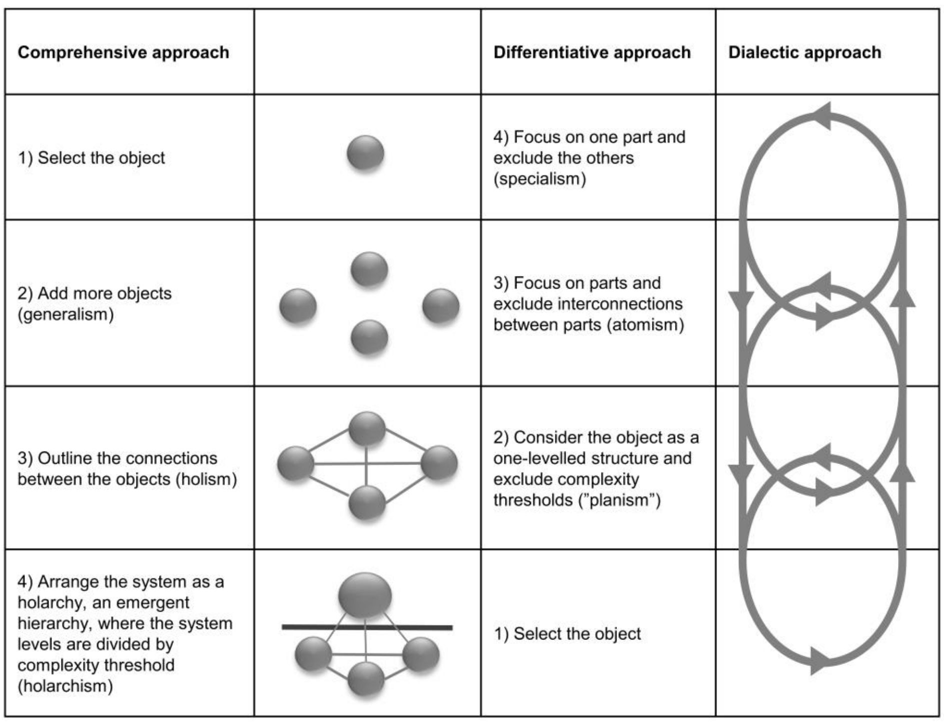

Figure 1. Simplified illustration of comprehensive, differentiative, and dialectical processes in the GHH framework.

The illustration of the comprehensive approach in Figure 1 is simplified: generalistic, holistic, and holarchistic phases follow each other neatly. In reality, the application of a comprehensive approach is hardly ever linear; rather, the steps are overlapping. However, presenting this kind of a "recipe" might be helpful in a situation where a person, or an organization, is unfamiliar with comprehensive thinking and is therefore unable to fully acknowledge the existence of multiple viewpoints, objects, interconnections and levels. The step-by-step process shown in Figure 1 might act as an exercise for systematically learning the three central elements of the comprehensive approach. After gaining sufficient skills in all the dimensions of a comprehensive approach, a person will be able to apply the differentiative approach more fruitfully and to link these two approaches together as a dialectical process which is illustrated in the last column of Figure 1.

It should be noted though that endless expansion, by indefinitely adding more perspectives, objects and interactions and constructing new holarchies, could cause confusion. For that reason, the learner also has to know how to draw up boundaries and to specify individual parts from the whole (see Gershenson & Heylighen, 2004).

Figure 2 illustrates the GHH framework as a system structure. The darkened disks describe all the objects (systems) viewed by the observer. In the object generalistic approach, the learner includes numerous different systems and subsystems in their observation. The lines between the disks represent the holistic dimension of the comprehensive approach. These interactions are present both between the disks at one level (*horizontal holism*), and between the parts and wholes across the levels (*vertical holism*). The more holistic the approach, the more interactions are examined.

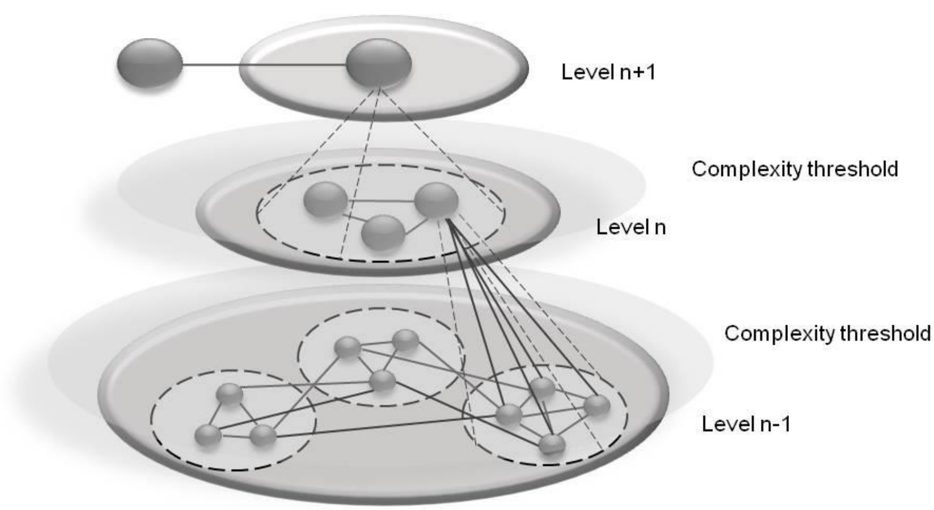

Figure 2. An illustration of the GHH framework as a system structure (Holmström, 2017).

