Chapter 3
Approaches for Framing Sustainability Challenges: Experiences from Swedish Sustainability Science Education

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Abstract Sustainability challenges are defined by their complex and multifaceted interactions between nature and society and contention as to how and where to direct problem-solving efforts. This chapter presents four different approaches that exist for framing sustainability challenge areas that are introduced and worked with by students in LUMES International Master Programme in Environmental Studies and Sustainability Science at Lund University in Sweden. The approaches include the (1) Driver-Pressure-State-Impact-Response (DPSIR) framework, (2) causal loop diagrams (CLDs), (3) multi-scale and level perspective, including transition theory and management, and the SES framework. Each approach is described and critically assessed, especially from the perspective of student mastery. The outcome of the chapter is a more comprehensive understanding of which approaches are useful for different sustainability problem constellations and a deeper comprehension of how the framing tools can be taught in sustainability science education.

Keywords Framing approaches · Sustainability education · DPSIR · CLDs · Transition theory · SES framework · Sweden

3.1 Introduction

The field of sustainability science (Kates et al. 2001; Ness 2013; Jerneck et al. 2011) has experienced rapid development since the turn of the twenty-first century. The advances have extended down multiple trajectories within the realms of research and education. One area where ambitions have been strongest is with efforts to more closely link scholars to knowledge creation and problem-solving processes outside of academia (Wiek et al. 2012; Spandenberg 2011). Many of the recent developments—with aspirations to guide societal change along more sustainable trajectories—have been carried out through a diverse set of transdisciplinary and transformative methods with diverse actors through unique processes as *transition*

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experiments or *(urban) living labs* (Nevens et al. 2013; Evans and Karvonen 2014; Baccarne et al. 2016; Buhr et al. 2016). However, before efforts to address targeted sustainability challenges can take place, it is common for a robust and preferably unified understanding—or *framing*—of problem areas to occur (Ness et al. 2010). How different actors carry this out can vary greatly. A number of conceptualization approaches have been developed, or adopted from other disciplines and fields, for the purpose of better comprehending coupled socio-ecological systems. They have been developed around the perspective of shared boundary concepts (e.g. resilience, vulnerability, ecosystem services), common objects (e.g. maps), a common theoretical perspective, or defined (sustainable) development priorities (Cash et al. 2003; Clark et al. 2016).

3.1.1 Education for Sustainability

For framings to be salient and robust, proficiencies to derive common problem conceptualizations must be developed amongst scholars, facilitators, and other actors. One important forum for fostering these skills is in university sustainability education programs. Although skills training in this area traditionally has been beyond the scope of most educational programs, where the focus is usually on *descriptive/analytical* modes of performing research, a number of sustainability programs have recently been established—or redeveloped—under the umbrella of transformative education (Schneidewind et al. 2016). The curricula in these programs respond to priorities that participants are *not only* able to analyze sustainability problems and suggest solutions; the education also empowers them to become agents of (sustainable) change, to predict and prepare for new challenges, and to create new opportunities to infuse sustainability into societal processes at different scales and levels. Focus and student proficiency development of these areas has been devised with an explicit focus on multiple and often competing comprehensions in sustainability problem areas as well as where solutions can be directed and experimented with. To operationalize these, a number of the programs have been augmented to include student development of *key competencies* for future researchers and sustainability practitioners (Wiek et al. 2012; Wiek and Kay 2015; Burns 2015). One prominent set of competencies developed by Wiek et al. (2011) include *systems thinking*, *strategic*, *anticipatory*, *normative* and *interpersonal* abilities. Focusing on these five areas creates opportunities for students to gain proficiencies and expertise in areas such as future visioning and scenarios, systems analysis, ethics, risk, and group facilitation to name just a few.

One useful educational forum to foster the competency development—especially concerning framing—is group work. Group work allows many students to gain an understanding that they almost certainly would not have developed individually, fostering reflexivity amongst participants where broader worldviews are exchanged, reflected on, challenged, and compromised on within the hopeful *safe-space* of trust and understanding amongst participants. Furthermore, the activities allow for a *division of labor* amongst students as an approach to managing complexity and the multifaceted nature of sustainability challenges.

3.1.2 Aims

Many approaches can be used in a participatory manner to frame sustainability challenges and help expose potential solution options for the challenges. Some approaches have been developed specifically for certain challenges; others are broad approaches that are useful for encapsulating the dynamics of a variety of systems or questions. Despite their existence and analyses of them, insufficient understanding remains as to which approaches are useful for which framing and problem assessment purposes. Furthermore, inadequate attention has been paid to how to best nurture student competencies in using the different approaches, especially training in settings where actors differ in societal facets.

