

Article

Addressing Misconceptions to the Concept of Resilience in Environmental Education

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Abstract: Environmental education is shaped in response to societal and environmental realities and it reflects new interests and demands that enable sustainable transformations. In recent years, the concept of resilience has taken an increasingly significant role among practitioners, researchers, policymakers, and especially within the Sustainable Development Goals (SDGs). Despite its growing importance, the literature surrounding the concept of resilience has struggled to find a consensus on definitions and measurements and therefore may be easily misconceived. In this avenue, a consensus among varying perspectives of resilience may be better achieved by understanding the interaction between students' prior knowledge (pre-conception) of resilience and the knowledge provided by educators. Based on the case study of five courses that teach the concept of this paper firstly identifies and discusses three common misconceptions among students, focusing on the concept of socio-ecological resilience. These include misconceptions to the value judgment, adaptability, and the costs that are relevant to the concept of resilience. Secondly, this paper discusses educational tools derived from scenario planning and theoretical foundations underlying empirical approaches to the concept of resilience, which may benefit educators in enabling critical thinking to address such common misconceptions. This paper may contribute to ongoing discussions in the environmental education literature, specifically to both pedagogy and curriculum focusing on the concept of resilience.

Keywords: environmental education; resilience; misconceptions; scenario planning; systems thinking

1. Introduction

Environmental education continues to be shaped in response to societal and environmental disturbances and it reflects new interests and demands that enable sustainable transformations. The concept of resilience is increasingly being used in the sustainability discourse by researchers and policy-makers. Resilience has been viewed as a necessary property for interdependent socio-ecological systems and therefore is emphasized as an important research frontier not only in sustainability science [1–3], but also in environmental education [4,5]. The concept of resilience has increasingly permeated the developmental and environmental discourse by UN agencies, the World Bank, Asian Development Bank, and the Asian Infrastructure Investment Bank, and other international aid agencies.

Most notably, the concept of resilience has been used numerously in the targets of the 2030 Agenda for Sustainable Development Goals (SDGs). As detailed in Table 1, these include the targets for goals

on Poverty: target 1.5; Hunger: target 2.4; Industry, Innovation, and Infrastructure: targets 9.1 and 9.A; Sustainable Cities and Communities: targets 11.B and 11.C; Climate Action: targets 13.1; and, Life Below Water: target 14.2. Environmental education rests on the tenant that every global citizen should be able to acquire relevant knowledge, skills, and values to advance humanity's collective progress towards sustainable futures. Towards this end, it is critical to include key sustainable development concepts such as resilience into the pedagogical curriculum at various learning stages [6]. Furthermore, it requires participatory, interdisciplinary, and holistically oriented teaching methods to inspire and empower people to apply their learning in the real world and be agents of meaningful and transformations towards sustainability.

Table 1. Targets of the 2030 Agenda for Sustainable Development Goals (SDGs) utilizing the concept of resilience.

Sustainable Development Goal (SDG)	SDG Target	Description
SDG # 1: No Poverty	1.5	By 2030, build the resilience of the poor and those in vulnerable situations and reduce their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters
SDG #2: Zero Hunger	2.4	2.4 By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding, and other disasters and that progressively improve land and soil quality.
SDG #9: Industries, Innovation, and Infrastructure	9.1	Develop quality, reliable, sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all
	9.A	Facilitate sustainable and resilient infrastructure development in developing countries through enhanced financial, technological and technical support to African countries, least developed countries, landlocked developing countries and small island developing States
SDG #11: Sustainable Cities and Communities	11.B	By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015-2030, holistic disaster risk management at all levels
	11.C	Support least developed countries, including through financial and technical assistance, in building sustainable and resilient buildings utilizing local materials
SDG #13: Climate Action: targets	13.1	Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries
SDG #14: Life Below Water	14.2	By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience , and take action for their restoration in order to achieve healthy and productive oceans

The etymology of resilience can be traced to Latin, where *resilio* means “to jump back” [7]. Over centuries, the word has gone through various and at times contradictory meanings, especially in psychology, engineering, sociology, environmentalism, and disaster management [8]. In its modern usage, especially in the developmental discourse, the concepts strength lies in its ability to link various challenges and responses within a communicable framework. However, despite its growing importance, the concept of resilience remains vague, on one hand hindering consistent meaningful application [9], while on the other hand, expanding its creative and trans-disciplinary scope [10]. The definition of the concept of resilience is influenced by one's disciplinary framework, socio-economic setting, and work experience [11]. While there are many definitions and measurements of resilience, a consensus among individual perspectives may be better achieved by understanding the common misconceptions of the concept.