The dotted circles and lines illustrate the process where entities at the lower level are incorporated into a higher level entity, or contrarily illustrating the wholes that are divided to parts at the lower level. Thus each element (disk at the level n) is a part of a larger entity (disk at the level n+1) and simultaneously can be divided to smaller parts (disks inside the light circle at the level n-1). This nested structure represents the holarchical aspect of the comprehensive approach: the structure consists of levels that are separated by a complexity threshold, therefore, emergent phenomena appear when shifting from one level to another.

Due to emergence, a higher-level entity is always something other than the sum of its parts and higher-level entities cannot be reduced to their parts without losing something essential. Figure 2 demonstrates only a small part of the overall structure, which will run up, down, and sideways "indefinitely." In this kind of a configuration, there is an endless space for new perspectives and connections. In addition, the structure changes dynamically with time and also appears different for each person. Every learner perceives the whole differently by narrowing the whole both vertically and horizontally. By applying viewpoint generalism, the learner can observe the system from several different perspectives and form many different interpretations when observing the same system.

This way, the GHH framework can be a helpful tool for organizing fragmented knowledge into larger wholes and understanding the connections between the different parts of a whole. To give an example: in order to come up with mitigation strategies for climate change, it is useful to assess the different drivers (e.g., fossil energy use, resource consumption, deforestation) together and also understand their interconnections and feedbacks. Furthermore, a holarchical understanding that some drivers are actually part of an upper-level driver (e.g., a consumerist lifestyle) can help targeting the mitigation efforts to the root causes instead of just addressing the symptoms.

We argue that an ideal approach is a mixture of differentiative and comprehensive thinking in suitable proportions dictated by the situation (Helenius, 2015, 93-97). We call this *a dialectical approach* (Figures 1 and 3) which consists in the constant alternation of widening (generalism) and narrowing (specialism), integrating (holism) and separating (atomism), and building holarchies (holarchism) and regarding objects under examination as one-levelled (“planism”).

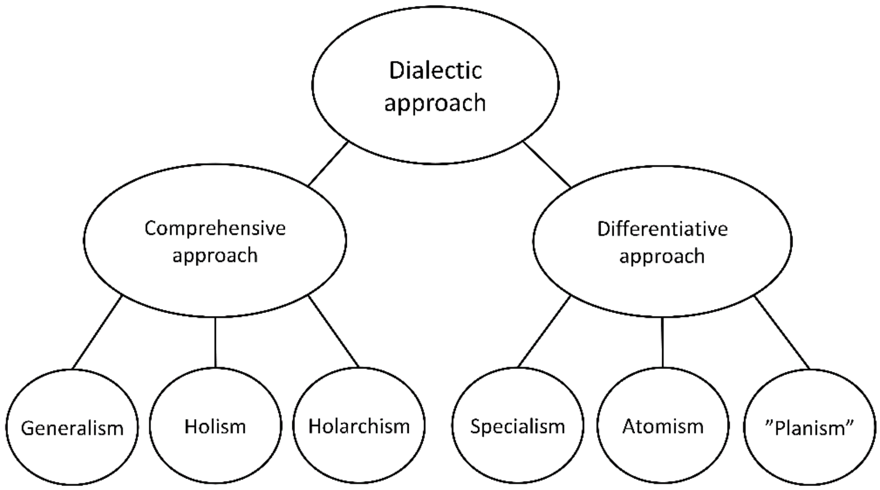

Figure 3. Elements of dialectical approach in this paper: it is a combination of comprehensive and differentiative approaches which, in turn, consist of three dimensions.

GHH framework can be interpreted as a description of an interdisciplinary approach. It is important to note that, in this kind of a process, a significant amount of input knowledge is acquired through a differentiative approach and specialized research. On the other hand, the new knowledge, or the output of the interdisciplinary and synthetizing process that emerges after surpassing a complexity threshold, inspires new questions some of which can only be answered by first forming new input knowledge with differentiative processes. In this way, the comprehensive and differentiative approaches complement each other.

In this regard, environmental sciences and sustainability science should be viewed as metadisciplines that cover all specialized fields relevant to sustainability issues (Caldwell,1983). That is, sustainability science is not parallel to (on the same level as) these specialized fields, but holarchistically on a higher, systemic level. The comprehensive approach is a central tool for these kinds of metadisciplines that focus on synthesis, integration, and analysis across disciplines (Thomas, 1992). The same applies to some other research fields, too, for instance, systems ecology as a metascience for many different fields of biology.

4. Applying the GHH framework in university education

The integration of the comprehensive approach into education can be implemented in multiple ways. In this section we present two practical examples from the University of Helsinki, Finland: first, of the design and development process of a degree program, and second, of the writing and guiding of theses and other student projects.

There are at least two main competences that *comprehensively designed* sustainability studies should enhance. These include 1) a comprehensive understanding of the substance of various sustainability issues and 2) skills and tools for comprehensive thinking itself. Learning these competences can be integrated in the courses as well as in the structure of the degree (see section 4.1 and Appendix A) and in the thesis writing process (see section 4.2).