This chapter presents and critically assesses four approaches for framing and structuring sustainability challenges. The assessment is conducted from how each is used by students in the sustainability science course of the Lund University International Master's Program in Environmental Studies and Sustainability Science (LUMES) in Sweden. It includes a set of approaches that can be applied to diverse sustainability challenges and is based on broader concepts of causality or scale. The approaches presented are the DPSIR framework, causal-loop perspective in transition theory, and the socio-ecological system framework because they are robust and commonly found in the sustainability literature. This review provides reflections and insights from both the perspective of student learning of the approaches and perceptions on how the approaches can be taught to foster student skills development, particularly in a limited time frame. Each approach is described and critically assessed, especially from the context of student learning activities. The outcome of the chapter is a more comprehensive understanding of the four approaches, including their respective strengths and weaknesses. In addition, there are insights on how student proficiency in using the approaches can be fostered. The main empirical material used in the study is course evaluations from course participants over the past 7 years (2011–2018), notes from face-to-face group follow-up course evaluation sessions, and where available, instructor reflection notes on individual student learning activities.

The chapter is structured as follows. First, the LUMES graduate program and more specifically the sustainability science course is presented. Next, a differentiation between the diverse terminologies used when describing the approaches is completed, followed by a presentation of each of the framing approaches. Subsequently, the possibilities, limitations, along with insights from student learning perspectives are carried out. The chapter concludes with a discussion covering what has been done in recent years to improve the student learning processes and general reflections on student key competency development.

3.2 The LUMES Program

3.2.1 Program Structure

The LUMES Program (Lund University International Master Program in Environmental studies and Sustainability Science) is a 2-year graduate program with approximately 40–50 students annually. Participants are from diverse academic backgrounds and nationalities. The program was launched in 1997 and has undergone two major curriculum redevelopment processes. It is a cohesive program where students take all first-year courses together as a single group. The program consists of three 10-credit core courses during the first term: earth system science, social theory, and sustainability science. During the second term, students take a number of broader thematic courses including governance for sustainability, urban and rural systems, economy and sustainability. In addition, there is one extended course, knowledge to action, which spans part of the first term and the entire second term. This course has strong ties to the sustainability science course. During the third term, students must successfully complete four of a variety of targeted courses offered during the term: energy, water, global health, gender, and social movements amongst numerous others. Students complete the program with the successful submission, presentation, and defense of a Master's thesis on a sustainability-related topic that they design individually and conduct research.

3.2.2 Sustainability Science Course

The LUMES Sustainability Science course is one of the three main courses of the first term of the program. It acts as a bridge to link the initial two courses, which greatly differ from each other. The course runs from late-November until late-January with the holiday break of around 2 weeks in the middle. The course has strong topical connections and schedule overlap with the knowledge to action course. Learning outcomes for the sustainability science course—in differing manners and degrees—center on the key competency areas with concentrated student knowledge and skills development efforts on the history and evolution of sustainability science, the main concepts in the field, (e.g., systems thinking, complexity, socio-ecological systems, inter- and transdisciplinarity, resilience, political ecology, transitions), interpersonal skills through multiple presentations, and group work activities. There also is training in anticipatory competencies via a short learning segment on scenarios and envisioning. In addition, and covering multiple competency areas, there is an emphasis on student comprehension of the different framing approaches with a strong focus on the applicability, strengths, and weaknesses, of each of them. The course structure is varied with learning activities on the development of sustainability science, broader systems thinking/tools for measuring sustainability, and a block on inter- and transdisciplinary sustainability research. Students are evaluated both individually and by groups. Individual assessment is carried out via targeted reflection assignments (e.g., literature reflection, systems thinking reflection); group assessment takes place through a collection of presentations, group reflection papers, and a final project report and presentation.

Depending on the approach, there are roughly 2 days devoted to each. Each approach block is supplemented with student reading of two to five scholarly articles, which students are instructed to read in advance. For each block there is a 1- to 2-h lecture by the course instructor explaining, for example, its developmental history, application, and examples of how and where the approach has been applied. Augmenting the lecture and readings, there also can be a presentation from an "expert" from outside of LUCSUS (Lund University Centre for Sustainability Studies) with greater research and/or practical experience with the specific approach.

For students to develop a greater understanding and increased competency levels with the approaches, learning activities for each are performed in smaller, randomly generated groups of five-six students. In these groups, students are paired to an ongoing—or desired—research topic carried out by an early-career researcher and project mentor based at LUCSUS. The researcher is responsible for ensuring that students receive an overview of the general topic, targeted topic advice, and/or basic readings on the theme. Final student group topics have varied greatly, focusing on, for example, coastal management in Florida, food security and production systems in Uganda, mangrove destruction from biofuel feedstock production in Indonesia, land grabbing in Tanzania, and bush meat production and trade in Ecuador, to name a few. Each group then concentrates and develops their respective topic as each new framework is presented to the entire class. However, one exception is the social ecological system framework where experience has demonstrated that performing a sufficient assessment using the approach for each topic would take far too long in the limited time available during the course. Instead, students work on one common case where each group concentrates on a particular subsystem (e.g., governance system, resource units).