Within the discipline of environmental education, the concept of resilience has gained importance and it is increasingly explored by researchers in the literature [4,5,7]. Researchers have explored the role

of environmental education in enabling the transformation of perceptions, development of practices, and enhanced governing strategies, which are in turn beneficial towards increasing the capacity of resilience in societies [4,12]. These studies emphasized the benefits of environmental education and learning towards resilient and sustainable futures. While many studies have highlighted the important role of environmental education for resilience [4,13], there have been very few studies on how the concept is communicated, taught, and learned within the environmental education practice. In this avenue, a recent study by Dubois and Krasny [5] examined changes in environmental education in New York City after a natural climatic disaster and explored the use and definition of the concept of resilience in educational practices. This study revealed that, while educators were not familiar with formal definitions of the concept, their usage of the concept of resilience varied widely and loosely echoed literature from, for example, the psychological and ecological disciplines. Given the increasing risk and vulnerabilities that are associated with climate change, sustainability challenges, and disaster risk management, environmental education needs to better incorporate the concept of resilience in its practices. While Dubois and Krasny [5] highlight the benefits of 'ground up' approach of an educator in applying working definitions of resilience through community interactions, they also suggest the need for greater interaction among researchers, educators, and practitioners focusing on the concept of resilience to achieve a common understanding. By doing so, educators can become better informed about the academic literature on the concept of resilience and develop new innovations in their teaching practice and curriculum development.

Within the constructivist models of environmental education, the understanding of student's prior knowledge and especially misconceptions has been emphasized. In this avenue, [14] examines the misconceptions of key ecological concepts and argues the need for environmental educators to encourage students to abandon their misconceptions. Similarly, Filho [15] examines common misconceptions regarding the concept of sustainability within the university community and emphasizes the need to address misconceptions to better engage in long-term sustainability action. Education and learning is a socially constructed phenomenon and by addressing misconceptions, environmental educators can better understand and address student's interpretation of their worldview and guide them towards attaining additional knowledge. In this avenue, a consensus among varying perspectives of resilience may be better achieved by understanding the interaction between students' prior knowledge (pre-conception) of resilience and the knowledge that is provided by educators.

This paper aims to examine common misconceptions to the concept of socio-ecological systems resilience. Towards this end, based on a case study of five courses that teach resilience concept, this paper advances the discourse on environmental education by highlighting and addressing common misconceptions to the concept of socio-ecological systems resilience. This paper should be of interest to both practitioners in the field of environmental education and to sustainability researchers focusing on the concept of resilience. The rest of this paper is organized, as follows: Section 2 introduces the methodology and case study underpinning the arguments of this paper. Section 3 discusses the findings and three common misconceptions to the concept of resilience, i.e., value judgment, adaptability, and cost of resilience. These findings are discussed in Section 4 and a conclusion follows in Section 5. It is hoped that this paper will lead to further innovations in the environmental education field and promote the reflection and application of the concept of socio-ecological systems resilience towards successful sustainable transformations.

2. Methodology

In this section, we first discuss the conceptual framework underlying this paper. Specifically, we discuss the literature on the misconception of students in other disciplines and the concept of educational reconstruction. Secondly, we introduce the case study underlying this research. Finally, we discuss the data gathering and data analysis of the case study.

2.1. Conceptual Framework

The literature on the scientific misconceptions of students and its impact on learning is quite robust in the physical sciences, for example, see works by [16–19]. However, misconceptions have been less elaborated in environmental education and less so relating to the concept of resilience [14]. To contribute to this gap, this paper attempts to provide insight into how to reconcile students' preconceived notions of resilience with that of existing scientific knowledge. As described in the previous section, theoretical developments of resilience have occurred in diverse fields, such as psychology, ecology, and sustainability discourse. However, even before students learn about scientific knowledge on resilience, they already possess an innate understanding of the concept that is based on their personal experiences and ideas. The gap between the academic definition of resilience and the students' understanding of resilience is the subject of examination in this study. We call this gap "misconception", because the pre-constructed understanding of resilience by students may limit the reflexivity, application, and understanding of the concept of social-ecological resilience concept.