Comprehensive thinking comes easier for some students than for others—although we consider it valuable for all to learn. The case presented here is an example of a university degree program in which, in each student cohort, there are at least some students who are very skillful in comprehensive thinking and eager to learn more about it. Especially for this type of student, teaching and guidance that provide the learner with methods, theories, and concepts for a comprehensive approach have proven to have great value in building the student's identity and self-confidence as a competent thinker.

4.1. The GHH framework in designing a degree program

The development of the degree program called Environmental Science and Policy[6] in the University of Helsinki provides us with an example of how a degree program in sustainability education can enhance comprehensive thinking. It also serves as an illustration of how the process of designing a degree program might look at other institutions.

The history of the degree program extends to the year 1975, when a professorship of Environmental Science and Policy was established in the University of Helsinki

[6] In Finnish *ympäristönsuojelutiede.*

(https://www.helsinki.fi/en). The yearly intake of the major has been 15 to 16 BS students and at the most 5 MS students. Over the years, the degree program and organizational structure of the faculty have undergone several changes.[7] We consider the curriculum of the years 2008–2011 as the most descriptive of the integration of the comprehensive approach and therefore it is presented in Appendix A. The curriculum could be described as a loose framework within which each student can tailor their own combinations of courses and modules.

A generalistic degree program should both provide the students with perspectives from different disciplines (viewpoint generalism) and also cover varying phenomena related to sustainability (object generalism). In this program, in the 1970s and the 1980s environmental thinking was strongly linked above all to natural sciences. However, within the framework of natural sciences, generalism was well represented in the variety of both aspects and the central phenomena.

This period of relatively narrow generalism was followed by a shift towards social sciences in the early 1990s. Since then it was obligatory for the students to also include social studies in their degree (see Appendix A; e.g., courses no. 5, 10, 11, 18, 23–24, 36). In addition, major courses started to cover societal factors – such as reasons, decision-making, and evaluation – that were seen as related to the anthropogenic environmental changes (see Appendix A; e.g., 1, 3–6, 8, 10, 39) (see Tapio & Willamo, 2008; Willamo, 2005, 214–217). A new multidisciplinary study module was also introduced in order to allow the student to integrate all the courses from different disciplines/subjects, e.g., biology, chemistry, history, aesthetics or politics, in one module (see Appendix A; 18–24). This invention enabled the student to include a broader selection of studies in one module, when normally all the modules were minors included under one discipline. The studying methods of the social sciences was also included in the curriculum (see Appendix A; e.g., 11, 36). All this reflected a wider change in environmental thinking in the surrounding society (see, e.g., Woodgate & Redclift, 1998).

The generalistic dimension of the GHH framework, the variety of aspects and objects, is relatively easy to include in a degree program, for example through the ways described above. This kind of multidisciplinary structure of the curriculum has been widely applied in environmental and sustainability sciences in higher education (see, e.g., Charli-Joseph et al.,

[7] During the years 2015–2017, the degree program was integrated into a new wide-ranging major of environmental science and the structure of the studies changed remarkably. Therefore we will not extend our review to the years after 2014.

2016; Vincent & Focht, 2009). Studying a generalistic set of courses can, however, lead to fragmented learning. To achieve a more coherent understanding, it is important to also offer holistic, integrative teaching where aspects and phenomena are synthesized (Stephens et al., 2008). The importance of this kind of curriculum integration is recognized at all levels of education (see, e.g., Todd, 2010). The GHH framework can be used as a guide in curriculum design processes assuring that also holistic and holarchistic elements are included in the degree program to avoid "hyper-diverse and shallow curricula" and "multidisciplinary illiteracy" (Soule & Press, 1998).

In the studies of Environmental Science and Policy, there were courses with a specific emphasis in creating holistic understanding. At first, a holistic approach was applied by connecting different phenomena to each other in time and place—environmental issues were viewed as processes with a long life span and their planetary nature was also taken into consideration. Moreover, student guidance had a significant role in providing the students with a holistic overall view of their studies in this interdisciplinary degree program (see Appendix A; 2, 26–28).

It was soon noticed that even wide and integrated teaching of sustainability challenges was not sufficient without courses focusing on comprehensive thinking itself. A one-semester-long course called "Environmental Thought and Argumentation" was introduced to meet this need in the middle of the 1990s. During this course all students had to write an essay, utilizing the technique of process writing, to define and argue their mindset and relationship to the most central issues related to sustainability (see Appendix A; 6). This course was mainly designed by students. Later, another course called "Interdisciplinary Approaches to Environmental Questions" (see Appendix A; 4) was introduced. The course focused on some of the most prominent variants of comprehensive thinking, such as systemic, complexity and chaos thinking, as well as dialectics. Also education in methodological integration was added to the curriculum in the form of a course named "Integrated Methods of Environmental Social Science" (see Appendix A; 36).