Important to the student comprehension of each approach and the broader project is the respective group's formulation of an appropriate focus/question and definition of "boundaries" (i.e., what parameters are included, what is left out). Collectively—and often in an iterative fashion—the group then devises a conceptualization (model) by using the approach to address the specific question posed. The groups then work through several iterations of a framing while receiving constructive feedback from one another and the respective topic mentor. For each approach course block, the groups also present their respective conceptualizations to classmates and the instructor in a small seminar session. This provides opportunities for students to learn through what others have done, and to gain additional insights on their own work through fellow student and instructor critique and feedback.

Additionally, there is a final project deliverable where each group combines a number of the approach conceptualizations (e.g., CLD and transition theory multilevel perspective, SES and DPSIR) in a hopefully coherent "package" based on a specific topic aim or question that they unify around. Through the lens, they then reflect more deeply on each approach employed (e.g., strengths, limitations), and on the broader context of framing complex sustainability challenges. Three examples of 2016–2017 projects included palm oil production transition using the multilevel perspective and a DPSIR scheme, barriers to the change to an organic viticulture system in California using CLDs and the SES framework, and small scale hydropower development in Nepal, also using the multilevel perspective and DPSIR. Student group work is presented in a final seminar at the end of the course where again the project is scrutinized by classmates, mentors, and the instructor. Furthermore, students deliver a final written group project summary of roughly eight pages text that is evaluated by the course instructor. The written summary helps students to further develop writing proficiencies, especially in the area of concise writing.

3.3 The Approaches

3.3.1 Terminology

The terminology used to describe each framing approach can differ. Those presented here go by a number of names including *tools*, *frameworks*, *schemes*, and *techniques* all with modest epistemological and definitional differences. In this chapter, *approach* is used as an encompassing term. Where appropriate, I also use the name that each is most often referred to in academic literature. *Schemes* are systematic or organized configurations of correlated things; whereas *tools* are purposive, used as a means of accomplishing some sort of assessment task. Nobel Laureate Elinor Ostrom (Ostrom 2011) provides some differentiation between the different descriptive terms used in a hierarchical manner. She describes a *framework* as a meta-language, or *metatheoretical map* (Ostrom and Cox 2010), denoting a generalized form of theoretical analysis. *Theories* (e.g. transition theory, rational choice), on the other hand, are the working assumptions and hypothesized specifications of the framework variables deemed sufficient to provide adequate explanations or diagnoses of social and/or ecological conditions. Related to the above, *models* use more targeted assumptions about variables, predictions about the results of combining these variables using a particular theory.

3.3.2 DPSIR

DPSIR is an analysis scheme for describing cause-effect relationships in connection with environmental and natural resource management challenges (Bowen and Riley 2003; EEA 1999; Giupponi 2007). DPSIR stands for *Driving forces-Pressure-State-Impact-Response*; the scheme has been associated significantly with the European Environment Agency in Copenhagen, Denmark. The intention and the strength of the DPSIR scheme are its ability for practitioners to gain an overview of targeted (environmental) policy issues, and to estimate the appropriateness and efficiency of different governance responses (EEA 1999). It also permits the integration of socio-economic and ecological system information into one framework (Bidone and Lacerda 2004). The scheme helps to structure information into the five distinct areas, making it possible to identify and structure the important causal relationships. DPSIR conceptualizations can be simplistic or sophisticated dependent on the focus and/or the question(s) they address. The scheme has been used extensively for challenges to water and coastal regions (Gari et al. 2015). Figure 3.1 represents a simple depiction of the DPSIR framework for Baltic Sea eutrophication from Swedish agriculture.

The DPSIR approach has evolved from a long line of more simplistic frameworks for environmental issues such as Statistics Canada's Stress-Response (S-R) framework from the late 1970s (Gari et al. 2015), the Pressure-State-Response (P-S-R) scheme launched by the Organization for Economic Cooperation and Development in the 1980s, and the United Nations Commissions on Sustainable Development's Drivers-Pressure-Response (D-P-R) framework (OECD 1994).