To address student misconceptions to the concept of resilience, this study employs the concept of educational reconstruction by [20]. Educational approaches, like the case study of this paper, enables teachers to (i) reveal students' misconception on a concept, (ii) provide practical applications of the concept, and (iii) guide students to be aware of the gap and integrate these two.

To address the misconceptions of students, educators need to develop novel teaching approaches. Specifically, traditional teaching formats that simply treat student misconception as voids that need to be filled with new knowledge may not be successful. Building on the constructivist perspective, it is undeniable that students may construct their own perception of the concept of resilience. It is important to mention that the students' interpretation is not 'wrong' per se, as it is 'socially constructed' through their personal experiences. However, such a construction may have been done without the theoretical and or practical knowledge. It has been suggested that the persistence of misconceptions results in difficulty in learning because of student's lack of understanding of the fundamental concepts, for example, see Nakhleh [16]. At the same time, it is claimed that once misconceptions are formed they are hard to change, thereby largely impacting the quality and pace of learning [21]. By adopting a constructivist theory view of learning, misconceptions about learning are seen as resources to build upon collective learning, not obstacles to hinder people from acquiring new knowledge.

2.2. Case Study

A case study approach was employed in this research to gain empirical insights in the application of educational reconstruction to bridge the gap between students' misconceptions and that of the scientific/academic knowledge of the concept of resilience [22]. A case study is a particular qualitative empirical strategy that is employed by researchers examining a group of people undergoing an activity [22–24]. This paper's findings are based on the specific case study of courses taught at the University of Tokyo. The case study describes specific phenomenon and it may be limited in its universality. Nevertheless, it is hoped that this case study inspires further research in this area and further case studies to compare and contrast the critical findings.

The case study contains five courses that were taught by the lead author at The University of Tokyo at the undergraduate level between 2016 and 2018. These courses included: (1) "Sustainable Futures: Concepts, Issues, and Actions", a course where students practiced the application of methods from system thinking and futures studies, e.g., backcasting, forecasting, and scenario planning, with discourse on environmental, economic, and social sustainability; (2) "Introduction to Sustainability Science: trans-disciplinary challenges and transformations", a course where students became familiar with the emerging trans-disciplinary field of Sustainability Science and sustainable development goals and explored practical solutions to wicked sustainability challenges across different systems, e.g., agricultural, urban, and energy systems; and, (3) "Sustainable development and global environmental governance", a course focusing on sustainable development and global environmental governance concepts and themes. The above courses had a dedicated session on the concept of socio-ecological

resilience and its related discussions surrounding the field of sustainability and environmental governance. These courses had an average of 15 students each. In addition to the above, the author lectured and supervised two research teams, six students each, for the Independent Research Project course of the Global Education for Innovation and Leadership program—an undergraduate two-year certificate honors program at The University of Tokyo from 2016 to 2018. These included: (4) the “Resilience of infrastructure to flooding due to climate change” and (5) the “Livelihood resilience in the face of flooding due to climate change”. In the fourth and fifth courses, students applied the concept of socio-ecological systems resilience to the specific scenario of climatic induced disasters in Myanmar.

These above courses either wholly focused or had a dedicated session on the concept of socio-ecological systems resilience. Within these courses, students actively defined, interpreted, and applied the concept of resilience in their studies. Within the disciplines of environmental science, sustainability science, and public policy studies, the concept of resilience has increasingly gained popularity. Interest in the concept of resilience has most significantly surged with the introduction of the Agenda 2030 United Nations Sustainable Development Goals (SDGs) and its related indicators and targets have increased the usage of the term across many disciplines. The concept of resilience was introduced to students through the SDGs and through discussions on environmental and climatic disasters. Within the literature surrounding socio-ecological systems, the leading empirical advancements on the concept of resilience were also introduced to the students. These included the adaptive cycle [25], the ecological information-based network analysis [26], and statistical evidence of resilience, such as modularity and diversity [27]. The focus on empirical perspectives on the concept of socio-ecological resilience within these courses follows the increasing call by researchers to advance the concept of resilience to be more objective, practical, and communicable [28]. Within these case studies, particular misconceptions of the students towards understanding and applying the concept of resilience was observed, analyzed, and critically reflected upon.