Recently we have begun to consider the idea of holarchism as one of the foundations of the comprehensive approach. Recognizing the holarchical relations of any set of systems is especially important in education related to sustainability sciences. For example, it is often useful to identify and analyze the impacts of a project at the local, national, and global level and to analyze also the interactions between the levels. Also, the ability to lift the discussion to a higher systemic level and, yet, communicate using an understandable language is an essential skill. It is emphasized when one has to manage with various types of knowledge and to communicate between different stakeholder groups, or between researchers in inter- and transdisciplinary groups. Therefore, education that enables the students to recognize and manage holarchism should also be integrated into the curriculum. In our degree program, the main idea of holarchism has been introduced to students in the course of interdisciplinary approaches mentioned above (see Appendix A; 4). In the future, it would be possible to integrate holarchism more deeply into the curriculum, for example, by utilizing holarchistic thinking explicitly in the design of the degree program that consists of modules which in turn are formed by individual courses.

4.2. A comprehensive approach and theses

4.2.1 Writing process and supervision

In addition to the degree program and individual courses, also thesis supervision and thesis writing (see Appendix A; 13, 40) processes hold vast potential for education in comprehensive thinking. In this paper, we focus mainly on Master's and Bachelor's theses. In the program of Environmental Science and Policy, students have always had the option—chosen by a large number of students—to do a thesis following the traditional, differentiative manner of specializing in a clearly defined and relatively narrow research subject. Yet, there have also always been students who find comprehensive thinking more suitable for their style of learning and for the questions they are interested in.

The main differences of comprehensive thesis projects when compared to specialized projects are in the *research and learning process* rather than in the *end result*. In this regard, we have stressed that the learning process is at least as important as the final result especially in the cases of Bachelor's or Master's theses. This should also be taken into account in the evaluation of the theses as is pointed out in the discussion concerning the pluralistic approach to assessment (see e.g. Birenbaum, 1996; Brown et al., 1997).

There is relatively little literature available on guiding comprehensive research processes, nor are there many empirical studies about the topic. The guidelines presented here are mostly based on the experience gained in the Environmental Science and Policy degree program during the last 30 years.[8] Although we have expressed here that writing a comprehensive thesis may not always be easy, we wish to highlight that the reality is complex and therefore comprehensive approaches are urgently needed. Next we suggest six guidelines for comprehensive thesis writers and their supervisors.

1) Support in the beginning. The complexity of sustainability challenges can be overwhelming, and the challenges are not easily tamed as research questions and positions. Therefore, a thesis writing process is likely to start with an intensive generalistic brainstorm, during which more ideas, topics and perspectives are collected than will eventually fit in the thesis. This is especially true for comprehensive theses, but probably also for many differentiative theses. The topic and perspective may change considerably especially during the early stages of the process, which may look messy to those who view the thesis process from outside. Also the student can experience this generalistic phase as chaotic and even frustrating and burdensome, if it lasts too long. However, this phase is crucial as it provides a stepping stone to the next holistic and holarchistic phase. Thereafter, when holistic and holarchistic thinking are utilized to connect topics and perspectives and organize them in holarchies, the focus and a suitable scope will slowly be found for the work.

All this implies that a great amount of guidance may be needed in the beginning of the thesis project. The supervisor should be there to convince the student with their experience that this generalistic phase is an inherent part of the process, and to help the student to enter the holistic and holarchistic phase. The supervisor should avoid urging the student to simplify the process by cutting out the different topics and perspectives. Instead, they should provide several alternative suggestions for carrying out the process of integrating them. Also, it is important to be aware that

[8] It is worth bearing in mind that traditions and practices related to thesis writing and to the relationship between the student and the supervisor can vary considerably depending on, for instance, the cultural and academic context. In the Environmental Science and Policy degree program and also in many other degree programs in Finland, the student usually can work rather freely, but they also have a considerable amount of responsibility in conducting their thesis process, and the supervisor is in the role of a mentor or advisor. That is, the Master's students are expected to make independent decisions regarding the topic, the approach, the research questions, the methods and all other central elements of the thesis. The supervisor can, of course, give suggestions and guide the student, but all final decisions should be made by the student.

solutions and answers, which are too ready-made by, for instance, the supervisor, rarely satisfy a comprehensively oriented student.

2) Early start. Comprehensive learning processes take time. Individual comprehensive thinking develops phase by phase and it is of utmost importance to let the student learn to understand their own thinking properly and even encourage them to develop it. One solution is to have an orientation phase before starting the actual compilation of the thesis. This is very important because, usually, there is a rather short period reserved for writing, and this may be too little for a comprehensive process.

3) Finding comprehensive tools also supports self-confidence and self-knowledge. When a student adopts an approach that involves considering several aspects of the topic and organizing the topic into wholes, they inevitably need to acknowledge the subjectivity of their selection of the question and its' framing (see, e.g., Cilliers, 2005; Montuori, 2013). This also leads to comparison of their perspective with others, which often improves self-knowledge and gives an opportunity to find one's own unique approach to the complex world.

It is very important that the supervisor encourages building self-confidence because many students oriented towards comprehensive thinking have had experiences of disapproval by the differentiative mainstream. In this regard, teaching and guidance that provide the students with relevant literature and methods, theories and concepts of comprehensive thinking, have turned out to have great value. In current research and education systems, and even in the society at large, much of the language and quite many concepts related to sustainability challenges are based on the differentiative tradition (Holm et al., 2013; Morin, 1992). This means that a comprehensively oriented student might not even have words for expressing their thoughts. At least partly due to this, many students with comprehensive thinking skills are not aware of their talent before the supervisor tells them about their skills and they discover comprehensive concepts, approaches and methodological tools, and with them a new language that enables them to explain, to themselves and to others, what their thesis is about. The feeling of relief can be very palpable: Hey, I'm not stupid or fuzzy, I'm holistic!