The DPSIR approach has received considerable critique as well; it has often been directed at the mechanistic nature and oversimplification of the scheme, its linearity, and the difficulty in handling parameters that may be a part of multiple DPSIR phases (e.g., driver and state conditions) (Klijn 2014). An additional challenge is with its ability in incorporating the multi-dimensional and multi-scalar causal relationships of problems where many sustainability issues are characterized by complex dynamics in time and space are worsened by multiple and interacting anthropogenic and natural driving forces (Kates et al. 2001). These issues include,

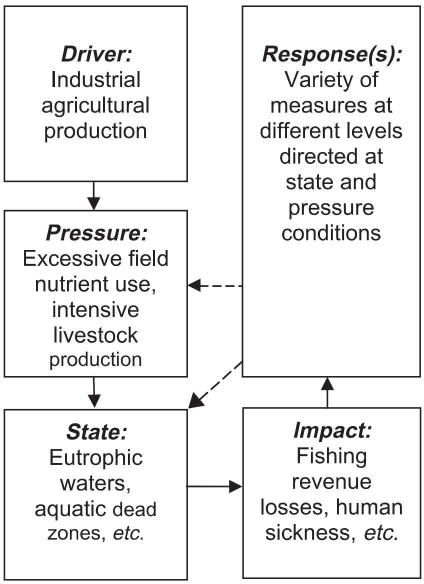

Fig. 3.1 Simple DPSIR for Baltic Sea eutrophication from Swedish agricultural production (Ness et al. 2010)

for example, global climate change, poverty, eutrophication, and biotic diversity. Finally, the DPSIR framework has historically been developed and used for presenting environmental impacts caused by socio-economic driving forces. Analyses of socio-economic system state conditions and impacts (e.g. HIV/AIDS, malaria, and poverty) have seldom been included in such analyses—thusly not reflecting the broad variety of sustainability challenges (Ness et al. 2010). To address many of the deficiencies along with making the scheme more useful for targeted areas, DPSIR has continued to be developed and augmented by scholars and practitioners to include, amongst numerous others, the 'EBM-DPSER' concentrating on ecosystem services (Kelble et al. 2013), the 'DPSWR' on human welfare (O'Higgins et al. 2014), the 'eDPSEEA' for Health (Reis et al. 2015), and the multi-level DPSIR (Ness et al. 2010).

3.3.3 Causal Loop Diagrams

A causal loop diagram (CLD) is a general approach to the qualitative analysis of systems; CLDs incorporate both human and social parameters into a single, sometimes sophisticated, conceptualization. They are often used as a part of a broader participatory systems analysis approach, including problem and system boundary definition, qualitative conceptualization creation, and quantitative system dynamics modeling. A strength of CLDs is that they are a flexible framework where creators identify and describe, in increasing levels of complexity, the cause-effect relationships of different sub-components of a larger system. Arrows are used to link cause-effect relationships, connecting the two components.

The diagrams use different symbols to denote different relationships. A positive plus [+] symbol between two variables indicates a parallel behavior of the two, meaning an increase in the causative variable also causes the effect variable to increase; furthermore, a decrease in the causative variable denotes a decrease in the affected variable. Conversely, a negative minus [−] symbol indicates an inverse relationship between the two variables, meaning as the causative variable increases, the affected variable decreases, or *vice-versa*. Numerous sub-components of a system can form loops, feeding back on one another, either directly or indirectly. A loop that has a reinforcing behavior is often denoted in the diagram with 'R'; this signifies exponential growth of that subsystem. Loops denoted with 'B' indicate a balancing behavior of the subsystem. Temporal aspects in the form of time lags can also be identified in the CLD using two parallel lines through the center of the arrow linking the variables. An example of a simplistic CLD for bush encroachment in southern Africa is shown in Fig. 3.2 (SAPECS 2016). The arrangement shows the causal relationships of two drivers of global climate change and human population growth in the region and their ultimate impacts on such factors as woody plant growth, land area and water availability.