2.3. Data Gathering

The data for this research were gathered through observation of lessons, post-lesson feedback discussions, and a reflexive classroom diary that was kept by the lecturer. Lesson observation is widely practiced methodology in educational research, whereby the researcher may take a participatory role, e.g., the lecturer would research on his or her own teaching session, or a non-participatory role where the researcher acts as a neutral and passive observer of events, e.g., listening and noting discussions among students on a particular topic. Educational research tends to rely on surveys or interviews to examine the experience of students after a lesson. However, the observation of students during a lesson may, in fact, lead to richer and deeper insights on the experience of students and has been recommended to be used more in educational and pedagogic research [29]. The observation of discussions is especially beneficial for gathering data for education research. Discussions may reveal new meanings and perspectives towards concepts, demonstrate the existence of different interpretations among students, and provide the lecturer with a real-time survey of heterogeneous conceptions that are held by students [30,31]. Observations of the lesson and feedback discussions were compiled through the use of a reflexive classroom diary. A classroom diary is a report containing qualitative data on the learning process compiled by the teacher-researcher during and after the conclusion of the class session [32]. Reflexive writing is a powerful and revealing method of inquiry arising from the interpretive research paradigm [33]. Through reflecting on the teaching and learning processes within the classroom, the teacher-researcher can better grasp how a meaning is negotiated, interpreted, and socially constructed [34]. A reflexive classroom diary enhances the awareness of the teacher-researcher of the classroom observations and discussions towards better narrating the processes of learning and the interpretation of concepts.

2.4. Data Analysis

Analysis of the data involved a detailed examination of the classroom interactions and discussions among students and the lecturer within the lessons. This was based on the observations during the lesson, post-lesson feedback discussions, and a reflexive classroom diary compiled by the lecturer. While survey or interview data are more structured by nature and can be grouped based on pre-coded responses, observational data are unstructured, more difficult to analyze, and 'naturalistic' by nature [35]. Therefore, the researcher is required to identify key concepts and reasoning processes, as evidenced by naturally occurring conversations within the classroom environment. In this avenue, a grounded theory approach was used to analyze the collected data.

A grounded theory approach is an inductive process that focuses on interpreting data and continually applying them to the research and vice-versa [36]. The main benefit of using grounded theory is that emergent theory is linked to the perceived and constructed reality of the research participants rather than what the researcher may assume in prior. Grounded theory, despite its name, should not be mistaken as a scientific theory. A scientific theory is repeatedly confirmed in various situations, while grounded theory may only be applied to a given study and it may not be confirmed in other conditions. This reflects the strength of grounded theory as being able to describe in more precision the events unfolding in a particular research setting and allowing for modification as new data or conditions are made available.

Through a grounded theory approach, the data was sorted, coded, and categorized, so that they can be analyzed for recurring dominant patterns. Towards this end, three types of coding were observed, i.e., open coding, where first impressions and patterns emerge from the data; axial coding, where characteristics of each pattern are defined; and, selective coding, where the core patterns are established [37]. We continually compiled, examined, compared, and reflected on the data until dominant patterns were exhibited and relatively fewer patterns emerged. After the establishment of the patterns, any additional collected data were tested to fit the patterns; if new data did not lead to a redefinition of the patterns, the theory was evaluated to have reached maturity and to have been saturated.

The grounded theory approach, however, is not necessarily linear, can follow a circular progression, and does not maintain any standard set rules for the identification of the pattern categories [38]. Furthermore, grounded theory may obscure the embedded agency of the researcher in interpreting the data [39]. Nevertheless, grounded theory produces an understanding based on the relationships between the categorical patterns and the circumstantial social reality. As an exploratory method, grounded theory is particularly good for investigating questions that have received little or no research attention and are therefore of great value in providing new insight on misconceptions to the concept of resilience in environmental education.