4) Diverging from the structures and practices of a differentiative thesis. A comprehensively oriented student may feel somewhat confused as the early outlines of their thesis might not resemble at all a traditional thesis, executed in a differentiative manner. The student may feel even deeper bewilderment if they are unable to express the essence or even the title of their work concisely. Furthermore, questioning the deeply held values in our thinking and language in our, in many ways, unsustainable society is not easy (Bowers, 2009). Here, the supervisor is needed to encourage the student to continue their work and emphasize that the confusion will pass as they advance in the thesis process. In our experience some students need to feel that they have a "permission" to study and explore what they find fruitful, and not what the mainstream implies they should study.

5) Support from peers. Forming peer groups for students who have chosen a comprehensive approach to their thesis enhances the thesis process. It is especially useful to have mentors who have completed their own thesis utilizing a comprehensive approach in these groups. The peer groups are not only for sharing practical advice and commenting each other's work, but also sharing feelings and experiences, good and bad ones. Sharing and exchanging perceptions with others enriches learning and is a crucial skill when dealing with complex sustainability challenges in real life situations (Hodges, 2014; Wals & Schwarzin, 2012).

6) Finding a suitable scope and focus. Much of the issues above can be condensed to one, very important dimension of the process: selection of the scope. Perhaps the most distinguishing difference between comprehensive and differentiative thesis processes are related to the scope of their research topic. In the differentiative approach, finding and establishing the scope of the thesis early in the process is considered desirable, an essential prerequisite for a successful thesis, and a central tool (Finn, 2005; Grinnell, 1992; Hart, 2005). Narrowing down the scope, however, requires specialistic, atomistic and "planistic" actions. Students who are oriented towards comprehensive thinking often experience early establishment of the scope as artificial and discouraging since they feel that it restricts their thinking and learning processes too much and leaves little room for creativity, which is essential when dealing with sustainability challenges. In a comprehensive thesis process, the scope is found gradually, as a result of the thesis process. We have also found that many students interested and also talented in comprehensive thinking are eager to ask big questions (such as "Why do solutions of environmental problems often create social problems?") rather than small, and big questions are not easily squeezed within the framework of a traditional thesis.

Finding a focus for a thesis does not necessarily have to be based on the substance of the thesis (see the examples in section 4.2.2). It is also worth bearing in mind that the discoveries made during the thesis process may be important to the student in other studies or the life in general, even if they are beyond the scope of the thesis. Furthermore, instead of abandoning them completely, the student may leave them to wait for the next research project. For example, in their Master's thesis the student may be able to further develop an insight that was left outside the scope of their Bachelor's thesis.

4.2.2. Example structures for theses

It has been found to be helpful to the student if the supervisor can present a few different thesis structure suggestions that are especially suitable for comprehensive learning processes. The structures represent broad, connective and multileveled thinking that help the student understand larger entities within the project. With the help of these structures the elements of holism and holarchism can be brought into the process together with the generalistic ones. A structure can function as the common thread in a thesis. A set of structural suggestions suitable for a comprehensive approach in theses are introduced below. They are presented at a very general level and can be modified or combined with each other case by case, depending on the details of each thesis. All the practical examples presented below, representing types A–E, are taken from actual student theses.

Examining sustainability challenges with these kinds of comprehensive structures often lead to the inclusion of elements from natural and social sciences, as well as philosophy, in theses. It is necessary to remember that the choice between comprehensive and differentiative approaches does not have to be exclusive even when using these kinds of structures; instead, there can be a dialectical mixture of both of these equally important dimensions.

A) Holarchical structure: In this example structure, which offers a good possibility for practicing holarchistic skills, a subject is examined at one or two higher systemic levels and a case example is studied at the lowest level. A three-leveled study (see Figure 4 A) could be formed, for example, as in the following example, taken from a thesis examining the challenges associated with balancing the relationship between different dimensions of sustainable development (Kolehmainen 2016): 1) the philosophical level (e.g., *relationship* as a concept and as a phenomenon that shapes our thinking), 2) the theoretical level (the relationship between the ecological and social dimensions of sustainable development), and 3) the practical level (the conflicts occurring in the relationship between the social and ecological dimensions of sustainable development in the context of the protection of mountain gorillas in central Africa). Compared to Figure 2, which illustrates a holarchical system, this three-leveled example represents a situation where one disk from each level of Figure 2 is chosen for closer examination. Students should prepare themselves for the fact that those unfamiliar with comprehensive thinking will see—in a reductionist manner—only the practical level of their thesis ("Oh, so you study mountain gorillas!").