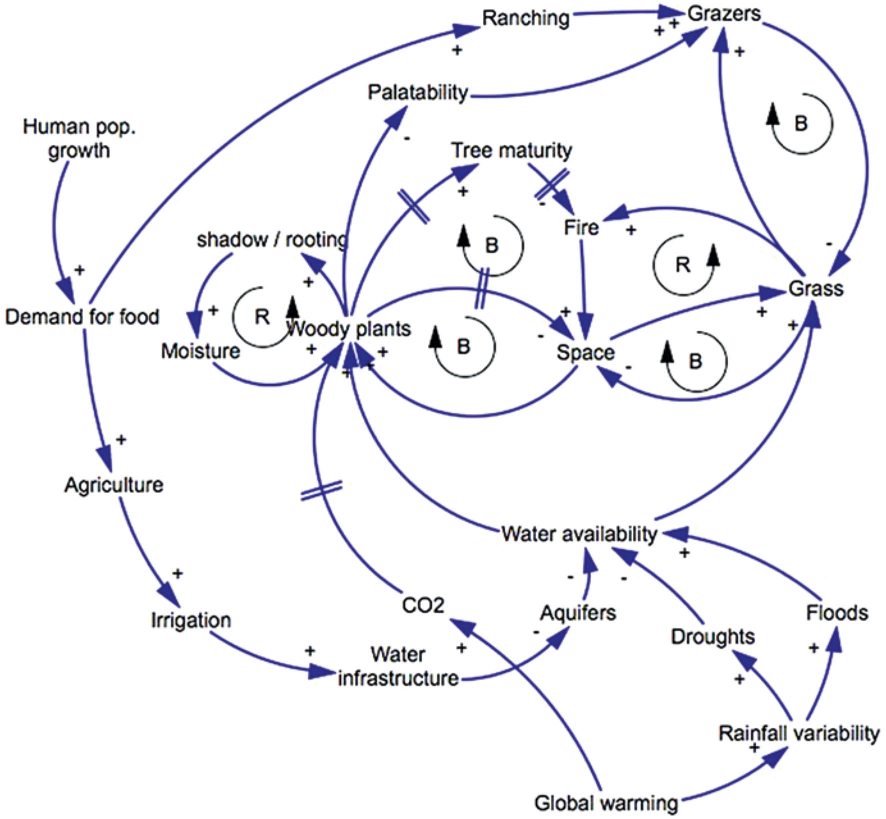

Fig. 3.2 Example of a simple causal loop diagram for bush encroachment in southern Africa. The conceptualization shows the main drivers of the encroachment and their causal impacts on other parameters. (Source: Southern African Program on Ecosystem Change and Society, n.d.)

CLDs are a useful approach for grasping the casual interactions of defined systems and like the DPSIR scheme, allow the practitioner to experiment with solutions to the particular challenge area. However, CLDs possess a number of shortcomings that can influence their usefulness in framing sustainability challenges. First, the labeling of the different sub-components can appear problematic. The parameters must always be labeled as more or less of something (e.g., human population, greenhouse gas releases, biodiversity loss). This can lead to difficulties in understanding the respective sub-components of a system. In addition, critique has been lodged against a CLD's *spaghetti-like* appearance, and related inability in understanding sophisticated conceptualizations of a problem area. Related, the aim of a CLD is to create causal relationships in as few steps as possible. Gross oversimplifications in processes also can often cause difficulties in interpreting a CLD therefore creating opportunities for creating false conclusions to be drawn about the system in question.

3.3.4 Multi-scale & -level Perspective (Including Transitions)

Another approach for understanding and structuring sustainability challenges is through the multi-scale and -level perspective. This form of assessment has been promoted and used for decades, and has been used for a variety of socio-ecological systems including sustainable tourism (Crnogaj et al. 2014), wastewater treatment systems (Molinos-Senante et al. 2014), water resources management (Daniell et al. 2014), climate change (Bulkeley and Betsill 2013), and renewable energy transformations (Di Lucia and Ericsson 2014), to name a few. *Scale* refers to the analytical dimensions for measuring and studying objects and processes. Examples of different scales can be spatial, administrative, jurisdictional, managerial, or temporal. *Levels* refer to locations along those scales (Gibson et al. 2000). Related to these is hierarchy. A *hierarchy* is a conceptually linked system for grouping phenomena along a particular scale.

The strength of the approach is not based on causal relationships between phenomena as with the initial two approaches; instead, applying the perspective creates the ability to match usually distinct bio-geo-physical systems scales with social system scales such as management systems (Cash and Moser 2000) where the practitioner gains a robust understanding of a problem constellation. Like the first two approaches described, conceptualizations can be simple or sophisticated depending on the phenomena assessed. Additionally, an important intention with this approach is to detect where *disconnects* or *mismatches* can lie between different scales or levels (Cash and Moser 2000).

Scales can be predominantly inclusive or exclusive (Gibson et al. 2000). An inclusive (or nested) hierarchy is a group of objects or processes that is contained in subdivisions of groups of higher systems such as the modern taxonomic classification. An exclusive hierarchy is where groups of objects (or processes) in a lower ranked hierarchy are not included or as subdivisions of higher ranked groups such as the military ranking system (Gibson et al. 2000).

3.3.5 Multi-level Perspective in Transition Theory

A particular type of approach for understanding processes of sustainable change, often over time, is the multi-level perspective (MLP) in transition theory and management. Broadly, transitions are deliberate processes of societal change in culture, practices and structure (e.g., agroecology in Uganda, renewable energy development in Sweden) (Nevens et al. 2013; Geels 2011). This mid-level theory is an extension of socio-technical systems rooted in sociology, institutional theory, and innovation studies (Geels 2004). Studies in this research field examine complex adaptive systems from the perspectives of long-term processes and non-linearity (Avelino and Rotmans 2009). The objects of focus of transitions are not abrupt, fast societal (sustainable) change; rather, a transition is an incremental and constant process of change where the fundamental character of society—or a sub-system of society—transforms (Rotmans et al. 2001). The field has extended to sustainability over the past decade-plus with a number of "experiments," especially in urban areas throughout Europe. A conceptualization of the three levels with more specific divisions of different socio-technical regimes and how a niche can emerge over time is displayed in Fig. 3.3.