3. Findings: Misconceptions to the Concept of Resilience

3.1. Value Judgment—Resilience Is Not Always Good

The concept of resilience may carry a value judgment among students whereby all resilient systems are viewed as positive and desirable. This misconception is perhaps influenced by the usage of the concept in society as having a positive attribute. However, the specific context of resilience matters most as a system may be resilient, but in conditions that would be undesirable and have negative value judgments. For example, a society may be locked into highly resilient yet undesirable states of poverty without any flexibility for social change [40]; a rural farming village is unable to attract health services and is resilient in an unhealthy lifestyle; a bacteria is resilient to antibiotics; societies may be resilient to status quo gender or racial barriers; and, eutrophic lakes are resilient to reversal. In these cases, students need to be familiarized with the 'duality of resilience' [3] and they need to understand that in these cases resilience is not positive and effort needs to focus on breaking the system out of the resilient state toward a more desirable state in tune with social, environmental, and economic values.

The reason fueling this misconception is difficult to ascertain. Perhaps this misconception partly arises from the social image of resilience as having positive attributes and its usage in environmental and developmental indices, most notably in the SDGs, is situated as such. In addition, one important observation on the participants of the courses in this study is that the majority were local Japanese students, which may have come across the concept of resilience for the first time only after the Great East Japan Earthquake of 2011 where the concept of resilience was promoted nationally as a guiding principle of recovery process from its massive damage. For instance, The Sendai Framework for Disaster Risk Reduction 2015–2030 uses resilience as a keyword throughout its document (See: www.unisdr.org/we/coordinate/sendai-framework). This fact may have likely influenced the initial understanding of students of the concept of resilience, whereby many students see the concept as positive notion.

Furthermore, the majority of the academic literature on the concept of resilience inherently assumes the concept as having a positive connotation [3,41]. The elusive syntactic usage of the noun ‘resilience’, as without any description of the *resilience of what to what*, also fuels the misconception that resilience always has a positive attribute. In this avenue, it is essential to illustrate to students the need for a more precise language in employing the concept of resilience and the need to always discuss the resilience of a precise function or system attribute to a precise threat, shock, or disturbance. In the context of a resilient system that is contrary to social, economic, and environmental values, the challenge would be to seek how to break away from the status quo and transform the system into a new desirable resilience state.

In the classroom setting, students must, therefore, understand that resilience is not always a positive attribute and that there are instances where the focus of study needs to be upon how to break the resilient state. Educators can illustrate this misconception through the approaches from scenario planning studies and systems thinking. In this first approach, educators can use scenario planning methods to illustrate to students the existence of multiple probable and yet undesirable futures [42]. By acknowledging multiple probable future states, for example, of an environmental system, students become accustomed to the resilience of each state—despite its undesirability. Using systems thinking approaches educators can illustrate multiple stability domains or multiple basins of attraction in environmental ecosystems [43,44], whereby external shocks may cause the system to shift from one basin of attraction to another.

3.2. Adaptability—Resilience May Not Mean a Return to a Previous Stable-Equilibrium

The concept of resilience is often thought of implying a return to an exact pre-shock state. This misconception implies the return of a function within a system with no damage or change following a shock or disruption. The return to a pre-shock equilibrium may only be relevant however only to inanimate objects, e.g., bridges and buildings, where adaptation is not considered.

This viewpoint has been challenged by research on coupled human-environmental systems, which emphasize the uncertainty of shocks and the dynamic element of adaptation. Towards this end, a useful categorization of resilience has been to consider two overarching categories, engineering resilience and adaptive resilience [45]. In engineering resilience, the emphasis rests on the need to develop the capacity to maintain elasticity and resistance without breaking and returning to the original equilibrium state. More realistically for socio-ecological systems, however, is to consider the element of adaptability. In the context of adaptability, to be resilient is different from returning to the previous normal state, and instead indicates the capacity to maintain a particular function while reorganizing into different operating structures [46].

The misconception that resilience implies a return to an ‘original’ state may in part lie with the cognitive bias to avoid uncertainty and envision what is already known. This cognitive disposition is widely prevalent and not particular to the classroom environment—hence the famous adage that humans are creatures of habit. In this context, students may tend to think that the resilience of an essential ecosystem service for human society, e.g., water purification, production of food, and climate

regulation, has only one stable and desirable state. In the adaptive perspective, a function or service of a system may be resilient to shocks or disturbances even though the system maintains distinct configuration basin. Given the sheer complexity or novelty of a perturbation or shock, it is indeed difficult, or perhaps nearly impossible, to identify the various configuration basins of the environmental system. However, by taking into consideration the adaptive capacity of a system, students are taught to anticipate failure and to guide their decisions based on emerging responses and possibilities.