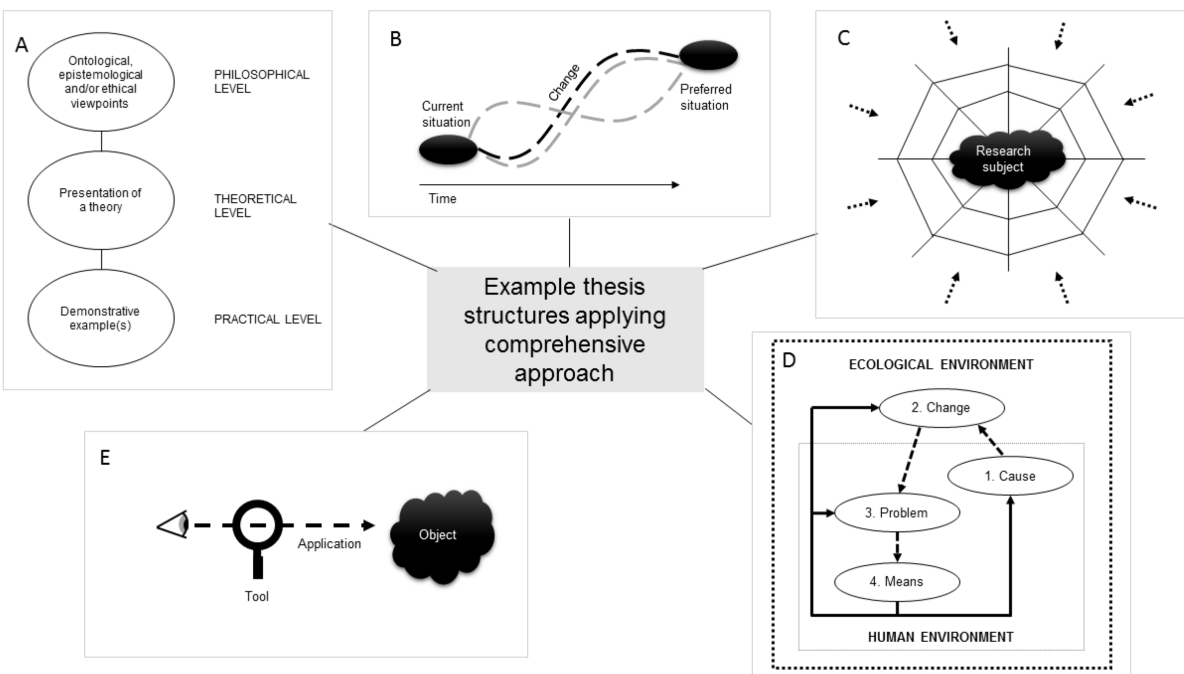

Figure 4. Examples of thesis structures applying comprehensive approach.

B) The three questions: The thesis structure is based on three types of questions that stem from the approach of Kuitunen (1988), whose approach draws on the idea of "trilateral scientific activity" formed by Galtung (1977, 56-65). According to Kuitunen (1988), the three questions are: 1) how reality should be, 2) how reality is, and 3) how reality could be changed. For students oriented towards comprehensive thinking it is often the most motivating to consider these questions together (see also Peters & Wals, 2013). To give one example, this structure was utilized in a Master's thesis that analyzed the activities of a center for environmental education and provided suggestions on how to improve them (Elo 1996). Interestingly, this thesis structure resembles the backcasting approach developed in futures research (see, e.g., Dreborg, 1996; Robinson, 1990). In backcasting, the first question is answered by determining a preferred future end-state, the second question is answered by analyzing the present state, and the third question by developing multiple scenarios backwards from the preferred future to the present state. The thesis structure is illustrated in Figure 4 B with some analogies to the way the backcasting approach is illustrated in futures research (see, e.g., Tuominen et al., 2014, 43).

C) A specific subject in a wide frame: If the research subject is specific enough—e.g. horse as a species (Halminen 2003) or indoor ice rink as a technical object (Sjövall 2015)—it can be an object of a comprehensive analysis within the framework of sustainability. That is, the student examines their research subject from various perspectives (viewpoint generalism) and describes how it is connected with the surrounding systems and different hierarchical or holarchical levels (Figure 4 C).

D) A problem: reasons – expression – experiencing – solutions: This type of structure has been successful when studying a certain environmental or other problem, for example littering (Virtanen 2016). It is illustrated in Figure 4 D (translated and modified from Willamo, 2005, 215). One of the greatest benefits is that it clearly expresses how humans, with their actions, institutions and responses, are a part of the examined system and a part of the nature. The structure is based on a chain that covers the different phases of a sustainability challenge and also the different roles that humans have to play in them (Tapio & Willamo, 2008; Willamo, 2005, 199 and 215). In the first phase (Cause, figure 4 D), the human acts as an originator of a change in the environment. These actions and their drivers (e.g., littering and its causes) are examined. In the second phase (Change), the environmental change and its effects (the amount and quality of litter in the environment) are analyzed. Here, the human—as a part of the nature—is an object and an experiencer of these changes. In the third phase (Problem), the human (society) is an evaluator of the environmental change and acknowledges it as a problem (to what extent is littering problematic? what kind of a problem is it?). In the fourth phase (Means), the human tries to find a solution to the problem and acts as a preventer, solver or at least reliever of the problem. The different means of dealing with the problem are analyzed and compared (how can we remove litter from the environment and prevent littering?).

E) Object – tool – application: In this structure type, the student chooses a question that is interesting in the context of sustainability science (e.g., climate change as a system) and a comprehensive research method (e.g., a certain branch of systemic, chaos or complexity thinking) (Huotari 2014). Both the question and the method are introduced adequately and after that the application of the method to this question is elaborated (Figure 4 E).