The MLP in transitions consists of three unique levels to encapsulate the social dynamics: *landscape*, *regime,* and *niche*. Landscape development (macro-level) refers to the broad societal material and immaterial elements. These landscape are the important elements that "surround" the particular system of study (Avelino and Rotmans 2009). Examples can include public infrastructure or concepts that dominate societal discourses (e.g. sustainable development, resilience, free-market economy). Regimes are patchworks of institutions and actors that support the societal *status quo* (Avelino and Rotmans 2009); they represent the rules that set the boundaries private action and public policies (Rotmans et al. 2001; Hägerstrand 2001) Finally, niches are small areas of experimentation, innovation, and learning that challenge the stability of socio-technical regimes. They are often protected spaces to deviate from the regime, and, if successful, eventually become a regime themselves (Geels 2004).

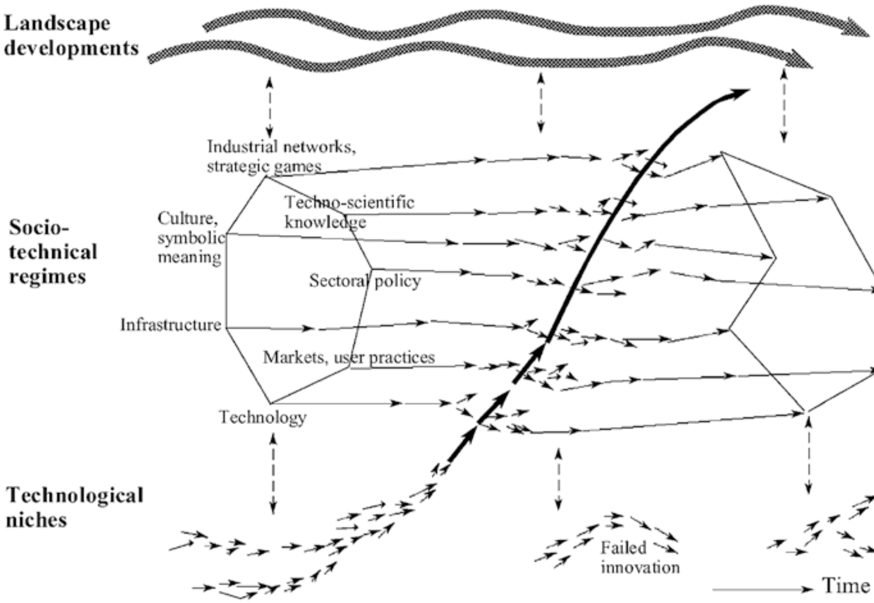

Fig. 3.3 Example of the main levels and parameters in a multi-level perspective in transition theory. The conceptualization shows the interplay play between socio-technical regimes, consisting of a number of societal institutions, and the landscape and niche levels. (Source: Geels 2004)

3.4 Socio-ecological System Framework

Another multi-level perspective approach for framing complex problems is the socio-ecological system (SES) framework. The approach has strong connections to the institutional analysis framework (IAD) (Ostrom 1990) work by Elinor Ostrom and colleagues to combine and to better understand the interactions and subsequent outcomes of complex social phenomena and ecological systems.

This classificatory framework is useful for how actors self-organize around the use of common pool resources, and around the identification of strategies to safeguard the resource in question (Ostrom 2007, 2009). A conceptualization, often constructed in a participatory manner, contributes to identifying common and relevant variables for a specific resource system. The strength of the framework is its capability for users to connect a number of multilevel nested systems. The core subsystems are the resource system, resource units, resource users, and the resource's governance system; each of these is influenced by related social, economic, and political settings as well as related ecosystems (Fig. 3.4). Each core subsystem consists of a number of examples of second-level variables that can be categorized; relevancy of each variable depends on the system in focus. Examples of the variables include size of resource system, economic value of the resources units, property-rights systems in place, and the history of use of the resource to name a few (Ostrom 2009). The intended outcome from using the framework is to devise a common set of hopefully relevant variables and sub-variables for further analysis