To challenge this misconception among students, educators can benefit from scenario approaches and derailment exercises. When employing a scenario planning exercise in the pedagogy, educators can choose one of two approaches for framing scenarios, i.e., the exploratory and normative approaches [47]. In the normative approach, students are asked to envision a resilient equilibrium that is based on a set of characteristics and work backwards to evaluate under what circumstances these characteristics may survive a shock or disruption. The normative approach is particularly useful when students have a degree of certainty of the possible disruption and desire to realize a preferred resilient scenario. Conversely, the exploratory approach can be used when there is a high degree of uncertainty on both possible shocks and also the possible and desirable equilibrium states. If students lack the initiative to partake an exploratory approach, the educator may then use mental derailment exercises to re-evaluate the possibility of the students' normative scenarios. In this avenue, educators can ask students to think of critical uncertainties that might derail their resilient stable equilibrium scenarios. Through such exercises, students can better understand the element of adaptation relevant to the concept of resilience.

3.3. Cost of Resilience: Resilience Is Not Without Trade-Offs

The concept of resilience tends to be viewed by students as a cost-free attribute without any trade-offs. However, everything arguably has an associated cost and nothing in nature is free. This critical point is reflected in ecological, environmental, and especially evolutionary sciences, where discussions of trade-offs are ubiquitous in the literature. Perhaps the trade-off and costs of system attributes are best captured in the Commoner's Four Laws of Ecology—"There Is No Such Thing As A Free Lunch" [48]. In the resilience research domain, trade-offs have been categorized into either temporal or spatial. In the first category, resilience is defined as the inverse return of time, i.e., the required time for a system to return to an equilibrium state following a disturbance [49]. Other researchers have proposed that resilience can be defined as trade-offs between long-term slow-moving and short-term fast-moving variables, e.g., short-term profit from resource consumption with the long-term ability of the ecosystem to regenerate itself [50]. In the second category, research emphasizes trade-offs in the spatial configurations of a network representation of coupled socio-ecological systems. In this category, resilience has been defined a trade-off between redundancy vs. efficiency of pathways, i.e., overly redundant systems are highly resilient but they lack growth and conversely overly efficient networks have high growth but are brittle [26,51].

In their initial examination of the sustainable development discourse, students are commonly exposed to the prevalent usage of the concept of resilience not only as a positive attribute but also as an attribute that is an 'add-on' and complimentary in nature. This perception is perhaps found more among students who lack systems thinking exercises in their curriculum. These students do not understand how feedback defines interrelationships within a system and therefore may not view resilience systematically. While the literature on defining the concept of resilience is vast and spread among different disciplines, empirical approaches that are relevant to coupled socio-ecological systems are few. Approaches, such as panarchy [52] and the ecological information-based analysis [53], are extremely useful for presenting system trade-offs that are useful for decision making.

To challenges this misconception, students can be introduced to the evolutionary theoretical foundations in environmental and ecological sciences underlying empirical approaches to resilience. These include the adaptive cycle, where natural systems are distinguished by their evolutionary phases [54], and ecological network theories, where natural systems are distinguished between system goals of growth or development [55]. By understanding these theoretical foundations, students can

better evaluate how different scenarios, based on the entailing system goals, exhibit system trade-offs to the resilience of the system. In this avenue, students can be presented with scenarios with conflicting system goals. For example, the panarchy approach can be used to discuss conflicting goals within a natural resource extraction scenario. In this scenario, the system trade-offs of achieving growth and the capacity for resilience can be evaluated. In another example, the ecological network analysis can be used to present a complex food web scenario where the trade-offs in an organism's ability to maintain nutritional resilience, based on redundant nutritional pathways, is evaluated against its ecological overhead costs. Through the combination of evolutionary theories that are relevant to the concept of resilience and scenario-based exercises, educators can better guide students in understanding that resilience is not without trade-offs.