5. Discussion

The GHH framework is a conceptual tool for learning, which can be used to correct the imbalance between differentiative and comprehensive thinking in education. It forms a solid base for developing skills in understanding complex issues. It also offers a practical tool for education that is dealing with sustainability challenges to identify wicked problems and teach comprehensive thinking. The framework underlines the significance of personal perspective in the systems analysis and emphasizes that every learner has a unique conception of the world. This kind of an approach is open and permissive. When dealing with wicked problems this is central, as there are no right or wrong answers to them.

One important characteristic of all complex systems is the dimension of time and transformation. Complexity and chaos theories as well as dialectics describe systems as dynamic processes, where stable structures are only temporary and causal relationships tend to be non-linear and chaotic (see, e.g., Cilliers, 2002; Gleick, 1987; Ison, 2010). The present behavior of complex systems is not only linked to the interconnected parts, but also to the history of the system (Cilliers, 2002, 4). As it is now, the GHH framework gives tools for understanding only snapshots of complex systems, rather than their dynamic movement through time. Adding the dimension of time is one of the most important targets for development in the framework.

If understanding the present behavior of a complex system is hard, mapping its alternative futures is perhaps an even more challenging venture. This is an important issue for the further development of the framework. In this regard, combining comprehensive thinking with the theories, concepts and methodology of futures research is an interesting area of research (for an introduction to futures research, see e.g. Bell, 1997a, b).

Another direction in which the framework should be developed in the future comes from the need of education to offer both comprehensive and differentiative tools for studying wicked problems. Introducing more comprehensive thinking in education can present both positive and negative aspects: it can diversify and widen the students' skills in managing a broad range of subjects, but without the dialetical balance between comprehensive and differentiative skills it can also lead to the lack of specialized expertise. The continuous dialectical discourse between comprehensive and differentiative approaches is valuable for a learner as they pursue a proper angle and outline, for example, in a thesis. On the one hand, comprehensive tools prevent the problems related to a too narrow research scope. On the other hand, differentiative tools help to deal with the difficulties of too broad a scope. So, there is a need for understanding better how we can support each learner in finding a good balance between comprehensive and differentiative approaches in various and continuously changing situations.

The framework for a comprehensive approach is, first and foremost, an epistemological tool. However, epistemological and methodological choices made in research are always interconnected and should form a coherent and logical whole. Thus, there is a need to analyze the methodological implications of utilizing, or not utilizing, this kind of an epistemological framework. Generalism, holism, and holarchism each set their own requirements for the methodological framework of a study. For example, when comparing alternative policies for tackling climate change, a multifaceted valuation method would fit the nature of generalism better than, say, calculating monetary values only. What kinds of methods, or rather, combinations of methods, match the epistemological approach described in the framework for the comprehensive approach? The majority of current research methods and even the prevailing research processes have been developed for the needs of differentiative research and they emphasize analysis at the expense of synthesis. These practices have their own merits but also limitations. Thus, there is a need to develop and tailor methods and processes that are more suitable for a comprehensive examination of complex wholes.

The conceptual framework presented here should be tested empirically in various education environments and cultural contexts, in order to find out the modifications needed for the framework to function in different contexts. What is more, the framework should be tested with different kinds of learners—also with those who are accustomed or even fixed on differentiative approaches. Empirical research with learners in different contexts would provide information about wider applicability and limitations of the framework. It could also provide vital, new perspectives on the nature and variations of comprehensive thinking. Also, we believe that the framework for the comprehensive approach is suitable for sustainability science and education but also to understanding and managing other complex issues. However, this should be tested as case studies.

6. Conclusions

Comprehensive or differentiative thinking do not exist in their pure forms; indeed, all approaches include characteristics of both. Both of these ways of thinking are necessary but excessive domination of either is likely to be highly problematic. An ideal case would be a dialectical harmony, where the two dimensions are integrated in a unique manner depending on the circumstances. Therefore sustainability education should offer both kinds of tools for studying wicked problems.

The dominance of differentiative thinking in the prevailing conception of the world is probably one of the important reasons for the fact that the sustainability crisis and other related wicked problems have been prolonged and escalated. One reason for this is that with differentiative thinking it is usually very hard to perceive and understand the connections within complex socio-ecological systems and the consequences that our actions have in nature and in the world at large. These problems are too broad and complex to be studied only with the tools of reductionism and specialization and therefore they have become visible only now when they are too wicked to be ignored (Massa, 1993; Savory, 1998).

Therefore we claim that societies around the planet are moving in a dangerous direction, if they continue to neglect taking a broader perspective. Education concerning sustainability challenges and other complex issues should tackle this urgent threat. University education still focuses too much on specialized skills, which makes it difficult to promote a more comprehensive research and teaching approach. While specialization is highly valued and rewarded, comprehensive work is often viewed as a defect instead of a strength. The ability to think comprehensively is a valuable skill and it can and should be taught and learned as any other academic skill. University education should respond rapidly to the increasing need for comprehensive thinking and offer possibilities for students to develop their skills in it.