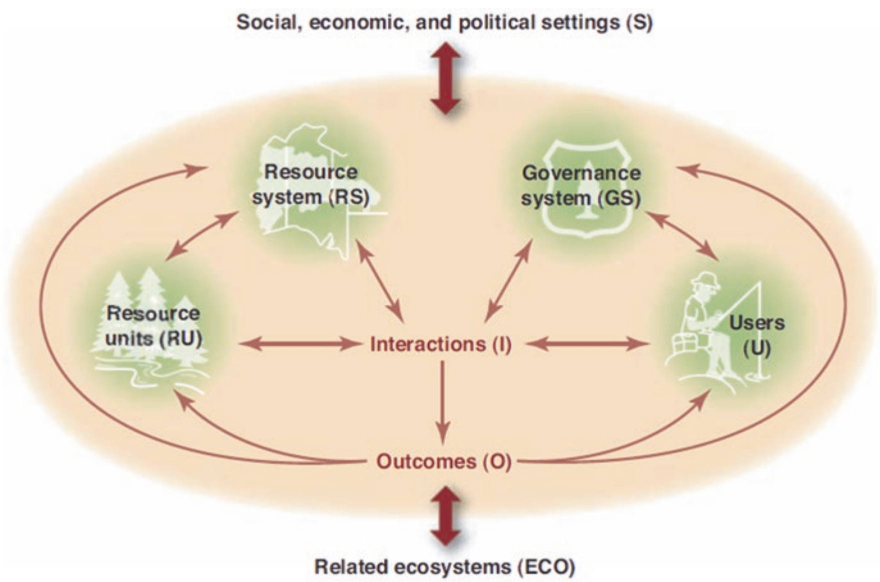

Fig. 3.4 Main subsystem interactions in the SES framework. Each subsystem also consists of a set of more targeted indicators that can be used to a more nuanced analysis (Ostrom 2009)

(e.g., data collection design, fieldwork, and analysis) for the common-pool resource (Ostrom 2009).

The SES framework, and earlier renditions of it have been applies to a variety of cases, both common-pool and non-common-pool resources. The cases include lobster fisheries in southern California (Partelow and Boda 2015), wetlands in the northern Sierra Nevada foothill oak woodlands (Hruska et al. 2014), Cambodian cattle-owning smallholders (Marshall 2015), and small-scale fisheries in Baja California Sur, Mexico (Leslie et al. 2015).

The intention of the SES framework is to undergo continuous development based on different shortcomings and case examples (Ostrom 2009). Framework development has been carried out on a number of areas where, for example, more relevant variables have been added for the case of Pacific lobster fisheries (Partelow and Boda 2015), a change in the attributes of governance systems, and ways to make the framework applicable to policy settings beyond natural resources (McGinnis and Ostrom 2014).

3.5 Discussion

3.5.1 Approach Learning Challenges

Responses from course evaluations and from classroom course evaluation sessions following the course have showed a general and diverse mix of student satisfaction around learning the approaches, as well as learning activities that need improvement. There was general displeasure, especially a number of years back, in two related areas. The first was with problems achieving a sufficient level of understanding with each approach introduced. Many of the comments from students concentrated on the lack of time and opportunities during the course to optimally learn the fundamentals of each approach. The second significant area of dissatisfaction was the existence of a common *thread* running through the entire course and the difficulty of students to see each approach in a broader perspective of sustainability science, frameworks, and tools.

More recently, and with several changes to the course learning activities, student evaluation comments have become more concentrated on single approaches with learning activity suggestions based on the individual styles of learning preferred by individual students. Course evaluation comments do not identify any single approach, lecture, or group work activity as problematic. Instead, there is a diverse mix of both positive and critical comments in all areas. This is interpreted as positive given the large size of the course and the diversity of cultural and academic backgrounds. As examples, a number of participants have been critical of the high degree of group work activities—and the activities that are graded in groups—throughout the course. Others, however, expressed the ongoing participatory knowledge creation processes as highly positive and the forums were where the most skills and competencies were fostered. Additional critical comments also were often centered on unclear instructions for the exercise, or the applicability, or difficulty, of applying a particular approach to the individual case that was assigned to the group where —depending on the questions posed by students—certain approaches just have a more natural fit with particular topics. Finally, another ongoing challenge voiced by students has concentrated on the reading materials used as a backdrop to each approach block, especially comments of the articles containing an insufficient amount of case examples.

3.5.2 Changes to Enhance Approach Understanding

A common challenge—which is not unique to the pedagogical challenges here—is fostering student depth and mastery of each approach in a (very) limited amount of time. The challenge is augmented when the student comprehension and mastery of the approaches is for 35–45 students with diverse cultural and academic backgrounds. The difficulty is also compounded by conscious efforts to create tangible connections to the earth system science and social theory courses.

Based on the feedback from students, an important characteristic of Swedish education, several changes to the course have been made to foster increased student comprehension of the framing approaches, and to create a more coherent structure throughout the entire course. With the changes, or small *tweaks*, the learning activities for the individual framing approaches have become progressively better, especially in recent years. A few of the main changes are presented here.