4. Discussion

A key goal in environmental education is the development of critical thinking among students, which not only is aimed at attaining sustainable outcomes but also at enabling thinking outside the confines of any preset goals, targets, and indicators. While advocated definitions and goals, e.g., within the SDGs, are instrumental in rallying various agents and unifying their cooperation towards common objectives, they should not be viewed in an educational setting as dogmatic and as the only attainable sustainable solutions. By advocating certain definitions, the thinking power of students may be bound and risk their indoctrination by limiting the scope of their knowledge [56]. Towards this end, it is essential that misconceptions to the concept of resilience for students are identified and reflected in the environmental education pedagogy. Within the environmental education literature, researchers have emphasized the need for greater interaction among researchers, educators, and practitioners focusing on the concept of resilience [5]. Within this context, this paper discusses common misconceptions to the concept of resilience and so students may become more familiarized with the theoretical underpinnings and academic research in the area of resilience and lead to more innovative learning in environmental education. By doing so, students are better enabled to understand the concept of resilience and its applications and limitations towards sustainable development.

This paper identifies and discusses three common misconceptions to the concept of resilience among students. These include misconceptions to the value judgment, adaptability, and the costs relevant to the concept of resilience. Resilience can be misconceived as having an inherently positive attribute in social and environmental systems. However, in systems where resilience goes against sustainability values, e.g., poverty and eutrophic lakes, the resilience of the system should be considered as negative and the objective should be to transform away from this state to a state that is more compatible to social environmental values. The concept of resilience is also often misconceived as without the element of adaptability. In this avenue, social and environmental systems are viewed as resilient only if they continue to return to the same equilibrium or status quo following a disruption or shock. In reality, however, many changes are irreversible and therefore systems adapt to their new environment by ensuring the resilience of a particular function, for example, within a new basin of attraction. Finally, the concept of resilience can be misconceived as being a complementary attribute and without any trade-off. In this setting, it is critical to understand the costs that reflect the increase of resilience in a system, these are often identified as system-level trade-offs, e.g., efficiency and growth, in the literature.

Reflecting the educational reconstruction theory, educators can benefit from tools from systems thinking and approaches from future studies to reveal and amend the students' misconceptions to the concept of resilience. Such tools, especially future scenario visioning, have frequently and successfully been used in environmental education pedagogy for empowering students with critical thinking [57]. The use of scenario visioning tools enables students to think outside of common and advocated molds and to critically approach misconception to the concept of resilience. In addition to scenario tools, educators should become more familiarized with current academic research on the concept of resilience and introduce students to evolutionary theoretical foundations in the environmental and ecological

sciences underlying empirical approaches to resilience. Through these two avenues, educators can better address the misconceptions to the concept of resilience in their pedagogy. Furthermore, students can obtain learning from the interactions between their prior knowledge (pre-conception) of resilience and the knowledge provided by educators.

This paper notes that the goal of learning should not be to completely eradicate the prior conceptual assumptions of students, but instead to guide them to make judgments that are based on available evidence. Findings from many studies since the 1980s show that students hold deeply rooted conceptions and ideas, even before undertaking science instruction [58]. At times, such conceptions are not in harmony with scientific views, as we have also demonstrated in the present study. However, based on the constructivist epistemological position of this paper, we acknowledge that the concept of resilience, presented herein as the true scientific knowledge, is actually a consensus of the scientific community working on resilience. Such consensus presented in the form of lectures largely depends on the explicit and implicit aims of the lecture. To address such misconceptions therefore, the objectives and content of the curriculum, need to be clarified and the teaching strategy scrutinized.

5. Conclusions

The concept of resilience is increasingly employed by researchers, practitioners, and policy-makers in different disciplines. Most significantly, this concept is increasingly employed in describing desired attributes of coupled socio-ecological systems within the sustainable development goals (SDGs). Despite its importance, however, the concept of resilience remains vague, difficult to measure, and easily misconceived. In this paper, based on the case study of five courses, three common misconceptions towards understanding and applying the concept of resilience was observed, analyzed, and critically reflected upon. Through scenario planning studies tools and theoretical foundations underlying empirical approaches to the concept of resilience, environmental educators can better address these misconceptions and enable critical thinking among students. The paper's findings are based on a specific case study that describes a specific phenomenon and may be limited in its universality. Nevertheless, it is hoped that this paper will contribute to ongoing discussions in environmental education literature and inspires further innovation in both pedagogy and curriculum involving the concept of resilience.

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