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Appendix A

Learning how to understand complexity and deal with sustainability challenges - framework for a comprehensive approach and its application in university education

Willamo, R., Helenius, L., Holmström, C., Haapanen, L., Sandström, V., Huotari, E., Kaarre, K., Värre, U., Nuotiomäki, A., Happonen, J., Kolehmainen, L.

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Curriculum of the degree program Environmental Science and Policy

2008-2011

University of Helsinki

Adapted from:

The study guide of the Faculty of Biological Sciences. The curriculum 2008–2009, 2009–2010, 2010–2011. [In Finnish.] The University of Helsinki. Pp. 145–148.
http://www.helsinki.fi/bio/liitetiedostot/opiskelu/Bio_opas_2008_2011.pdf

BACHELOR OF SCIENCE IN ENVIRONMENTAL SCIENCE AND POLICY, 180 CR

BASIC STUDIES 25 CR

1. Basics of Environmental Science and Policy, 5 cr
2. Introduction to the Studies in Environmental Science and Policy, 1 cr
3. Basic Literature in Environmental Sciences, 5 cr
4. Interdisciplinary Approaches to Environmental Questions, 3 cr
5. Introduction to Environmental Policy, 6 cr
6. Environmental Thought and Argumentation (process writing on student’s own view of environmental protection), 5 cr

INTERMEDIATE STUDIES 41 CR

7. Tools for Scientific Communication and Mother Tongue, 3 cr
8. Intermediate Level Literature in Environmental Sciences, 12 cr (Literature from natural sciences, 6 cr, and literature from social sciences, 6 cr)
9. Field Course in Ecology, 5 cr

10. Environmental Legislation and Administration, 2 cr
11. (Research Methods of Social Sciences, 5 cr, added to the curriculum in 2009)
12. Seminar for Bachelor's thesis, 3 cr
13. Bachelor's Thesis, 6 cr
14. Maturity Test for the BS degree, 0 cr
15. Optional special courses in the Department of Environmental Sciences, 5 cr
16. Other applicable optional courses in the field of environmental science (also courses from other programs), 5 cr

MINOR STUDIES 25 CR (mandatory) or more

17. Minor studies may include a variety of study modules from higher education. It is mandatory for the student to include one minor in their studies, but one degree may also include several minors.

GENERALISTIC STUDIES IN SUBSTANCE AREAS 42 CR

(Methodological courses cannot be included in these studies. Recommended year of completion in brackets)

A) Philosophy 3 cr (I–III)

18. Basic or general studies, 3 cr

B) Chemistry and/or Physics, 12 cr (I–II)

19. Basic studies* 7–12 cr
20. Applicable environmental studies** 0–5 cr

C) Biology, 15 cr (I–II)

21. Basic studies* 9–15 cr
22. Applicable environmental studies** 0–6 cr

D) Humanities and/or Social Studies, 12 cr (I–III)

23. Basic studies* 7–12 cr
24. Applicable environmental studies** 0–5 cr

*For example "Introduction to Chemistry" or "The History of Sociology" (not "Chemistry of Climate Change" or "Environmental Sociology")

**An applied course with an environmental context, for example "Chemistry of Climate Change" or "Environmental Sociology"

Individual courses or other parts of the generalistic studies can be included in the mandatory minor studies (see above). But if they are not, the student can form a module of them called *The Multidisciplinary Study Module (25 cr)*. This module can be included as a non-mandatory minor in the degree of Bachelor of Science. The module must comprise at least 25 credits and at least three of the four above listed components (A–D) must cover at least 3 credits each.

OTHER STUDIES 18 CR

25. Information and Communications Technology Studies, 5 cr (I)
26. Orientation Period, 1 cr
27. Study Planning I, 1. semester, 1 cr
28. Study Planning II, revision of the personal study plan in a later phase, 1 cr
29. Career Planning, 3 cr (I–III)
30. The other domestic language (Swedish or Finnish depending on the student's mother tongue), 3 cr (II–III)
31. Foreign language, 4 cr (I–II)

ELECTIVE STUDIES 29 CR (or enough to reach the total of 180 cr)

32. In the elective studies, the student can select various kinds of studies as long as they form a reasonable combination. The content of these studies is agreed on during personal study planning sessions and other discussions with the study adviser.

    In minor and/or elective studies it is advisable to include courses in communications, meeting techniques, negotiation skills, and language studies.

MASTER OF SCIENCE IN ENVIRONMENTAL SCIENCE AND POLICY, 120 CR

ADVANCED STUDIES 86 CR

33. Personal Study Plan in MS studies, 1 cr
34. Field Course in Environmental Research, 5 cr
35. Internship in the Field of Environmental Sciences, 6 cr
36. Integrated Methods of Environmental Social Science, 5 cr
37. Methods of Environmental Science and Policy, 3 cr
38. Master Thesis seminar, 14 cr
39. Advanced Level Literature in Environmental Sciences, 9 cr
40. Master's Thesis, 40 cr
41. Maturity Test for the MS degree, 0 cr
42. Optional special courses in the Department of Environmental Sciences, 3 cr

ELECTIVE STUDIES 34 CR

43. In the elective studies, the student can include various kinds of studies as long as they form a reasonable combination. The content of these studies is agreed on during personal study planning sessions and other discussions with the study adviser.