3.5.3 Single Case

A common critique in the past was the disparate nature of the course, especially related to the approaches. To add coherency, single group topics (with mentors) were introduced. Although originally intended to better link student learning activities to actual research taking place at LUCSUS, an ongoing recommendation of students in past years, the introduction of the topics has helped to nurture a connection to the respective mentors—albeit for only a brief period. Furthermore, they have provided an effective medium to test each framing approach in real-world sustainability problem research contexts. It has also been an important approach to create opportunities for students to see the possibilities and related pitfalls for each approach introduced. Related, the single case has also fostered increased depth in understanding with each of the approaches (or combinations of them) through an implicit object of focus of the particular case (e.g., understanding processes of change over time, governance dynamics of a system, complex causal interactions). Because of these reasons, the students have been positive about the concentration of the individual topic throughout most of the approach learning activities.

Despite the added value of the single cases, they have not been without challenges. With the introduction of staff research topics, there has, at times, been the excessive group concentration on the themes themselves (e.g., targeted problems, geographic region, potential solutions) and an insufficient focus and greater reflection on the approaches themselves. Groups have placed excessive amounts of time on the details of their respective cases, and significantly less time on learning the suitability, strengths, limitations, and weaknesses of the individual approach, or understanding each in a broader context. One additional measure to keep the focus adequately on the framing approaches has been to inform the respective mentors of the objectives of the learning activities.

3.5.4 Learning Activity Streamlining

One simple way of reducing the intensity of the course is reducing the amount of content introduced, especially the sheer number of framing approaches. Although there has been a limited amount of content streamlining over recent years largely because of ulterior reasons (e.g. resilience, removal of systems dynamics). However, when surveyed, students have been strongly opposed to the further removal of framing approaches covered during the course. Instead, efforts have concentrated on fostering greater efficiency within individual learning activities, advancing both comprehension depth and learning activity diversity for each approach. Measures taken include schedule changes to enable students to have sufficient time to read the literature in advance of the respective learning activities; the addition of extended, single-day learning sessions including both lectures and group work, varied learning activities (e.g. World Cafés, role plays), and clearer communication of expected objectives and outcomes to students. Course evaluations have shown that the changes have greatly improved satisfaction levels amongst sustainability science course participants.

3.5.5 Reflection Sessions

In addition to the two areas described above, and to create more approach coherency and generate deeper reflections for each framing approach, there has also been additional scheduled reflection sessions added to the end of each approach-learning block. The class discussions and reflections last for 15- to 45-min depending on the approach. The sessions are a forum for students to reflect deeper on the approaches and pose questions to the instructor, and one another. The sessions also serve as an opportunity to introduce the next approach to be covered and introduce the readings for the subsequent discussion.

3.5.6 Approach Readings

One challenge in teaching the individual approaches has been the assigned reading for each. More comprehensive textbooks in sustainability science have only recently started to appear, including this one. However, because of the unique collection of approaches taught in the course, no single textbook is adequate. This warrants the use of scholarly articles for each approach. A challenge has been to find readings that provide an adequate overview for each approach, are not repetitive, and hopefully also provide a case example of how the approach can be applied. This challenge has resulted in the continual updating of preparatory reading materials for each framing approach, often informed by student reflections of each reading. The adequacy of the readings, however, is expected to increase in the future as additional articles—especially case examples (e.g. multi-level perspective, SES framework)—become available in the academic literature.

3.5.7 Final Reflections

Teaching and working with LUMES students over the past years generating competencies with framing complex sustainability challenges has been challenging. Simultaneously, it has also been one of the most fulfilling aspects of academic work. The seven-plus years of working with students through the different iterations of learning activities has contributed to fostering a new generation of transformative thinkers, groups with skill sets that extend far beyond any competencies developed by students merely 10 years earlier. Combined with the LUMES knowledge to action course, there are more opportunities to understand and build capabilities as transformative sustainability scientists. However, more opportunities are still needed throughout program to grow fully engaged competent change agents.

New framing approaches will appear in coming years that even better encapsulate the complexity of socio-ecological systems. This will create the need for how to integrate them into the sustainability course. In addition, development of pedagogical approaches is not stagnant. New insights into this area will also mean new techniques to foster improved student comprehension and competency development. Finally, as societal needs change, so will the key competencies that must be nurtured in sustainability education programs at all levels. They will move beyond the key priorities of today and focus on proficiency development in areas that we still have yet to imagine. Like today, they will also present both new opportunities and challenges to grow future generations of sustainability scientists.

3.6 Conclusion

The aim of this chapter has been to present four approaches for framing complex sustainability challenges. It was done from the perspective of how the approaches are learned by graduate students in one course of an international, interdisciplinary graduate education program. Student reflections on approach competency development show that there have been challenges in achieving adequate depth in understanding of each approach. Experiences also revealed that there will be more modest ongoing challenges in student comprehension based on individual learning style preferences of students. Positive attributes for learning the framing approaches have been mainly the single topic/theme used throughout the course.

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